

PRELIMINARY DATA SHEET

MAS 3587F
MPEG Layer 3
Audio Encoder/Decoder

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MPEG Layer 3 Audio Encoder/Decoder

This data sheet applies to MAS 3587F version B2.

Release Note: Revision bars indicate significant changes to the previous edition.

1. Introduction

The MAS 3587F is a single-chip MPEG layer 3 audio encoder/decoder designed for use in memory-based recording/playback applications, e.g. MP3 record/playback equipment. The IC contains a DSP engine with embedded RAM and ROM. It provides flexible digital interfaces for serial and S/PDIF audio data input and output. Also integrated are power management functions and two DC/DC converters for single cell power supply. A high-quality stereo D/A converter and a stereo A/D converter on chip provide the analog functions required in an advanced portable audio player.

In encoding mode, audio data is input via the integrated A/D converter, serial PCM, or S/PDIF interface. The compressed digital data stream is sent via the parallel interface. In decoding mode, compressed digital data streams are accepted in the parallel or serial format. The audio data is output via the high quality D/A converter. A digital output in serial PCM format and/or S/PDIF format is also provided.

Thus, the MAS 3587F provides a true 'ALL-IN-ONE' solution that is ideally suited for highly optimized memory based music recorders.

Additional functionality is achieved via download software (e.g. Micronas SC4 encoder/decoder). SC4 is a proprietary Micronas speech codec technology based on ADPCM. The codec can be downloaded to the MAS 3587F to allow high quality speech recording and playing back at various sampling rates. (Please contact your local Micronas Sales Representative about availability of SC4 downloads).

In MPEG 1 (ISO 11172-3), three hierarchical layers of compression have been standardized. The most sophisticated and complex, layer 3, allows compression rates of approximately 12:1 for mono and stereo signals while still maintaining CD audio quality.

The MAS 3587F is available in the PMQFP64 package.

1.1. Features

Firmware

- MPEG 1/2 layer 3 encoder
- Encoding with adaptive bit rate up to 192 kbit/s
- MPEG 1/2 layer 2 and layer 3 decoder
- Decoder-extension to MPEG 2 layer 3 for low bit rates ("MPEG 2.5")
- Extraction of MPEG Ancillary Data
- Adaptive bit rates (bit rate switching)
- SDMI-compliant security technology for decoder
- Stereo channel mixer
- Bass, treble and loudness function
- Micronas Dynamic Bass (MDB)
- Automatic Volume Correction (AVC)

Interfaces

- 2 serial asynchronous interfaces for bitstreams and uncompressed digital audio
- Parallel handshake bit stream input/output
- Serial audio output via I²S and related formats
- S/PDIF audio input
- S/PDIF audio output
- Controlling via I²C interface

Hardware Features

- Two independent embedded DC/DC converters (e.g. for DSP and flash RAM supply)
- Low DC/DC converter start-up voltage (0.9 V)
- DC converter efficiency up to 95%
- Battery voltage monitor
- Low supply voltage (down to 2.5 V for decoder, 3.5 V for encoder)
- Low power dissipation (down to 70 mW for decoder, down to 450 mW for MPEG 1 encoder)
- Hardware power management and power-off functions
- Microphone amplifier
- Stereo A/D converter for FM/AM-radio and speech input
- CD quality stereo D/A converter
- Headphone amplifier
- On-chip crystal oscillator
- External clock or crystal frequency of 13...28 MHz
- Standby current < 10 μ A

1.2. Application Overview

The following block diagram shows an example application for the MAS 3587F in a portable audio recorder device. Besides a simple controller and the external flash memories, all required components are integrated in the MAS 3587F. By means of the embedded A/D-converter, the MAS 3587F supports both speech and FM radio quality audio encoding. CD-quality encoding/decoding is achieved by using digital inputs/embedded D/A-converter.

Fig. 1–1 depicts a portable audio application that is power optimized. The two embedded DC/DC converters of the MAS 3587F generate optimum power supply voltages for the DSP core and also for state-of-the-art flash memories that typically require 2.7 to 3.3 V supply.

The performance of the DC/DC converters reaches efficiencies up to 95%.

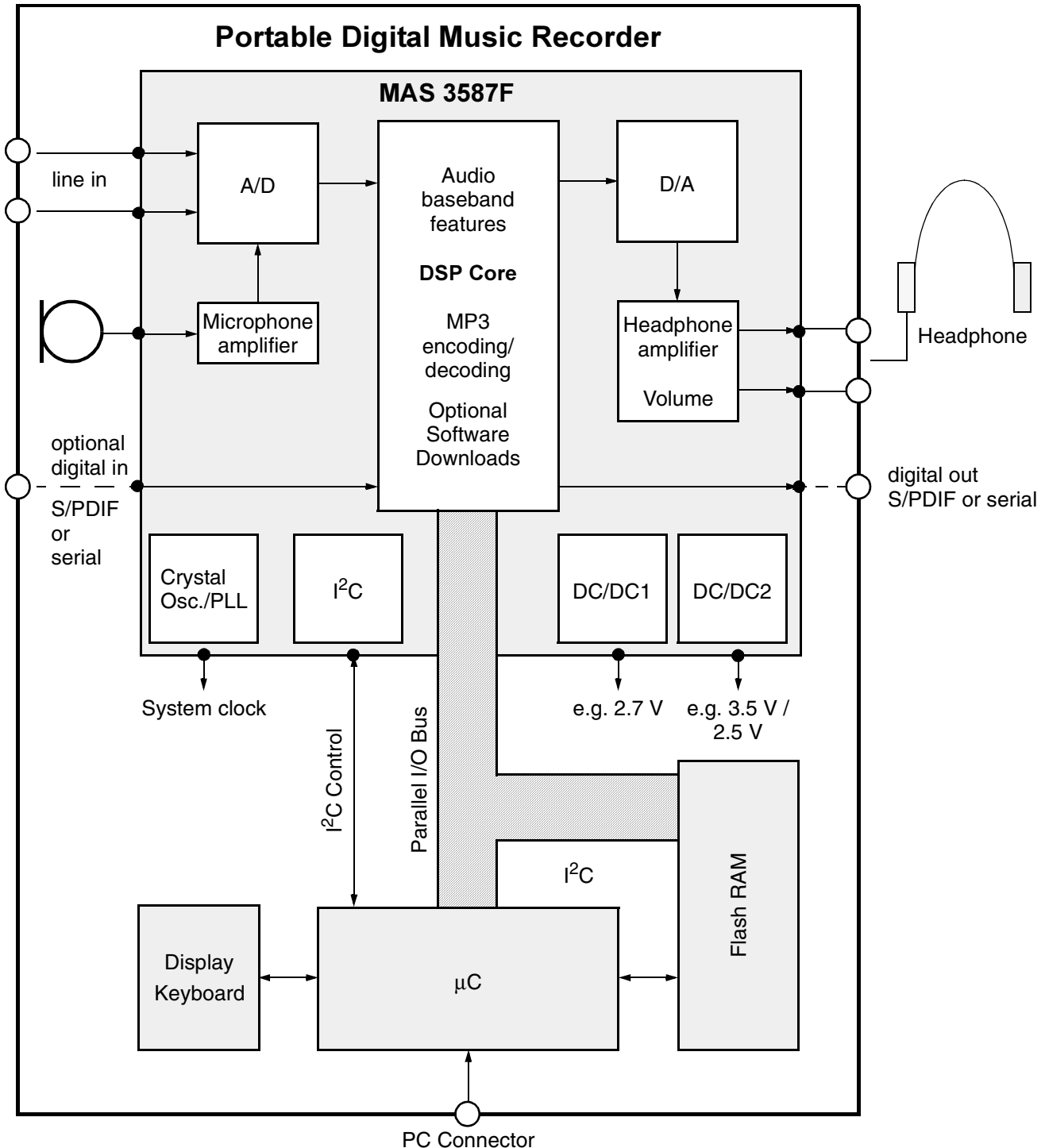


Fig. 1–1: Example application for the MAS 3587F in a portable audio recorder device

2. Functional Description

2.1. Overview

The MAS 3587F is intended for use in consumer audio applications. It encodes analog audio input, PCM data or S/PDIF signals to variable bit rate MPEG 1/2 Layer 3 data streams. The compressed data is stored in an external memory via the parallel port. For playback it receives parallel or serial data streams and decodes MPEG Layer 2 and 3 (including the low sampling frequency extensions).

2.2. Architecture of the MAS 3587F

The hardware of the MAS 3587F consists of a high-performance RISC Digital Signal Processor (DSP), and appropriate interfaces. A hardware overview of the IC is shown in Fig. 2-1.

2.3. DSP Core

The internal processor is a dedicated DSP for advanced audio applications.

2.4. RAM and Registers

The DSP core has access to two RAM banks denoted D0 and D1. All RAM addresses can be accessed in a 20-bit or a 16-bit mode via I²C bus. For fast access of internal DSP states the processor core has an address space of 256 data registers which can be accessed by I²C bus. For more details please refer to Section 3.3. on page 23.

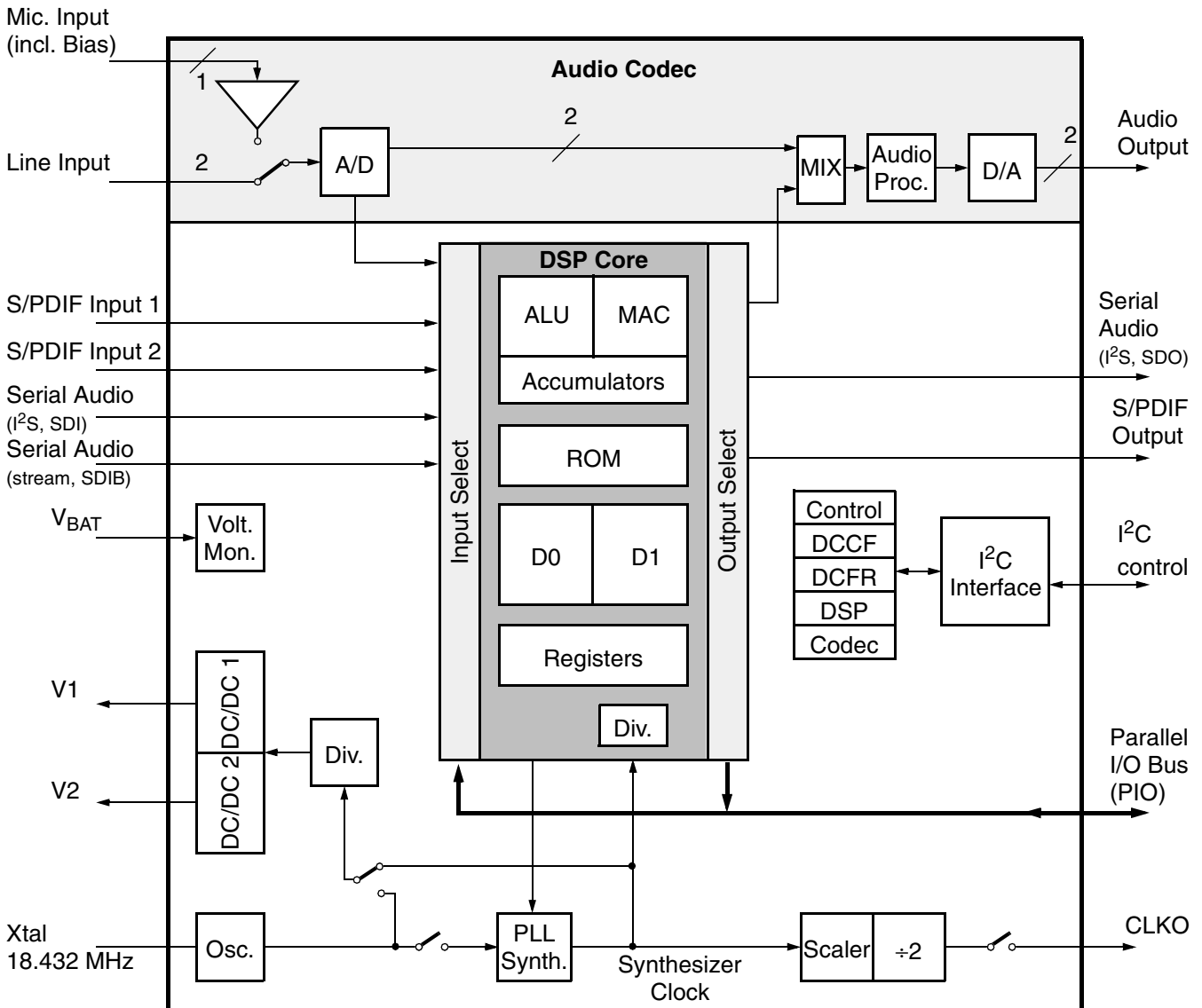


Fig. 2-1: The MAS 3587F architecture

2.5. Firmware and Software

2.5.1. Internal Program ROM and Firmware, MPEG-Encoding/Decoding

The firmware implemented in the program ROM of the MAS 3587F provides MPEG 1/2 Layer 3 encoding and decoding of MPEG 1/2 Layer 2 and MPEG 1/2 Layer 3.

The DSP operating system starts the firmware in the "Application Selection Mode". By setting the appropriate bit in the Application Select memory cell (see Table 3-7 on page 28), the MPEG audio encoder or decoder can be activated.

The MPEG decoder provides an automatic standard detection mode. If all MPEG audio decoders are selected, the Layer 2 or Layer 3 bitstream is recognized and decoded automatically.

For general control purposes, the operation system provides a set of I²C instructions that give access to internal DSP registers and memory areas.

An auxiliary digital volume control and mixer matrix is applied to the digital stereo audio data. This matrix is capable of performing the balance control and a simple kind of stereo basewidth enhancement. All four factors LL, LR, RL, and RR are adjustable, please refer to Fig. 3-3 on page 39.

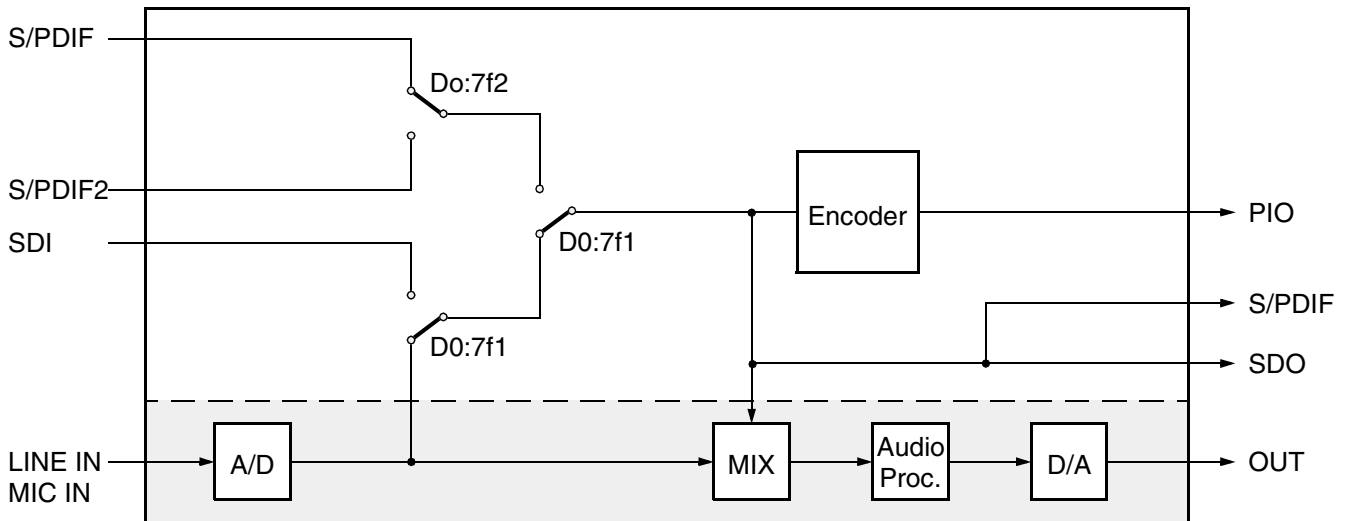


Fig. 2-2: Encoder Signal Flow (Reset setting shown)

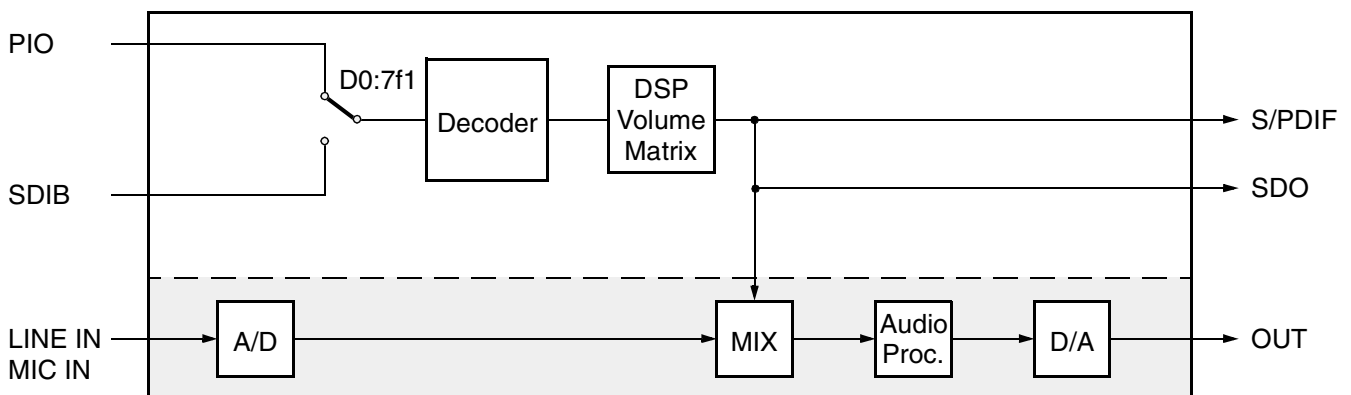


Fig. 2-3: Decoder Signal Flow (Reset setting shown)

2.5.2. Program Download Feature

The standard functions of the MAS 3587F can be extended or substituted by downloading up to 4 kWords (1 Word = 20 bits) of program code and additionally up to 4 kWords of coefficients into the internal RAM.

The code must be downloaded by the *Fast Program Download* command (see Section 3.3.2.10. on page 26) into an area of RAM that is switchable from data memory to program memory. A *Run* command (see Section 3.3.2.1. on page 24) starts the operation.

2.6. Audio Codec

A sophisticated set of audio converters and sound features has been implemented to comply with various kinds of operating environments that range up to high-end equipment (see Fig. 2-4).

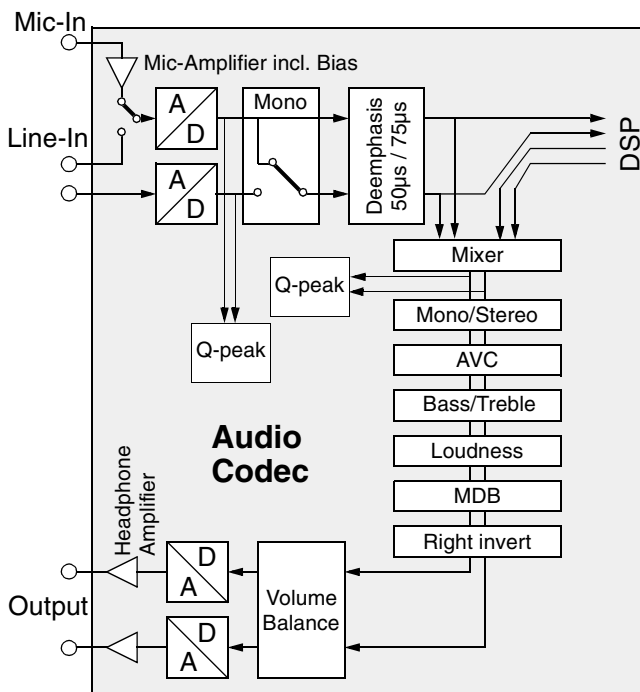


Fig. 2-4: Signal flow block diagram of the Audio Codec

2.7. A/D Converter and Microphone Amplifier

A pair of A/D converters is provided for recording or loop-through purposes. In addition, a microphone amplifier including voltage supply function for an electret type microphone has been integrated.

2.7.1. Baseband Processing

Several baseband functions are applied to the digital audio signal immediately before D/A conversion.

2.7.1.1. Bass, Treble, and Loudness

Standard baseband functions such as bass, treble, and loudness are provided (refer to Table 3-17 for details).

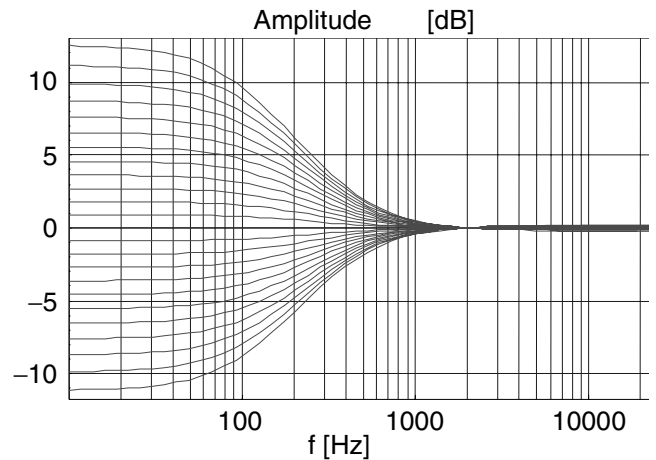


Fig. 2-5: Bass Frequency Response

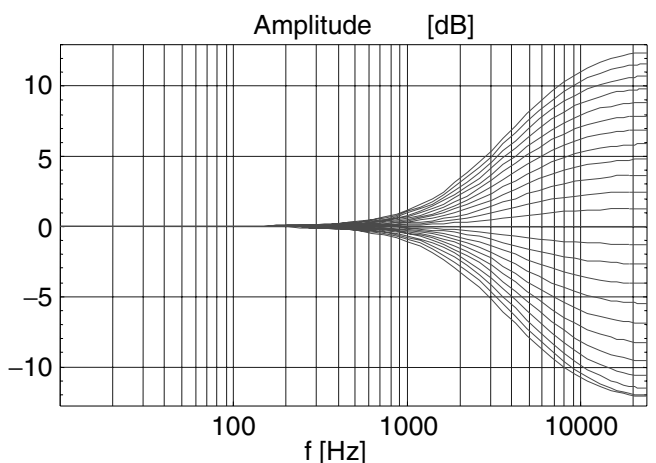


Fig. 2-6: Treble Frequency Response

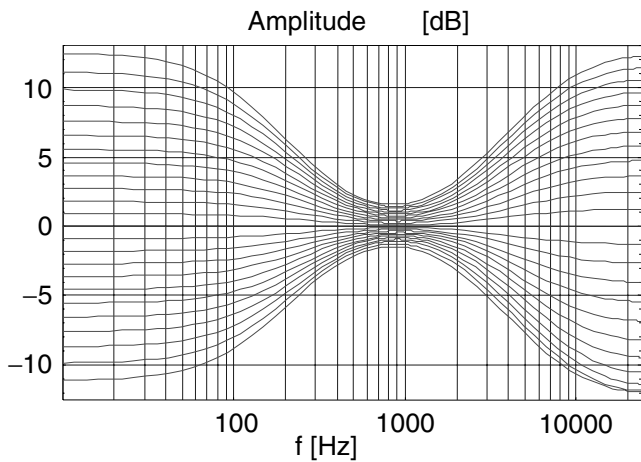


Fig. 2-7: Bass/Treble Frequency Response

2.7.2. Micronas Dynamic Bass (MDB)

The Micronas Dynamic Bass system (MDB) was developed to extend the frequency range of loudspeakers or headphones below the cutoff frequency of the speakers. In addition to dynamically amplifying the low frequency bass signals, the MDB exploits the psychoacoustic phenomenon of the ‘missing fundamental’. Adding harmonics of the frequency components below the cutoff frequency gives the impression of actually hearing the low frequency fundamental, while at the same time retaining the loudness of the original signal. Due to the parametric implementation of the MDB, it can be customized to create different bass effects and adapted to various loudspeaker characteristics (see Section 3.4.4. on page 46).

2.7.2.1. Automatic Volume Correction (AVC)

In a collection of tracks from different sources fairly often the average volume level varies. Especially in a noisy listening environment the user must adjust the volume to achieve a comfortable listening enjoyment. The Automatic Volume Correction (AVC) solves this problem by equalizing the volume level.

To prevent clipping, the AVC’s gain decreases quickly in dynamic boost conditions. To suppress oscillation effects, the gain increases rather slowly for low level inputs. The decay time is programmable by means of the AVC register (see Table 3-17).

For input levels of -18 dB_r to 0 dB_r, the AVC maintains a fixed output level of -9 dB_r. Fig. 2-8 shows the AVC output level versus its input level. For volume and baseband registers set to 0 dB, a level of 0 dB_r corresponds to full scale input/output.

2.7.2.2. Balance and Volume

To minimize quantization noise, the main volume control is automatically split into a digital and an analog part. The volume range is -114...+12 dB with an additional mute position. A balance function is provided (see Table 3-17).

2.7.3. D/A Converters

A pair of Micronas’ unique multibit sigma-delta D/A converters is used to convert the audio data with high linearity and a superior S/N. In order to attenuate high-frequency noise caused by noise-shaping, internal low-pass filters are included. They require additional external capacitors between pins FILTR and O_{UTR}, and FILTL and O_{UTL} respectively (see Section 4.7. on page 81).

2.7.4. Output Amplifiers

The integrated output amplifiers are capable of driving stereo headphones of 16...32 Ω impedance via 22-Ω series resistors or built-in loudspeakers of 16 Ω impedance directly. If more output power is required, the right output signal can be inverted and a single loudspeaker can be connected as a bridge between pins O_{UTL} and O_{UTR}. In this case the minimum impedance is 32 Ω, and for optimized power the source should be set to mono.

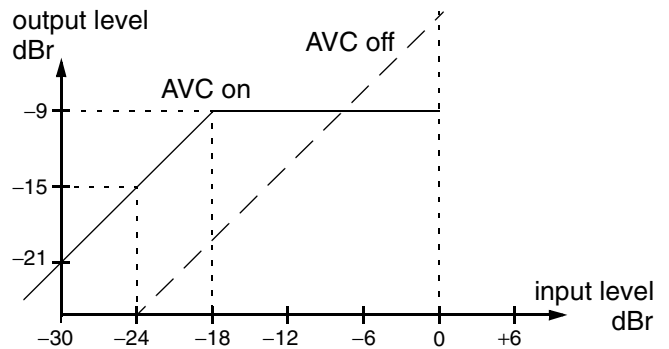


Fig. 2-8: Simplified AVC characteristics

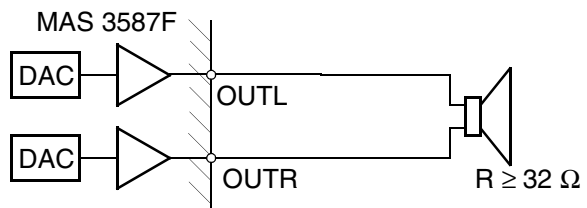


Fig. 2-9: Bridge operation mode

2.8. Clock Management

The MAS 3587F is driven by a single crystal-controlled clock with a frequency of 18.432 MHz. It is possible to drive the MAS 3587F with other reference clocks. In this case, the nominal crystal frequency must be written into memory location D0:7F3. The crystal clock acts as a reference for the embedded synthesizer that generates the internal clock.

For compressed audio data reception, the MAS 3587F may act either as the clock master (Demand Mode) or as a slave (Broadcast Mode) as defined by bit 1 in IOControlMain memory cell (see Table 3–9). In both modes, the output of the clock synthesizer depends on the sample rate of the decoded data stream as shown in Table 2–1.

In the 'Broadcast Mode' (PLL on), the incoming audio data controls the clock synthesizer via a PLL.

In the 'Demand Mode' (PLL off) the MAS 3587F acts as the system master clock, the internal clock. The data transfer is triggered by a demand signal at pin EOD. This mode is used in most applications.

In the encoder application, the MAS 3587F is clock master in case of I²S audio input. For S/PDIF input, the MAS 3587F synchronizes the clock to the incoming S/PDIF signal.

Table 2–1: Settings of bits 8 and 17 in OutClkConfig and resulting CLKO output frequencies

f _s /kHz	Output Frequency at CLKO/MHz				
	Synth. Clock bit 8=1	Scaler On bit 8=0, bit 17=0		Scaler Plus Extra Division bit 8=0, bit 17=1	
48	24.576	512·f _s	24.576	256·f _s	12.288
44.1	22.5792		22.5792		11.2896
32	24.576	768·f _s	24.576	384·f _s	12.288
24		512·f _s	12.288	256·f _s	6.144
22.05	22.5792		11.2896		5.6448
16	24.576	768·f _s	12.288	384·f _s	6.144
12		512·f _s	6.144	256·f _s	3.072
11.025	22.5792		5.6448		2.8224
8	24.576	768·f _s	6.144	384·f _s	3.072

2.8.1. DSP Clock

The DSP clock has a separate divider. For power conservation it is set to the lowest acceptable rate of the synthesizer clock which is capable to allow the processor core to perform all tasks.

2.8.2. Clock Output at CLKO

If the DSP or audio codec functions are enabled (bits 11 or 10 in the CONTROL Register at I²C subaddress 6A_{hex}), the reference clock at pin CLKO is derived from the synthesizer clock.

Dependent on the sample rate of the decoded signal a scaler is applied which automatically divides the clock-out by 1, 2, or 4, as shown in Table 2–1. An additional division by 2 may be selected by setting bit 17 of the Output Clock Configuration memory cell, OutClkConfig (see Table 3–9 on page 30). The scaler can be disabled by setting bit 8 of this cell.

The controlling at OutClkConfig is only possible as long as the DSP is operational (bit 10 of the CONTROL Register). Settings remain valid if the DSP is disabled by clearing bit 10.

2.9. Power Supply Concept

The MAS 3587F has been designed for minimal power dissipation. In order to optimize the battery management in portable players, two DC/DC converters have been implemented to supply the complete portable audio player with regulated voltages.

2.9.1. Power Supply Regions

The MAS 3587F has five power supply regions.

The VDD/VSS pin pair supplies all digital parts including the DSP core, the XVDD/XVSS pin pair is connected to the digital signal pin output buffers, the AVDD0/AVSS0 supply is for the analog output amplifiers, AVDD1/AVSS1 for all other analog circuits like clock oscillator, PLL circuits, system clock synthesizer and A/D and D/A converters. The I²C interface has an own supply region via pin I2CVDD. Connecting this to the microcontroller supply assures that the I²C bus always works as long as the microcontroller is alive so that the operating modes can be selected.

Beside these regions, the DC/DC converters have start-up circuits of their own which get their power via pin VSENSx.

2.9.2. DC/DC Converters

The MAS 3587F has two embedded high-performance step-up DC/DC converters with synchronous rectifiers to supply both the DSP core itself and external circuitry such as a controller or flash memory at two different voltage levels. An overview is given in Fig. 2–10 on page 13.

The DC/DC converters are designed to generate an output voltage between 2.0 V and 3.5 V which can be programmed separately for each converter via the I²C interface (see Table 3–3 on page 20). Both converters are of the bootstrapped type which allow start up from a voltage down to 0.9 V for use with a single battery or NiCd/NiMH cell. The default output voltages are 3.0 V. Both converters are enabled with a high level at pin DCEN and enabled/disabled by the I²C interface.

The MAS 3587F DC/DC converters feature a constant-frequency, low noise pulse width modulation (PWM) mode and a low quiescent current, pulse frequency modulation (PFM) mode for improved efficiencies at low current loads. Both modes – PWM or PFM – can be selected independently for each converter via I²C interface. The default mode is PWM.

In the PWM mode, the switching frequency of the power-MOSFET-switches is derived from the crystal oscillator. Switching harmonics generated by constant frequency operation are consistent and predictable. When the audio codec is enabled the switching frequency of the converters is synchronized to the audio codec clock to avoid interferences into the audio band. The actual switching frequency can be selected via the I²C-interface between 300 kHz and 580 kHz (for details see DCFR Register in Table 3–3).

In the PFM operation mode, the switching frequency is controlled by the converters themselves, it will be just high enough to service the output load thus resulting in the best possible efficiency at low current loads. PFM mode does not need a clock signal from the crystal oscillator. If both converters do not use the PWM-mode, the crystal clock will be shut down as long it is not needed from other internal blocks.

The synchronous rectifier bypasses the external Schottky diode to reduce losses caused by the diode forward voltage providing up to 5% efficiency improvement. By default, the P-channel synchronous rectifier switch is turned on when the voltage at pin(s) DCSON exceeds the converter's output voltage at pin(s) VSENSn and turns off when the inductor current drops below a threshold. If one or both converters are disabled, the corresponding P-channel switch will be turned on, connecting the battery voltage to the DC/DC converters output voltage at pin VSENSn.

If both DC/DC-converters are off, a high signal may be applied at pin DCEN. This will start the converters in their default mode (PWM with 3.0 V output voltage). The PUP signal will change from low to high when both converters have reached their nominal output voltage and will return to low when both converters output voltages have dropped 200 mV below their programmed output voltage. The signal at pin PUP can be used to control the reset of an external microcontroller (see Section 2.13.2. on page 16 for details on start up procedure).

If only DC/DC-converter 1 is used, the output of the unused converter 2 (VSENS2) must be connected to the output of converter 1 (VSENS1) to make the PUP signal work properly. Also, if a DC/DC-converter is not used (no inductor connected), the pin DCSO must be left vacant.

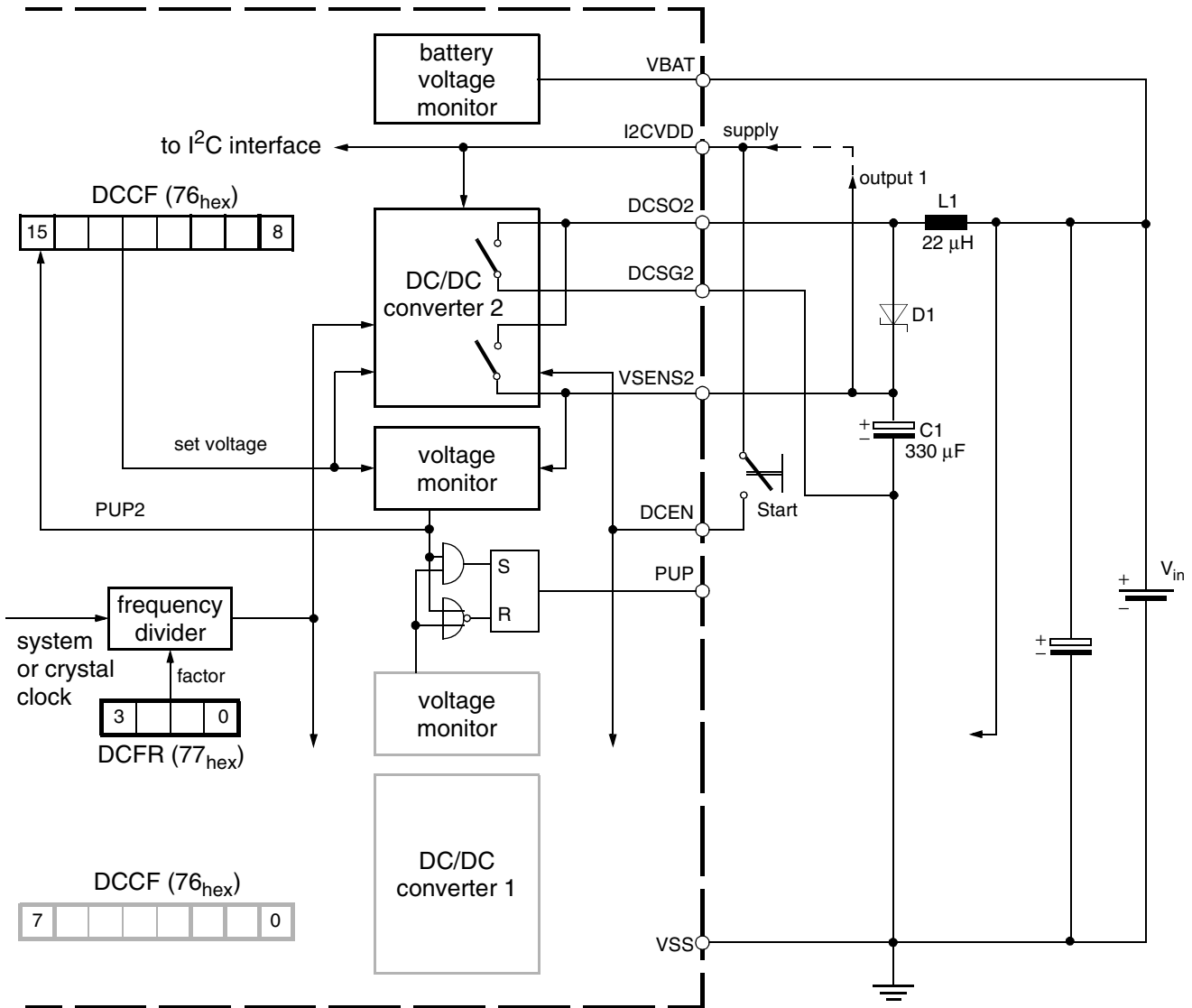


Fig. 2-10: DC/DC converter overview (DCEN input must be connected to pin I2CVDD via the start-up push button)

2.9.3. Power Supply Configurations

One of the following supply configurations may be used:

- Configuration 1: DC/DC 1 (e.g. 2.7 V) supplies controller, flash and MAS 3587F audio parts, DC/DC 2 generates e.g. 2.5 V/3.5 V for the MAS 3587F DSP (see Fig. 2–11).
- Configuration 2: All components are powered by an external source, no DC/DC converter is used (see Fig. 2–12).
- Configuration 3: The external source has a constant voltage of 2.7 V or 3 V, one DC/DC-converter is used to generate the higher DSP-Voltage needed for encoding (see Fig. 2–13)

If DC/DC converter 1 is used, it must supply the analog circuits (pins AVDD0, AVDD1) of the MAS 3587F.

If the DC/DC converters are not used, pin DCEN must be connected to VSS, DCISOx must be left vacant.

2.10. Battery Voltage Supervision

A battery voltage supervision circuit (at pin VBAT) is provided which is independent of the DC/DC converters. It can be programmed to supervise one or two battery cells. The voltage is measured by subsequently setting a series of voltage thresholds and checking the respective comparison result in register 77_{hex} (see Table 3–3).

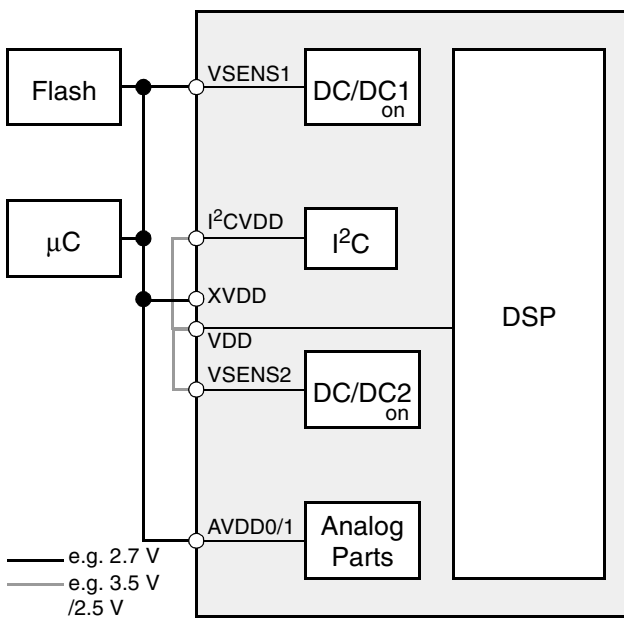


Fig. 2–11: Configuration1: DC/DC-converter supply

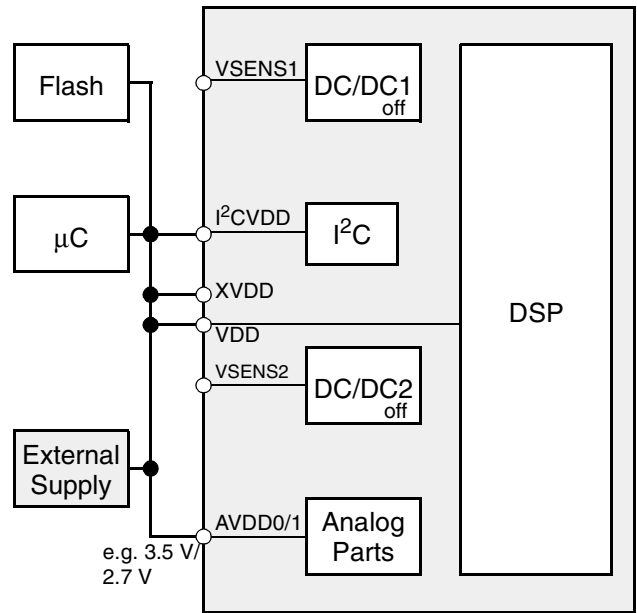


Fig. 2–12: Configuration 2: External power supply

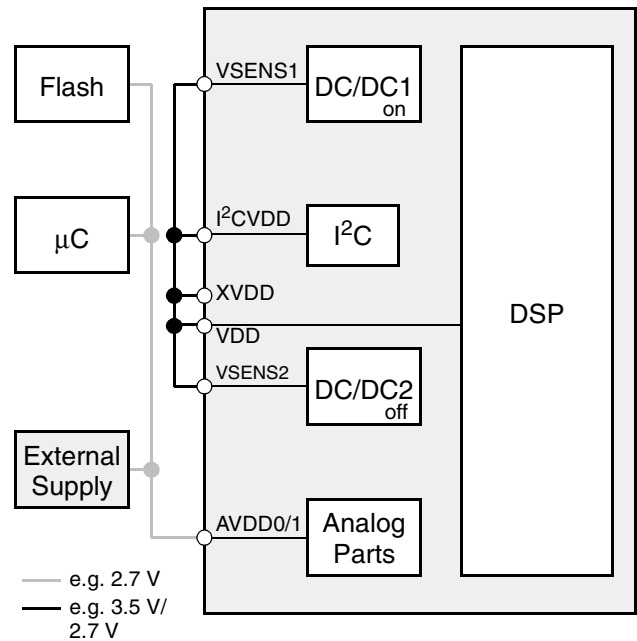


Fig. 2–13: Configuration 3: External constant power supply

2.11. Interfaces

The MAS 3587F uses an I²C control interface, a parallel I/O interface (PIO) for MPEG bit streams and digital audio interfaces for the incoming/outgoing audio data (I²S or similar). Alternatively, SPDIF input and output interfaces can be used. MPEG bit stream input to the decoder is also possible via a second serial input interface.

2.11.1. I²C Control Interface

For controlling and program download purposes, a standard I²C slave interface is implemented. A detailed description of all functions can be found in Section 3.

2.11.2. S/PDIF Input Interface

The S/PDIF interface receives a one-wire serial bus signal. In addition to the signal input pin SPD11/SPD12, a reference pin SPD1R is provided to support balanced signal sources or twisted pair transmission lines.

The synchronization time on the input signal is < 50 ms.

The S/PDIF input signal can also be switched to the SPDO pin. In this case the analog input circuit of the S/PDIF inputs (see Fig. 4–18 on page 55) restores the S/PDIF input signal to a full swing signal at SPDO.

For controlling details please refer to Table 3–9 on page 30.

2.11.3. S/PDIF Output

The S/PDIF output of the baseband audio signals is provided at pin SPDO.

Note that the S/PDIF output is available only for MPEG 1 sampling frequencies (32, 44.1, 48 kHz).

2.11.4. Multiline Serial Audio Input (SDI, SDIB)

There are two multiline serial audio input interfaces (SDI, SDIB) each consisting of the three pins SIC, SII, SID, and SIBC, SIBI, SIBD. The firmware supports SDI for audio signals and SDIB for bitstream signals.

The interfaces can be configured as continuous bit stream or word-oriented inputs. For the MPEG bit-streams the word strobe pin SIBI must always be connected to V_{SS}, bits must be sent MSB first as created by the encoder. During enabling the DSP and its interfaces, it is strongly recommended to hold the SIBC Pin low.

In case of the Demand Mode in decoding applications (see Section 2.8.), the signal clock coming from the data source must be higher than the nominal data transmission rate (e.g. 128 kbit/s). Pin EOD is used to interrupt the data flow whenever the input buffer of the MAS 3587F is filled.

For controlling details please refer to Table 3–9.

2.11.5. Multiline Serial Output (SDO)

The serial audio output interface of the MAS 3587F is a standard I²S-like interface consisting of the data lines SOD, the word strobe SOI and the clock signal SOC. It is possible to choose between two standard interface configurations (16-bit data words with word strobe time offset or 32-bit data words with inverted SOI-signal).

If the serial output generates 32 bits per audio sample, only the first 20 bits will carry valid audio data. The 12 trailing bits are set to zero by default.

2.11.6. Parallel Input/Output Interface (PIO)

The parallel interface of the MAS 3587F consists of the 8 data lines PI12...PI19 (MSB) and the control lines PCS, PR, PRTR, PRTW, and EOD. It can be used for data exchange with an external memory and for other special purposes as defined by the DSP software.

The PIO interface is always used for MPEG-data output. For the handshake protocol please refer to Section 4.6.3.8.

For MPEG-data input, the PIO interface is activated by setting bits 9,8 in D0:7F1 to 01. For the handshake protocol please refer to Section 4.6.3.6.

2.12. MPEG Synchronization Output

The signal at pin SYNC is set to '1' after the internal decoding for the MPEG header has been finished for one frame. The rising edge of this signal can be used as an interrupt input for the controller that triggers the read out of the control information and ancillary data. As soon as the MAS 3587F has received the SYNC reset command (see Section 3.3.2.8. on page 26), the SYNC signal is cleared. If the controller does not issue a reset command, the SYNC signal returns to '0' as soon as the decoding of the next MPEG frame is started. MPEG status and ancillary data become invalid until the frame is completely decoded and the signal at pin SYNC rises again. The controller must have finished reading all MPEG information before it becomes invalid. The MPEG Layer 2/3 frame lengths are given in Table 2-2.

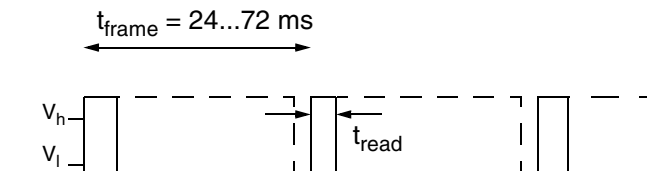


Fig. 2-14: Schematic timing of the signal at pin SYNC. The signal is cleared at t_{read} when the controller has issued a Clear SYNC Signal command (see Section 3.3.2.8. on page 26). If no command is issued, the signal returns to '0' just before the decoding of the next MPEG frame.

Table 2-2: Frame length in MPEG Layer 2/3

f_s /kHz	Frame Length Layer 2	Frame Length Layer 3
48	24 ms	24 ms
44.1	26.12 ms	26.12 ms
32	36 ms	36 ms
24	24 ms	24 ms
22.05	26.12 ms	26.12 ms
16	36 ms	36 ms
12	not available	48 ms
11.025	not available	52.24 ms
8	not available	72 ms

2.13. Default Operation

This sections refers to the standard operation mode "Configuration 1" (see Section 2.9.3.).

2.13.1. Stand-by Functions

After applying the battery voltage, the system will remain stand-by, as long as the DCEN pin level is kept low. Due to the low stand-by current of CMOS circuits, the battery may remain connected to DCSON/VSENSn at all times.

2.13.2. Power-Up of the DC/DC Converters and Reset

The battery voltage must be applied to pin DCSON via the 22 μ H inductor and, furthermore, to the sense pin VSENSn via a Schottky diode (see Fig. 2-10 on page 13).

For start-up, the pin DCEN must be connected via an external "start" push button to the I2CVDD supply, which is equivalent to the battery supply voltage (> 0.9 V) at start-up.

The supply at DCEN must be applied until the DC/DC converters have started up (signal at pin PUP) and then removed for normal operation.

As soon as the output voltage at VSENSn reaches the default voltage monitor reset level of 3.0 V, the respective internal PUPn bit will be set. When both PUPn bits are set, the signal at pin PUP will go high and can be used to start and reset the microcontroller.

Before transmitting any I²C commands, the controller must issue a power-on reset to pin POR. The separate supply pin I2CVDD assures that the I²C interface works independently of the DSP or the audio codec. Now the desired supply voltage can be programmed at I²C subaddress 76_{hex} (see Table 3-3).

The signal at pin PUP will return to low only when both PUPn flags (I²C subaddress 76_{hex}) have returned to zero. Care must be taken when changing both DC/DC output voltages to higher values. In this case, both output voltages are momentarily insufficient to keep the PUPn flags up; the resulting dip in the signal at the PUP pin may in turn reset the microcontroller. To avoid this condition, only one DC/DC output voltage should be changed at a time. Before modifying the second voltage, the microcontroller must wait for the PUPn flag of the first voltage to be set again.

If only DC/DC converter 1 is used, the reference voltage of the second unused should be set to a lower value than that of converter 1 and its pin VSENS2 should be connected to VDD.

The operating mode (pulse width modulation or pulse frequency modulation) are controlled at I²C subaddress 76_{hex}, the operating frequency at I²C subaddress 77_{hex}.

2.13.3. Control of the Signal Processing

Before starting the DSP, the controller should check for a sufficient voltage supply (respective flag PUPn at I²C subaddress 76_{hex}). The DSP is enabled by setting the appropriate bit in the CONTROL register (I²C subaddress 6A_{hex}). The nominal frequency of the crystal oscillator must be written into D0:7F3. After an initialization phase of 5 ms, the DSP data registers can be accessed via I²C (see Table 3–3).

Input and output control is performed via memory location D0:7F1 and D0:7F2. The parallel interface (PIO) is the default setting for compressed data. The decoded audio can be routed to either the S/PDIF, the SDO and the analog outputs. The output clock signal at pin CLKO is defined in D0:7F4. The specific settings for audio encoding are written to memory location D0:7F0.

All changes in the D0-memory cells become effective synchronously upon setting the LSB of Main I/O Control D0:7F1 (see Table 3–9).

The common way to start encoding or decoding is to perform all necessary settings and switch on the application by selecting the desired bit(s) in the Application Selection memory cell (D0:7F6) (see Table 3–9).

The digital volume control (see Table 3–9) is applied to the output signal of the DSP. The decoded audio data is by default available at the S/PDIF output interface (for MPEG 1 sampling frequencies).

The DSP does not have to be started if its functions are not needed, e.g. for routing audio via the A/D and the D/A converters through the codec part of the IC.

2.13.4. Start-up of the Audio Codec

Before enabling the audio codec, the controller should check for a sufficient voltage supply (respective flag PUPn at I²C subaddress 76_{hex}).

The audio codec is enabled by setting the appropriate bit at the CONTROL register (I²C subaddress 6A_{hex}). After an initialization phase of 5 ms, the DSP data registers can be accessed via I²C. The A/D and the D/A converters must be switched on explicitly (00 00_{hex} at I²C subaddress 6c_{hex}). The D/A converters may either accept data from the A/D converters or the output of the DSP, or a mix of both (register 00 06_{hex} and 00 07_{hex} at I²C subaddress 6C_{hex}). Finally, an appropriate output volume (00 10_{hex} at I²C subaddress 6C_{hex}) must be selected.

2.13.5. Power-Down

All analog outputs should be muted and the A/D and the D/A converters must be switched off (register 00 10_{hex} and 00 00_{hex} at I²C subaddress 6C_{hex}). The DSP and the audio codec must be disabled (clear DSP_EN and CODEC_EN bits in the CONTROL register, I²C subaddress 6A_{hex}). By clearing both DC/DC enable flags in the CONTROL register (I²C subaddress 6A_{hex}), the microcontroller can power down the complete system.

3. Controlling

3.1. I²C Interface

Controlling between the MAS 3587F and the external controller is done via an I²C slave interface.

3.1.1. Device Address

The device addresses are 3C/3E_{hex} (device write “DW”) and 3D/3F_{hex} (device read, “DR”) as shown in Table 3–1. The device address pair 3C/3D_{hex} applies if the DVS pin is connected to VSS, the device address pair 3E/3F_{hex} applies if the DVS pin is connected to I2CVDD.

Table 3–1: I²C device address

A7	A6	A5	A4	A3	A2	A1	W/R
0	0	1	1	1	1	DVS	0/1

I²C clock synchronization is used to slow down the interface if required.

3.1.2. I²C Registers and Subaddresses

The interface uses one level of subaddresses. The MAS 3587F interface has 7 subaddresses allocated for the corresponding I²C registers. The registers can be divided into three categories as shown in Table 3–2.

The address 6A_{hex} is used for basic control, i.e. reset and task select. The other addresses are used for data transfer from/to the MAS 3587F.

The I²C registers of the MAS 3587F are 16 bits wide, the MSB is denoted as bit[15]. Transmissions via I²C bus have to take place in 16-bit words (two byte transfers, MSB sent first); thus, for each register access, two 8-bit data words must be sent/received via I²C bus.

Table 3–2: I²C Subaddresses

Sub-address (hex)	I ² C-Register Name	Function
Direct Configuration		
6A	CONTROL	Controller writes to MAS 3587F CONTROL register
76	DCCF	Controller writes to first DC/DC configuration register
77	DCFR	Controller writes to second DC/DC configuration register
DSP Core Access		
68	data_write	Controller writes to MAS 3587F DSP
69	data_read	Controller reads from MAS 3587F DSP
Codec Access		
6C	codec_write	Controller writes to MAS 3587F codec register
6D	codec_read	Controller reads from MAS 3587F codec register

3.1.3. Naming Convention

The description of the various controller commands uses the following formalism:

- **Abbreviations** used in the following descriptions:
 - a** address
 - d** data value
 - n** count value
 - o** offset value
 - r** register number
 - x** don't care
- Memory addresses like D1:89F are always in hexadecimal notation.
- A data value is split into 4-bit nibbles which are numbered beginning with 0 for the least significant nibble.
- Data values in nibbles are always shown in hexadecimal notation.
- A hexadecimal 20-bit number **d** is written, e.g. as **d = 17C63_{hex}**, its five nibbles are **d0 = 3_{hex}**, **d1 = 6_{hex}**, **d2 = C_{hex}**, **d3 = 7_{hex}**, and **d4 = 1_{hex}**.
- **Variables** used in the following descriptions:
 - I²C address:
 - DW 3C/3E_{hex} I²C device write
 - DR 3D/3F_{hex} I²C device read
 - DSP core:
 - data_write 68_{hex} DSP data write
 - data_read 69_{hex} DSP data read
 - Codec:
 - codec_write 6C_{hex} codec write
 - codec_read 6D_{hex} codec read

- **Bus signals**

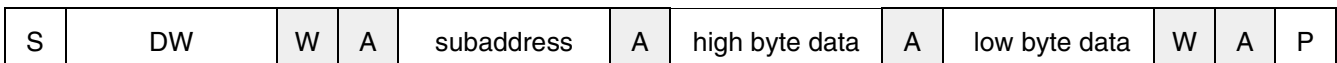
- S Start
- P Stop
- A ACK = Acknowledge
- N NAK = Not acknowledge
- W Wait = I²C clock line is held low while the MAS 3587F is processing the current I²C command

- **Symbols** in the telegram examples

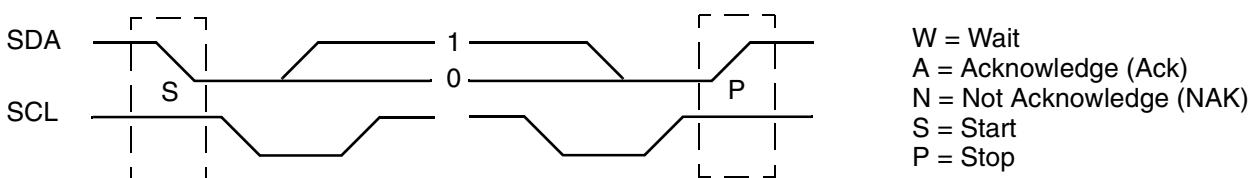
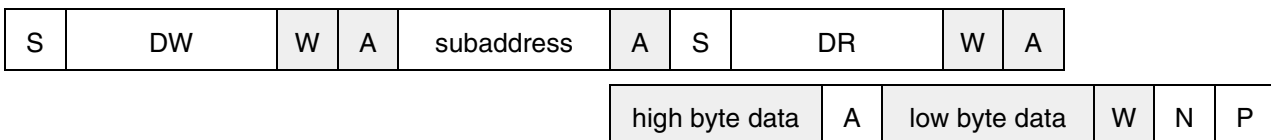
- < Start Condition
 - > Stop
 - dd data bytes
 - xx ignore
- All telegram numbers are hexadecimal, data originating from the MAS 3587F are greyed.
- Example:
- ```
<DW 68 dd dd > write data to DSP
<DW 69 <DR dd dd > read data from DSP
```

Fig. 3-1 shows I<sup>2</sup>C bus protocols for write and read operations of the interface; the read operations require an extra start condition and repetition of the chip address with the device read command (DR). Fields with signals/data originating from the MAS 3587F are marked by a gray background. Note that in some cases the data reading process must be concluded by a NAK condition.

Example: I<sup>2</sup>C write access



Example: I<sup>2</sup>C read access

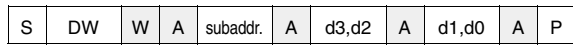


**Fig. 3-1:** Example of an I<sup>2</sup>C bus protocol for the MAS 3587F (MSB first; data must be stable while clock is high)

**3.2. Direct Configuration Registers**

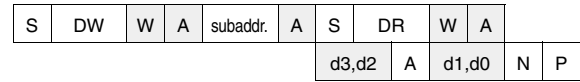
The task selection of the DSP and the DC/DC converters are controlled in the direct configuration registers CONTROL, DCCF, and DCFR.

**3.2.1. Write Direct Configuration Registers**



The write protocol for the direct configuration registers only consists of device address, subaddress and one 16-bit data word.

**3.2.2. Read Direct Configuration Register**



To check the PUP1 and PUP2 power-up flags, it is necessary to read back the content of the direct configuration registers.

**Table 3–3:** Direct Configuration Registers

| I <sup>2</sup> C Sub-address (hex) | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Name                                  |       |                                       |    |       |                       |    |       |               |    |       |               |    |          |          |         |
|------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------|-------|---------------------------------------|----|-------|-----------------------|----|-------|---------------|----|-------|---------------|----|----------|----------|---------|
| 6A                                 | <p><b>Control Register</b> (reset value = 3000<sub>hex</sub>)</p> <p>bit[15:14] Analog supply voltage range</p> <table border="1"> <tr> <td>Code</td> <td>AGNDC</td> <td>recommended for voltage range of AVDD</td> </tr> <tr> <td>00</td> <td>1.1 V</td> <td>2.0 ... 2.4 V (reset)</td> </tr> <tr> <td>01</td> <td>1.3 V</td> <td>2.4 ... 3.0 V</td> </tr> <tr> <td>10</td> <td>1.6 V</td> <td>3.0 ... 3.6 V</td> </tr> <tr> <td>11</td> <td>reserved</td> <td>reserved</td> </tr> </table> <p>Higher voltage ranges permit higher output levels and thus a better signal-to-noise ratio.</p> <p>bit[13] Enable DC/DC 2 (reset = 1)<br/>                     bit[12] Enable DC/DC 1 (reset = 1)</p> <p>Both DC/DC converters are switched on by default with DCEN = high (1).</p> <p>bit[11] Enable and reset audio codec<br/>                     bit[10] Enable and reset DSP core</p> <p>For normal operation (MPEG-decoding and D/A conversion), both, the DSP core and the audio codec have to be enabled after the power-up procedure. The DSP can be left off if an audio signal is routed from the analog inputs to the analog outputs (set bit[15] in codec register 00 0F<sub>hex</sub>). The audio codec can be left off if the DSP uses digital inputs and outputs only.</p> <p>bit[9] Reset codec<br/>                     bit[8] Reset DSP core</p> <p>bit[7] Enable crystal input clock divider of 1.5 (extended range up to 28 MHz)<sup>1)</sup></p> <p>bit[6:0] Reserved, must be set to zero</p> <p><sup>1)</sup> refer to Table 4–2 on page 58</p> | Code                                  | AGNDC | recommended for voltage range of AVDD | 00 | 1.1 V | 2.0 ... 2.4 V (reset) | 01 | 1.3 V | 2.4 ... 3.0 V | 10 | 1.6 V | 3.0 ... 3.6 V | 11 | reserved | reserved | CONTROL |
| Code                               | AGNDC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | recommended for voltage range of AVDD |       |                                       |    |       |                       |    |       |               |    |       |               |    |          |          |         |
| 00                                 | 1.1 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2.0 ... 2.4 V (reset)                 |       |                                       |    |       |                       |    |       |               |    |       |               |    |          |          |         |
| 01                                 | 1.3 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2.4 ... 3.0 V                         |       |                                       |    |       |                       |    |       |               |    |       |               |    |          |          |         |
| 10                                 | 1.6 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 3.0 ... 3.6 V                         |       |                                       |    |       |                       |    |       |               |    |       |               |    |          |          |         |
| 11                                 | reserved                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | reserved                              |       |                                       |    |       |                       |    |       |               |    |       |               |    |          |          |         |

**Table 3–3:** Direct Configuration Registers, continued

| I <sup>2</sup> C Sub-address (hex) | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Name              |                      |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
|------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------|-------------------|---------------------|------|-------|-------|-------|------|-------|-------|-------|------|-------|-------|-------|------|-------|-------|-------|------|-------|-------|-------|------|-------|-------|---------------|------|-------|-------|-------|------|-------|-------|-------|------|-------|-------|-------|------|-------|-------|-------|------|-------|-------|-------|--------------------|-------|-------|-------|--------------------|-------|-------|-------|--------------------|-------|-------|-------|---|----------------------------------|---|--------------------------------------|---|----------------------------------|---|--------------------------------------|------|
| 76                                 | <p><b>DCCF Register</b> (reset = 5050<sub>hex</sub>)</p> <hr/> <p><b>DC/DC Converter 2</b></p> <p>bit[15] PUP2: Voltage monitor 2 flag (readback)</p> <p>bit[14:11] Converter 2 output voltage with respect to VREF</p> <table border="1" data-bbox="438 600 1023 1093"> <thead> <tr> <th>Code</th> <th>Nominal output volt.</th> <th>set level of PUP2</th> <th>reset level of PUP2</th> </tr> </thead> <tbody> <tr><td>1111</td><td>3.5 V</td><td>3.4 V</td><td>3.3 V</td></tr> <tr><td>1110</td><td>3.4 V</td><td>3.3 V</td><td>3.2 V</td></tr> <tr><td>1101</td><td>3.3 V</td><td>3.2 V</td><td>3.1 V</td></tr> <tr><td>1100</td><td>3.2 V</td><td>3.1 V</td><td>3.0 V</td></tr> <tr><td>1011</td><td>3.1 V</td><td>3.0 V</td><td>2.9 V</td></tr> <tr><td>1010</td><td>3.0 V</td><td>2.9 V</td><td>2.8 V (reset)</td></tr> <tr><td>1001</td><td>2.9 V</td><td>2.8 V</td><td>2.7 V</td></tr> <tr><td>1000</td><td>2.8 V</td><td>2.7 V</td><td>2.6 V</td></tr> <tr><td>0111</td><td>2.7 V</td><td>2.6 V</td><td>2.5 V</td></tr> <tr><td>0110</td><td>2.6 V</td><td>2.5 V</td><td>2.4 V</td></tr> <tr><td>0101</td><td>2.5 V</td><td>2.4 V</td><td>2.3 V</td></tr> <tr><td>0100<sup>1)</sup></td><td>2.4 V</td><td>2.3 V</td><td>2.2 V</td></tr> <tr><td>0011<sup>1)</sup></td><td>2.3 V</td><td>2.2 V</td><td>2.1 V</td></tr> <tr><td>0010<sup>1)</sup></td><td>2.2 V</td><td>2.1 V</td><td>2.0 V</td></tr> </tbody> </table> <p>bit[10] Mode</p> <table border="1" data-bbox="438 1137 1038 1200"> <tbody> <tr><td>1</td><td>pulse frequency modulation (PFM)</td></tr> <tr><td>0</td><td>pulse width modulation (PWM) (reset)</td></tr> </tbody> </table> <p>bit[9:8] Reserved, must be set to zero</p> <p>The DC/DC converters are up-converters only. Thus, if the battery voltage is higher than the selected nominal voltage, the output voltage will exceed the nominal voltage.</p> <p><sup>1)</sup> refer to Section 4.6.2. on page 57</p> <p><b>DC/DC Converter 1</b></p> <p>bit[7] PUP1: Voltage monitor 1 flag (readback)</p> <p>bit[6:3] Converter 1 output voltage at VSNS1 with respect to VREF (see bits 14 to 11)</p> <p>bit[2] Mode</p> <table border="1" data-bbox="438 1619 1038 1682"> <tbody> <tr><td>1</td><td>pulse frequency modulation (PFM)</td></tr> <tr><td>0</td><td>pulse width modulation (PWM) (reset)</td></tr> </tbody> </table> <p>bit[1:0] Reserved, must be set to zero</p> <p>Note, that the reference voltage for DC/DC converter 1 is derived from the main reference source supplied via pin AVDD1. Therefore, if this DC/DC converter is used, its output must be connected to the analog supply.</p> <p>The DC/DC converters are up-converters only. Thus, if the battery voltage is higher than the selected nominal voltage, the output voltage will exceed the nominal voltage.</p> | Code              | Nominal output volt. | set level of PUP2 | reset level of PUP2 | 1111 | 3.5 V | 3.4 V | 3.3 V | 1110 | 3.4 V | 3.3 V | 3.2 V | 1101 | 3.3 V | 3.2 V | 3.1 V | 1100 | 3.2 V | 3.1 V | 3.0 V | 1011 | 3.1 V | 3.0 V | 2.9 V | 1010 | 3.0 V | 2.9 V | 2.8 V (reset) | 1001 | 2.9 V | 2.8 V | 2.7 V | 1000 | 2.8 V | 2.7 V | 2.6 V | 0111 | 2.7 V | 2.6 V | 2.5 V | 0110 | 2.6 V | 2.5 V | 2.4 V | 0101 | 2.5 V | 2.4 V | 2.3 V | 0100 <sup>1)</sup> | 2.4 V | 2.3 V | 2.2 V | 0011 <sup>1)</sup> | 2.3 V | 2.2 V | 2.1 V | 0010 <sup>1)</sup> | 2.2 V | 2.1 V | 2.0 V | 1 | pulse frequency modulation (PFM) | 0 | pulse width modulation (PWM) (reset) | 1 | pulse frequency modulation (PFM) | 0 | pulse width modulation (PWM) (reset) | DCCF |
| Code                               | Nominal output volt.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | set level of PUP2 | reset level of PUP2  |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
| 1111                               | 3.5 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 3.4 V             | 3.3 V                |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
| 1110                               | 3.4 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 3.3 V             | 3.2 V                |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
| 1101                               | 3.3 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 3.2 V             | 3.1 V                |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
| 1100                               | 3.2 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 3.1 V             | 3.0 V                |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
| 1011                               | 3.1 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 3.0 V             | 2.9 V                |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
| 1010                               | 3.0 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2.9 V             | 2.8 V (reset)        |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
| 1001                               | 2.9 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2.8 V             | 2.7 V                |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
| 1000                               | 2.8 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2.7 V             | 2.6 V                |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
| 0111                               | 2.7 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2.6 V             | 2.5 V                |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
| 0110                               | 2.6 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2.5 V             | 2.4 V                |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
| 0101                               | 2.5 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2.4 V             | 2.3 V                |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
| 0100 <sup>1)</sup>                 | 2.4 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2.3 V             | 2.2 V                |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
| 0011 <sup>1)</sup>                 | 2.3 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2.2 V             | 2.1 V                |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
| 0010 <sup>1)</sup>                 | 2.2 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2.1 V             | 2.0 V                |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
| 1                                  | pulse frequency modulation (PFM)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                   |                      |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
| 0                                  | pulse width modulation (PWM) (reset)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                   |                      |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
| 1                                  | pulse frequency modulation (PFM)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                   |                      |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |
| 0                                  | pulse width modulation (PWM) (reset)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                   |                      |                   |                     |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |               |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |      |       |       |       |                    |       |       |       |                    |       |       |       |                    |       |       |       |   |                                  |   |                                      |   |                                  |   |                                      |      |

**Table 3–3:** Direct Configuration Registers, continued

| I <sup>2</sup> C Sub-address (hex) | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Name    |                   |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
|------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|-------------------|---------|------|-----|-------|------|------|-------|-----|--|--|------|------|-------|------|-----|-------|------|-----------------------------------------|--|------------|--------|---------|------------|------|-------|-------|-----------|------|-------|-------|-----------|------|-------|-------|-----------|------|-------|-------|-----------|------|-------|-------|-----------|------|-------|-------|-----------|------|-------|-------|-----------|------|-------|-------|-------------------|------|-------|-------|-----------|------|-------|-------|-----------|------|-------|-------|-----------|------|-------|-------|-----------|------|-------|-------|-----------|------|-------|-------|-----------|------|-------|-------|-----------|------|-------|-------|-----------|------|
| 77                                 | <p><b>DCFR Register</b> (reset = 00<sub>hex</sub>)</p> <p><b>Battery Voltage Monitor</b></p> <p>bit[15] Comparison result (readback)<br/>           1 input voltage at pin VBAT above defined threshold<br/>           0 input voltage at pin VBAT below defined threshold</p> <p>bit[14] Number of battery cells<br/>           0 1 cell (range 0.8...1.5 V) (reset)<br/>           1 2 cells (range 1.6...3.0 V)</p> <p>bit[13:10] Voltage threshold level</p> <table border="1" data-bbox="438 750 821 974"> <thead> <tr> <th></th> <th>1 cell</th> <th>2 cells</th> </tr> </thead> <tbody> <tr> <td>1111</td> <td>1.5</td> <td>3.0 V</td> </tr> <tr> <td>1110</td> <td>1.45</td> <td>2.9 V</td> </tr> <tr> <td>...</td> <td></td> <td></td> </tr> <tr> <td>0010</td> <td>0.85</td> <td>1.7 V</td> </tr> <tr> <td>0001</td> <td>0.8</td> <td>1.6 V</td> </tr> <tr> <td>0000</td> <td colspan="2">battery voltage supervision off (reset)</td> </tr> </tbody> </table> <p>bit[9:8] Reserved, must be set to 0</p> <p>The result is stable 1 ms after enabling. The setup time for switching between two thresholds is negligibly small.</p> <p>For power management reasons, the battery voltage monitor should be switched off by setting bit[13:10] to zero when the measurement is completed.</p> <p><b>DC/DC Converter Frequency Control (PWM)</b></p> <p>bit[7:4] Reserved, must be set to 0</p> <p>bit[3:0] Frequency of DC/DC converter</p> <table border="1" data-bbox="438 1332 1037 1848"> <thead> <tr> <th>Reference:</th> <th>24.576</th> <th>22.5792</th> <th>18.432 MHz</th> </tr> </thead> <tbody> <tr><td>0111</td><td>315.1</td><td>289.5</td><td>297.3 kHz</td></tr> <tr><td>0110</td><td>323.4</td><td>297.1</td><td>307.2 kHz</td></tr> <tr><td>0101</td><td>332.1</td><td>305.1</td><td>317.8 kHz</td></tr> <tr><td>0100</td><td>341.3</td><td>313.6</td><td>329.1 kHz</td></tr> <tr><td>0011</td><td>351.1</td><td>322.6</td><td>341.3 kHz</td></tr> <tr><td>0010</td><td>361.4</td><td>332.0</td><td>354.5 kHz</td></tr> <tr><td>0001</td><td>372.4</td><td>342.1</td><td>368.6 kHz</td></tr> <tr><td>0000</td><td>384.0</td><td>352.8</td><td>384.0 kHz (reset)</td></tr> <tr><td>1111</td><td>396.4</td><td>364.2</td><td>400.7 kHz</td></tr> <tr><td>1110</td><td>409.6</td><td>376.3</td><td>418.9 kHz</td></tr> <tr><td>1101</td><td>423.7</td><td>389.3</td><td>438.9 kHz</td></tr> <tr><td>1100</td><td>438.9</td><td>403.2</td><td>460.8 kHz</td></tr> <tr><td>1011</td><td>455.1</td><td>418.1</td><td>485.1 kHz</td></tr> <tr><td>1010</td><td>472.6</td><td>434.2</td><td>512.0 kHz</td></tr> <tr><td>1001</td><td>491.5</td><td>451.6</td><td>542.1 kHz</td></tr> <tr><td>1000</td><td>512.0</td><td>470.4</td><td>576.0 kHz</td></tr> </tbody> </table> <p>If the audio codec is not enabled (bit 11 of the CONTROL register at I<sup>2</sup>C-sub-address 6A<sub>hex</sub> is zero), the clock for the DC/DC converters is directly derived from the crystal frequency (nominal 18.432 MHz). Otherwise, the synthesizer clock is used as the reference (please refer to the respective column in Table 2–1 on page 11).</p> |         | 1 cell            | 2 cells | 1111 | 1.5 | 3.0 V | 1110 | 1.45 | 2.9 V | ... |  |  | 0010 | 0.85 | 1.7 V | 0001 | 0.8 | 1.6 V | 0000 | battery voltage supervision off (reset) |  | Reference: | 24.576 | 22.5792 | 18.432 MHz | 0111 | 315.1 | 289.5 | 297.3 kHz | 0110 | 323.4 | 297.1 | 307.2 kHz | 0101 | 332.1 | 305.1 | 317.8 kHz | 0100 | 341.3 | 313.6 | 329.1 kHz | 0011 | 351.1 | 322.6 | 341.3 kHz | 0010 | 361.4 | 332.0 | 354.5 kHz | 0001 | 372.4 | 342.1 | 368.6 kHz | 0000 | 384.0 | 352.8 | 384.0 kHz (reset) | 1111 | 396.4 | 364.2 | 400.7 kHz | 1110 | 409.6 | 376.3 | 418.9 kHz | 1101 | 423.7 | 389.3 | 438.9 kHz | 1100 | 438.9 | 403.2 | 460.8 kHz | 1011 | 455.1 | 418.1 | 485.1 kHz | 1010 | 472.6 | 434.2 | 512.0 kHz | 1001 | 491.5 | 451.6 | 542.1 kHz | 1000 | 512.0 | 470.4 | 576.0 kHz | DCFR |
|                                    | 1 cell                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2 cells |                   |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 1111                               | 1.5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 3.0 V   |                   |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 1110                               | 1.45                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 2.9 V   |                   |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| ...                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |         |                   |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 0010                               | 0.85                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 1.7 V   |                   |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 0001                               | 0.8                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1.6 V   |                   |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 0000                               | battery voltage supervision off (reset)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |         |                   |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| Reference:                         | 24.576                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 22.5792 | 18.432 MHz        |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 0111                               | 315.1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 289.5   | 297.3 kHz         |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 0110                               | 323.4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 297.1   | 307.2 kHz         |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 0101                               | 332.1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 305.1   | 317.8 kHz         |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 0100                               | 341.3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 313.6   | 329.1 kHz         |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 0011                               | 351.1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 322.6   | 341.3 kHz         |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 0010                               | 361.4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 332.0   | 354.5 kHz         |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 0001                               | 372.4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 342.1   | 368.6 kHz         |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 0000                               | 384.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 352.8   | 384.0 kHz (reset) |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 1111                               | 396.4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 364.2   | 400.7 kHz         |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 1110                               | 409.6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 376.3   | 418.9 kHz         |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 1101                               | 423.7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 389.3   | 438.9 kHz         |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 1100                               | 438.9                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 403.2   | 460.8 kHz         |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 1011                               | 455.1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 418.1   | 485.1 kHz         |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 1010                               | 472.6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 434.2   | 512.0 kHz         |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 1001                               | 491.5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 451.6   | 542.1 kHz         |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |
| 1000                               | 512.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 470.4   | 576.0 kHz         |         |      |     |       |      |      |       |     |  |  |      |      |       |      |     |       |      |                                         |  |            |        |         |            |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |                   |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |       |       |           |      |

**3.3. DSP Core**

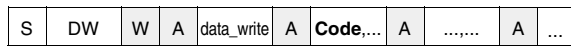
**3.3.1. Access Protocol**

The I<sup>2</sup>C data register is used to communicate with the internal firmware of the MAS 3506D. It is readable (subaddress “data\_read”) and writable (subaddress “data\_write”) and also has a length of 16 bits. The data transfer is done with the most significant bit (m) first.

**Table 3–4:** Data register bit assignment

|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 15 | 14 | 13 | 12 | 11 | 10 | 09 | 08 | 07 | 06 | 05 | 04 | 03 | 02 | 01 | 00 |
| m  |    |    |    |    |    |    |    |    |    |    |    |    |    |    | l  |

A special command language is used that allows the controller to access the DSP-registers and RAM-cells and thus monitor internal states, set the parameters for the DSP-firmware, control the hardware, and even provide a download of alternative software modules. The DSP-commands consist of a “Code” which is sent to I<sup>2</sup>C-data register together with additional parameters.



**Fig. 3–2:** General core access protocol

Table 3–5 on page 24 gives an overview over the different commands which the DSP Core receives via the I<sup>2</sup>C data register. The “Code” is always the first data nibble transmitted after the “data\_write” subaddress byte. A second auxiliary code nibble is used for the short memory (16-bit) access commands.

The MAS 3587F firmware scans the I<sup>2</sup>C interface periodically and checks for pending or new commands.

The commands are then executed by the DSP during its normal operation without any loss or interruption of the incoming data or outgoing audio data stream. However, due to some time critical firmware parts, a certain latency time for the response has to be expected at the locations marked with a “W” (= wait). The theoretical worst case response time does not exceed 4 ms. However, the typical response time is less than 0.5 ms.

Due to the 16-bit width of the I<sup>2</sup>C data register, all actions transmit telegrams with multiples of 16 data bits.

**3.3.2. Data Formats**

The internal data word size is 20 bits. All RAM-addresses can be accessed in a 20-bit mode via I<sup>2</sup>C-bus. Because of the 16-bit width of the I<sup>2</sup>C-data register the full transfer of all 20 bits requires two 16-bit I<sup>2</sup>C-words. Some commands only access the lower 16 bits of a cell. For fast access of internal DSP-states the processor core also has an address space of 256 data registers.

The internal data format is a 20 bit two’s complement denoted “r”. If in some cases a fixed point notation “v” is necessary. The conversion between the two forms of notation is done as follows:

$$r = v * 524288.0 + 0.5; (-1.0 \leq v < 1.0)$$

$$v = r / 524288.0; (-524288 < r < 524287)$$

**Table 3–5:** Basic controller command codes

| Code (hex) | Command               | Function                                                                                                   |
|------------|-----------------------|------------------------------------------------------------------------------------------------------------|
| 0...3      | Run                   | Start execution of an internal program. <i>Run</i> with start address 0 means freeze the operating system. |
| 5          | Read Ancillary Data   | The controller reads a block of MPEG Ancillary Data from the MAS 3587F                                     |
| 6          | Fast Program Download | The controller downloads custom software via the PIO interface                                             |
| 7          | Read IC Version       | The controller reads the version information of the IC                                                     |
| A          | Read from Register    | The controller reads an internal register of the MAS 3587F                                                 |
| B          | Write to Register     | The controller writes an internal register of the MAS 3587F                                                |
| C          | Read D0 Memory        | The controller reads a block of the DSP memory                                                             |
| D          | Read D1 Memory        | The controller reads a block of the DSP memory                                                             |
| E          | Write D0 Memory       | The controller writes a block of the DSP memory                                                            |
| F          | Write D1 Memory       | The controller writes a block of the DSP memory                                                            |

**3.3.2.1. Run and Freeze (Codes 0<sub>hex</sub> to 3<sub>hex</sub>)**

|   |    |   |   |            |   |       |   |       |   |   |   |
|---|----|---|---|------------|---|-------|---|-------|---|---|---|
| S | DW | W | A | data_write | A | a3,a2 | A | a1,a0 | W | A | P |
|---|----|---|---|------------|---|-------|---|-------|---|---|---|

The *Run* command causes the start of a program part at address **a** = (a3,a2,a1,a0). Since nibble a3 is also the command code (see Table 3–5), it is restricted to values between 0 and 3. This command is used to start alternate code or downloaded code from a RAM-area that has been configured as program RAM.

If the start address is  $1000_{hex} \leq a < 3FFF_{hex}$  and the respective RAM area has been configured as program RAM (see Table 3–7 on page 28), the MAS 3587F continues execution with a custom program already downloaded to this area.

Example 1: Start program execution at address 345<sub>hex</sub>:

```
<DW 68 03 45>
```

Example 2: Start execution of a downloaded code at address 1000<sub>hex</sub>:

```
<DW 68 10 00>
```

*Freeze* is a special run command with start address 0. It suspends all normal program execution. The operating system will enter an idle loop so that all registers and memory cells can be watched. This state is useful for operations like downloading code or contents of memory cells because the internal program cannot overwrite these values. This freezing will be required if alternative software is downloaded into the internal RAM of the MAS 3587F.

Freeze has the following I<sup>2</sup>C protocol:

```
<DW 68 00 00>
```

The entry point of the default software will be accessed automatically after a reset, thus issuing a *Run* or *Freeze* command is only necessary for starting downloaded software or special program modules which are not part of the standard set.



**3.3.2.2. Read Register (Code A<sub>hex</sub>)**

1) send command

|   |    |   |   |            |   |      |   |      |   |   |   |
|---|----|---|---|------------|---|------|---|------|---|---|---|
| S | DW | W | A | data_write | A | A,r1 | A | r0,0 | W | A | P |
|---|----|---|---|------------|---|------|---|------|---|---|---|

2) get register value

|   |     |   |      |           |   |       |    |       |   |   |   |
|---|-----|---|------|-----------|---|-------|----|-------|---|---|---|
| S | DW  | W | A    | data_read | A | S     | DR | W     | A |   |   |
|   | x,x | A | x,d4 | W         | A | d3,d2 | A  | d1,d0 | W | N | P |

The MAS 3587F has an address space of 256 DSP-registers. Some of the registers ( $r = r1,r0$  in the figure above) are direct control inputs for various hardware blocks, others control the internal program flow. In Table 3–7, the registers of interest are described in detail. In contrast to memory cells, registers cannot be accessed as a block but must always be addressed individually.

Example:

Read the content of register C8<sub>hex</sub>:

```
<DW 68 ac 80> define register
<DW 69 <DR xx xd dd dd > and read
```

**3.3.2.3. Write Register (Code B<sub>hex</sub>)**

|   |    |   |   |            |   |       |   |       |   |   |   |
|---|----|---|---|------------|---|-------|---|-------|---|---|---|
| S | DW | W | A | data_write | A | B,r1  | A | r0,d4 | W | A |   |
|   |    |   |   |            |   | d3,d2 | A | d1,d0 | W | A | P |

The controller writes the 20-bit value ( $d = d4,d3,d2,d1,d0$ ) into the MAS 3587F register ( $r = r1,r0$ ). A list of registers needed for control purposes is given in Table 3–7.

Example: Writing the value 81234<sub>hex</sub> into the register with the number AA<sub>hex</sub>:

```
<DW 68 ba a8 12 34>
```

**3.3.2.4. Read Memory (Codes C<sub>hex</sub> and D<sub>hex</sub>)**

The MAS 3587F has 2 memory areas of 2048 words denoted D0 and D1 . The memory areas D0 and D1 can be written by using the codes C<sub>hex</sub> and D<sub>hex</sub>, respectively.

1) send command (Read D0)

|   |    |   |   |            |   |       |   |       |   |   |   |
|---|----|---|---|------------|---|-------|---|-------|---|---|---|
| S | DW | W | A | data_write | A | C,0   | A | 0,0   | W | A |   |
|   |    |   |   |            |   | n3,n2 | A | n1,n0 | W | A |   |
|   |    |   |   |            |   | a3,a2 | A | a1,a0 | W | A | P |

2) get register value

|   |     |   |      |           |   |                                  |    |       |   |   |   |
|---|-----|---|------|-----------|---|----------------------------------|----|-------|---|---|---|
| S | DW  | W | A    | data_read | A | S                                | DR | W     | A |   |   |
|   | x,x | A | x,d4 | W         | A | d3,d2                            | A  | d1,d0 | W | A |   |
|   |     |   |      |           |   | ....repeat for n data values.... |    |       |   |   |   |
|   | x,x | A | x,d4 | W         | A | d3,d2                            | A  | d1,d0 | W | N | P |

The *Read D0 Memory* command gives the controller access to all 20 bits of the D0/D1 memory cells. The telegram to read 3 words starting at location D1:100 is

```
<DW 68 d0 00 00 03 01 00>
<DW 69 <DR xx xd dd dd
xx xd dd dd xx xd dd dd >
```

**3.3.2.5. Short Read Memory (Codes C4<sub>hex</sub> and D4<sub>hex</sub>)**

Because most cells in the user interface are only 16 bits wide, it is faster and more convenient to access the memory locations with a special 16 bit mode for reading:

1) send command (e.g. Short Read D0)

|   |    |   |   |            |   |       |   |       |   |   |   |
|---|----|---|---|------------|---|-------|---|-------|---|---|---|
| S | DW | W | A | data_write | A | C,4   | A | 0,0   | W | A |   |
|   |    |   |   |            |   | n3,n2 | A | n1,n0 | W | A |   |
|   |    |   |   |            |   | a3,a2 | A | a1,a0 | W | A | P |

2) get register value

|   |    |   |   |           |   |                                  |    |       |   |   |   |
|---|----|---|---|-----------|---|----------------------------------|----|-------|---|---|---|
| S | DW | W | A | data_read | A | S                                | DR | W     | A |   |   |
|   |    |   |   |           |   | d3,d2                            | A  | d1,d0 | W | A |   |
|   |    |   |   |           |   | ....repeat for n data values.... |    |       |   |   |   |
|   |    |   |   |           |   | d3,d2                            | A  | d1,d0 | W | N | P |

This command is similar to the normal 20 bit read command and uses the same command code C<sub>hex</sub> and D<sub>hex</sub> for D0 and D1-memory, respectively, however it is followed by a 4<sub>hex</sub> rather than a 0<sub>hex</sub>.

Example: Read 16 bits of D1:123 has the following I<sup>2</sup>C protocol:

```
<DW 68 d4 00 read 16 bits from D1
00 01 1 word to be read
01 23 start address
<DW 69 DR start reading
dd dd > and read
```

**3.3.2.6. Write Memory (Codes E<sub>hex</sub> and F<sub>hex</sub>)**

The memory areas D0 and D1 can be written by using the codes E<sub>hex</sub> and F<sub>hex</sub>, respectively.

|                                  |    |      |   |            |       |       |       |       |   |   |
|----------------------------------|----|------|---|------------|-------|-------|-------|-------|---|---|
| S                                | DW | W    | A | data_write | A     | E,0   | A     | 0,0   | W | A |
|                                  |    |      |   |            |       | n3,n2 | A     | n1,n0 | W | A |
|                                  |    |      |   |            |       | a3,a2 | A     | a1,a0 | W | A |
| x,x                              | A  | x,d4 | W | A          | d3,d2 | A     | d1,d0 | W     | A |   |
| ....repeat for n data values.... |    |      |   |            |       |       |       |       |   |   |
| x,x                              | A  | x,d4 | W | A          | d3,d2 | A     | d1,d0 | W     | A | P |

With the *Write D0/D1 Memory* command n 20-bit memory cells in D0 can be initialized with new data.

Example: Write 80234<sub>hex</sub> to D1:456 has the following I<sup>2</sup>C protocol:

```
<3a 68 f0 00 write D1 memory
 00 01 1 word to write
 04 56 start address
 00 08 value = 80234hex
 02 34 >
```

**3.3.2.7. Short Write Memory (Codes E4<sub>hex</sub> and F4<sub>hex</sub>)**

|                                  |    |   |   |            |   |       |   |       |   |   |   |
|----------------------------------|----|---|---|------------|---|-------|---|-------|---|---|---|
| S                                | DW | W | A | data_write | A | E,4   | A | 0,0   | W | A |   |
|                                  |    |   |   |            |   | n3,n2 | A | n1,n0 | W | A |   |
|                                  |    |   |   |            |   | a3,a2 | A | a1,a0 | W | A |   |
|                                  |    |   |   |            |   | d3,d2 | A | d1,d0 | W | A |   |
| ....repeat for n data values.... |    |   |   |            |   |       |   |       |   |   |   |
|                                  |    |   |   |            |   | d3,d2 | A | d1,d0 | W | A | P |

For faster access only the lower 16 bits of each memory cell are written. The 4 MSBs of the cell are cleared. The command uses the same codes E<sub>hex</sub> and F<sub>hex</sub> for D0/D1 as for the 20-bit command but followed by a 4 rather than a 0.

**3.3.2.8. Clear SYNC Signal (Code 5<sub>hex</sub>)**

|   |    |   |   |            |   |     |   |     |   |   |   |
|---|----|---|---|------------|---|-----|---|-----|---|---|---|
| S | DW | W | A | data_write | A | 5,0 | A | 0,0 | W | A | P |
|---|----|---|---|------------|---|-----|---|-----|---|---|---|

After a successful decoding of an MPEG frame the signal at pin SYNC rises and thus generates an interrupt event for the microcontroller. Issuing this command lets the signal at pin SYNC return to '0'.

**3.3.2.9. Default Read**

The *Default Read* command is the fastest way to get information from the MAS 3587F. Executing the *Default Read* in a polling loop can be used to detect a special state during decoding.

|   |    |   |   |           |   |   |       |   |       |   |   |   |  |  |  |
|---|----|---|---|-----------|---|---|-------|---|-------|---|---|---|--|--|--|
| S | DW | W | A | data_read | A | S | DR    | W | A     |   |   |   |  |  |  |
|   |    |   |   |           |   |   | d3,d2 | A | d1,d0 | W | N | P |  |  |  |

The *Default Read* command immediately returns the lower 16 bit content of a specific RAM location as defined by the pointer D0:FFB. The pointer must be loaded before the first *Default Read* action occurs. If the MSB of the pointer is set, it points to a memory location in D1 rather than to one in D0.

Example: For watching D1:123 the pointer D0:FFB must be loaded with 8123<sub>hex</sub>:

```
<DW 68 e0 00 write to D0 memory
 00 01 1 word to write
 0f fb start address ffb
 00 08 value = 8...
 01 23 > ...0123hex
```

Now the *Default Read* commands can be issued as often as desired:

```
<DW 69 <DR Default Read command
 dd dd > 16 bit content of the
 address as defined by the
 pointer
<DW 69 <DR dd dd > ... and do it again
```

**3.3.2.10. Fast Program Download (Code 6<sub>hex</sub>)**

|   |    |   |   |            |   |       |   |       |   |   |   |  |  |  |  |
|---|----|---|---|------------|---|-------|---|-------|---|---|---|--|--|--|--|
| S | DW | W | A | data_write | A | 6,n2  | A | n1,n0 | W | A |   |  |  |  |  |
|   |    |   |   |            |   | a3,a2 | A | a1,a0 | W | A | P |  |  |  |  |

The *Fast Program Download* command introduces a data transfer via the parallel port. n = n2,n1,n0 denotes the number of 20-bit data words to be transferred, a = a3,a2,a1,a0 gives the start address. The data must be organized in two times five nibbles to get two words of 20-bit length. If the number n of 20-bit data words is odd, the very last word has to be padded with one additional nibble.

The download must be initiated in the following order:

- Issue *Freeze* command
- Stop all DMA-transfers
- Issue *Fast Program Download* command
- Download code via PIO-interface
- Switch appropriate memory area to act as program RAM (register  $ed_{hex}$ )
- Issue a *Run* command to start program execution at entry point of downloaded code

Example for *Fast Program Download* command:  
 Download 5 words starting at D0:800,  
 then download 4 words starting at D1:200:

```
<DW 68 00 00 00> Freeze

<DW 68 b3 b0 03 18> Stop all internal transfers
<DW 68 b4 30 03 00>
<DW 68 b4 b0 00 00>
<DW 68 b5 30 03 18>
<DW 68 b6 b0 00 00>
<DW 68 bb b0 03 18>
<DW 68 bc 30 03 00>
<DW 68 b0 60 00 00>

<DW 68 60 05 initiate download of 5 words
 08 00> start at address D0:800
```

Now transfer 5 20-bit words via the parallel PIO-port:

```
d4, d3 d2, d1 d0, d4 d3, d2 d1, d0
d4, d3 d2, d1 d0, d4 d3, d2 d1, d0
d4, d3 d2, d1 d0, x

<DW 68 60 05 initiate download of 4 words
 82 00> start at address D1:200
```

Now transfer 4 20-bit words via the parallel PIO-port:

```
d4, d3 d2, d1 d0, d4 d3, d2 d1, d0
d4, d3 d2, d1 d0, d4 d3, d2 d1, d0

<DW 68 b6 bc 00 00> switch the memory area
 D0:800 ... D0:FFF from
 data to program usage

<DW 68 10 0a> start program execution at
 address D0:100a
```

**3.3.2.11. Serial Program Download**

Program downloads may also be performed via the I<sup>2</sup>C-interface by using the *Write D0/D1 Memory* commands. A similar command sequence as in the Fast Program Download (*Freeze*, stop transfers...) applies.

**3.3.2.12. Read IC Version (Code 7<sub>hex</sub>)**

1) send command

|   |    |   |   |            |   |     |   |     |   |   |   |
|---|----|---|---|------------|---|-----|---|-----|---|---|---|
| S | DW | W | A | data_write | A | 7,0 | A | 0,0 | W | A | P |
|---|----|---|---|------------|---|-----|---|-----|---|---|---|

2) get version information

|   |    |   |   |           |   |       |    |       |   |   |   |
|---|----|---|---|-----------|---|-------|----|-------|---|---|---|
| S | DW | W | A | data_read | A | S     | DR | W     | A |   |   |
|   |    |   |   |           |   | n3,n2 | A  | n1,n0 | W | A |   |
|   |    |   |   |           |   | d3,d2 | A  | d1,d0 | W | N | P |

With this command the version of the IC is read in two 16 bit words. The first word **n** = n3,n2,n1,n0 contains the IC's major number (one nibble for each digit). The second word (**d** = d3,d2,d1,d0) returns the version as shown in Table 3–6.

**Table 3–6:** Second word of version information

| Bit   | Nibble | Content                                                                                    |
|-------|--------|--------------------------------------------------------------------------------------------|
| 15:12 | d3     | IC family derivate                                                                         |
| 11:8  | d2     | Coded character of order version (add 41 <sub>hex</sub> to the content of d2 to get ASCII) |
| 7:0   | d1,d0  | Digit of order version                                                                     |

Example:

Read the version information for MAS 3587F, derivate 0, order version B2:

```
<DW 68 70 00 send version command
<DW 69 <DR and read
35 87 MAS3587
01 02 > derivate 0, version B2
```

**3.3.3. List of DSP Registers**

Table 3–7 lists the registers used in the standard firmware (MPEG) and for the download option (Download).

**Note:** Registers not given in the tables must not be written.

**3.3.4. List of DSP Memory Cells**

Among the user interface control memory cells there are some which have a global meaning and some which control application specific parts of the DSP core. In the tables below this is reflected by the mode keywords All, Encoder and Decoder. The operation mode is chosen in the AppSelect cell.

**3.3.4.1. Application Selection and Application Running**

The AppSelect cell is a global user interface configuration cell which has to be written in order to start a specific application. The AppRunning cell is a global user interface status cell, which indicates, which application loop is actually running.

Following steps have to be performed to switch between applications:

1. Write “0” to AppSelect
2. Check AppRunning for “0”
3. For encoder (version B2 only):
  - write 98<sub>hex</sub> to register a3<sub>hex</sub>
  - write FFFFF<sub>hex</sub> to register 94<sub>hex</sub>
  - write 0 to D1:000
  - write 90<sub>hex</sub> to register A3<sub>hex</sub>
4. Apply necessary/wanted control settings (D0: 7F0..7FF)
5. Write value to AppSelect according to Table 3–8 (determines start time of Application program)

**Table 3–7:** DSP Register Table

| Address (hex) | R/W | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Mode            | Default (hex) | Name             |
|---------------|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|---------------|------------------|
| 6B            | R/W | <p><b>Configuration of Variable RAM Areas</b></p> <p>Affected RAM area</p> <p>bit[19] D0:800 ... D0:BFF</p> <p>bit[18] D0:c00 ... D0:FFF</p> <p>bit[17] D1:800 ... D1:BFF</p> <p>bit[16] D1:c00 ... D1:FFF</p> <p>This register is used to switch four RAM areas from data to program usage and thus enabling the DSP’s program counter to access downloaded program code stored at these locations. For normal operation (firmware in ROM) this register must be kept to zero.</p> <p>For details of program code download please refer to Section 3.3.2.10. on page 26</p> | <b>Download</b> | 0000          | PSelect_Shadow   |
| 56            | R   | <p><b>S/PDIF<sup>1)</sup> Input Channel Status Bits</b></p> <p>bit[15:0] channel status bits of incoming signal.</p> <p><sup>1)</sup> IEC 958 Amendment1, “Digital Audio Interface”</p>                                                                                                                                                                                                                                                                                                                                                                                      | <b>MPEG</b>     | 0000          | SPIChannelStatus |

**3.3.4.2. Application Specific Control**

The configuration of the MPEG encoder and decoder firmware is done via the control memory cells described in Table 3–9. The changes applied to any of the control memory cells have to be validated by setting bit[0] of memory cell Main I/O Control except when the application is started by writing the AppSelect memory cell. The validate bit will be reset automatically after the changes have been taken over by the DSP.

The status memory cells are used to read the encoder/decoder status and to get additional MPEG bitstream information.

**Note:** Memory cells not given in the tables must not be written.

**Table 3–8:** D0 Memory Cells: Mode Selection

| Memory Address (hex) | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Mode | Name       |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------------|
| D0:7F6               | <p><b>Application Selection</b></p> <p>AppSelect is used for selecting an application. This is done by setting the appropriate bit to one. It is principally allowed to set more than one bit to one, e.g. setting AppSelect to 0C<sub>hex</sub> will select all MPEG audio decoders. The auto-detection feature will automatically detect the Layer 2 or Layer 3 data. When bit[0]/bit[1] are asserted, the DSP begins to loop inside the OS loop/Top Level loop respectively.</p> <p>It is recommended to perform the necessary settings for the firmware before the application is started by writing this memory cell.</p> <p>bit[19:7] Reserved, must be set to zero</p> <p>bit[5:4] Reserved, must be set to zero</p> <p>bit[6] MPEG Layer 3 Encoder</p> <p>bit[3] MPEG Layer 3 Decoder</p> <p>bit[2] MPEG Layer 2 Decoder</p> <p>bit[1:0] Reserved, must be set to zero</p> | All  | AppSelect  |
| D0:7F7               | <p><b>Application Running</b></p> <p>The AppRunning cell is a global user interface status cell, that indicates which application loop is actually running. After writing AppSelect, it has to be checked whether the appropriate bit(s) in the AppRunning cell is set, prior to any changes in the configuration registers or memory cells.</p> <p>bit[19:7] Reserved, must be set to zero</p> <p>bit[5:4] Reserved, must be set to zero</p> <p>bit[6] MPEG Layer 3 Encoder</p> <p>bit[3] MPEG Layer 3 Decoder</p> <p>bit[2] MPEG Layer 2 Decoder</p> <p>bit[1:0] Reserved, must be set to zero</p>                                                                                                                                                                                                                                                                               | All  | AppRunning |

**Table 3–9:** D0 Control Memory Cells

| Memory Address (hex)                | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Mode   | Name                     |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
|-------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|--------------------------|-----|---|-----|---|-----|---|-----|---|-------------|-----------------------|-----|---|-----|---------------------------|-------------------------------------|--------|--------|------------|------|-------|----|----|----|----|----|----|----|----------|--|---|--------|-----------|--------|-----------|-----------------------|---|------------------------|----|----------|------------|--------------|----|----------|----|----------------|---|----------------------------|-----------|---------------------------|-----------|---------------------------------------|---|-----------------------------------|---|----------------------|-----------|---------------------------|------------|------|----|----------|----|----------|----|------------|----------------|----------------|
| D0:7F0 <sup>1)</sup>                | <p><b>Encoder Control</b> (reset = A0264<sub>hex</sub>)</p> <p>EncoderControl is used for selecting the quality level, sample frequency and other options for encoding.</p> <p>bit[19:17] Quality Setting (see Section 3.3.7.1. on page 39)</p> <table border="0"> <tr><td>000</td><td>0 lowest bitrate/quality</td></tr> <tr><td>001</td><td>1</td></tr> <tr><td>010</td><td>2</td></tr> <tr><td>011</td><td>3</td></tr> <tr><td>100</td><td>4</td></tr> <tr><td>101 (reset)</td><td>5 recommended quality</td></tr> <tr><td>110</td><td>6</td></tr> <tr><td>111</td><td>7 highest bitrate/quality</td></tr> </table> <p>bit[16:12] Reserved, must be set to zero</p> <table border="0"> <tr> <td>bit[11:10] Sampling Frequency (kHz)</td> <td>MPEG 1</td> <td>MPEG 2</td> </tr> <tr> <td>00 (reset)</td> <td>44.1</td> <td>22.05</td> </tr> <tr> <td>01</td> <td>48</td> <td>24</td> </tr> <tr> <td>10</td> <td>32</td> <td>16</td> </tr> <tr> <td>11</td> <td>reserved</td> <td></td> </tr> </table> <p>bit[9] MPEG Selection</p> <table border="0"> <tr><td>0</td><td>MPEG 2</td></tr> <tr><td>1 (reset)</td><td>MPEG 1</td></tr> </table> <p>Note that the clock frequency (bit[3] in D0:7F1) must be set accordingly.</p> <p>Bit[11:9] are only evaluated for SDI audio input (selected in D0:7F1<sup>1)</sup>, bit[9:8]). In case of S/PDIF audio input, MPEG 1 is used and the sampling frequency is auto detected.</p> <p>bit[8] CRC protection</p> <table border="0"> <tr><td>0 (reset)</td><td>enable CRC protection</td></tr> <tr><td>1</td><td>disable CRC protection</td></tr> </table> <p>bit[7:6] Channel Mode</p> <table border="0"> <tr><td>00</td><td>reserved</td></tr> <tr><td>01 (reset)</td><td>joint stereo</td></tr> <tr><td>10</td><td>reserved</td></tr> <tr><td>11</td><td>single channel</td></tr> </table> <p>bit[5] Channel Mode Extension (for joint stereo)</p> <table border="0"> <tr><td>0</td><td>disable MS-Stereo encoding</td></tr> <tr><td>1 (reset)</td><td>enable MS-Stereo encoding</td></tr> </table> <p>bit[4] Reserved, must be set to zero</p> <p>bit[3] Copyright (see Section 3.3.5. on page 37)</p> <table border="0"> <tr><td>0 (reset)</td><td>bit stream is not copyright protected</td></tr> <tr><td>1</td><td>bit stream is copyright protected</td></tr> </table> <p>bit[2] Copy/Original (see Section 3.3.5. on page 37)</p> <table border="0"> <tr><td>0</td><td>bit stream is a copy</td></tr> <tr><td>1 (reset)</td><td>bit stream is an original</td></tr> </table> <p>bit[1:0] Emphasis</p> <table border="0"> <tr><td>00 (reset)</td><td>none</td></tr> <tr><td>01</td><td>50/15 μs</td></tr> <tr><td>10</td><td>reserved</td></tr> <tr><td>11</td><td>CCITT J.17</td></tr> </table> | 000    | 0 lowest bitrate/quality | 001 | 1 | 010 | 2 | 011 | 3 | 100 | 4 | 101 (reset) | 5 recommended quality | 110 | 6 | 111 | 7 highest bitrate/quality | bit[11:10] Sampling Frequency (kHz) | MPEG 1 | MPEG 2 | 00 (reset) | 44.1 | 22.05 | 01 | 48 | 24 | 10 | 32 | 16 | 11 | reserved |  | 0 | MPEG 2 | 1 (reset) | MPEG 1 | 0 (reset) | enable CRC protection | 1 | disable CRC protection | 00 | reserved | 01 (reset) | joint stereo | 10 | reserved | 11 | single channel | 0 | disable MS-Stereo encoding | 1 (reset) | enable MS-Stereo encoding | 0 (reset) | bit stream is not copyright protected | 1 | bit stream is copyright protected | 0 | bit stream is a copy | 1 (reset) | bit stream is an original | 00 (reset) | none | 01 | 50/15 μs | 10 | reserved | 11 | CCITT J.17 | <b>Encoder</b> | EncoderControl |
| 000                                 | 0 lowest bitrate/quality                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 001                                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 010                                 | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 011                                 | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 100                                 | 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 101 (reset)                         | 5 recommended quality                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 110                                 | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 111                                 | 7 highest bitrate/quality                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| bit[11:10] Sampling Frequency (kHz) | MPEG 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | MPEG 2 |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 00 (reset)                          | 44.1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 22.05  |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 01                                  | 48                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 24     |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 10                                  | 32                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 16     |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 11                                  | reserved                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 0                                   | MPEG 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 1 (reset)                           | MPEG 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 0 (reset)                           | enable CRC protection                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 1                                   | disable CRC protection                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 00                                  | reserved                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 01 (reset)                          | joint stereo                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 10                                  | reserved                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 11                                  | single channel                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 0                                   | disable MS-Stereo encoding                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 1 (reset)                           | enable MS-Stereo encoding                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 0 (reset)                           | bit stream is not copyright protected                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 1                                   | bit stream is copyright protected                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 0                                   | bit stream is a copy                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 1 (reset)                           | bit stream is an original                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 00 (reset)                          | none                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 01                                  | 50/15 μs                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 10                                  | reserved                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |
| 11                                  | CCITT J.17                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |        |                          |     |   |     |   |     |   |     |   |             |                       |     |   |     |                           |                                     |        |        |            |      |       |    |    |    |    |    |    |    |          |  |   |        |           |        |           |                       |   |                        |    |          |            |              |    |          |    |                |   |                            |           |                           |           |                                       |   |                                   |   |                      |           |                           |            |      |    |          |    |          |    |            |                |                |

**Table 3–9:** D0 Control Memory Cells, continued

| Memory Address (hex) | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Mode | Name          |
|----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|---------------|
| D0:7F1 <sup>1)</sup> | <p><b>Main I/O Control</b> (reset = 125<sub>hex</sub>)</p> <p>IOControlMain is used for selecting/deselecting the appropriate data input interface and for setting up the serial data output interface. In serial input mode the coded audio data (Layer 2, Layer 3) is expected at the serial input interface SDIB. In the 8-bit-parallel input mode (default) the PIO pins PI[19:12] are used.</p> <p>bit[15] Reserved, must be set to zero</p> <p>bit[14] Invert serial output clock (SOC)<br/>                     0 (reset) do not invert SOC<br/>                     1 invert SOC</p> <p>bit[13] Reserved, must be set to zero</p> <p>bit[12] <b>Encoder:</b> Add timecode to encoded bitstream<br/>                     0 (reset) no timecode is inserted<br/>                     1 insert timecode into ancillary data bits</p> <p>The format of the timecode is explained in Section 3.3.7.1. on page 39</p> <p>bit[11] Serial data output delay<br/>                     0 (reset) no additional delay (reset)<br/>                     1 additional delay of data related to word strobe</p> <p>bit[10] <b>Encoder:</b> Low power loop-through mode<br/>                     0 (reset) normal encoder operation<br/>                     1 audio data loop-through without encoding</p> <p>The low power loop-through mode is for monitoring audio signals without encoding and data transfer to the PIO interface. It is controlled just like in normal encoding mode (audio input/MPEG mode selection), but power consumption and voltage requirements are as in decoding mode.</p> <p>bit[9:8] <b>Encoder:</b> Audio input select<br/>                     00 SDI input with PLL<br/>                     01 (reset) SDI input without PLL<br/>                     10 S/PDIF input<br/>                     11 reserved</p> <p><b>Decoder:</b> Data input select<br/>                     00 serial input at interface B<br/>                     01 (reset) parallel input at PIO pins PI[19...12]<br/>                     10 reserved<br/>                     11 reserved</p> <p>bit[7] <b>Encoder:</b> Invert serial input clock (SIC)<br/>                     0 (reset) do not invert SIC<br/>                     1 invert SIC</p> <p>bit[6] <b>Encoder:</b> Serial data input delay<br/>                     0 (reset) no additional delay (reset)<br/>                     1 additional delay of data related to word strobe</p> <p>bit[5] SDO Word strobe invert<br/>                     0 do not invert<br/>                     1 (reset) invert outgoing word strobe signal</p> <p>...</p> | All  | IOControlMain |

<sup>1)</sup> Changes at this memory address must be validated by setting bit[0] of D0:7F1<sup>1)</sup>.

**Table 3–9:** D0 Control Memory Cells, continued

| Memory Address (hex)  | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Mode | Name |
|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|
| D0:7F1<br>(continued) | <p><b>Main I/O Control</b> (continued)</p> <p>bit[4]      Bits per sample at SDO<br/>                   0 (reset)    32 bits/sample<br/>                   1            16 bits/sample</p> <p>bit[3]      <b>Encoder:</b> Clock setting<br/>                   0 (reset)    MPEG 1<br/>                   1            MPEG 2</p> <p>Please note the supply voltage restrictions for MPEG 1.</p> <p>bit[2]      <b>Decoder:</b> Serial data input interface B clock invert (pin SIBC)<br/>                   0            not inverted (data latched at rising clock edge)<br/>                   1 (reset)    incoming clock signal is inverted (data latched at falling clock edge)</p> <p>              <b>Encoder:</b> SDI word strobe invert<br/>                   0            do not invert<br/>                   1 (reset)    invert incoming word strobe signal</p> <p>bit[1]      <b>Decoder:</b><br/>                   0 (reset)    DEMAND MODE (PLL off, MAS 3587F is clock master)<br/>                   1            BROADCAST MODE (PLL on, clock of MAS 3587F locks on data stream)</p> <p>bit[0]      Validate<br/>                   0 (reset)<br/>                   1            changes in control memory will become effective</p> <p>Bit[0] is reset after the DSP has recognized the changes. The controller should set this bit after the other D0 control memory cells have been initialized with the desired values.</p> |      |      |



**Table 3–9:** D0 Control Memory Cells, continued

| Memory Address (hex)                                                                                                                                                                                                              | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Mode       | Name             |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|
| D0:7F2 <sup>1)</sup>                                                                                                                                                                                                              | <p><b>Interface Status Control</b> (reset = 05<sub>hex</sub>)</p> <p>This control cell allows to enable/disable the data I/O interfaces. In addition, the clock of the output data interfaces, S/PDIF and SDO, can be set to a low-impedance mode.</p> <p>bit[6]      S/PDIF input selection<br/> 0 (reset)    select S/PDIF input 1<br/> 1             select S/PDIF input 2</p> <p>bit[5]      Enable/disable S/PDIF output<br/> 0 (reset)    enable S/PDIF output<br/> 1             S/PDIF output invalid</p> <p><b>Note</b> that S/PDIF audio output is only available for MPEG 1 (sampling frequencies 32, 44.1, and 48 kHz)</p> <p>bit[4]      Reserved, must be set to zero</p> <p>bit[3]      Enable/disable serial data output SDO<br/> 0 (reset)    SDO valid data<br/> 1             SDO invalid data</p> <p>bit[2]      Output clock characteristic (SDO and S/PDIF outputs)<br/> 0             low impedance<br/> 1 (reset)    high impedance</p> <p>bit[1]      reserved, must be set to zero</p> <p>bit[0]      Enable/disable external serial data input SDI<sup>2)</sup><br/> 0             use external audio source (SDI)<br/> 1 (reset)    use internal A/D converter as audio source</p> <p>For details regarding the SDI-interface please see the MAS 3587F Application Note.</p> <p>Both digital outputs, S/PDIF and SDO, and the D/A converters may use the outgoing audio independent of each other.</p> | <b>All</b> | InterfaceControl |
| D0:7F3 <sup>1)</sup>                                                                                                                                                                                                              | <p><b>Oscillator Frequency</b> (reset = 18432<sub>dec</sub>)</p> <p>bit[19:0]   oscillator frequency in kHz</p> <p>In order to achieve a correct internal operating frequency of the DSP, the nominal crystal frequency has to be written into this memory cell.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>All</b> | OfreqControl     |
| <p><sup>1)</sup> Changes at this memory address must be validated by setting bit[0] of D0:7F1<sup>1)</sup>.</p> <p><sup>2)</sup> <b>Note:</b> The pins SIC, SII, SID are switched to output mode if bit[0] = 1 (reset value).</p> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |            |                  |

**Table 3–9:** D0 Control Memory Cells, continued

| Memory Address (hex)                                                                                            | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Mode | Name         |
|-----------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|--------------|
| D0:7F4 <sup>1)</sup>                                                                                            | <p><b>Output Clock Configuration</b> (pin CLKO) (reset = 80000<sub>hex</sub>)</p> <p>bit[19] CLKO configuration<br/>                     0 output clock signal at CLKO<br/>                     1 (reset) CLKO is tristate</p> <p>The CLKO output pin of the MAS 3587F can be disabled via bit [19].</p> <p>bit[18] Reserved, must be set to zero</p> <p>bit[17] Additional division by 2 if scaler is on (bit[8] cleared)<br/>                     0 (reset) oversampling factor 512/768<br/>                     1 oversampling factor 256/384</p> <p>bit[16:9] Reserved, must be set to zero</p> <p>bit[8] Output clock scaler<br/>                     0 (reset) set output clock according to audio sample rate (see Table 2–1)<br/>                     1 output clock fixed at 24.576 or 22.5792 MHz</p> <p>For a list of output frequencies at pin CLKO please refer to Table 2–1.</p> <p>bit[7:0] Reserved, must be set to zero</p>                                                                                                                                                                                                                                                                                                 | All  | OutClkConfig |
| D0:7F8                                                                                                          | <p><b>S/PDIF Channel Status Bits Category Code Setting</b> (reset = 8200<sub>hex</sub>)</p> <p>(see Section 3.3.5. on page 37)</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | All  | SpdOutBits   |
| D0:7F9 <sup>1)</sup>                                                                                            | <p><b>Soft Mute</b> (reset = 0<sub>hex</sub>)</p> <p>bit[2] <b>Encoder:</b> Bitreservoir mode<br/>                     0 (reset) bit reservoir is used<br/>                     1 bit reservoir is kept empty</p> <p>Although the encoder uses Variable Bitrate Encoding (VBR), the bit reservoir in the MPEG bitstream is used to compensate the differences between the pre-defined frame sizes. If the reservoir is kept to zero, it is more easy to cut and paste complete frames for audio editing purposes, but bitstreams may grow up to 25% in the worst case.</p> <p>bit[1] <b>Encoder:</b> Pause mode<br/>                     0 (reset) normal encoder operation<br/>                     1 encoding process is paused</p> <p>The encoding process may be stopped temporarily by setting the pause bit. While in pause mode, the audio monitoring still works, but no data is encoded. When the pause bit is reset again, the encoding continues seamlessly. If the pause bit is set before enabling the encoder, a record+pause mode can be realized by the controller software.</p> <p>bit[0] Mute audio output<br/>                     0 (reset) no mute of audio output<br/>                     1 audio output is muted</p> | All  | SoftMute     |
| <p><sup>1)</sup> Changes at this memory address must be validated by setting bit[0] of D0:7F1<sup>1)</sup>.</p> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |      |              |

**Table 3–9:** D0 Control Memory Cells, continued

| Memory Address (hex) | Function                                                                                | Mode           | Name   |
|----------------------|-----------------------------------------------------------------------------------------|----------------|--------|
| D0:7FC <sup>1)</sup> | <b>Volume Output Control: Left</b> → <b>Left Gain</b> (reset = 80000 <sub>hex</sub> )   | <b>Decoder</b> | out_LL |
| D0:7FD <sup>1)</sup> | <b>Volume Output Control: Left</b> → <b>Right Gain</b> (reset = 0 <sub>hex</sub> )      | <b>Decoder</b> | out_LR |
| D0:7FE <sup>1)</sup> | <b>Volume Output Control: Right</b> → <b>Left Gain</b> (reset = 0 <sub>hex</sub> )      | <b>Decoder</b> | out_RL |
| D0:7FF <sup>1)</sup> | <b>Volume Output Control: Right</b> → <b>Right Gain</b> (reset = 80000 <sub>hex</sub> ) | <b>Decoder</b> | out_RR |

<sup>1)</sup> Changes at this memory address must be validated by setting bit[0] of D0:7F1<sup>1)</sup>.

**Table 3–10:** D0 Status Memory Cells

| Memory Address | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Mode       | Name           |
|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|----------------|
| D0:FD0         | <p><b>MPEG Frame Counter</b></p> <p>bit[19:0]    number of MPEG frames after synchronization</p> <p>The counter will be incremented with every new frame that is encoded/decoded. With an invalid MPEG bit stream at its input while decoding (e.g. an invalid header is detected), the MAS 3587F resets the MPEGFrameCount to '0'. In encoding mode, the counter is reset on audio data time-outs and after restarting the encoder.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>All</b> | MPEGFrameCount |
| D0:FD1         | <p><b>MPEG Header and Status Information</b></p> <p>bit[15]    reserved, must be set to zero</p> <p>bit[14:13]    MPEG ID, bits 12, 11 of the MPEG header</p> <p>          00        MPEG 2.5 (decoding only)</p> <p>          01        reserved</p> <p>          10        MPEG 2</p> <p>          11        MPEG 1</p> <p>bit[12:11]    Bits 14 and 13 of the MPEG header</p> <p>          00        reserved</p> <p>          01        Layer 3</p> <p>          10        Layer 2 (decoding only)</p> <p>          11        Layer 1 (decoding only)</p> <p>bit[10]        CRC protection</p> <p>          0        bitstream protected by CRC</p> <p>          1        bitstream not protected by CRC</p> <p>bit[9:2]        Reserved</p> <p>bit[1]        CRC error (decoding only)</p> <p>          0        no CRC error</p> <p>          1        CRC error</p> <p>bit[0]        Invalid frame (decoding only)</p> <p>          0        no invalid frame</p> <p>          1        invalid frame</p> <p>This location contains bits 15...11 of the original MPEG header and other status bits. It will be set each frame directly after the header has been encoded/decoded from the bit stream.</p> | <b>All</b> | MPEGStatus1    |



**Table 3–10:** D0 Status Memory Cells, continued

| Memory Address          | Function                                                                                                                                                                                                                                                                                                                                                                                                             | Mode           | Name                  |
|-------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|-----------------------|
| D0:FD2<br>(continued)   | <p><b>MPEG Header Information</b> (continued)</p> <p>bit[1:0]      Emphasis, indicates the type of emphasis</p> <p>          00          none</p> <p>          01          50/15 <math>\mu</math>s</p> <p>          10          reserved</p> <p>          11          CCITT J.17</p> <p>This memory cell contains the 16 LSBs of the MPEG header. It will be set directly after synchronizing to the bit stream.</p> |                | MPEGStatus2           |
| D0:FD3                  | <p><b>MPEG CRC Error Counter</b></p> <p>The counter will be increased by each CRC error detected in the MPEG bit-stream. It will not be reset when losing the synchronization.</p>                                                                                                                                                                                                                                   | <b>Decoder</b> | CRCErrCount           |
| D0:FD4                  | <p><b>Number of Bits in Ancillary Data</b></p> <p>Number of valid ancillary bits in the current MPEG frame.</p>                                                                                                                                                                                                                                                                                                      | <b>Decoder</b> | NumberOfAncillaryBits |
| D0:FD5<br>...<br>D0:FD1 | <p><b>Ancillary Data</b></p> <p>(see Section 3.3.7. on page 38).</p>                                                                                                                                                                                                                                                                                                                                                 | <b>Decoder</b> | AncillaryData         |

**3.3.5. Copyright Management**

The controller software is responsible for the interpretation of the copyright information contained in received bitstreams and the correct setting of the copyright bits in output bitstreams.

Copyright information is included in both, the S/PDIF and the MPEG bitstreams. One bit indicates if the signal is copyright protected at all. The second shows whether the signal was already copied.

In the S/PDIF bitstream the copyright information is carried in the channel status bit area which is part of the S/PDIF signal (see IEC 958: “Digital Audio Interface”). The copyright information (Cp-bit) is located in bit 2 (0 = protected, 1 = no copyright), and the generation information (L-bit) is in bit 15 (0 = copy, 1 = original). The status information of received signals can be read from DSP-register 56<sub>hex</sub>, the copyright bits of originating bitstreams are controlled in memory address D0:7F8.

For MPEG bitstreams, this information is located in bit 3 (copyright) and bit 2 (original) of the frame header. The firmware uses the memory cells D0:FD2 for incoming signals, D0:7F0 for outgoing signals.

**3.3.5.1. Encoding of Analog or PCM-Audio**

In case of analog input or PCM-input at the serial interface SDI, the indication in the originating bitstream has to be set according to the application. If the copyright status is not known, the signal shall be asserted as a copyright protected original.

If the S/PDIF-input is used, the copyright bits have to be evaluated. Table 3–11 gives an example in case of a DAT-Recorder input signal (category code 300<sub>hex</sub>).

As the S/PDIF signal is only looped through the encoder, the copyright indication of the output must be set to the same as that of the input signal. Signals from CD (category code 100<sub>hex</sub>) are usually originals and in this case the generation bit at the output must be set to one.

**Table 3–11:** Encoding copyright propagation with a DAT-recorder source

| S/PDIF in ch. status (hex) | MPEG copyright bit  | MPEG original bit | S/PDIF Out Ch. Status (hex) |
|----------------------------|---------------------|-------------------|-----------------------------|
| 0304                       | 0                   | 0                 | 0204                        |
| 8304                       | 0                   | 0                 | 8204                        |
| 0300                       | recording forbidden |                   | 0200                        |
| 8300                       | 1                   | 0                 | 8200                        |

**3.3.5.2. Decoding**

If the S/PDIF output is used, the copyright indication has to be set according to the input bitstream. Table 3–12 gives an example in case of setting the category information in the S/PDIF signal to PCM-encoder/decoder (category code 200<sub>hex</sub>).

**Table 3–12:** Decoding copyright propagation (PCM-encoder/decoder)

| MPEG Copyright Bit | MPEG Original Bit | S/PDIF Out Channel Status (hex) |
|--------------------|-------------------|---------------------------------|
| 0                  | 0                 | 0204                            |
| 0                  | 1                 | 8204                            |
| 1                  | 0                 | 0200                            |
| 1                  | 1                 | 8200                            |

**3.3.6. Variable Bitrate Encoding**

The encoder uses Variable Bitrate Encoding (VBR) to realize optimal compression of the audio data. The setting of a fixed bitrate is replaced with setting a quality level that preserves audio quality in critical sections and enhances compression otherwise.

The minimum bitrate (in case of digital zero samples) is 32 kbit/s for MPEG 1 and 8 kbit/s for MPEG 2. The maximum bitrate is 192 kbit/s for MPEG 1 and 160 kbit/s for MPEG 2. This theoretically holds for all quality settings, but experience shows that the maximum rate does not vary too much from the average bitrate.

Table 3–13 gives an overview on the average encoding bitrate that can be expected for common audio signals at different quality settings and sample rates.

**Table 3–13:** Quality setting vs. average bitrate

| Quality Setting “q” in D0:7F0 | Average bitrate in kbit/s for fs/kHz |              |           |            |
|-------------------------------|--------------------------------------|--------------|-----------|------------|
|                               | 44.1 stereo                          | 22.05 stereo | 44.1 mono | 22.05 mono |
| 0                             | 75                                   | 39           | 65        | 35         |
| 1                             | 80                                   | 41           | 68        | 38         |
| 2                             | 90                                   | 45           | 73        | 40         |
| 3                             | 100                                  | 50           | 80        | 45         |
| 4                             | 120                                  | 60           | 90        | 50         |
| 5                             | 140                                  | 80           | 105       | 60         |
| 6                             | 160                                  | 110          | 125       | 75         |
| 7                             | 170                                  | 130          | 140       | 90         |

**3.3.7. Ancillary Data**

The memory fields D0:FD5...D0:FF1 contain the ancillary data. It is organized in 28 words of 16 bit each. The last ancillary bit of a frame is placed at bit 0 in D0:FD5. The position of the first ancillary data bit received can be located via the content of NumberOfAncillaryBits because

$$\text{int}[(\text{NumberOfAncillaryBits}-1)/16] + 1$$

of memory words are used.

Example:

First get the content of ‘NumberOfAncillaryBits’

```
<DW 68 c4 00 00 01 0f d4>
<DW 69 <DR dd dd >
```

Assume that the MAS 3587F has received 19 ancillary data bits. Therefore, it is necessary to read two 16-bit words:

```
<DW 68 c4 00 00 02 0f d5> Short Read from D0
00 02 0f d5> read 2 words starting at D0:fd5
<DW 69 <DR dd dd dd dd > start reading
dd dd dd dd > receive the 2 16-bit words
```

The first bit received from the MPEG source is at position 2 of D0:fd6; the last bit received is at the LSB of D0:FD5.

**Table 3–14:** Content of D0:fd5 after reception of 19 ancillary bits.

| D0:fd5         | MSB     | 14      | 13      | 12  | 11  | 10  | 9   | 8   | 7   | 6   | 5   | 4   | 3   | 2        | 1        | LSB      |
|----------------|---------|---------|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----------|----------|----------|
| Ancillary Data | 4th bit | 5th bit | 6th bit | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 17th bit | 18th bit | last bit |

**Table 3–15:** Content of D0:fd6 after reception of 19 ancillary bits.

| D0:fd6         | MSB | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2         | 1       | LSB     |
|----------------|-----|----|----|----|----|----|---|---|---|---|---|---|---|-----------|---------|---------|
| Ancillary Data | x   | x  | x  | x  | x  | x  | x | x | x | x | x | x | x | first bit | 2nd bit | 3rd bit |

**3.3.7.1. Timecode Information**

As the encoder uses VBR encoding, it is quite difficult to calculate the actual elapsed time in the MPEG bitstream. Therefore the encoder provides an option to insert timecodes into the MPEG bitstream.

The timecode is the number of frames processed from the start of encoding. It occupies 3 bytes at the end of the ancillary data region in each MPEG frame and contains of the tag nibble 5<sub>hex</sub> followed by a 20 bit number (5<sub>hex</sub>,d4,d3,d2,d1,d0).

A frame number can be translated to the absolute time in seconds by the following formulas:

MPEG 1:  $time[s] = frame * 1152 / sampling\ freq [Hz]$   
 MPEG 2:  $time[s] = frame * 576 / sampling\ freq [Hz]$

While decoding, the controller can check the presence/validity of the timecode information by first reading the NumberOfAncillaryBits. If the number is greater than or equal to 24 bits, two words of the ancillary data bits have to be read. D0:FD5 contains the 16 LSBs of the timecode (d3,d2,d1,d0) and D0:FD6 contains the tag nibble and the 4 MSBs (x,x,5<sub>hex</sub>,d4). If the tag nibble does not match, the timecode is not valid.

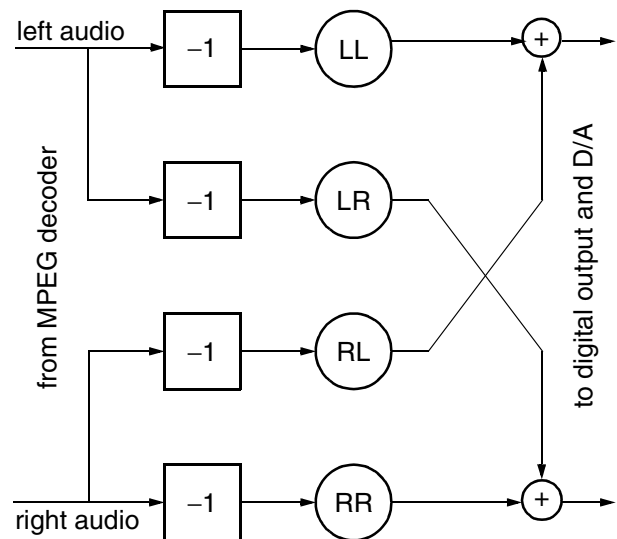
As the ancillary data may contain any kind of information, it is advisable to check several successive timecodes for validity and the sequence of numbers before accepting it.

**3.3.8. DSP Volume Control**

The digital baseband volume matrix is used for controlling the digital gain of the decoder as shown in Fig. 3–3. This volume control is effective on both, the digital audio output and the data stream to the D/A converters. The values are in 20-bit 2's complement notation.

Table 3–16 shows the proposed settings for the 4 volume matrix coefficients for stereo, left and right mono. The gain factors are given in fixed point notation as described in Section 3.3.2.

The DSP volume control is available in Decoder Mode only.



**Fig. 3–3:** Digital volume matrix

**Table 3–16:** Settings for the digital volume matrix.  
 $-1.0 \times 2^{19} = 80000_{\text{hex}}$

| Memory           | D0:7FC | D0:7FD | D0:7FE | D0:7FF |
|------------------|--------|--------|--------|--------|
| Name             | LL     | LR     | RL     | RR     |
| Stereo (default) | -1.0   | 0      | 0      | -1.0   |
| Mono left        | -1.0   | -1.0   | 0      | 0      |
| Mono right       | 0      | 0      | -1.0   | -1.0   |

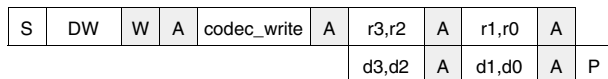
If channels are mixed, care must be taken to prevent clipping at high amplitudes. Therefore the sum of the absolute values of coefficients for one output channel must be less than or equal to 1.0.

For normal operating conditions it is recommended to use the main volume control of the audio codec instead (register 00 10<sub>hex</sub> of the audio codec).

**3.4. Audio Codec Access Protocol**

The MAS 3587F has 16-bit wide registers for the control of the audio codec. These registers are accessed via the I<sup>2</sup>C subaddresses `codec_write` (6C<sub>hex</sub>) and `codec_read` (6D<sub>hex</sub>).

**3.4.1. Write Codec Register**



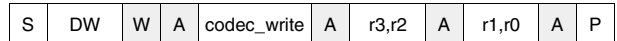
The controller writes the 16-bit value (**d** = d3,d2,d1,d0) into the MAS 3587F codec register (**r** = r3,r2,r1,r0). A list of registers is given in Table 3–17.

Example: Writing the value 1234<sub>hex</sub> into the codec register with the number 00 1B<sub>hex</sub>:

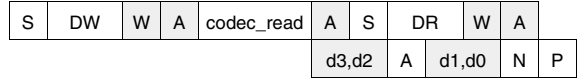
```
<DW 6c 00 1b 12 34>
```

**3.4.2. Read Codec Register**

1) send command



2) get register value



Reading the codec registers also needs a set-up for the register address and an additional start condition during the actual read cycle. A list of status registers is given in Table 3–18.



## 3.4.3. Codec Registers

Table 3–17: Codec control registers on I<sup>2</sup>C subaddress 6C<sub>hex</sub>

| Register Address (hex)         | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Name |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
|--------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-------------------|------|-----------------------------------------------|-----|----------------|------|-----------------------|------|-----------------------|-------------|---------|------|----------|------|----------|------|----------|-----|-----|------|----------|------|----------|---|---------|---|------------|-----------|
| <b>CONVERTER CONFIGURATION</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| 00 00                          | <p><b>Audio Codec Configuration</b></p> <p>0 dB is related to the D/A full-scale output voltage<br/>(Please refer to Section 4.6.4. on page 72)</p> <p>bit[15:12] A/D converter left amplifier gain = <math>n \cdot 1.5 - 3</math> [dB]</p> <p>bit[11:8] A/D converter right amplifier gain = <math>n \cdot 1.5 - 3</math> [dB]</p> <table> <tr><td>1111</td><td>+19.5 dB</td></tr> <tr><td>1110</td><td>+18.0 dB</td></tr> <tr><td>...</td><td>...</td></tr> <tr><td>0011</td><td>+1.5 dB</td></tr> <tr><td>0010</td><td>0.0 dB</td></tr> <tr><td>0001</td><td>-1.5 dB</td></tr> <tr><td>0000</td><td>- 3.0 dB</td></tr> </table> <p>bit[7:4] Microphone amplifier gain = <math>n \cdot 1.5 + 21</math> [dB]</p> <table> <tr><td>1111</td><td>+43.5 dB</td></tr> <tr><td>1110</td><td>+42.0 dB</td></tr> <tr><td>...</td><td>...</td></tr> <tr><td>0001</td><td>+22.5 dB</td></tr> <tr><td>0000</td><td>+21.0 dB</td></tr> </table> <p>bit[3] Input selection for left A/D converter channel</p> <table> <tr><td>0</td><td>line-in</td></tr> <tr><td>1</td><td>microphone</td></tr> </table> <p>bit[2] Enable left A/D converter</p> <p>bit[1] Enable right A/D converter</p> <p>bit[0] Enable D/A converter<sup>1)</sup></p> <p><sup>1)</sup> The generation of the internal DC reference voltage for the D/A converter is also controlled with this bit. In order to avoid click noise, the reference voltage at pin AGNDC should have reached a near ground potential before repowering the D/A converter after a short down phase.</p> <p>Alternatively at least one of the A/D converters (bits [2] or [1]) should remain set during short power-down phases of the D/A. Then the DC reference voltage generation for the D/A converter will not be interrupted.</p> | 1111 | +19.5 dB          | 1110 | +18.0 dB                                      | ... | ...            | 0011 | +1.5 dB               | 0010 | 0.0 dB                | 0001        | -1.5 dB | 0000 | - 3.0 dB | 1111 | +43.5 dB | 1110 | +42.0 dB | ... | ... | 0001 | +22.5 dB | 0000 | +21.0 dB | 0 | line-in | 1 | microphone | CONV_CONF |
| 1111                           | +19.5 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| 1110                           | +18.0 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| ...                            | ...                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| 0011                           | +1.5 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| 0010                           | 0.0 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| 0001                           | -1.5 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| 0000                           | - 3.0 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| 1111                           | +43.5 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| 1110                           | +42.0 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| ...                            | ...                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| 0001                           | +22.5 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| 0000                           | +21.0 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| 0                              | line-in                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| 1                              | microphone                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| <b>INPUT MODE SELECT</b>       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| 00 08                          | <p><b>Input Mode Setting</b></p> <p>bit[15] Mono switch</p> <table> <tr><td>0</td><td>stereo input mode</td></tr> <tr><td>1</td><td>left channel is copied into the right channel</td></tr> </table> <p>bit[14:2] Reserved, must be set to 0</p> <p>bit[1:0] Deemphasis select</p> <table> <tr><td>0</td><td>deemphasis off</td></tr> <tr><td>1</td><td>deemphasis 50 <math>\mu</math>s</td></tr> <tr><td>2</td><td>deemphasis 75 <math>\mu</math>s</td></tr> </table>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0    | stereo input mode | 1    | left channel is copied into the right channel | 0   | deemphasis off | 1    | deemphasis 50 $\mu$ s | 2    | deemphasis 75 $\mu$ s | ADC_IN_MODE |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| 0                              | stereo input mode                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| 1                              | left channel is copied into the right channel                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| 0                              | deemphasis off                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| 1                              | deemphasis 50 $\mu$ s                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |
| 2                              | deemphasis 75 $\mu$ s                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |      |                   |      |                                               |     |                |      |                       |      |                       |             |         |      |          |      |          |      |          |     |     |      |          |      |          |   |         |   |            |           |

**Table 3–17:** Codec control registers on I<sup>2</sup>C subaddress 6C<sub>hex</sub>, continued

| Register Address (hex)    | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Name         |
|---------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|
| <b>OUTPUT MODE SELECT</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |              |
| 00 06                     | <b>D/A Converter Source Mixer</b><br><b>MIX ADC scale</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | DAC_IN_ADC   |
| 00 07                     | <b>MIX DSP scale</b><br>bit[15:8] 00 <sub>hex</sub> ... 7F <sub>hex</sub> Linear scaling factor<br>Example:<br>00 <sub>hex</sub> off<br>20 <sub>hex</sub> 50% (–6 dB gain)<br>40 <sub>hex</sub> 100% (0 dB gain)<br>7F <sub>hex</sub> 200% (+6 dB gain)<br><br>In the sum of both mixing inputs exceeds 100%, clipping may occur in the successive audio processing.                                                                                                                                                                                                                                                                                                              | DAC_IN_DSP   |
| 00 0E                     | <b>D/A Converter Output Mode</b><br>bit[15] Mono switch<br>0 stereo through<br>1 mono matrix applied<br><br>bit[14] Invert right channel<br>0 through<br>1 right channel is inverted<br><br>bit[13:0] Reserved, must be set to 0<br><br>In order to achieve more output power a single loudspeaker can be connected as a bridge between pins OUTL and OUTR. In this mode bit[15] and bit[14] must be set.                                                                                                                                                                                                                                                                         | DAC_OUT_MODE |
| <b>BASEBAND FEATURES</b>  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |              |
| 00 14                     | <b>Bass</b><br>bit[15:8] Bass range<br>60 <sub>hex</sub> +12 dB<br>58 <sub>hex</sub> +11 dB<br>...<br>08 <sub>hex</sub> +1 dB<br>00 <sub>hex</sub> 0 dB<br>F8 <sub>hex</sub> –1 dB<br>...<br>A8 <sub>hex</sub> –11 dB<br>A0 <sub>hex</sub> –12 dB<br><br>Higher resolution is possible, one LSB step results in a gain step of about 1/8 dB.<br><br>With positive bass settings clipping of the output signal may occur. Therefore it is not recommended to set bass to a value that, in conjunction with volume, would result in an overall positive gain.<br><br>The settings require: max (bass, treble) + loudness + volume ≤ 0 dB<br><br>bit[7:0] Not used, must be set to 0 | BASS         |

**Table 3–17:** Codec control registers on I<sup>2</sup>C subaddress 6C<sub>hex</sub>, continued

| Register Address (hex) | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Name              |        |                   |        |     |  |                   |       |                   |      |                   |                                   |                   |                                       |                   |        |                   |        |        |
|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|--------|-------------------|--------|-----|--|-------------------|-------|-------------------|------|-------------------|-----------------------------------|-------------------|---------------------------------------|-------------------|--------|-------------------|--------|--------|
| 00 15                  | <p><b>Treble</b></p> <p>bit[15:8] Treble range</p> <table> <tr><td>60<sub>hex</sub></td><td>+12 dB</td></tr> <tr><td>58<sub>hex</sub></td><td>+11 dB</td></tr> <tr><td>...</td><td></td></tr> <tr><td>08<sub>hex</sub></td><td>+1 dB</td></tr> <tr><td>00<sub>hex</sub></td><td>0 dB</td></tr> <tr><td>F8<sub>hex</sub></td><td>-1 dB</td></tr> <tr><td>...</td><td></td></tr> <tr><td>A8<sub>hex</sub></td><td>-11 dB</td></tr> <tr><td>A0<sub>hex</sub></td><td>-12 dB</td></tr> </table> <p>Higher resolution is possible, one LSB step results in a gain step of about 1/8 dB.</p> <p>With positive treble settings, clipping of the output signal may occur. Therefore, it is not recommended to set treble to a value that, in conjunction with loudness and volume, would result in an overall positive gain.</p> <p>The settings require: max (bass, treble) + loudness + volume ≤ 0 dB</p> <p>bit[7:0] Not used, must be set to 0</p>                                                                                                                                                                                                                                                                                                                                                                              | 60 <sub>hex</sub> | +12 dB | 58 <sub>hex</sub> | +11 dB | ... |  | 08 <sub>hex</sub> | +1 dB | 00 <sub>hex</sub> | 0 dB | F8 <sub>hex</sub> | -1 dB                             | ...               |                                       | A8 <sub>hex</sub> | -11 dB | A0 <sub>hex</sub> | -12 dB | TREBLE |
| 60 <sub>hex</sub>      | +12 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                   |        |                   |        |     |  |                   |       |                   |      |                   |                                   |                   |                                       |                   |        |                   |        |        |
| 58 <sub>hex</sub>      | +11 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                   |        |                   |        |     |  |                   |       |                   |      |                   |                                   |                   |                                       |                   |        |                   |        |        |
| ...                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                   |        |                   |        |     |  |                   |       |                   |      |                   |                                   |                   |                                       |                   |        |                   |        |        |
| 08 <sub>hex</sub>      | +1 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                   |        |                   |        |     |  |                   |       |                   |      |                   |                                   |                   |                                       |                   |        |                   |        |        |
| 00 <sub>hex</sub>      | 0 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                   |        |                   |        |     |  |                   |       |                   |      |                   |                                   |                   |                                       |                   |        |                   |        |        |
| F8 <sub>hex</sub>      | -1 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                   |        |                   |        |     |  |                   |       |                   |      |                   |                                   |                   |                                       |                   |        |                   |        |        |
| ...                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                   |        |                   |        |     |  |                   |       |                   |      |                   |                                   |                   |                                       |                   |        |                   |        |        |
| A8 <sub>hex</sub>      | -11 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                   |        |                   |        |     |  |                   |       |                   |      |                   |                                   |                   |                                       |                   |        |                   |        |        |
| A0 <sub>hex</sub>      | -12 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                   |        |                   |        |     |  |                   |       |                   |      |                   |                                   |                   |                                       |                   |        |                   |        |        |
| 00 1E                  | <p><b>Loudness</b></p> <p>bit[15:8] Loudness gain</p> <table> <tr><td>44<sub>hex</sub></td><td>+17 dB</td></tr> <tr><td>40<sub>hex</sub></td><td>+16 dB</td></tr> <tr><td>...</td><td></td></tr> <tr><td>04<sub>hex</sub></td><td>+1 dB</td></tr> <tr><td>00<sub>hex</sub></td><td>0 dB</td></tr> </table> <p>bit[7:0] Loudness mode</p> <table> <tr><td>00<sub>hex</sub></td><td>normal (constant volume at 1 kHz)</td></tr> <tr><td>04<sub>hex</sub></td><td>Super Bass (constant volume at 2 kHz)</td></tr> </table> <p>Higher resolution of loudness gain is possible: An LSB step results in a gain step of about 1/4 dB.</p> <p>Loudness increases the volume of low- and high-frequency signals, while keeping the amplitude of the 1 kHz reference frequency constant. The intended loudness has to be set according to the actual volume setting. Because loudness introduces gain, it is not recommended to set loudness to a value that, in conjunction with volume, would result in an overall positive gain.</p> <p>The settings should be: max (bass, treble) + loudness gain + volume ≤ 0 dB</p> <p>The corner frequency for bass amplification can be set to two different values. In Super Bass mode, the corner frequency is shifted up. The point of constant volume is shifted from 1 kHz to 2 kHz.</p> | 44 <sub>hex</sub> | +17 dB | 40 <sub>hex</sub> | +16 dB | ... |  | 04 <sub>hex</sub> | +1 dB | 00 <sub>hex</sub> | 0 dB | 00 <sub>hex</sub> | normal (constant volume at 1 kHz) | 04 <sub>hex</sub> | Super Bass (constant volume at 2 kHz) | LOUDNESS          |        |                   |        |        |
| 44 <sub>hex</sub>      | +17 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                   |        |                   |        |     |  |                   |       |                   |      |                   |                                   |                   |                                       |                   |        |                   |        |        |
| 40 <sub>hex</sub>      | +16 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                   |        |                   |        |     |  |                   |       |                   |      |                   |                                   |                   |                                       |                   |        |                   |        |        |
| ...                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                   |        |                   |        |     |  |                   |       |                   |      |                   |                                   |                   |                                       |                   |        |                   |        |        |
| 04 <sub>hex</sub>      | +1 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                   |        |                   |        |     |  |                   |       |                   |      |                   |                                   |                   |                                       |                   |        |                   |        |        |
| 00 <sub>hex</sub>      | 0 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                   |        |                   |        |     |  |                   |       |                   |      |                   |                                   |                   |                                       |                   |        |                   |        |        |
| 00 <sub>hex</sub>      | normal (constant volume at 1 kHz)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                   |        |                   |        |     |  |                   |       |                   |      |                   |                                   |                   |                                       |                   |        |                   |        |        |
| 04 <sub>hex</sub>      | Super Bass (constant volume at 2 kHz)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                   |        |                   |        |     |  |                   |       |                   |      |                   |                                   |                   |                                       |                   |        |                   |        |        |



**Table 3–17:** Codec control registers on I<sup>2</sup>C subaddress 6C<sub>hex</sub>, continued

| Register Address (hex) | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Name              |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|--------------------------|-------------------|--------------------------|-----|--|-------------------|------------------------|-------------------|-----------------------|-------------------|------------------------|-----|--|-------------------|--------------------------|-------------------|--------------------------|-------------------|--------------|--------|
| <b>VOLUME</b>          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| 00 10                  | <p><b>Volume Control</b></p> <p>bit[15:8] Volume table with 1 dB step size</p> <table> <tr><td>7F<sub>hex</sub></td><td>+12 dB (maximum volume)</td></tr> <tr><td>7E<sub>hex</sub></td><td>+11 dB</td></tr> <tr><td>...</td><td></td></tr> <tr><td>74<sub>hex</sub></td><td>+1 dB</td></tr> <tr><td>73<sub>hex</sub></td><td>0 dB</td></tr> <tr><td>72<sub>hex</sub></td><td>-1 dB</td></tr> <tr><td>...</td><td></td></tr> <tr><td>02<sub>hex</sub></td><td>-113 dB</td></tr> <tr><td>01<sub>hex</sub></td><td>-114 dB</td></tr> <tr><td>00<sub>hex</sub></td><td>mute (reset)</td></tr> </table> <p>bit[7:0] Not used, must be set to 0</p> <p>This main volume control is applied to the analog outputs only. It is split between a digital and an analog function. In order to avoid noise due to large changes of the setting, the actual setting is internally low-pass filtered.</p> <p>With large scale input signals, positive volume settings may lead to signal clipping.</p> | 7F <sub>hex</sub> | +12 dB (maximum volume)  | 7E <sub>hex</sub> | +11 dB                   | ... |  | 74 <sub>hex</sub> | +1 dB                  | 73 <sub>hex</sub> | 0 dB                  | 72 <sub>hex</sub> | -1 dB                  | ... |  | 02 <sub>hex</sub> | -113 dB                  | 01 <sub>hex</sub> | -114 dB                  | 00 <sub>hex</sub> | mute (reset) | VOLUME |
| 7F <sub>hex</sub>      | +12 dB (maximum volume)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| 7E <sub>hex</sub>      | +11 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| ...                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| 74 <sub>hex</sub>      | +1 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| 73 <sub>hex</sub>      | 0 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| 72 <sub>hex</sub>      | -1 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| ...                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| 02 <sub>hex</sub>      | -113 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| 01 <sub>hex</sub>      | -114 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| 00 <sub>hex</sub>      | mute (reset)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| 00 11                  | <p><b>Balance</b></p> <p>bit[15:8] Balance range</p> <table> <tr><td>7F<sub>hex</sub></td><td>left -127 dB, right 0 dB</td></tr> <tr><td>7E<sub>hex</sub></td><td>left -126 dB, right 0 dB</td></tr> <tr><td>...</td><td></td></tr> <tr><td>01<sub>hex</sub></td><td>left -1 dB, right 0 dB</td></tr> <tr><td>00<sub>hex</sub></td><td>left 0 dB, right 0 dB</td></tr> <tr><td>FF<sub>hex</sub></td><td>left 0 dB, right -1 dB</td></tr> <tr><td>...</td><td></td></tr> <tr><td>81<sub>hex</sub></td><td>left 0 dB, right -127 dB</td></tr> <tr><td>80<sub>hex</sub></td><td>left 0 dB, right -128 dB</td></tr> </table> <p>Positive balance settings reduce the left channel without affecting the right channel; negative settings reduce the right channel leaving the left channel unaffected.</p>                                                                                                                                                                                   | 7F <sub>hex</sub> | left -127 dB, right 0 dB | 7E <sub>hex</sub> | left -126 dB, right 0 dB | ... |  | 01 <sub>hex</sub> | left -1 dB, right 0 dB | 00 <sub>hex</sub> | left 0 dB, right 0 dB | FF <sub>hex</sub> | left 0 dB, right -1 dB | ... |  | 81 <sub>hex</sub> | left 0 dB, right -127 dB | 80 <sub>hex</sub> | left 0 dB, right -128 dB | BALANCE           |              |        |
| 7F <sub>hex</sub>      | left -127 dB, right 0 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| 7E <sub>hex</sub>      | left -126 dB, right 0 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| ...                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| 01 <sub>hex</sub>      | left -1 dB, right 0 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| 00 <sub>hex</sub>      | left 0 dB, right 0 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| FF <sub>hex</sub>      | left 0 dB, right -1 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| ...                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| 81 <sub>hex</sub>      | left 0 dB, right -127 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| 80 <sub>hex</sub>      | left 0 dB, right -128 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                   |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |
| 00 12                  | <p><b>Automatic Volume Correction (AVC) Loudspeaker Channel</b></p> <p>bit[15:12] 0<sub>hex</sub> AVC off (and reset internal variables)<br/>8<sub>hex</sub> AVC on</p> <p>bit[11:8] 8<sub>hex</sub> 8 s decay time<br/>4<sub>hex</sub> 4 s decay time<br/>2<sub>hex</sub> 2 s decay time<br/>1<sub>hex</sub> 20 ms decay time (intended for quick adaptation to the average volume level after track or source change)</p> <p><b>Note:</b> To reset the internal variables, the AVC should be switched off and then on again during any track or source change. For standard applications, the recommended decay time is 4 s.</p>                                                                                                                                                                                                                                                                                                                                                       | AVC               |                          |                   |                          |     |  |                   |                        |                   |                       |                   |                        |     |  |                   |                          |                   |                          |                   |              |        |

**Table 3–18:** Codec status registers on I<sup>2</sup>C subaddress 6D<sub>hex</sub>

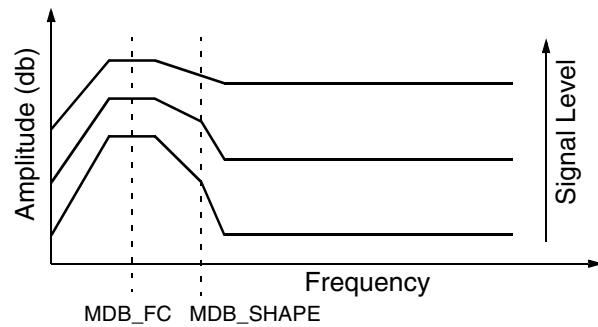
| Register Address (hex)   | Function                                                                                                                                                                                                 | Name     |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>INPUT QUASI-PEAK</b>  |                                                                                                                                                                                                          |          |
| 00 0A                    | <b>A/D Converter Quasi-Peak Detector Readout Left</b><br>bit[14:0] Positive 15-bit value, linear scale<br><br>For example:<br>0000 0%<br>2000 25% (-12 dBFS)<br>4000 50% (-6 dBFS)<br>7FFF 100% (0 dBFS) | QPEAK_L  |
| 00 0B                    | <b>A/D Converter Quasi-Peak Detector Readout Right</b><br>bit[14:0] Positive 15-bit value, linear scale                                                                                                  | QPEAK_R  |
| <b>OUTPUT QUASI-PEAK</b> |                                                                                                                                                                                                          |          |
| 00 0C                    | <b>Audio Processing Input Quasi-Peak Detector Readout Left</b><br>bit[14:0] Positive 15-bit value, linear scale                                                                                          | DQPEAK_L |
| 00 0D                    | <b>Audio Processing Input Quasi-Peak Detector Readout Right</b><br>bit[14:0] Positive 15-bit value, linear scale                                                                                         | DQPEAK_R |

**3.4.4. Basic MDB Configuration**

With the parameters described in Table 3–17, the Micronas Dynamic Bass system (MDB) can be customized to create different bass effects as well as to fit the MDB to various loudspeaker characteristics. The easiest way to find a good set of parameter is by selecting one of the settings below, listening to music with strong bass content and adjusting the MDB parameters:

- MDB\_STR: Increase/decrease the strength of the MDB effect
- MDB\_HAR: Increase/decrease the content of low frequency harmonics
- MDB\_FC: Shift the MDB effect to lower/higher frequencies

- MDB\_SHAPE: Widen/narrow MDB frequency range (which results in a softer/harder bass sound), turn on/off the MDB



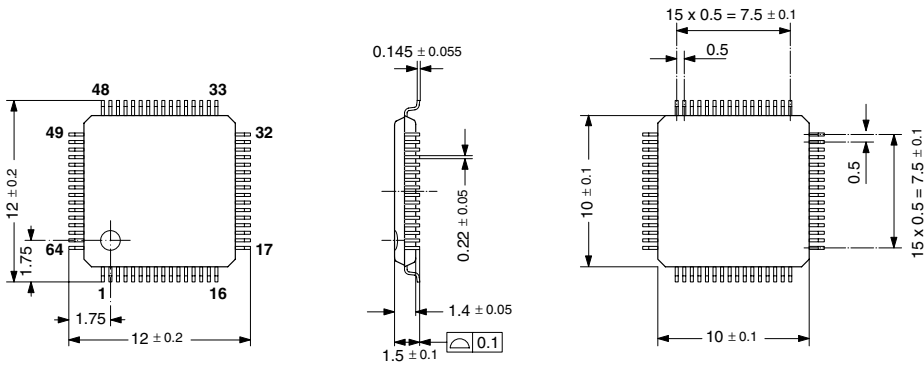
**Fig. 3–4:** Micronas Dynamic Bass (MDB): Bass boost in relation to input signal level

**Table 3–19:** Suggested MDB settings (all addresses and values are in hexadecimal notation)

| Function (Address)                | MDB_STR (00 22) | MDB_HAR (00 23) | MDB_FC (00 24) | MDB_SHAPE (00 21) |
|-----------------------------------|-----------------|-----------------|----------------|-------------------|
| MDB off                           | xxxx            | xxxx            | xxxx           | 0000              |
| Low end headphones, medium effect | 5000            | 3000            | 0600           | 0902              |

### 4. Specifications

#### 4.1. Outline Dimensions

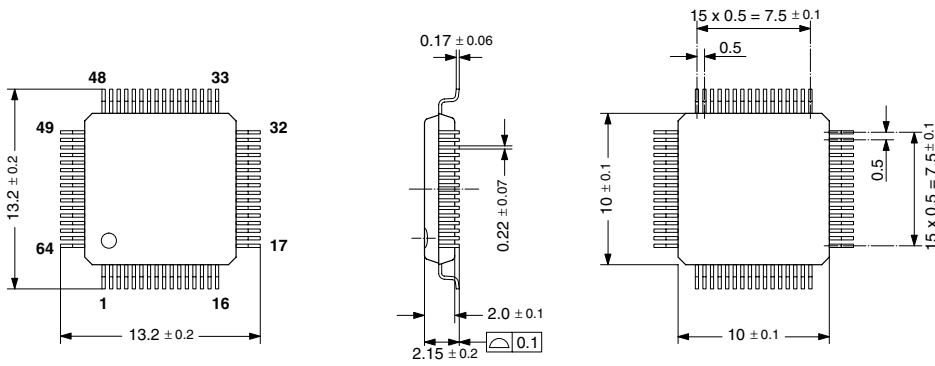


SPGS707000-1/1E

**Fig. 4-1:**  
64-Pin Plastic Low-Profile Quad Flat Pack  
(PLQFP64)

Weight approximately 0.35 g  
Dimensions in mm

(not usable for new design)



SPGS706000-6(P64)/1E

**Fig. 4-2:**  
64-Pin Plastic Metric Quad Flat Pack  
(PMQFP64)

Weight approximately 0.4 g  
Dimensions in mm

**4.2. Pin Connections and Short Descriptions**

- NC not connected, leave vacant
- LV If not used, leave vacant
- X obligatory, pin must be connected as described in application information (see Fig. 4–34 on page 81)
- VDD connect to positive supply
- VSS connect to ground

| Pin No.<br>PLQFP/<br>PMQFP<br>64-pin | Pin Name                | Type   | Default Connection<br>(if not used) | Short Description                                 |
|--------------------------------------|-------------------------|--------|-------------------------------------|---------------------------------------------------|
| 1                                    | AGNDC                   |        | X                                   | Analog reference voltage                          |
| 2                                    | MICIN                   | IN     | LV                                  | Input for internal microphone amplifier           |
| 3                                    | MICBI                   | IN     | LV                                  | Bias for internal microphone                      |
| 4                                    | INL                     | IN     | LV                                  | Left A/D input                                    |
| 5                                    | INR                     | IN     | LV                                  | Right A/D input                                   |
| 6                                    | TE                      | IN     | X                                   | Test enable                                       |
| 7                                    | XTI                     | IN     | X                                   | Crystal oscillator (ext. clock) input             |
| 8                                    | XTO                     | OUT    | LV                                  | Crystal oscillator output                         |
| 9                                    | $\overline{\text{POR}}$ | IN     | X                                   | Power on reset, active low                        |
| 10                                   | VSS                     | SUPPLY | X                                   | DSP supply ground                                 |
| 11                                   | XVSS                    | SUPPLY | X                                   | Digital output supply ground                      |
| 12                                   | VDD                     | SUPPLY | X                                   | DSP supply                                        |
| 13                                   | XVDD                    | SUPPLY | X                                   | Digital output supply                             |
| 14                                   | I2CVDD                  | SUPPLY | X                                   | I <sup>2</sup> C supply                           |
| 15                                   | DVS                     | IN     | X                                   | I <sup>2</sup> C device address selector          |
| 16                                   | VSENS1                  | IN/OUT | VDD                                 | Sense input and power output of DC/DC converter 1 |
| 17                                   | DCSO1                   | SUPPLY | LV                                  | DC/DC 1 switch output                             |
| 18                                   | DCSG1                   | SUPPLY | VSS                                 | DC/DC 1 switch ground                             |
| 19                                   | DCSG2                   | SUPPLY | VSS                                 | DC/DC 2 switch ground                             |
| 20                                   | DCSO2                   | SUPPLY | LV                                  | DC/DC 2 switch output                             |
| 21                                   | VSENS2                  | IN/OUT | VDD                                 | Sense input and power output of DC/DC converter 2 |
| 22                                   | DCEN                    | IN     | VSS                                 | DC/DC enable (both converters)                    |
| 23                                   | CLKO                    | OUT    | LV                                  | Clock output                                      |
| 24                                   | I2CC                    | IN/OUT | X                                   | I <sup>2</sup> C clock                            |



| Pin No.<br>PLQFP/<br>PMQFP<br>64-pin | Pin Name                 | Type   | Default<br>Connection<br>(if not used) | Short Description                             |
|--------------------------------------|--------------------------|--------|----------------------------------------|-----------------------------------------------|
| 25                                   | I2CD                     | IN/OUT | X                                      | I <sup>2</sup> C data                         |
| 26                                   | SYNC                     | OUT    | LV                                     | Sync output                                   |
| 27                                   | VBAT                     | IN     | LV                                     | Battery voltage monitor input                 |
| 28                                   | PUP                      | OUT    | LV                                     | DC Converters Power-Up Signal                 |
| 29                                   | $\overline{\text{EOD}}$  | OUT    | LV                                     | PIO end of DMA, active low                    |
| 30                                   | $\overline{\text{PRTR}}$ | OUT    | LV                                     | PIO ready to read, active low                 |
| 31                                   | $\overline{\text{PRTW}}$ | OUT    | LV                                     | PIO ready to write, active low                |
| 32                                   | PR                       | IN     | VDD                                    | PIO DMA request, active high                  |
| 33                                   | $\overline{\text{PCS}}$  | IN     | VSS                                    | PIO chip select, active low                   |
| 34                                   | PI19                     | IN/OUT | LV                                     | PIO data bit[7] (MSB)                         |
| 35                                   | PI18                     | IN/OUT | LV                                     | PIO data bit[6]                               |
| 36                                   | PI17                     | IN/OUT | LV                                     | PIO data bit[5]                               |
| 37                                   | PI16                     | IN/OUT | LV                                     | PIO data bit[4]                               |
| 38                                   | PI15                     | IN/OUT | LV                                     | PIO data bit[3]                               |
| 39                                   | PI14                     | IN/OUT | LV                                     | PIO data bit[2]                               |
| 40                                   | PI13                     | IN/OUT | LV                                     | PIO data bit[1]                               |
| 41                                   | PI12                     | IN/OUT | LV                                     | PIO data bit[0] (LSB)                         |
| 42                                   | SOD                      | OUT    | LV                                     | Serial output data                            |
| 43                                   | SOI                      | OUT    | LV                                     | Serial output word identification             |
| 44                                   | SOC                      | OUT    | LV                                     | Serial output clock                           |
| 45                                   | SID                      | IN/OUT | X                                      | Serial input data, interface A                |
| 46                                   | SII                      | IN/OUT | X                                      | Serial input word identification, interface A |
| 47                                   | SIC                      | IN/OUT | X                                      | Serial input clock, interface A               |
| 48                                   | SPDO                     | OUT    | LV                                     | S/PDIF output interface                       |
| 49                                   | SIBD                     | IN     | VSS                                    | Serial input data, interface B                |
| 50                                   | SIBC                     | IN     | VSS                                    | Serial input clock, interface B               |
| 51                                   | SIBI                     | IN     | VSS                                    | Serial input word identification, interface B |
| 52                                   | SPDI2                    | IN     | LV                                     | Active differential S/PDIF input 2            |
| 53                                   | SPDI1                    | IN     | LV                                     | Active differential S/PDIF input 1            |

| Pin No.<br>PLQFP/<br>PMQFP<br>64-pin | Pin Name | Type   | Default<br>Connection<br>(if not used) | Short Description                            |
|--------------------------------------|----------|--------|----------------------------------------|----------------------------------------------|
| 54                                   | SPDIR    | IN     | LV                                     | Reference differential S/PDIF inputs 1 and 2 |
| 55                                   | FILTL    | IN     | X                                      | Feedback input for left amplifier            |
| 56                                   | AVDD0    | SUPPLY | X                                      | Analog supply for output amplifiers          |
| 57                                   | OUTL     | OUT    | LV                                     | Left analog output                           |
| 58                                   | OUTR     | OUT    | LV                                     | Right analog output                          |
| 59                                   | AVSS0    | SUPPLY | X                                      | Analog ground for output amplifiers          |
| 60                                   | FILTR    | IN     | X                                      | Feedback for right output amplifier          |
| 61                                   | AVSS1    | SUPPLY | X                                      | Analog ground                                |
| 62                                   | VREF     |        | X                                      | Analog reference ground                      |
| 63                                   | PVDD     | SUPPLY | X                                      | Internal power supply                        |
| 64                                   | AVDD1    | SUPPLY | X                                      | Analog supply                                |

### 4.3. Pin Descriptions

#### 4.3.1. Power Supply Pins

The use of all power supply pins is mandatory to achieve correct function of the MAS 3587F.

**VDD, VSS** **SUPPLY**  
Digital supply pins.

**XVDD, XVSS** **SUPPLY**  
Supply for digital output pins.

**I<sup>2</sup>CVDD** **SUPPLY**  
Supply for I<sup>2</sup>C interface circuitry. This net uses VSS or XVSS as the ground return line.

**PVDD** **SUPPLY**  
Auxiliary pin for analog circuitry. This pin has to be connected via a 3-nF capacitor to AVDD1. Extra care should be taken to achieve a low inductance PCB line.

**AVDD0/AVSS0** **SUPPLY**  
Supply for analog output amplifier (output stage).

**AVDD1/AVSS1** **SUPPLY**  
Supply for internal analog circuits (A/D, D/A converters, clock, PLL, S/PDIF input).

AVDD0/AVSS0 and AVDD1/AVSS1 should receive the same supply voltages.

#### 4.3.2. Analog Reference Pins

**AGNDC**  
Internal analog reference voltage. This pin serves as the internal ground connection for the analog circuitry.

**VREF**  
Analog reference ground. All analog inputs and outputs should drive their return currents using separate traces to a ground starpoint close to this pin. Connect to AVSS1. This reference pin should be as noise free as possible.

#### 4.3.3. DC/DC Converters and Battery Voltage Supervision

**DCSG1/DCSG2** **SUPPLY**  
DC/DC converters switch ground. Connect using separate wide trace to negative pole of battery cell. Connect also to AVSS0/1 and VSS/XVSS, VREF.

**DCSO1/DCSO2** **SUPPLY**  
DC/DC converter switch connection. If the respective DC/DC converter is not used, this pin must be left vacant.

**VSENS1/VSENS2** **IN**  
Sense input and power output of DC/DC converters. If the respective DC/DC converter is not used, this pin should be connected to a supply to enable proper function of the PUP-signals.

**DCEN** **IN**  
Enable signal for both DC/DC converters. If none of the DC/DC converters is used, this pin must be connected to VSS.

**PUP** **OUT**  
Power-up. This signal is set when the required voltages are available at both DC/DC converter output pins VSENS1 and VSENS2. The signal is cleared when both voltages have dropped below the level is set in the DCCF Register.

**VBAT** **IN**  
Analog input for battery voltage supervision.

#### 4.3.4. Oscillator Pins and Clocking

**XTI** **IN**  
**XTO** **OUT**  
The XTI pin is connected to the input of the internal crystal oscillator, the XTO pin to its output. Each pin should be directly connected to the crystal and to a ground-connected capacitor (see application diagram).

**CLKO** **OUT**  
The CLKO can drive an output clock line.

#### 4.3.5. Control Lines

**I<sup>2</sup>CC** **SCL** **IN/OUT**  
**I<sup>2</sup>CD** **SDA** **IN/OUT**  
Standard I<sup>2</sup>C control lines.

**DVS** **IN**  
I<sup>2</sup>C device address selector. Connect this pin either to VDD (I<sup>2</sup>C device address: 3E/3F<sub>hex</sub>) or VSS (I<sup>2</sup>C device address: 3C/3D<sub>hex</sub>) to select a proper I<sup>2</sup>C device address (see also Table 3–1 on page 18).

#### 4.3.6. Parallel Interface Lines

**PI12..PI19** **IN/OUT**  
The PIO input pins PI12..PI19 are used as 8-bit I/O interface to a microcontroller in order to transfer compressed and uncompressed data. PI12 is the LSB, PI19 the MSB.

**4.3.6.1. PIO Handshake Lines**

**PCS** **IN**  
 The PIO chip select **PCS** must be set to '0' to activate the PIO in operation mode.

**PR** **IN**  
 Pin PR must be set to '1' when ready to send/receive data to/from MAS 3587F PIO pins.

**PRTR** **OUT**  
 Ready to read. This signal indicates that the MAS 3587F is able to receive data in PIO input mode.

**PRTW** **OUT**  
 Ready to write. This pin indicates that MAS 3587F has data available in PIO output mode.

**EOD** **OUT**  
 EOD indicates the end of an DMA cycle in the IC's PIO input/output mode. In 'serial' input mode it is used as Demand signal, that indicates that new input data are required.

**4.3.7. Serial Input Interface (SDI)**

|            |                    |               |
|------------|--------------------|---------------|
| <b>SID</b> | <b>DATA</b>        | <b>IN/OUT</b> |
| <b>SII</b> | <b>WORD STROBE</b> | <b>IN/OUT</b> |
| <b>SIC</b> | <b>CLOCK</b>       | <b>IN/OUT</b> |

I<sup>2</sup>S compatible serial interface A for digital audio data. In the standard firmware this interface is not used.  
 Note: Please refer to Interface Status Register (D0:7f2) bit[0] (Table 3–9).

**4.3.8. Serial Input Interface B (SDIB)**

|             |                    |           |
|-------------|--------------------|-----------|
| <b>SIBD</b> | <b>DATA</b>        | <b>IN</b> |
| <b>SIBI</b> | <b>WORD STROBE</b> | <b>IN</b> |
| <b>SIBC</b> | <b>CLOCK</b>       | <b>IN</b> |

The serial interface B is used as bitstream input interface. The SIBI line must be connected to VSS in the serial decoder application.

**4.3.9. Serial Output Interface (SDO)**

|            |                    |               |
|------------|--------------------|---------------|
| <b>SOD</b> | <b>DATA</b>        | <b>OUT</b>    |
| <b>SOI</b> | <b>WORD STROBE</b> | <b>OUT</b>    |
| <b>SOC</b> | <b>CLOCK</b>       | <b>IN/OUT</b> |

Data, Frame Indication, and Clock line of the serial output interface. The SDO is reconfigurable and can be adapted to several I<sup>2</sup>S compliant modes.

**4.3.10. S/PDIF Input Interface**

|              |           |
|--------------|-----------|
| <b>SPDI1</b> | <b>IN</b> |
| <b>SPDI2</b> | <b>IN</b> |
| <b>SPDIR</b> | <b>IN</b> |

SPDI1 and SPDI2 are alternative input pins for S/PDIF sources according to the IEC 958 consumer specification. A switch at D0:7F2 selects one of these pins at a time. The SPDIR pin is a common reference for both input lines (see Fig. 4–34 on page 81).

**4.3.11. S/PDIF Output Interface**

|             |            |
|-------------|------------|
| <b>SPDO</b> | <b>OUT</b> |
|-------------|------------|

The SPDO pin provides an digital output with standard CMOS level that is compliant to the IEC 958 consumer specification.

**4.3.12. Analog Input Interfaces**

In the standard MPEG-decoding DSP firmware the analog inputs are not used. However, they can be selected as a source for the D/A converters (set MIX ADC scale of the D/A Converter Source Mixer, Register 00 06<sub>hex</sub> in Table 3–15 on page 39).

|              |           |
|--------------|-----------|
| <b>MICIN</b> | <b>IN</b> |
| <b>MICBI</b> | <b>IN</b> |

The MICIN input may be directly used as electret microphone input, which should be connected as described in application information (see Fig. 4–34 on page 81). The MICBI signal provides the supply voltage for these microphones.

|            |           |
|------------|-----------|
| <b>INL</b> | <b>IN</b> |
| <b>INR</b> | <b>IN</b> |

INL and INR are analog line-in input lines. They are connected to the embedded stereo A/D converter of the MAS 3587F. The sources should be AC coupled. The reference ground for these analog input pins is the VREF pin.

**4.3.13. Analog Output Interfaces**

|             |            |
|-------------|------------|
| <b>OUTL</b> | <b>OUT</b> |
| <b>OUTR</b> | <b>OUT</b> |

OUTL and OUTR are left and right analog outputs, that may be directly connected to a pair of 16 Ω loudspeakers, to one 32 Ω loudspeaker in a bridge mode (see Section 2.7.4. on page 10), or via 22 Ω series resistance to the headphones as described in the application information (see Fig. 4–34 on page 81).

|              |           |
|--------------|-----------|
| <b>FILT</b>  | <b>IN</b> |
| <b>FILTR</b> | <b>IN</b> |

Connection to input terminal of output amplifier. Can be used to connect capacitors from OUTL to FILT and from OUTR to FILTR and thus implement low pass fil-

ters to reduce the out-of-band noise of the D/A converters.

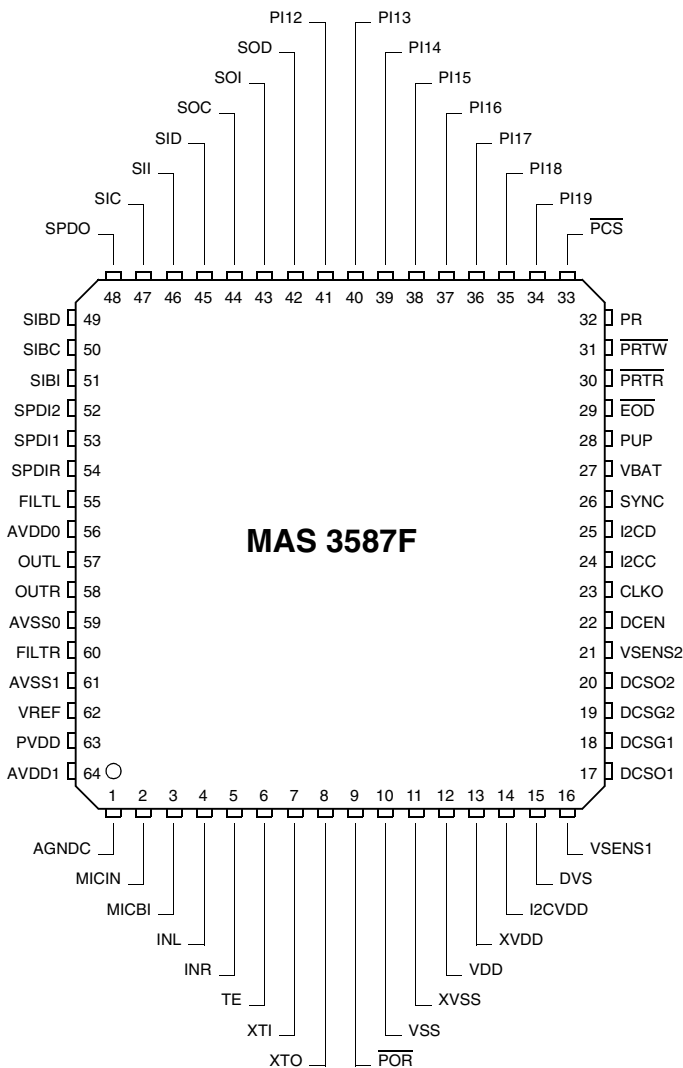
**4.3.14. Miscellaneous**

**SYNC** **OUT**  
 The SYNC signal indicates the detection of a frame start in the input data of MAS 3587F. Usually this signal generates an interrupt in the controller.

**POR** **IN**  
 The Power-On Reset pin completely resets the MAS 3587F. The POR is an active-low signal (see Fig. 4-34 on page 81).

**TE** **IN**  
 The TE pin is for production test only and must be connected with VSS in all applications.

**4.4. Pin Configurations**



**Fig. 4-3:** PLQFP64/PMQFP64 package (Top view)

4.5. Internal Pin Circuits

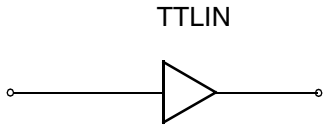


Fig. 4-4: Input pins  $\overline{PCS}$ , PR

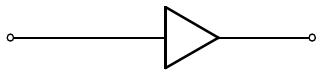


Fig. 4-5: Input pin TE, DVS,  $\overline{POR}$

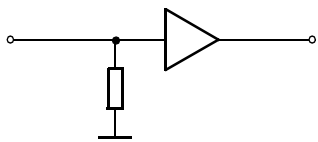


Fig. 4-6: Input pin DCEN

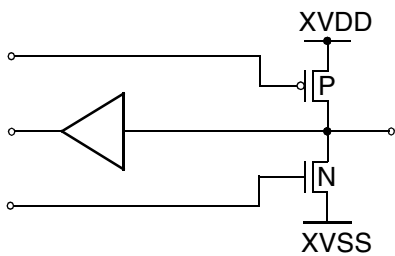


Fig. 4-7: Input/output pins SOC, SOI, SOD, PI12...PI19, SPDO

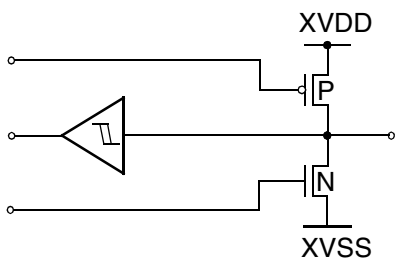


Fig. 4-8: Input pins SI(B)C, SI(B)I, SI(B)D

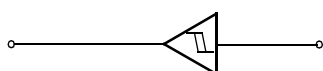


Fig. 4-9: Input pins SIBC, SIBI, SIBD

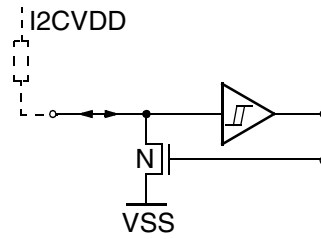


Fig. 4-10: Input/output pins I2CC, I2CD

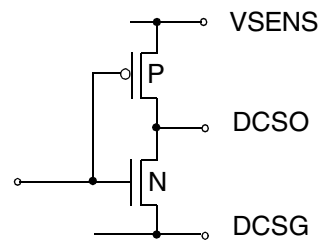


Fig. 4-11: Input/output pins DCSSO1/2, DCSG1/2, VSENS1/2

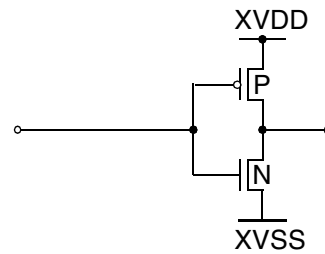


Fig. 4-12: Output pins  $\overline{PRTW}$ ,  $\overline{EOD}$ ,  $\overline{PRTR}$ , CLKO, SYNC, PUP

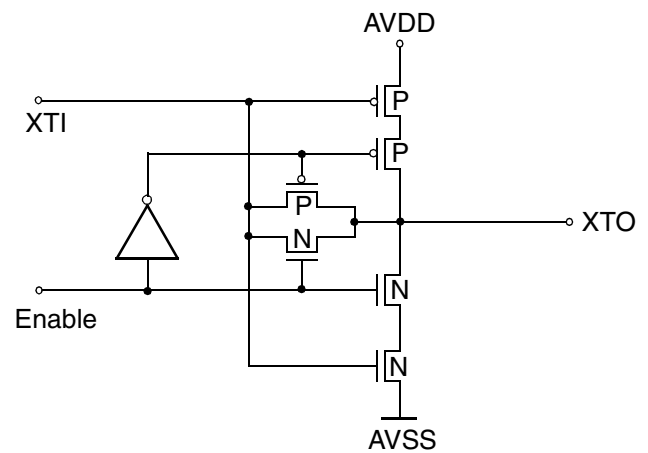
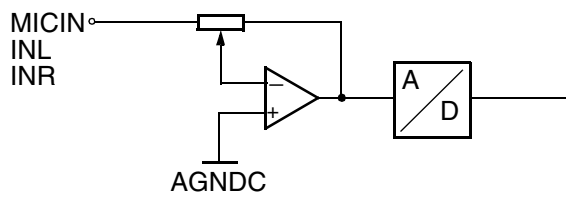
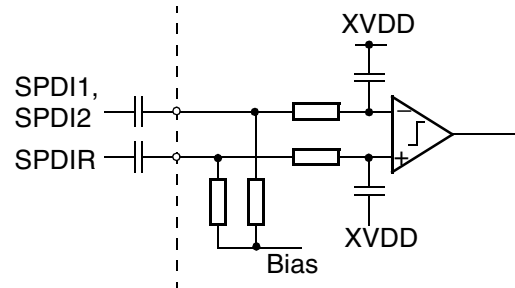


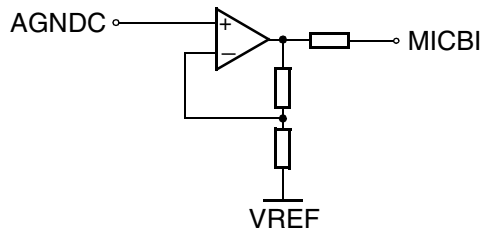
Fig. 4-13: Clock oscillator XTI, XTO



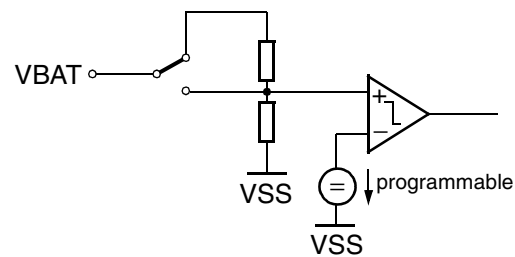
**Fig. 4-14:** Analog input pins MICIN, INL, INR



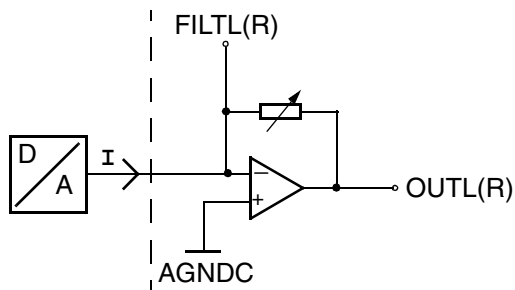
**Fig. 4-18:** S/PDIF inputs



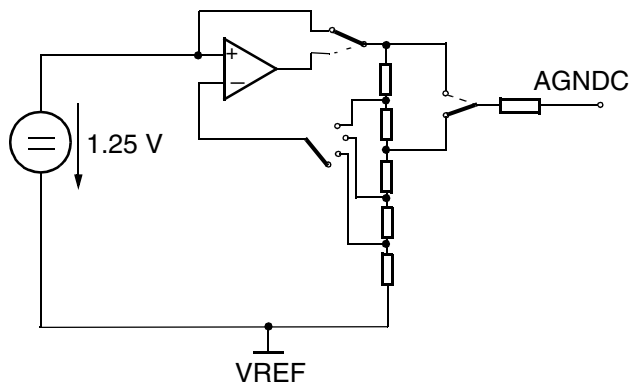
**Fig. 4-15:** Microphone bias pin (MICBI)



**Fig. 4-19:** Battery voltage monitor VBAT



**Fig. 4-16:** Analog outputs OUTL(R) and connections for filter capacitors FILTL(R)



**Fig. 4-17:** Analog ground generation with pin to connect external capacitor

4.6. Electrical Characteristics

4.6.1. Absolute Maximum Ratings

| Symbol                                                                                                                                                                                                                                                                                                                                                                                                                            | Parameter                                                                                             | Pin Name                                      | Min.     | Max.            | Unit     |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|-----------------------------------------------|----------|-----------------|----------|
| $T_A$                                                                                                                                                                                                                                                                                                                                                                                                                             | Ambient operating temperature<br>- operating conditions<br>- extended temperature range <sup>1)</sup> |                                               | 0<br>-40 | 70<br>70        | °C<br>°C |
| $T_{C\_LQFP}$                                                                                                                                                                                                                                                                                                                                                                                                                     | Case temperature PLQFP64                                                                              |                                               | -40      | 80              | °C       |
| $T_{C\_MQFP}$                                                                                                                                                                                                                                                                                                                                                                                                                     | Case temperature PMQFP64                                                                              |                                               | -40      | <b>TBD</b>      | °C       |
| $T_S$                                                                                                                                                                                                                                                                                                                                                                                                                             | Storage Temperature                                                                                   |                                               | -40      | 125             | °C       |
| $P_{TOT}$                                                                                                                                                                                                                                                                                                                                                                                                                         | Power dissipation                                                                                     | VDD, XVDD,<br>AVDD0/1,<br>I2CVDD              |          | 650             | mW       |
| $V_{SUP}$                                                                                                                                                                                                                                                                                                                                                                                                                         | Supply voltage                                                                                        | VDD, XVDD,<br>I2CVDD<br>AVDD0/1 <sup>2)</sup> | -0.3     | 6               | V        |
| $V_{I2C}$                                                                                                                                                                                                                                                                                                                                                                                                                         | Input voltage, I <sup>2</sup> C-Pins                                                                  | I2CC,<br>I2CD                                 | -0.3     | 6               | V        |
| $V_{Idig}$                                                                                                                                                                                                                                                                                                                                                                                                                        | Input voltage, all digital inputs                                                                     |                                               | -0.3     | $V_{SUP} + 0.3$ | V        |
| $I_{Idig}$                                                                                                                                                                                                                                                                                                                                                                                                                        | Input current, all digital inputs                                                                     |                                               | -20      | +20             | mA       |
| $V_{Iana}$                                                                                                                                                                                                                                                                                                                                                                                                                        | Input voltage, all analog inputs                                                                      |                                               | -0.3     | $V_{SUP} + 0.3$ | V        |
| $I_{Iana}$                                                                                                                                                                                                                                                                                                                                                                                                                        | Input current, all analog inputs                                                                      |                                               | -5       | +5              | mA       |
| $I_{Oaudio}$                                                                                                                                                                                                                                                                                                                                                                                                                      | Output current, audio output <sup>3)</sup>                                                            | OUTL/R                                        | -0.2     | 0.2             | A        |
| $I_{Odig}$                                                                                                                                                                                                                                                                                                                                                                                                                        | Output current, all digital outputs <sup>4)</sup>                                                     |                                               | -50      | +50             | mA       |
| $I_{Odcdc1}$                                                                                                                                                                                                                                                                                                                                                                                                                      | Output current DCDC converter 1                                                                       | DCSO1                                         |          | 1.5             | A        |
| $I_{Odcdc2}$                                                                                                                                                                                                                                                                                                                                                                                                                      | Output current DCDC converter 2                                                                       | DCSO2                                         |          | 1.5             | A        |
| <sup>1)</sup> The functionality of the device in the “extended temperature range” was checked by electrical characterization on sample base. Data sheet parameters are valid for “operating conditions” only.<br><sup>2)</sup> Both AVDD0 and AVDD1 have to be connected together!<br><sup>3)</sup> These pins are not short-circuit proof!<br><sup>4)</sup> Total chip power dissipation must not exceed absolute maximum rating |                                                                                                       |                                               |          |                 |          |

Stresses beyond those listed in the “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only. Functional operation of the device at these or any other conditions beyond those indicated in the “Recommended Operating Conditions/Characteristics” of this specification is not implied. Exposure to absolute maximum ratings conditions for extended periods may affect device reliability.



## 4.6.2. Recommended Operating Conditions

Table 4–1: Temperature range and supply voltages

| Symbol                                                                                                                                                                                                                                 | Parameter                                                                                             | Pin Name  | Min.                                       | Typ.       | Max.       | Unit               |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|-----------|--------------------------------------------|------------|------------|--------------------|
| T <sub>A</sub>                                                                                                                                                                                                                         | Ambient operating temperature<br>- operating conditions<br>- extended temperature range <sup>1)</sup> |           | 0                                          |            | 70         | °C                 |
|                                                                                                                                                                                                                                        |                                                                                                       |           | –40                                        |            | 70         | °C                 |
| V <sub>SUPD1</sub>                                                                                                                                                                                                                     | Digital supply voltage<br>(MPEG decoder)                                                              | VDD, XVDD | 2.5                                        | 2.7        | 3.9        | V                  |
| V <sub>SUPD2</sub>                                                                                                                                                                                                                     | Digital supply voltage<br>(MPEG 1 encoder)<br><br>48, 32 kHz<br>44.1 kHz                              |           | 3.5<br>3.3                                 | 3.7<br>3.5 | 3.9<br>3.9 |                    |
|                                                                                                                                                                                                                                        | Digital supply voltage<br>(MPEG 2 encoder)                                                            |           | 2.7                                        | 2.9        | 3.9        |                    |
| V <sub>SUPI2C</sub>                                                                                                                                                                                                                    | I <sup>2</sup> C bus supply voltage                                                                   | I2CVDD    | V <sub>SUPDn</sub> <sup>2)</sup><br>at VDD |            | 3.9        | V                  |
| V <sub>SUPA</sub>                                                                                                                                                                                                                      | Analog audio supply voltage                                                                           | AVDD0/1   | 2.2                                        | 2.7        | 3.9        | V                  |
|                                                                                                                                                                                                                                        | Analog audio supply voltage in<br>relation to the digital supply volt-<br>age                         |           | 0.62                                       |            | 1.6        | V <sub>SUPDn</sub> |
| V <sub>SUPx</sub>                                                                                                                                                                                                                      | PIN supply voltage                                                                                    | XVDD      | 2.5                                        |            | 3.9        | V                  |
|                                                                                                                                                                                                                                        | PIN supply voltage in relation to<br>digital supply voltage                                           |           | 0.62                                       |            | 1.6        | V <sub>SUPDn</sub> |
| <sup>1)</sup> The functionality of the device in the “extended temperature range” was checked by electrical characterization on sample base. Data sheet parameters are valid for “operating conditions” only.<br><sup>2)</sup> n = 1,2 |                                                                                                       |           |                                            |            |            |                    |

**Table 4–2:** Reference frequency generation and crystal recommendation

| Symbol                                                                                                                                    | Parameter                                                                   | Pin Name | Min.               | Typ.   | Max.               | Unit     |
|-------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|----------|--------------------|--------|--------------------|----------|
| <b>External Clock Input Recommendations</b>                                                                                               |                                                                             |          |                    |        |                    |          |
| $f_{CLK}$                                                                                                                                 | Clock frequency                                                             | XTI, XTO | 13.0 <sup>2)</sup> | 18.432 | 20.0 <sup>1)</sup> | MHz      |
| $V_{CLKI}$                                                                                                                                | Clock amplitude of external clock fed into XTI at $V_{SUPA} = 2.2\text{ V}$ | XTI      | 0.7                |        | 1.05               | $V_{PP}$ |
|                                                                                                                                           | Clock amplitude of external clock fed into XTI at $V_{SUPA} = 2.7\text{ V}$ |          | 0.55               |        | 1.5                |          |
|                                                                                                                                           | Clock amplitude of external clock fed into XTI at $V_{SUPA} = 3.3\text{ V}$ |          | 0.45               |        | 1.75               |          |
|                                                                                                                                           | Clock amplitude of external clock fed into XTO at $V_{SUPA} = 2.2\text{ V}$ | XTO      | 1.25               |        | 2.2                |          |
|                                                                                                                                           | Clock amplitude of external clock fed into XTO at $V_{SUPA} = 2.7\text{ V}$ |          | 0.75               |        | 2.7                |          |
|                                                                                                                                           | Clock amplitude of external clock fed into XTO at $V_{SUPA} = 3.3\text{ V}$ |          | 0.55               |        | 3.3                |          |
|                                                                                                                                           | Duty cycle                                                                  | XTI, XTO | 45                 | 50     | 55                 | %        |
| <b>Crystal Recommendations</b>                                                                                                            |                                                                             |          |                    |        |                    |          |
| $T_A$                                                                                                                                     | Ambient operating temperature                                               |          | –40                |        | 70                 | °C       |
| $f_P$                                                                                                                                     | Load resonance frequency at $C_1 = 20\text{ pF}$                            | XTI, XTO |                    | 18.432 |                    | MHz      |
| $\Delta f/f_S$                                                                                                                            | Accuracy of frequency adjustment                                            |          | –50                |        | 50                 | ppm      |
| $\Delta f/f_S$                                                                                                                            | Frequency variation vs. temperature                                         |          | –50                |        | 50                 | ppm      |
| $R_{EQ}$                                                                                                                                  | Equivalent series resistance                                                |          |                    | 12     | 30                 | $\Omega$ |
| $C_0$                                                                                                                                     | Shunt (parallel) capacitance                                                |          |                    | 3      | 5                  | pF       |
| <sup>1)</sup> extended to 28 MHz by divider 1/1.5 (refer to Table 3–3 on page 20)<br><sup>2)</sup> depending on mode (refer to Table 4–3) |                                                                             |          |                    |        |                    |          |

**Table 4–3:** Input clock frequency

| Symbol           | Parameter                      | Pin Name | Min. | Typ. | Max. | Unit |
|------------------|--------------------------------|----------|------|------|------|------|
| f <sub>CLK</sub> | MPEG 1 Encoder<br>MPEG Decoder | XTI      | 11.0 |      |      | MHz  |
|                  | MPEG 2 Encoder                 |          | 13.7 |      |      | MHz  |

**Table 4–4:** Input levels

| Symbol           | Parameter                                                  | Pin Name                                                       | Min.                      | Typ. | Max. | Unit |
|------------------|------------------------------------------------------------|----------------------------------------------------------------|---------------------------|------|------|------|
| I <sub>IL</sub>  | Input low voltage<br>at V <sub>SUPI2C</sub> = 2.5...3.9 V  | I2CC,<br>I2CD                                                  |                           |      | 0.3  | V    |
| I <sub>IH</sub>  | Input high voltage<br>at V <sub>SUPI2C</sub> = 2.5...3.9 V |                                                                | 1.4                       |      |      | V    |
| I <sub>IL</sub>  | Input low voltage<br>at V <sub>SUPI2C</sub> = 2.5...3.9 V  | $\overline{\text{POR}}$ ,<br>DCEN                              |                           |      | 0.2  | V    |
| I <sub>IH</sub>  | Input high voltage<br>at V <sub>SUPI2C</sub> = 2.5...3.9 V |                                                                | 0.9                       |      |      | V    |
| I <sub>ILD</sub> | Input low voltage                                          | PI<I>,<br>SI(B)I,<br>SI(B)C,<br>SI(B)D, PR,<br>PCS,<br>TE, DVS |                           |      | 0.3  | V    |
| I <sub>IHD</sub> | Input high voltage                                         |                                                                | V <sub>SUPD</sub><br>–0.5 |      |      | V    |

Table 4–5: Analog input and output recommendations

| Symbol                                                                          | Parameter                                                                 | Pin Name            | Min. | Typ. | Max. | Unit          |
|---------------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------|------|------|------|---------------|
| <b>Analog Reference</b>                                                         |                                                                           |                     |      |      |      |               |
| $C_{AGNDC1}$                                                                    | Analog filter capacitor                                                   | AGNDC               | 1.0  | 3.3  |      | $\mu\text{F}$ |
| $C_{AGNDC2}$                                                                    | Ceramic capacitor in parallel                                             |                     |      | 10   |      | nF            |
| $C_{PVDD}$                                                                      | Capacitor for analog circuitry                                            | PVDD                | 3    |      |      | nF            |
| <b>Analog Audio Inputs</b>                                                      |                                                                           |                     |      |      |      |               |
| $C_{inAD}$                                                                      | DC-decoupling capacitor at A/D-converter inputs                           | INL/R               |      | 390  |      | nF            |
| $C_{inMI}$                                                                      | DC-decoupling capacitor at microphone-input                               | MICIN               |      | 390  |      | nF            |
| $C_{LMICBI}$                                                                    | Minimum-Capacitance at microphone bias                                    | MICBI               | 3.3  |      |      | nF            |
| <b>Analog Audio Filter Outputs</b>                                              |                                                                           |                     |      |      |      |               |
| $C_{FILT}$                                                                      | Filter capacitor for headphone amplifier high-Q type, NP0 or C0G material | FILT/L/R<br>OUTL/R  | -20% | 470  | +20% | $\mu\text{F}$ |
| <b>Analog Audio Output</b>                                                      |                                                                           |                     |      |      |      |               |
| $Z_{AOL\_HP}$                                                                   | Analog output load with stereo headphones                                 | OUTL/R              | 16   |      |      | $\Omega$      |
|                                                                                 |                                                                           |                     |      | 100  |      | $\mu\text{F}$ |
| <b>DC/DC-Converter External Circuitry (please refer to application example)</b> |                                                                           |                     |      |      |      |               |
| $C_1$                                                                           | VSENS blocking (<100 m $\Omega$ ESR)                                      | VSENS1/2            |      | 330  |      | $\mu\text{F}$ |
| $V_{TH}$                                                                        | Schottky diode threshold voltage                                          | DCSO1/2<br>VSENS1/2 |      | 0.39 |      | V             |
| L                                                                               | Ferrite core coil inductance                                              | DCSO1/2             |      | 22   |      | $\mu\text{H}$ |
| <b>S/PDIF Interface Analog Input</b>                                            |                                                                           |                     |      |      |      |               |
| $C_{SPI}$                                                                       | S/PDIF coupling capacitor                                                 | SPDI1/2<br>SPDIR    |      | 100  |      | nF            |

### 4.6.3. Digital Characteristics

at  $T = T_A$ ,  $V_{SUPDn}$ ,  $V_{SUPA}$ ,  $V_{SUPx} = 2.5 \dots 3.6$  V,  $f_{Crystal} = 18.432$  MHz, Typ. values for  $T_A = 25$  °C, in PMQFP64/PLQFP64 package

| Symbol                            | Parameter                           | Pin Name                                                                                       | Min.             | Typ. | Max. | Unit    | Test Conditions                         |
|-----------------------------------|-------------------------------------|------------------------------------------------------------------------------------------------|------------------|------|------|---------|-----------------------------------------|
| <b>Digital Supply Voltage</b>     |                                     |                                                                                                |                  |      |      |         |                                         |
| $I_{SUPD1}$                       | Current consumption (MPEG decoding) | VDD,<br>XVDD,<br>I2CVDD                                                                        |                  | 35   |      | mA      | 2.5 V, sampling frequency $\geq 32$ kHz |
|                                   |                                     |                                                                                                |                  | 18   |      |         | 2.5 V, sampling frequency $\leq 24$ kHz |
|                                   |                                     |                                                                                                |                  | 10   |      |         | 2.5 V, sampling frequency $\leq 12$ kHz |
| $I_{SUPD2}$                       | Current consumption (MPEG encoding) |                                                                                                |                  | 130  |      |         | 3.5 V, sampling frequency $\geq 32$ kHz |
|                                   |                                     |                                                                                                |                  | 63   |      |         | 2.7 V, sampling frequency $\leq 24$ kHz |
| $I_{STANDBY}$                     | Total current at stand-by           |                                                                                                |                  |      |      | 10      | $\mu$ A                                 |
| <b>Digital Outputs and Inputs</b> |                                     |                                                                                                |                  |      |      |         |                                         |
| $O_{DigL}$                        | Output low voltage                  | PI<i>,</i><br>SOI,<br>SOC,<br>SOD,<br>EOD,<br>PRTR,<br>PRTW,<br>CLKO,<br>SYNC,<br>PUP,<br>SPDO |                  |      | 0.3  | V       | $I_{load} = 2$ mA                       |
| $O_{DigH}$                        | Output low voltage                  |                                                                                                | $V_{SUPD} - 0.3$ |      |      |         | V                                       |
| $Z_{DigI}$                        | Input impedance                     | all digital Inputs                                                                             |                  |      | 7    | pF      |                                         |
| $I_{DLeak}$                       | Digital input leakage current       |                                                                                                | -1               |      | 1    | $\mu$ A | $0 \text{ V} < V_{pin} < V_{SUPD}$      |

4.6.3.1. I<sup>2</sup>C Characteristics

at T = 25°C, V<sub>SUPI2C</sub> = 2.5...3.6 V, in PMQFP64/PLQFP64 package

| Symbol                                     | Parameter                                                           | Pin Name   | Min. | Typ. | Max. | Unit                | Test Conditions            |
|--------------------------------------------|---------------------------------------------------------------------|------------|------|------|------|---------------------|----------------------------|
| <b>I<sup>2</sup>C Input Specifications</b> |                                                                     |            |      |      |      |                     |                            |
| f <sub>I2C</sub>                           | Upper limit I <sup>2</sup> C bus frequency operation                | I2CC       | 400  |      |      | kHz                 |                            |
| t <sub>I2C1</sub>                          | I <sup>2</sup> C START condition setup time                         | I2CC, I2CD | 300  |      |      | ns                  |                            |
| t <sub>I2C2</sub>                          | I <sup>2</sup> C STOP condition setup time                          | I2CC, I2CD | 300  |      |      | ns                  |                            |
| t <sub>I2C3</sub>                          | I <sup>2</sup> C clock low pulse time                               | I2CC       | 1250 |      |      | ns                  |                            |
| t <sub>I2C4</sub>                          | I <sup>2</sup> C clock high pulse time                              | I2CC       | 1250 |      |      | ns                  |                            |
| t <sub>I2C5</sub>                          | I <sup>2</sup> C data setup time before rising edge of clock        | I2CC       | 80   |      |      | ns                  |                            |
| t <sub>I2C6</sub>                          | I <sup>2</sup> C data hold time after falling edge of clock         | I2CC       | 80   |      |      | ns                  |                            |
| V <sub>I2COL</sub>                         | I <sup>2</sup> C output low voltage                                 | I2CC, I2CD |      |      | 0.4  | V                   | I <sub>load</sub> = 3 mA   |
| I <sub>I2COH</sub>                         | I <sup>2</sup> C output high leakage current                        | I2CC, I2CD |      |      | 1    | μA                  |                            |
| t <sub>I2COL1</sub>                        | I <sup>2</sup> C data output hold time after falling edge of clock  | I2CC, I2CD | 20   |      |      | ns                  |                            |
| t <sub>I2COL2</sub>                        | I <sup>2</sup> C data output setup time before rising edge of clock | I2CC, I2CD | 250  |      |      | ns                  | f <sub>I2C</sub> = 400 kHz |
| V <sub>I2CIL</sub>                         | I <sup>2</sup> C input low voltage                                  | I2CC; I2CD |      |      | 0.3  | V <sub>SUPI2C</sub> |                            |
| V <sub>I2CIH</sub>                         | I <sup>2</sup> C input high voltage                                 | I2CC, I2CD | 0.6  |      |      | V <sub>SUPI2C</sub> |                            |
| t <sub>w</sub>                             | Wait time                                                           | I2CC, I2CD | 0    | 0.5  | 4    | ms                  |                            |

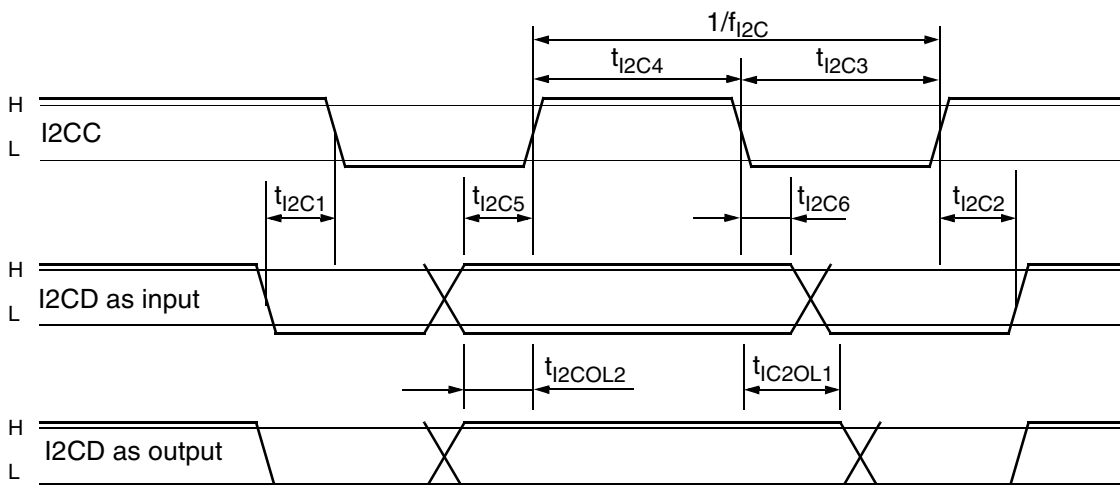
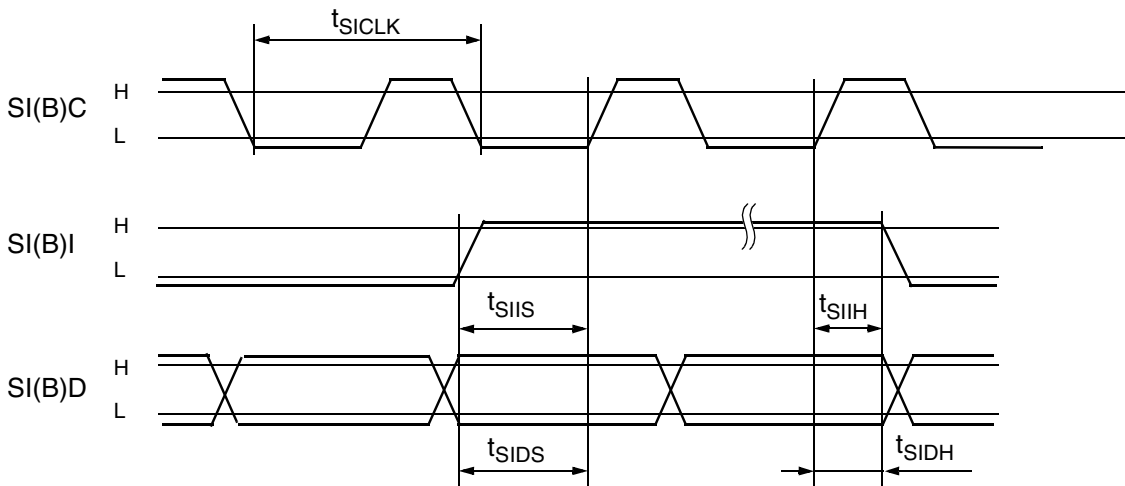


Fig. 4–20: I<sup>2</sup>C timing diagram

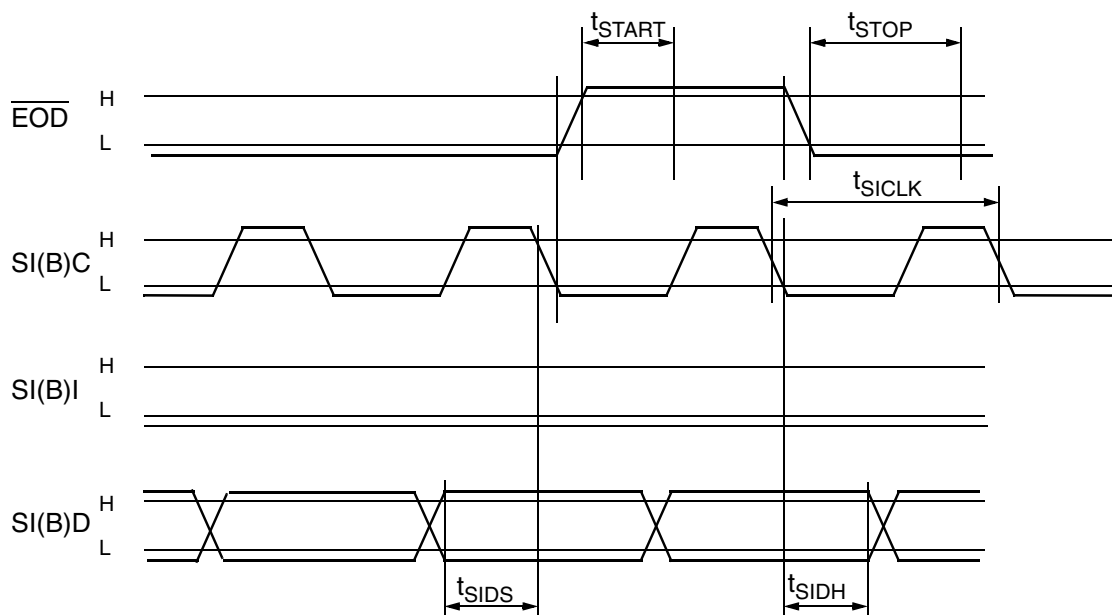
**4.6.3.2. Serial (I<sup>2</sup>S) Input Interface Characteristics (SDI, SDIB)**

at  $T = T_A$ ,  $V_{SUPDn}$ ,  $V_{SUPA}$ ,  $V_{SUPx} = 2.5 \dots 3.6 \text{ V}$ ,  $f_{Crystal} = 18.432 \text{ MHz}$ , Typ. values for  $T_A = 25 \text{ }^\circ\text{C}$ , in PMQFP64/PLQFP64 package

| Symbol      | Parameter                                                                                                | Pin Name          | Min. | Typ. | Max. | Unit | Test Conditions                                                                                        |
|-------------|----------------------------------------------------------------------------------------------------------|-------------------|------|------|------|------|--------------------------------------------------------------------------------------------------------|
| $t_{SICLK}$ | I <sup>2</sup> S clock input clock period                                                                | SI(B)C            |      | 325  |      | ns   | $f_S = 48 \text{ kHz Stereo}$ ,<br>32 bits per sample<br>(for demand mode see<br>Table 4–6 on page 64) |
| $t_{SIDS}$  | I <sup>2</sup> S data setup time before rising edge of clock (for continuous data stream: falling edge)  | SI(B)C,<br>SI(B)D | 50   |      |      | ns   |                                                                                                        |
| $t_{SIDH}$  | I <sup>2</sup> S data hold time                                                                          | SI(B)D            | 50   |      |      | ns   |                                                                                                        |
| $t_{SIIS}$  | I <sup>2</sup> S ident setup time before rising edge of clock (for continuous data stream: falling edge) | SI(B)C,<br>SI(B)I | 50   |      |      | ns   |                                                                                                        |
| $t_{SIIH}$  | I <sup>2</sup> S ident hold time                                                                         | SI(B)I            | 50   |      |      | ns   |                                                                                                        |
| $t_{bw}$    | Burst wait time                                                                                          | SI(B)C,<br>SI(B)D | 480  |      |      |      |                                                                                                        |



**Fig. 4–21:** Serial input of I<sup>2</sup>S signal



**Fig. 4–22:** Continuous data stream at serial input A or B. In this mode, the word strobe  $\text{SI(B)I}$  is not used and the data are read at the falling edge of the clock (bit 2 in  $\text{D0:7F1}$  is set).

**Table 4–6:** Maximum allowed sample clock frequency in Demand Mode

| $f_{\text{Sample}}$ (kHz) | $f_{\text{Cmax}}$ (MHz) | min. $t_{\text{SICLK}}$ (ns) |
|---------------------------|-------------------------|------------------------------|
| 48, 32                    | 6.144                   | 162                          |
| 44.1                      | 5.6448                  | 177                          |
| 24, 16                    | 3.072                   | 325                          |

**Table 4–6:** Maximum allowed sample clock frequency in Demand Mode

| $f_{\text{Sample}}$ (kHz) | $f_{\text{Cmax}}$ (MHz) | min. $t_{\text{SICLK}}$ (ns) |
|---------------------------|-------------------------|------------------------------|
| 22.05                     | 2.8224                  | 354                          |
| 12, 8                     | 1.536                   | 651                          |
| 11.025                    | 1.4112                  | 708                          |



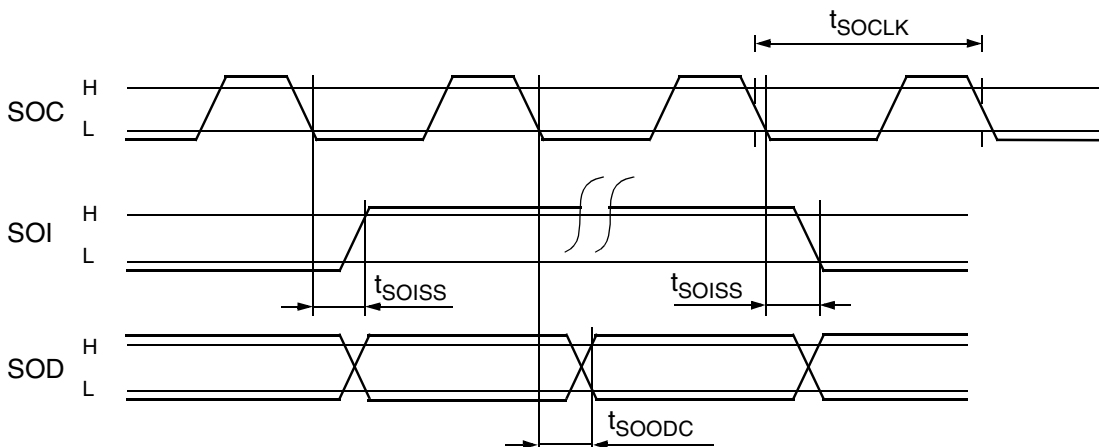
**Table 4-7:** Allowed transmission delays of external data source

| Symbol            | Parameter                                                                                                  | Pin Name         | Min. | Typ. | Max. | Unit | Test Conditions                   |
|-------------------|------------------------------------------------------------------------------------------------------------|------------------|------|------|------|------|-----------------------------------|
| $t_{START48-320}$ | Allowed delay time before start of serial data transmission after assertion of signal at $\overline{EOD}$  | $\overline{EOD}$ |      |      | 3.1  | ms   | 48 kHz/s, 320 kbit/s              |
| $t_{START48-64}$  |                                                                                                            |                  |      |      | 5.7  | ms   | 48 kHz/s, 64 kbit/s               |
| $t_{START24-320}$ |                                                                                                            |                  |      |      | 4.2  | ms   | 24 kHz/s, 320 kbit/s              |
| $t_{START24-32}$  |                                                                                                            |                  |      |      | 9.2  | ms   | 24 kHz/s, 32 kbit/s               |
| $t_{START12-64}$  |                                                                                                            |                  |      |      | 23.1 | ms   | 12 kHz/s, 64 kbit/s               |
| $t_{START12-16}$  |                                                                                                            |                  |      |      | 25.6 | ms   | 12 kHz/s, 16 kbit/s               |
| $t_{START8-64}$   |                                                                                                            |                  |      |      | 34.8 | ms   | 8 kHz/s, 64 kbit/s                |
| $t_{START8-8}$    |                                                                                                            |                  |      |      | 38.4 | ms   | 8 kHz/s, 8 kbit/s                 |
| $t_{STOP}$        | Allowed delay time before stop of serial data transmission after deassertion of signal at $\overline{EOD}$ | $\overline{EOD}$ |      |      | 1.3  | ms   | Clock rate of input data 1 Mbit/s |

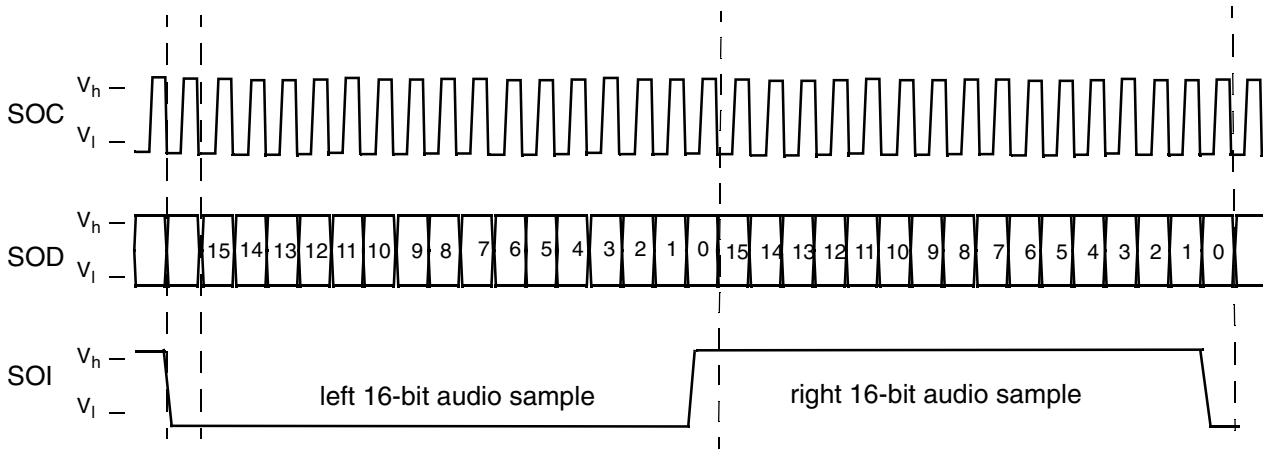
**4.6.3.3. Serial Output Interface Characteristics (SDO)**

at  $T = T_A$ ,  $V_{SUPDn}$ ,  $V_{SUPA}$ ,  $V_{SUPx} = 2.5 \dots 3.6 \text{ V}$ ,  $f_{Crystal} = 18.432 \text{ MHz}$ , Typ. values for  $T_A = 25 \text{ }^\circ\text{C}$ , in PMQFP64/PLQFP64 package

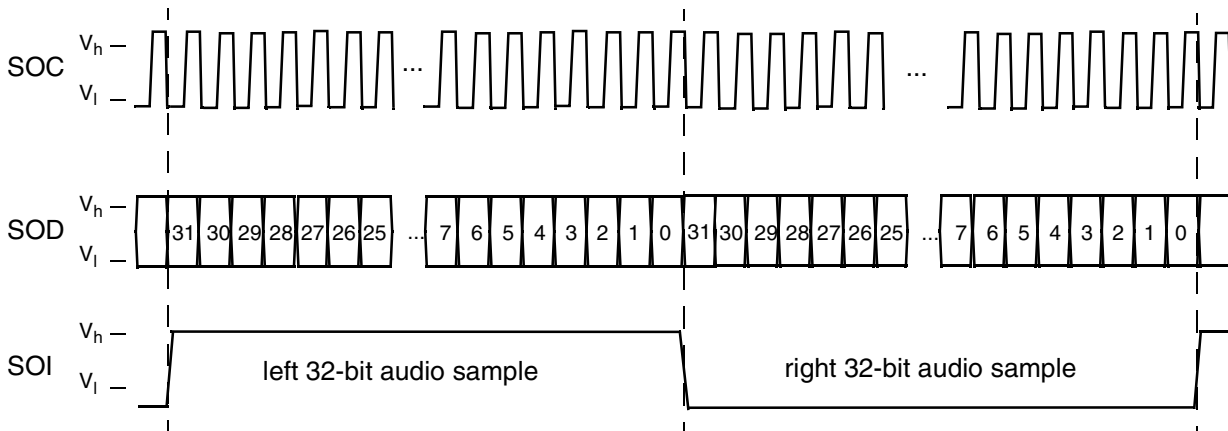
| Symbol      | Parameter                                                           | Pin Name    | Min. | Typ. | Max. | Unit | Test Conditions                                     |
|-------------|---------------------------------------------------------------------|-------------|------|------|------|------|-----------------------------------------------------|
| $t_{SOCLK}$ | I <sup>2</sup> S clock output frequency                             | SOC         |      | 325  |      | ns   | $f_S = 48 \text{ kHz Stereo}$<br>32 bits per sample |
| $t_{SOISS}$ | I <sup>2</sup> S word strobe delay time after falling edge of clock | SOC,<br>SOI | 0    |      |      | ns   |                                                     |
| $t_{SOODC}$ | I <sup>2</sup> S data delay time after falling edge of clock        | SOC,<br>SOD | 0    |      |      | ns   |                                                     |



**Fig. 4-23:** Serial output interface timing.



**Fig. 4-24:** Sample timing of the SDO interface in 16 bit/sample mode. D0:7F1 settings are: Bit 14 = 0 (SOC not inverted), bit 11 = 1 (SOI delay), bit 5 = 0 (word strobe not inverted), bit 4 = 1 (16 bits/sample).



**Fig. 4-25:** Sample timing of the SDO interface in 32 bit/sample mode. D0:7F1 settings are: Bit 14 = 0 (SOC not inverted), bit 11 = 0 (no SOI delay), bit 5 = 1 (word strobe inverted), bit 4 = 0 (32 bits/sample).

4.6.3.4. S/PDIF Input Characteristics

at  $T = T_A$ ,  $V_{SUPDn}$ ,  $V_{SUPA}$ ,  $V_{SUPx} = 2.5 \dots 3.6$  V,  $f_{Crystal} = 18.432$  MHz, Typ. values for  $T_A = 25$  °C, in PMQFP64/PLQFP64 package.

| Symbol      | Parameter          | Pin Name            | Min. | Typ.  | Max. | Unit             | Test Conditions                                                                          |
|-------------|--------------------|---------------------|------|-------|------|------------------|------------------------------------------------------------------------------------------|
| $V_S$       | Signal amplitude   | SPDI1, SPDI2, SPDIR | 200  | 500   | 1000 | mV <sub>pp</sub> |                                                                                          |
| $f_{s1}$    | Bi-phase frequency | SPDI1, SPDI2, SPDIR |      | 2.048 |      | MHz              | $\pm 1000$ ppm, $f_s = 48$ kHz                                                           |
| $f_{s2}$    | Bi-phase frequency | SPDI1, SPDI2, SPDIR |      | 2.822 |      | MHz              | $\pm 1000$ ppm, $f_s = 44.1$ kHz                                                         |
| $f_{s3}$    | Bi-phase frequency | SPDI1, SPDI2, SPDIR |      | 3.072 |      | MHz              | $\pm 1000$ ppm, $f_s = 32$ kHz                                                           |
| $t_P$       | Bi-phase period    | SPDI1, SPDI2, SPDIR |      | 326   |      | ns               | at $f_s = 48$ kHz, (highest sampling rate)                                               |
| $t_R$       | Rise time          | SPDI1, SPDI2, SPDIR | 0    |       | 65   | ns               | at $f_s = 48$ kHz, (highest sampling rate)                                               |
| $t_F$       | Fall time          | SPDI1, SPDI2, SPDIR | 0    |       | 65   | ns               | at $f_s = 48$ kHz, (highest sampling rate)                                               |
|             | Duty cycle         | SPDI                | 40   | 50    | 60   | %                | at bit value = 1 and $f_s = 48$ kHz                                                      |
| $t_{H1,L1}$ |                    | SPDI                | 81   |       | 163  | ns               | minimum/maximum pulse duration with a level above 90% or below 10% and at $f_s = 48$ kHz |
| $t_{H0,L0}$ |                    | SPDI                | 163  |       | 244  | ns               | minimum/maximum pulse duration with a level above 90% or below 10% and at $f_s = 48$ kHz |

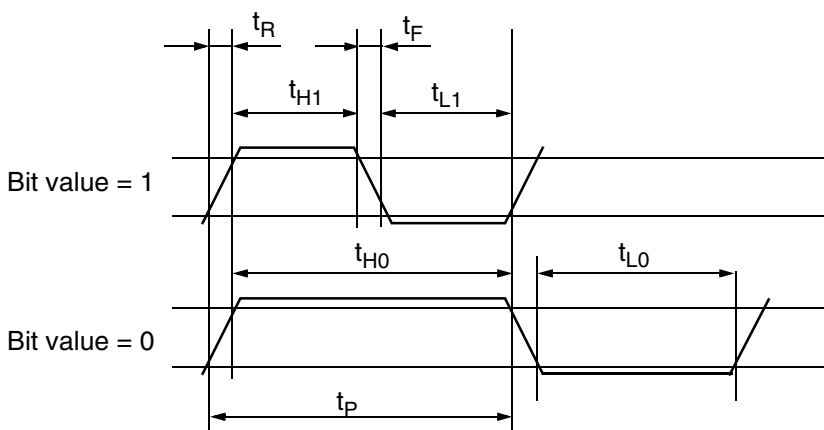


Fig. 4–26: Timing of the S/PDIF input

4.6.3.5. S/PDIF Output Characteristics

at  $T = T_A$ ,  $V_{SUPDn}$ ,  $V_{SUPA}$ ,  $V_{SUPx} = 2.5 \dots 3.6 \text{ V}$ ,  $f_{Crystal} = 18.432 \text{ MHz}$ , Typ. values for  $T_A = 25 \text{ }^\circ\text{C}$ , in PMQFP64/PLQFP64 package.

| Symbol      | Parameter          | Pin Name | Min. | Typ.       | Max. | Unit | Test Conditions                                                                                  |
|-------------|--------------------|----------|------|------------|------|------|--------------------------------------------------------------------------------------------------|
| $f_{s1}$    | Bi-phase frequency | SPDO     |      | 3.072      |      | MHz  | $f_s = 48 \text{ kHz}$                                                                           |
| $f_{s2}$    | Bi-phase frequency | SPDO     |      | 2.822      |      | MHz  | $f_s = 44.1 \text{ kHz}$                                                                         |
| $f_{s3}$    | Bi-phase frequency | SPDO     |      | 2.048      |      | MHz  | $f_s = 32 \text{ kHz}$                                                                           |
| $t_p$       | Bi-phase period    | SPDO     |      | 326        |      | ns   | at $f_s = 48 \text{ kHz}$ , (highest sampling rate)                                              |
| $t_R$       | Rise time          | SPDO     | 0    |            | 2    | ns   | $C_{load} = 10 \text{ pF}$                                                                       |
| $t_F$       | Fall time          | SPDO     | 0    |            | 2    | ns   | $C_{load} = 10 \text{ pF}$                                                                       |
|             | Duty cycle         | SPDO     |      | 50         |      | %    |                                                                                                  |
| $t_{H1,L1}$ |                    | SPDO     |      | 163        |      | ns   | minimum/maximum pulse duration with a level above 90% or below 10% and at $f_s = 48 \text{ kHz}$ |
| $t_{H0,L0}$ |                    | SPDO     |      | 326        |      | ns   | minimum/maximum pulse duration with a level above 90% or below 10% and at $f_s = 48 \text{ kHz}$ |
| $V_S$       | Signal amplitude   | SPDO     |      | $V_{SUPD}$ |      |      |                                                                                                  |

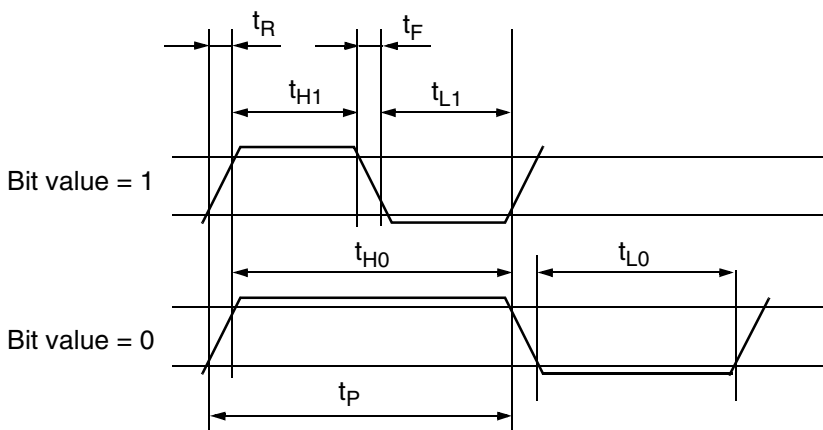


Fig. 4–27: Timing of the S/PDIF output

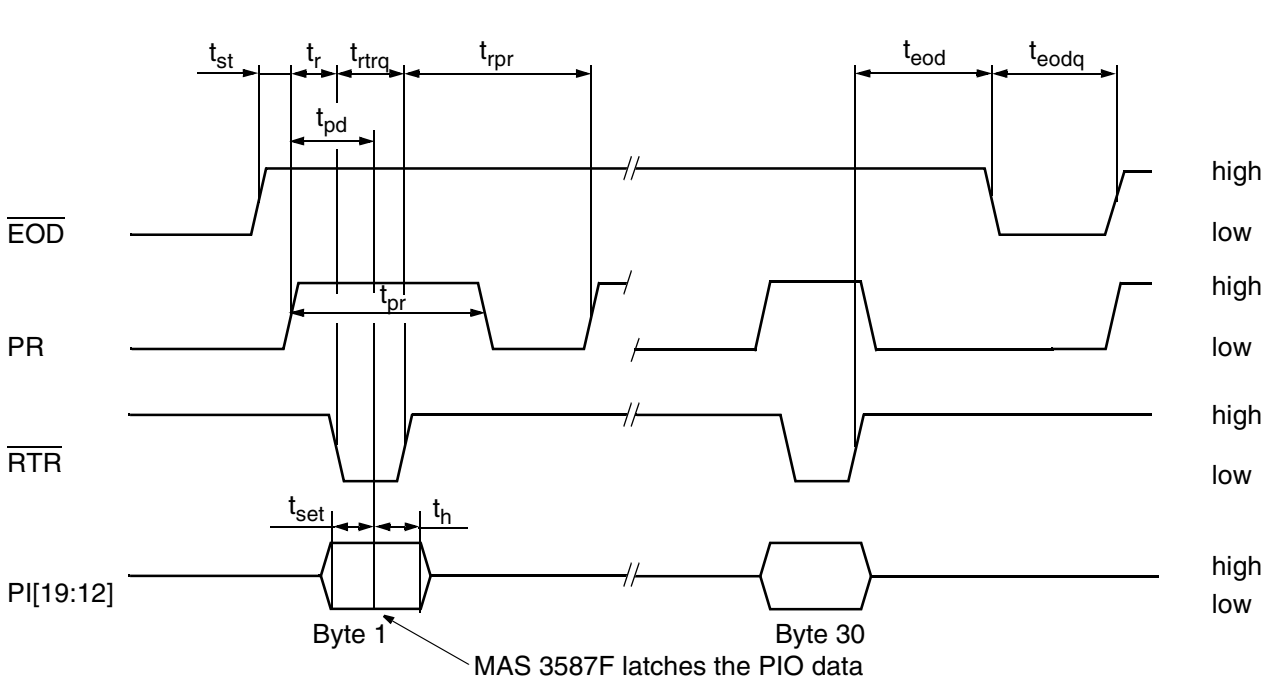
**4.6.3.6. PIO as Parallel Input Interface: DMA Mode**

In decoding mode, the data transfer can be started after the EOD pin of the MAS 3587F is set to “high”. After verifying this, the controller signalizes the sending of data by activating the PR line. The MAS 3587F responds by setting the RTR line to the “low” level and reads the data at PI[19:12]. After RTR is set to high again, the controller sets PR to low. The next data word write operation will be initialized again by setting the PR line via the controller. Please refer to Figure 4–28 for the exact timing

The procedure above will be repeated until the MAS 3587F sets the EOD signal to “0” which indicates that the transfer of one data block has been executed. Subsequently, the controller should set PR to “0”, wait until EOD rises again and then repeat the procedure to send the next block of data. The DMA buffer is 30 bytes long.

**Table 4–8: DMA input timing**

| Symbol     | Pin Name             | Min.  | Max.  | Unit    |
|------------|----------------------|-------|-------|---------|
| $t_{st}$   | PR, $\overline{EOD}$ | 0.010 | 2000  | $\mu s$ |
| $t_r$      | PR, $\overline{RTR}$ | 40    | 160   | ns      |
| $t_{pd}$   | PR, PI[19:12]        | 120   | 480   | ns      |
| $t_{set}$  | PI[19:12]            | 160   |       | ns      |
| $t_h$      | PI[19:12]            | 160   |       | ns      |
| $t_{rtrq}$ | RTR                  | 200   | 30000 | ns      |
| $t_{pr}$   | PR                   | 480   |       | ns      |
| $t_{rpr}$  | PR, $\overline{RTR}$ | 160   |       | ns      |
| $t_{eod}$  | PR, $\overline{EOD}$ | 40    | 160   | ns      |
| $t_{eodq}$ | EOD                  | 2.5   | 500   | $\mu s$ |



**Fig. 4–28: Handshake protocol for writing MPEG data to the PIO-DMA**

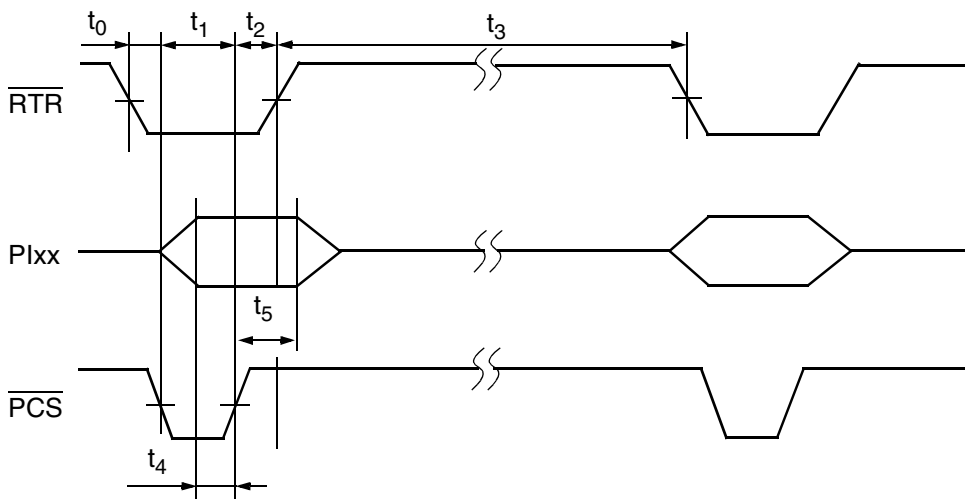
**4.6.3.7. PIO As Parallel Input Interface:  
Program Download Mode**

Handshaking for PIO input in Program Download Mode is accomplished through the RTR, PCS, and PI12..PI19 signal lines (see Fig. 4–29). The PR line should be set to low level.

The MAS 3587F will drive  $\overline{\text{RTR}}$  low as soon as it is ready to receive a byte and  $\overline{\text{RTR}}$  will stay low until one byte has been written. Writing of a byte is performed with a PCS pulse, driven by the microcontroller. The MAS 3587F reads data after the falling edge of PCS and will finish the cycle by setting RTR to high level after the rising edge of PCS. The next data transfer initialized by the MAS 3587F by driving the RTR line.

**Table 4–9:** PIO Program Download Mode timing

| Symbol | Pin Name                                       | Min. | Max. | Unit          |
|--------|------------------------------------------------|------|------|---------------|
| $t_0$  | $\overline{\text{RTR}}, \overline{\text{PCS}}$ | 0    |      | $\mu\text{s}$ |
| $t_1$  | PCS                                            | 150  |      | ns            |
| $t_2$  | $\overline{\text{PCS}}, \overline{\text{RTR}}$ | 0    | 30   | ns            |
| $t_3$  | RTR                                            | 0.4  | 5    | $\mu\text{s}$ |
| $t_4$  | PI                                             | 50   |      | ns            |
| $t_5$  | PI                                             | 50   |      | ns            |



**Fig. 4–29:** Input timing for Program Download Mode

**4.6.3.8. PIO as Parallel Output Interface:  
DMA Mode**

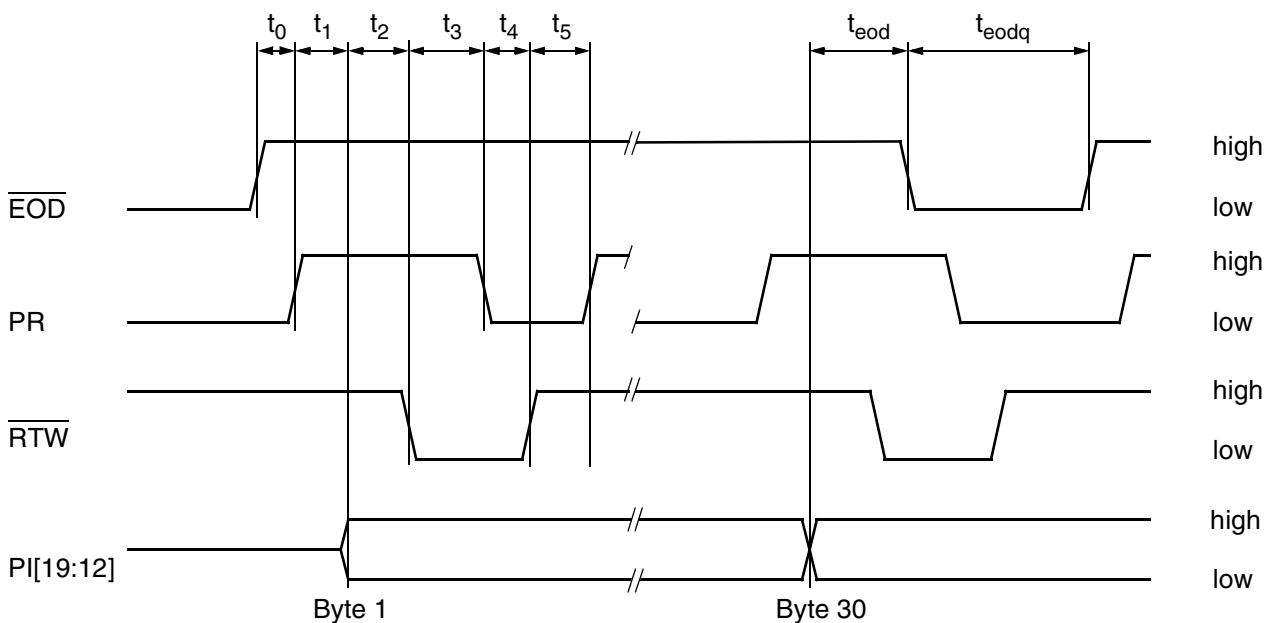
In encoding mode, the MAS 3587F signals available data by setting the EOD pin to "high". After verifying this, the controller signals its capability to receive one byte of data by activating the PR line. The MAS 3587F responds by setting the RTW line to the "low" level when the actual byte is set on the data lines PI[19:12]. After PR is set to "low" level, the RTW line is set to "high" again. The next data word write operation will be initialized again by setting the PR line via the controller. Please refer to Figure 4-30 for the exact timing.

The procedure above will be repeated until the MAS 3587F sets the EOD signal to "0" which indicates that the transfer of one data block has been executed. Subsequently, the controller should set PR to "0", wait until EOD rises again and then repeat the procedure to receive the next block of data. The DMA buffer is currently 30 bytes long.

In order to transfer the worst case data rate of 192 kbit/s, the controller must react sufficiently fast. The mean response times (t<sub>0</sub>, t<sub>3</sub>, t<sub>5</sub>) must be faster than 10 ms. Due to internal buffering in the MAS 3587F, this time can be expanded up to 4.8 ms once within each frame (see Table 2-2 on page 16) in any case.

**Table 4-10: PIO output mode timing**

| Symbol            | Pin Name                     | Min.  | Max. | Unit |
|-------------------|------------------------------|-------|------|------|
| t <sub>0</sub>    | $\overline{\text{EOD}}$ , PR | 0.010 | 2000 | μs   |
| t <sub>1</sub>    | PR, PI                       | 110   | 310  | ns   |
| t <sub>2</sub>    | PI, $\overline{\text{RTW}}$  | 18    | 55   | ns   |
| t <sub>3</sub>    | $\overline{\text{RTW}}$ , PR | 18    |      | ns   |
| t <sub>4</sub>    | PR, $\overline{\text{RTW}}$  | 90    | 260  | ns   |
| t <sub>5</sub>    | $\overline{\text{RTW}}$ , PR | 35    |      | ns   |
| t <sub>eod</sub>  |                              | 140   | 8000 | ns   |
| t <sub>eodq</sub> |                              | 2.5   |      | μs   |



**Fig. 4-30: Handshake protocol for reading MPEG data from the PIO-DMA**

**4.6.4. Analog Characteristics**

at  $T = T_A$   $V_{SUPDn}$ ,  $V_{SUPx} = 2.5...3.6$  V,  $V_{SUPA} = 2.2 ... 3.6$  V,  $f_{Crystal} = 13...20$  MHz,  
 typical values at  $T_A = 25$  °C and  $f_{CRYSTAL} = 18.432$  MHz, in PMQFP64/PLQFP64 package

| Symbol                    | Parameter                              | Pin Name | Min. | Typ. | Max.             | Unit                                             | Test Conditions                                  |
|---------------------------|----------------------------------------|----------|------|------|------------------|--------------------------------------------------|--------------------------------------------------|
| <b>Analog Supply</b>      |                                        |          |      |      |                  |                                                  |                                                  |
| $I_{AVDD}$                | Current consumption analog audio       | AVDD0/1  |      | 5    |                  | mA                                               | $V_{SUPA} = 2.2$ V, Mute                         |
| $I_{QOSC}$                | Current consumption crystal oscillator | AVDD0/1  |      | 200  |                  | $\mu$ A                                          | Codec = off<br>DSP = off<br>DC/DC = on           |
| $I_{STANDBY}$             |                                        |          |      |      | 10               |                                                  | Codec = off<br>DSP = off<br>DC/DC = off          |
| <b>Crystal Oscillator</b> |                                        |          |      |      |                  |                                                  |                                                  |
| $V_{DCCLK}$               | DC voltage at oscillator pins          | XTI, XTO |      | 0.5  |                  | $V_{SUPA}$                                       |                                                  |
| $V_{ACLK}$                | Clock amplitude                        |          | 0.5  |      | $V_{SUPA} - 0.5$ | $V_{PP}$                                         | if crystal is used                               |
| $C_{IN}$                  | Input capacitance                      |          |      | 3    |                  | pF                                               |                                                  |
| $R_{OUT}$                 | Output resistance                      | XTO      |      | 220  |                  | $\Omega$                                         | $V_{SUPA} = 2.2$ V                               |
|                           |                                        |          |      | 125  |                  |                                                  | $V_{SUPA} = 2.7$ V                               |
|                           |                                        |          |      | 94   |                  |                                                  | $V_{SUPA} = 3.3$ V                               |
| <b>Analog References</b>  |                                        |          |      |      |                  |                                                  |                                                  |
| $V_{AGNDC}$               | Analog Reference Voltage               | AGNDC    |      |      |                  | V                                                | $R_L \gg 10$ M $\Omega$ , referred to VREF       |
|                           |                                        |          |      |      |                  |                                                  | $V_{SUPA}$ Bits 15, 14 in Reg. 6A <sub>hex</sub> |
|                           |                                        |          |      | 1.1  |                  |                                                  | >2.2 V 00                                        |
|                           |                                        |          |      | 1.3  |                  |                                                  | >2.4 V 01                                        |
|                           |                                        |          |      | 1.6  |                  |                                                  | >3.0 V 10                                        |
| $V_{MICBI}$               | Bias voltage for microphone            | MICBI    |      |      |                  | $V_{SUPA}$ Bits 15, 14 in Reg. 6A <sub>hex</sub> |                                                  |
|                           |                                        |          |      | 1.8  |                  | >2.2 V 00                                        |                                                  |
|                           |                                        |          |      | 2.13 |                  | >2.4 V 01                                        |                                                  |
|                           |                                        |          |      | 2.62 |                  | >3.0 V 10                                        |                                                  |
| $R_{MICBI}$               | Source resistance                      | MICBI    |      | 180  |                  | $\Omega$                                         |                                                  |
| $I_{MAX}$                 | Maximum current microphone bias        | MICBI    |      |      |                  | $\mu$ A                                          | $V_{SUPA}$ Bits 15, 14 in Reg. 6A <sub>hex</sub> |
|                           |                                        |          |      | 300  |                  |                                                  | >2.2 V 00                                        |



| Symbol                     | Parameter                                                                   | Pin Name                   | Min. | Typ. | Max. | Unit       | Test Conditions                                                                                                  |
|----------------------------|-----------------------------------------------------------------------------|----------------------------|------|------|------|------------|------------------------------------------------------------------------------------------------------------------|
| <b>Analog Audio Inputs</b> |                                                                             |                            |      |      |      |            |                                                                                                                  |
| $V_{AI}$                   | Analog line input clipping level (at minimum analog input gain, i.e. -3 dB) | INL/R                      |      |      |      | $V_{pp}$   | $V_{SUPA}$ Bits 15, 14 in Reg. 6A <sub>hex</sub>                                                                 |
|                            |                                                                             |                            |      | 2.2  |      |            | >2.2 V 00                                                                                                        |
|                            |                                                                             |                            |      | 2.6  |      |            | >2.4 V 01                                                                                                        |
|                            |                                                                             |                            |      | 3.2  |      |            | >3.0 V 10                                                                                                        |
| $V_{MI}$                   | Microphone input clipping level (at minimum analog input gain, i.e. +21 dB) | MICIN                      |      |      |      | $mV_{pp}$  | $V_{SUPA}$ Bits 15, 14 in Reg. 6A <sub>hex</sub>                                                                 |
|                            |                                                                             |                            |      | 141  |      |            | >2.0 V 00                                                                                                        |
|                            |                                                                             |                            |      | 167  |      |            | >2.4 V 01                                                                                                        |
|                            |                                                                             |                            |      | 282  |      |            | >3.0 V 10                                                                                                        |
| $R_{inAI}$                 | Analog line input resistance                                                | INL/R                      |      | 97   |      | k $\Omega$ | at minimum analog input gain, i.e. -3 dB                                                                         |
|                            |                                                                             |                            |      | 20   |      |            | at maximum analog input gain, i.e. +19.5 dB                                                                      |
|                            |                                                                             |                            |      | 67   |      |            | not selected                                                                                                     |
| $R_{inMI}$                 | Microphone input resistance                                                 | MICIN                      |      | 94   |      | k $\Omega$ | at minimum analog input gain, i.e. -21 dB                                                                        |
|                            |                                                                             |                            |      | 8    |      |            | at maximum analog input gain, i.e. +43.5 dB                                                                      |
|                            |                                                                             |                            |      | 94   |      |            | not selected                                                                                                     |
| $SNR_{AI}$                 | Signal-to-noise ratio of line input                                         | INL/R                      |      | 74   |      | dB(A)      | BW = 20 Hz...20 kHz, analog gain = 0 dB, input 1 kHz at $V_{AI}-20$ dB                                           |
| $SNR_{MI}$                 | Signal-to-noise ratio of microphone input                                   | MICIN                      |      | 73   |      | dB(A)      | BW = 20 Hz...20 kHz, analog gain = +21 dB, input 1 kHz at $V_{MI}-20$ dB                                         |
| $THD_{AI}$                 | Total harmonic distortion of analog inputs                                  | INL/R<br>MICIN             |      | 0.01 | 0.02 | %          | BW = 20 Hz...20 kHz, analog gain = 0 dB, resp. 24 dB, input 1 kHz at -3 dBFS = $V_{AI}-6$ dB resp. $V_{MI}-6$ dB |
| $XTALK_{AI}$               | Crosstalk attenuation left/right channel (analog inputs)                    | INL/R<br>MICIN             |      | 80   |      | dB         | f = 1 kHz, sine wave, analog gain = 0 dB, input = -3 dBFS                                                        |
| $PSRR_{AI}$                | Power supply rejection ratio for analog audio inputs                        | AVDD0/1,<br>INL/R<br>MICIN |      | 45   |      | dB         | 1 kHz sine at 100 mV <sub>rms</sub>                                                                              |
|                            |                                                                             |                            |      | 20   |      | dB         | ≤100 kHz sine at 100 mV <sub>rms</sub>                                                                           |

| Symbol                | Parameter                                                | Pin Name | Min. | Typ.  | Max.      | Unit            | Test Conditions                                                                                                                                                               |                                                                                       |
|-----------------------|----------------------------------------------------------|----------|------|-------|-----------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| <b>Audio Output</b>   |                                                          |          |      |       |           |                 |                                                                                                                                                                               |                                                                                       |
| V <sub>AO1</sub>      | Analog output voltage AC                                 | OUTL/R   |      |       |           |                 | R <sub>L</sub> ≥ 1 kΩ<br>Input = 0 dBFS digital<br>V <sub>SUPA</sub> Bits 15, 14<br>in Reg 6A <sub>hex</sub>                                                                  |                                                                                       |
|                       | at 0 dB output gain                                      |          |      | 1.56  |           | V <sub>pp</sub> | >2.2 V 00                                                                                                                                                                     |                                                                                       |
|                       |                                                          |          |      | 1.84  |           |                 | >2.4 V 01                                                                                                                                                                     |                                                                                       |
|                       |                                                          |          |      | 2.27  |           |                 | >3.0 V 10                                                                                                                                                                     |                                                                                       |
|                       | at +3 dB output gain                                     |          |      | 2.20  |           | V <sub>pp</sub> | >2.2 V 00                                                                                                                                                                     |                                                                                       |
|                       |                                                          |          |      | 2.60  |           |                 | >2.6 V 01                                                                                                                                                                     |                                                                                       |
|                       |                                                          | 3.20     |      |       | >3.2 V 10 |                 |                                                                                                                                                                               |                                                                                       |
| dV <sub>AO1</sub>     | Deviation of DC-level at analog output for AGNDC-voltage | OUTL/R   | -20  |       | 20        | mV              |                                                                                                                                                                               |                                                                                       |
| V <sub>AO2</sub>      | Analog output voltage AC                                 | OUTL/R   |      |       |           |                 | R <sub>L</sub> is 16 Ω Headphone and 22 Ω seriesresistor<br>Input = 0 dBFS digital<br>(see Fig. 4–34 on page 81)<br>V <sub>SUPA</sub> Bits 15, 14<br>in Reg 6A <sub>hex</sub> |                                                                                       |
|                       | at 0 dB output gain                                      |          |      | 1.56  |           | V <sub>pp</sub> | >2.2 V 00                                                                                                                                                                     |                                                                                       |
|                       |                                                          |          |      | 1.84  |           |                 | >2.4 V 01                                                                                                                                                                     |                                                                                       |
|                       |                                                          |          |      | 2.27  |           |                 | >3.0 V 10                                                                                                                                                                     |                                                                                       |
|                       | at +3 dB output gain                                     |          |      | 2.00  |           | V <sub>pp</sub> | >2.2 V 00                                                                                                                                                                     |                                                                                       |
|                       |                                                          |          |      | 2.40  |           |                 | >2.6 V 01                                                                                                                                                                     |                                                                                       |
|                       |                                                          | 3.00     |      |       | >3.2 V 10 |                 |                                                                                                                                                                               |                                                                                       |
| R <sub>outAO</sub>    | Analog output resistance                                 | OUTL/R   |      |       | 6         | Ω               | analog gain = +3 dB,<br>Input = 0 dBFS digital                                                                                                                                |                                                                                       |
| SNR <sub>AO</sub>     | Signal-to-noise ratio of analog output                   | OUTL/R   |      | 94    |           |                 | dB(A)<br>R <sub>L</sub> ≥ 16 Ω<br>BW = 20 Hz...20 kHz,<br>analog gain = 0 dB<br>input = -20 dBFS                                                                              |                                                                                       |
| THD <sub>AO</sub>     | Total harmonic distortion (headphone)                    | OUTL/R   |      | 0.03  | 0.05      |                 | %                                                                                                                                                                             | for R <sub>L</sub> ≥ 16 Ω plus 22 Ω<br>series resistor<br>(see Fig. 4–34 on page 81)  |
|                       |                                                          |          |      | 0.003 | 0.01      |                 | %                                                                                                                                                                             | for R <sub>L</sub> ≥ 1 kΩ                                                             |
| Lev <sub>MuteAO</sub> | Mute level                                               | OUTL/R   |      | -113  |           |                 | dBV                                                                                                                                                                           | A-weighted<br>BW = 20 Hz...22 kHz , no<br>digital input signal,<br>analog gain = mute |

| Symbol              | Parameter                                             | Pin Name          | Min. | Typ. | Max. | Unit | Test Conditions                                                                                                   |
|---------------------|-------------------------------------------------------|-------------------|------|------|------|------|-------------------------------------------------------------------------------------------------------------------|
| XTALK <sub>AO</sub> | Crosstalk attenuation left/right channel (headphone)  | OUTLR             |      | 80   |      | dB   | f = 1 kHz, sine wave, OUTL/R: R <sub>L</sub> ≥ 16 Ω (see Fig. 4-34 on page 81) analog gain = 0 dB input = -3 dBFS |
| PSRR <sub>AO</sub>  | Power supply rejection ratio for analog audio outputs | AVDD0/1<br>OUTL/R |      | 70   |      | dB   | 1 kHz sine at 100 mV <sub>rms</sub>                                                                               |
|                     |                                                       |                   |      | 35   |      | dB   | ≤100 kHz sine at 100 mV <sub>rms</sub>                                                                            |

**4.6.5. DC/DC Converter Characteristics**

at  $T = T_A$ ,  $V_{in} = 1.2\text{ V}$ ,  $V_{outn} = 3.0\text{ V}$ ,  $f_{clk} = 18.432\text{ MHz}$ ,  $f_{sw} = 384\text{ kHz}$ , PWM-mode,  $L = 22\text{ }\mu\text{H}$ , in PMQFP64/PLQFP64 package  
(unless otherwise noted) Typ. values for  $T_A = 25\text{ }^\circ\text{C}$

| Symbol                             | Parameter                                      | Pin Name         | Min. | Typ. | Max. | Unit          | Test Conditions                                                           |
|------------------------------------|------------------------------------------------|------------------|------|------|------|---------------|---------------------------------------------------------------------------|
| $V_{IN}$                           | Minimum start-up input voltage                 | *                |      | 0.9  |      | V             | $I_{LOAD} \leq 1\text{ mA}$ ,<br>DCCF = 5050 <sub>hex</sub> (reset)       |
| $V_{IN}$                           | Minimum operating input voltage                |                  |      |      |      |               | 1)                                                                        |
|                                    | DC1                                            |                  |      | 0.7  |      | V             | $I_{LOAD} = 50\text{ mA}$ ,<br>DCCF = 5050 <sub>hex</sub> (reset)         |
|                                    | DC2                                            |                  |      | 0.8  |      | V             | $I_{LOAD} = 200\text{ mA}$ ,<br>DCCF = 5050 <sub>hex</sub> (reset)        |
| $V_{OUT}$                          | Programmable output voltage range              | VSENSn           | 2.0  |      | 3.5  | V             | Voltage settings in DCCF register ( $I^2C$ subaddress 76 <sub>hex</sub> ) |
| $V_{OTOL}$                         | Output voltage tolerance                       | VSENSn           | -4   |      | 4    | %             | $I_{LOAD} = 20\text{ mA}$<br>$T_A = 25\text{ }^\circ\text{C}$ 2)          |
| $I_{LOAD1}$                        | Output current 1 battery cell                  | VSENSn           |      |      | 200  | mA            | $V_{IN} = 0.9...1.5\text{ V}$ , 330 $\mu\text{F}$                         |
| $I_{LOAD2}$                        | Output current 2 battery cells                 |                  |      |      | 600  | mA            | $V_{IN} = 1.8...3.0\text{ V}$ , 330 $\mu\text{F}$                         |
| $\frac{dV_{OUT}}{dV_{IN}/V_{OUT}}$ | Line regulation                                | VSENSn           |      | 0.7  |      | %/V           | $I_{LOAD} = 20\text{ mA}$                                                 |
| $\frac{dV_{OUT}}{V_{OUT}}$         | Load regulation                                | VSENSn           |      | -1.8 |      | %             | $I_{LOAD} = 20...200\text{ mA}$                                           |
| $h_{max}$                          | Maximum efficiency                             |                  |      | 95   |      | %             | $V_{IN} = 2.4\text{ V}$ , $V_{OUT} = 3.5\text{ V}$                        |
| $f_{switch}$                       | Switching frequency                            | DCSON            | 297  | 384  | 576  | kHz           | (see Section 2.9.2. on page 12), (see Table 3-3 on page 20)               |
| $f_{startup}$                      | Switching frequency during start-up            | DCSON            |      | 250  |      | kHz           | $V_{SENSn} < 1.9\text{ V}$                                                |
| $I_{supPFM1}$                      | Supply current in PFM mode                     | VSENS1           |      | 75   |      | $\mu\text{A}$ | 3)                                                                        |
| $I_{supPFM2}$                      |                                                | VSENS2           |      | 135  |      |               |                                                                           |
| $I_{supPWM1}$                      | Supply current in PWM mode                     | VSENS1           |      | 265  |      | $\mu\text{A}$ | VSENSn<br>3)<br>4)                                                        |
| $I_{supPWM2}$                      |                                                | VSENS2           |      | 325  |      |               |                                                                           |
| $I_{Inmax}$                        | NMOS switch current limit (low side switch)    | DCSON,<br>DCSGn  |      | 1    |      | A             | PWM-mode                                                                  |
|                                    |                                                |                  |      | 0.4  |      |               | PFM-mode                                                                  |
| $I_{ptoff}$                        | PMOS switch turnoff current (rectifier switch) | DCSON,<br>VSENSn |      | 70   |      | mA            |                                                                           |
| $R_{ON}$                           | NMOS switch on resistance (low side switch)    | DCSO1,<br>DCSG1  |      | 170  |      | m $\Omega$    |                                                                           |
|                                    |                                                | DCSO2,<br>DCSG2  |      | 280  |      |               |                                                                           |

| Symbol     | Parameter       | Pin Name        | Min. | Typ. | Max. | Unit    | Test Conditions         |
|------------|-----------------|-----------------|------|------|------|---------|-------------------------|
| $I_{LEAK}$ | Leakage current | DCSON,<br>DCSGn |      | 0.1  |      | $\mu A$ | Converters off, no load |

1) Since the regulators are bootstrapped, once started they will operate down to 0.7 V input voltage  
2) PFM-mode regulates approx. 1% higher  
3) Current into VSENSn Pin.  $V_{IN} > V_{OUT} + 0.4$  V; no DC/DC-Converter switching action present  
4) Add. current of oscillator at PIN AVDD0/1, (see Section 4.6.4. on page 72)

4.6.6. Typical Performance Characteristics

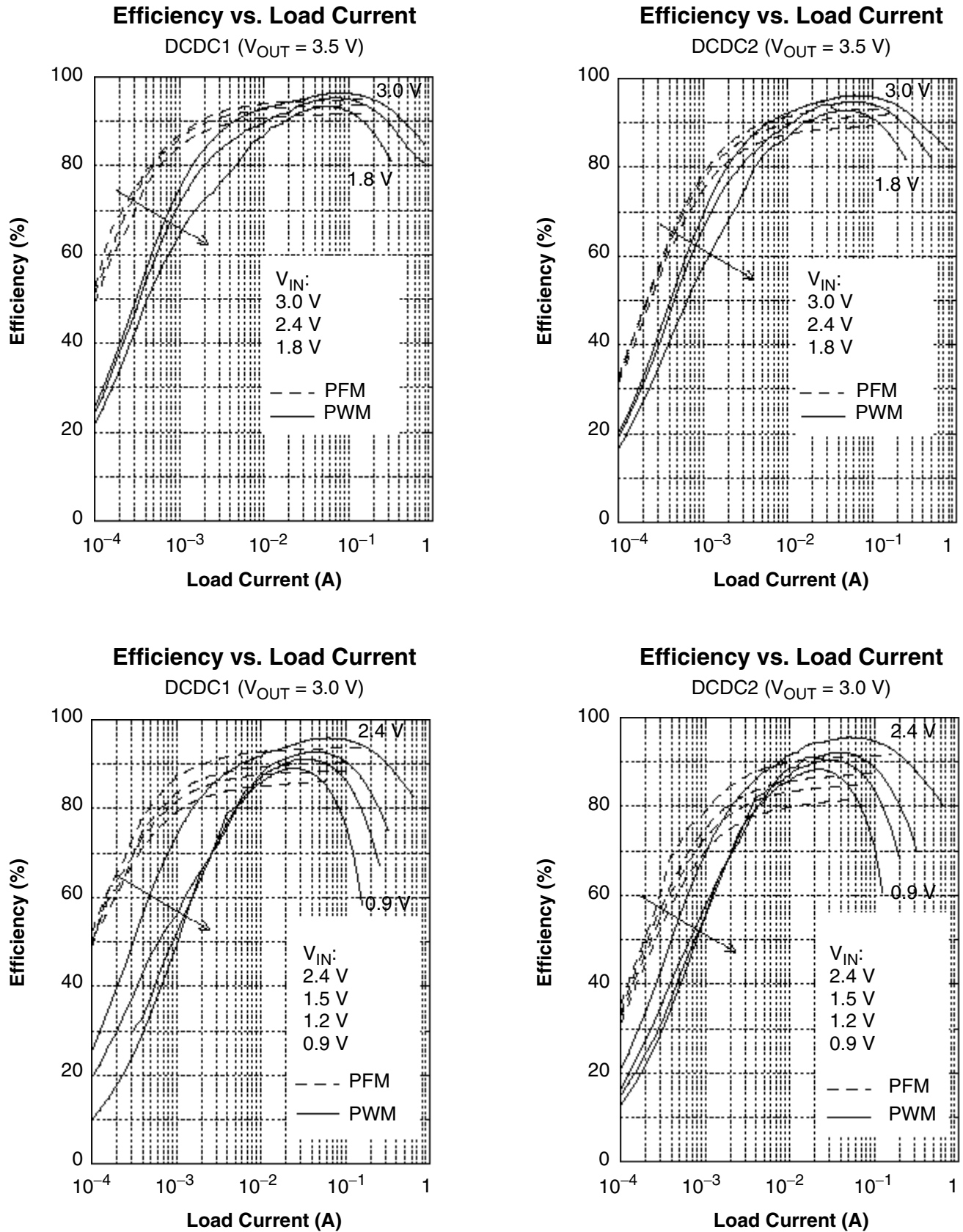


Fig. 4-31: Efficiency vs. Load Current

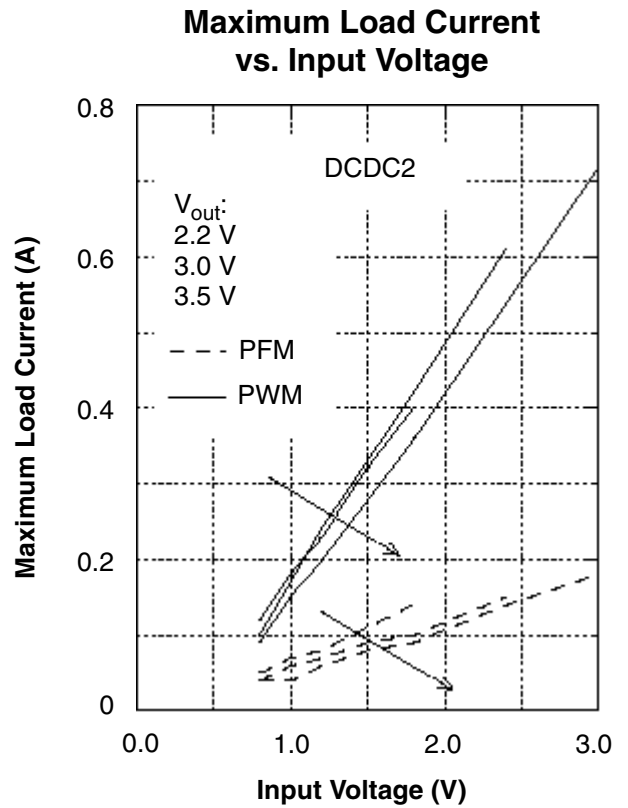
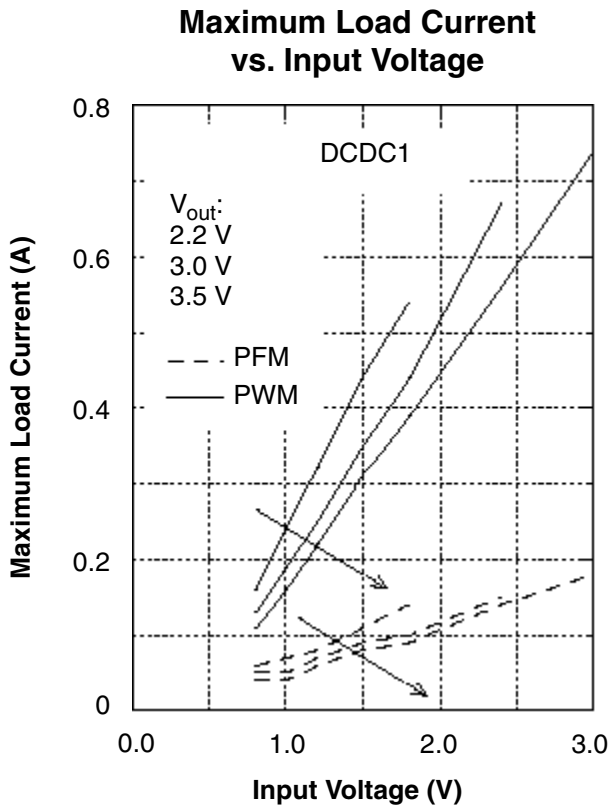
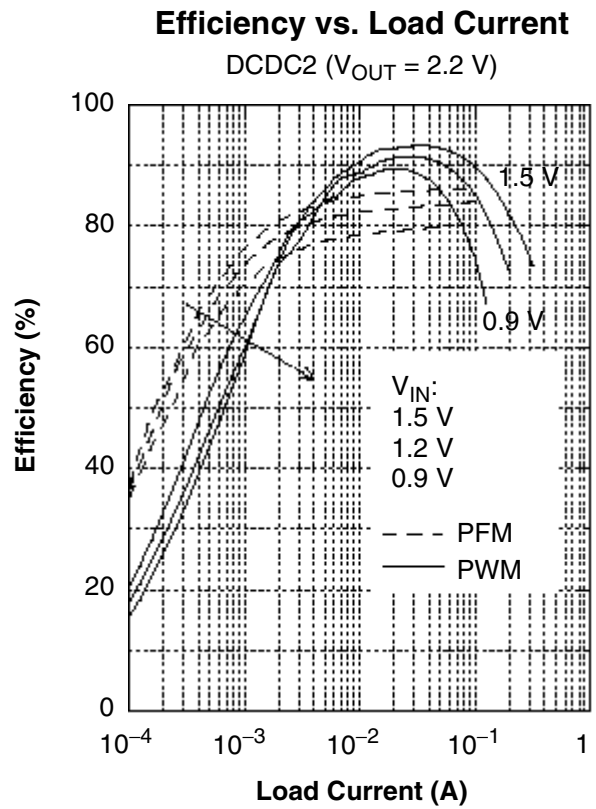
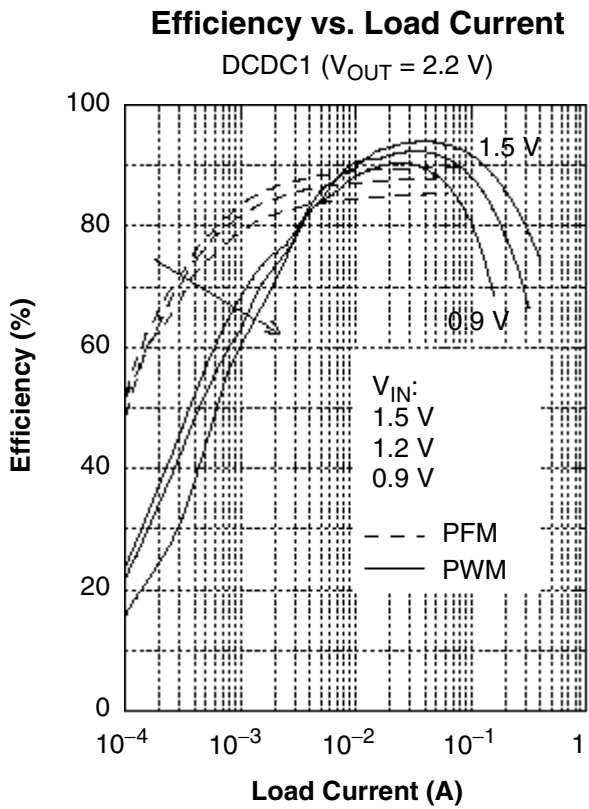


Fig. 4-32: Maximum Load Current vs. Input Voltage

**Note:** Efficiency is measured as  $V_{\text{SENSn}} \times I_{\text{LOAD}} / (V_{\text{in}} \times I_{\text{in}})$ .  $I_{\text{AVDD}}$  is not included (Oscillator current)

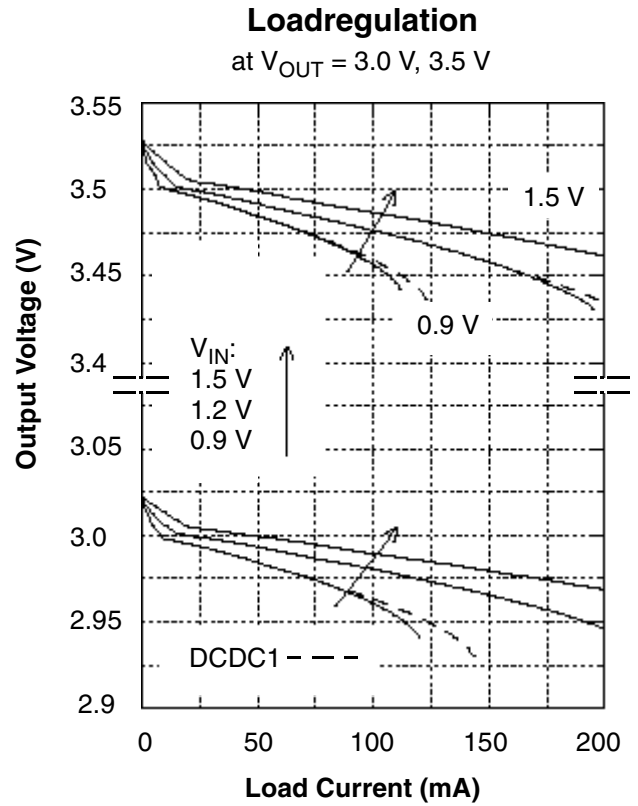
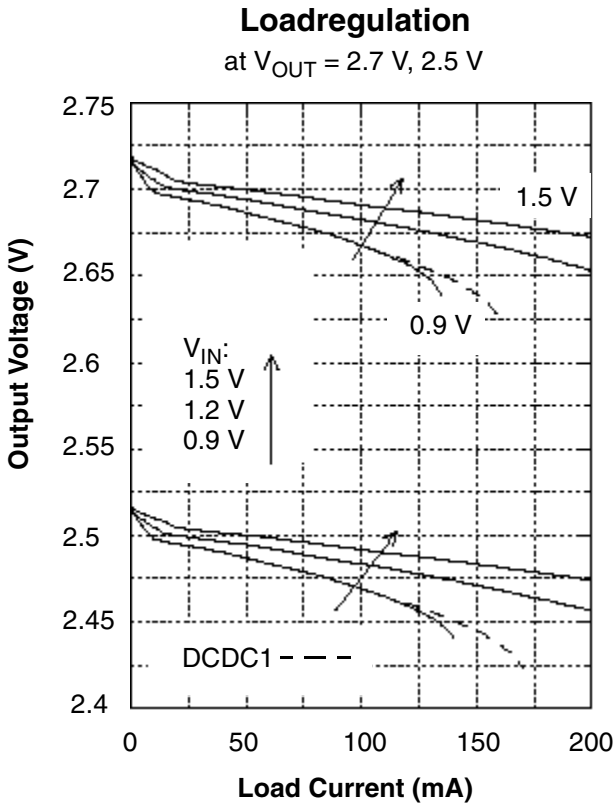
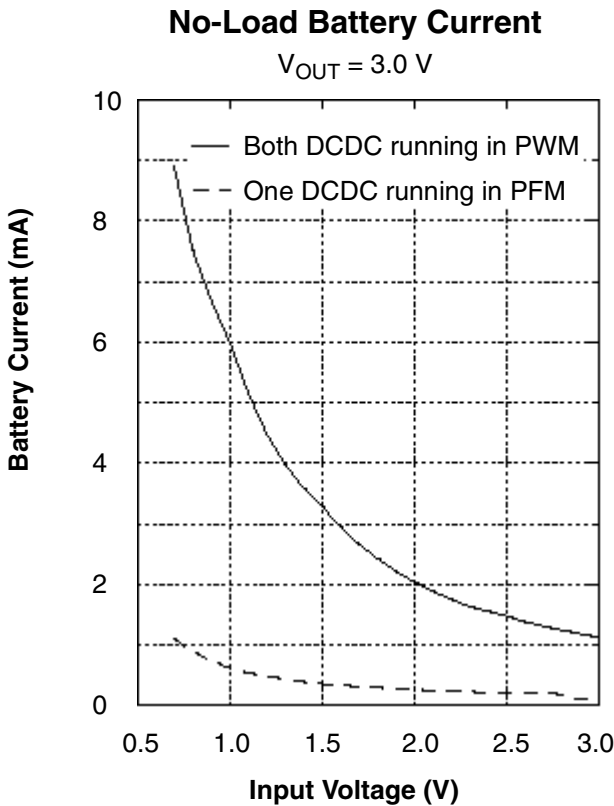


Fig. 4-33: Loadregulation





4.7. Typical Application in a Portable Player

- MMC/SDI-Card or SMC/CF2+ used as storage media
- Dashed lines show optional (external) devices

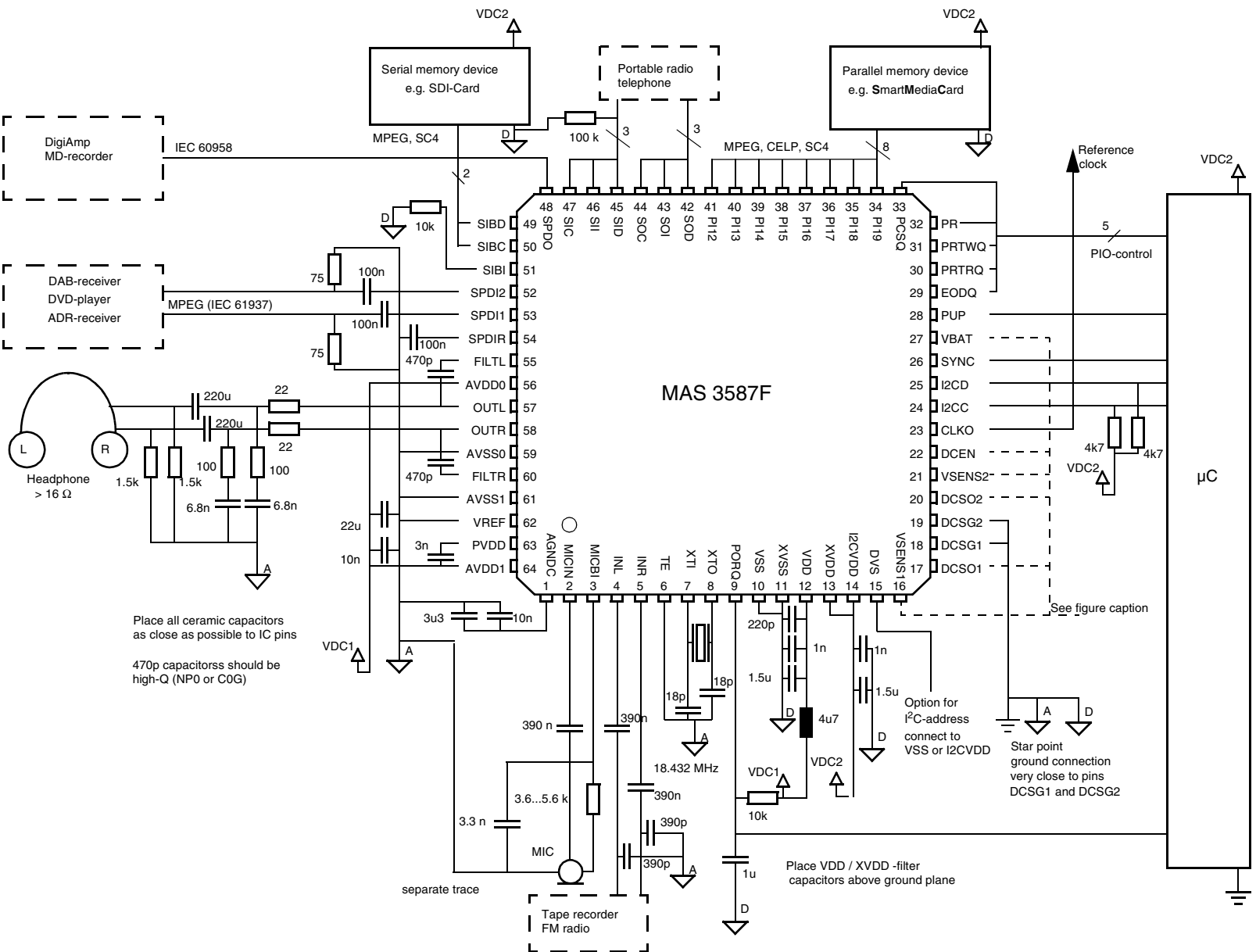


Fig. 4-34: Application circuit of the MAS 3587F. For connections of the DC/DC converters, please refer to Fig. 4-35 on page 82.

4.8. Recommended DC/DC Converter Application Circuit

Configuration 1 (see Fig. 2–11 on page 14)

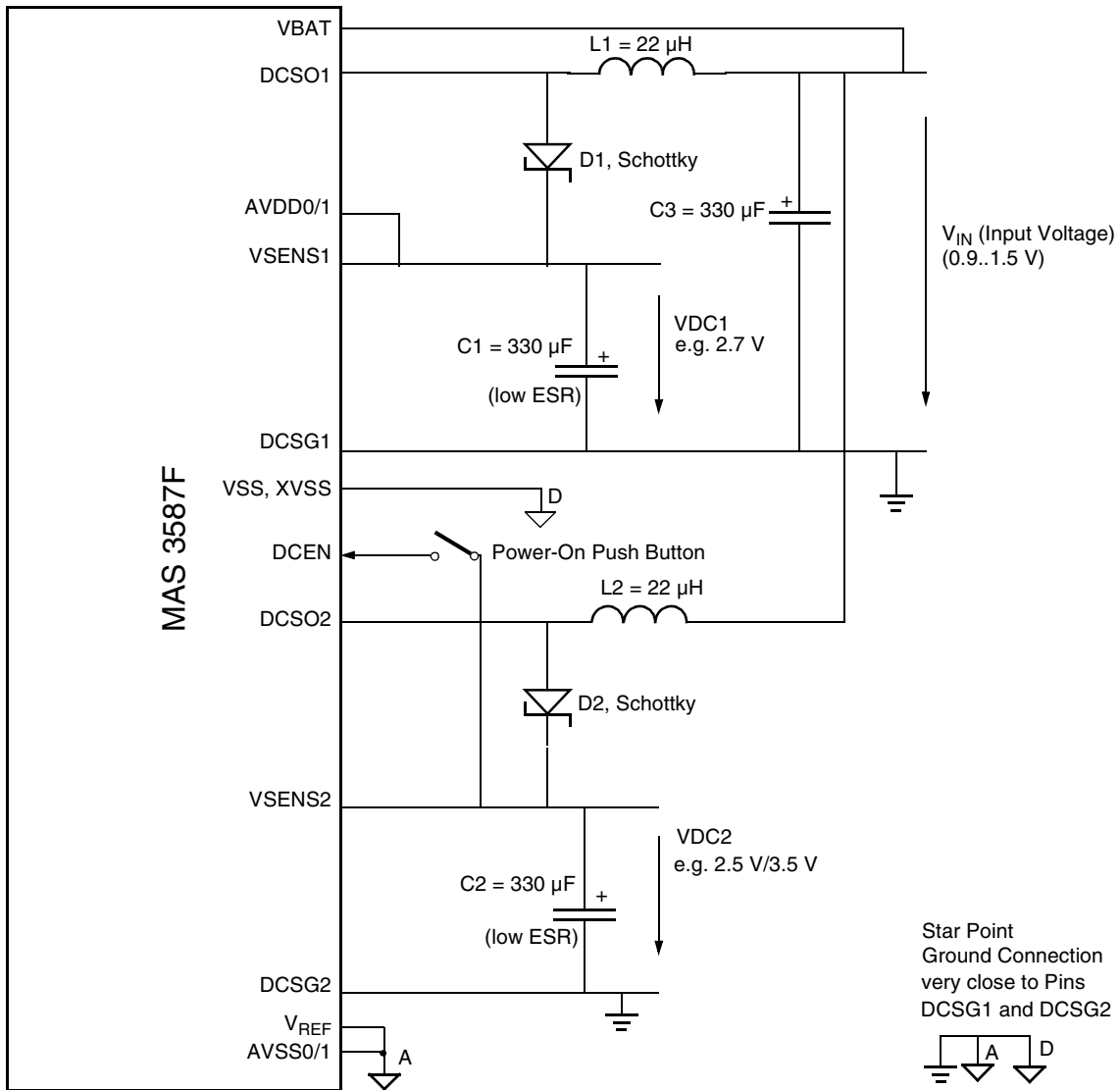


Fig. 4–35: External circuitry for the DC/DC converters



## 5. Data Sheet History

1. Preliminary data sheet: "MAS 3587F MPEG Layer 3 Audio Encoder/Decoder", July 9, 2001, 6251-542-1PD. First release of the preliminary data sheet.

2. Preliminary data sheet: "MAS 3587F MPEG Layer 3 Audio Encoder/Decoder", Nov. 7, 2001, 6251-542-2PD. Second release of the preliminary data sheet.

Major changes:

- definition of ambient operating temperature range  
   $T_A$  specified

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