



K51 Sub-Family Data Sheet

Supports the following:

MK51X256CMC100,
MK51N512CMC100

Features

- Operating Characteristics
 - Voltage range: 1.71 to 3.6 V
 - Flash write voltage range: 1.71 to 3.6 V
 - Temperature range (ambient): -40 to 85°C
- Performance
 - Up to 100 MHz ARM Cortex-M4 core with DSP instructions delivering 1.25 Dhrystone MIPS per MHz
- Memories and memory interfaces
 - Up to 512 KB program flash memory on non-FlexMemory devices
 - Up to 256 KB program flash memory on FlexMemory devices
 - Up to 256 KB FlexNVM on FlexMemory devices
 - 4 KB FlexRAM on FlexMemory devices
 - Up to 128 KB RAM
 - Serial programming interface (EzPort)
- Clocks
 - 3 to 32 MHz crystal oscillator
 - 32 kHz crystal oscillator
 - Multi-purpose clock generator
- System peripherals
 - 10 low-power modes to provide power optimization based on application requirements
 - Memory protection unit with multi-master protection
 - 16-channel DMA controller, supporting up to 64 request sources
 - External watchdog monitor
 - Software watchdog
 - Low-leakage wakeup unit
- Security and integrity modules
 - Hardware CRC module to support fast cyclic redundancy checks
 - 128-bit unique identification (ID) number per chip
- Human-machine interface
 - Segment LCD controller supporting up to 40 frontplanes and 8 backplanes, or 44 frontplanes and 4 backplanes
 - Low-power hardware touch sensor interface (TSI)
 - General-purpose input/output
- Analog modules
 - Two 16-bit SAR ADCs
 - Programmable gain amplifier (up to x64) integrated into each ADC
 - Two 12-bit DACs
 - Two operational amplifiers
 - Two transimpedance amplifiers
 - Three analog comparators (CMP) containing a 6-bit DAC and programmable reference input
 - Voltage reference
- Timers
 - Programmable delay block
 - Eight-channel motor control/general purpose/PWM timer
 - Two 2-channel quadrature decoder/general purpose timers
 - Periodic interrupt timers
 - 16-bit low-power timer
 - Carrier modulator transmitter
 - Real-time clock
- Communication interfaces
 - USB full-/low-speed On-the-Go controller with on-chip transceiver
 - Three SPI modules
 - Two I2C modules
 - Six UART modules
 - Secure Digital host controller (SDHC)
 - I2S module

K51P121M100SF2



This document contains information on a product under development. Freescale reserves the right to change or discontinue this product without notice.

Table of Contents

| | | | | | |
|-------|--|----|-------|---|----|
| 1 | Ordering parts..... | 4 | 6.1 | Core modules..... | 21 |
| 1.1 | Determining valid orderable parts..... | 4 | 6.1.1 | Debug trace timing specifications..... | 21 |
| 2 | Part identification..... | 4 | 6.1.2 | JTAG electricals..... | 21 |
| 2.1 | Description..... | 4 | 6.2 | System modules..... | 25 |
| 2.2 | Format..... | 4 | 6.3 | Clock modules..... | 25 |
| 2.3 | Fields..... | 4 | 6.3.1 | MCG specifications..... | 25 |
| 2.4 | Example..... | 5 | 6.3.2 | Oscillator electrical specifications..... | 27 |
| 3 | Terminology and guidelines..... | 5 | 6.3.3 | 32kHz Oscillator Electrical Characteristics..... | 29 |
| 3.1 | Definition: Operating requirement..... | 5 | 6.4 | Memories and memory interfaces..... | 30 |
| 3.2 | Definition: Operating behavior..... | 6 | 6.4.1 | Flash (FTFL) electrical specifications..... | 30 |
| 3.3 | Definition: Attribute..... | 6 | 6.4.2 | EzPort Switching Specifications..... | 34 |
| 3.4 | Definition: Rating..... | 7 | 6.5 | Security and integrity modules..... | 35 |
| 3.5 | Result of exceeding a rating..... | 7 | 6.6 | Analog..... | 35 |
| 3.6 | Relationship between ratings and operating requirements..... | 7 | 6.6.1 | ADC electrical specifications..... | 36 |
| 3.7 | Guidelines for ratings and operating requirements..... | 8 | 6.6.2 | CMP and 6-bit DAC electrical specifications..... | 43 |
| 3.8 | Definition: Typical value..... | 8 | 6.6.3 | 12-bit DAC electrical characteristics..... | 46 |
| 3.9 | Typical value conditions..... | 9 | 6.6.4 | Op-amp electrical specifications..... | 49 |
| 4 | Ratings..... | 9 | 6.6.5 | Transimpedance amplifier electrical specifications — full range..... | 50 |
| 4.1 | Thermal handling ratings..... | 10 | 6.6.6 | Transimpedance amplifier electrical specifications — limited range..... | 51 |
| 4.2 | Moisture handling ratings..... | 10 | 6.6.7 | Voltage reference electrical specifications..... | 52 |
| 4.3 | ESD handling ratings..... | 10 | 6.7 | Timers..... | 53 |
| 4.4 | Voltage and current operating ratings..... | 10 | 6.8 | Communication interfaces..... | 54 |
| 5 | General..... | 11 | 6.8.1 | USB electrical specifications..... | 54 |
| 5.1 | Nonswitching electrical specifications..... | 11 | 6.8.2 | USB DCD electrical specifications..... | 54 |
| 5.1.1 | Voltage and current operating requirements..... | 11 | 6.8.3 | USB VREG electrical specifications..... | 54 |
| 5.1.2 | LVD and POR operating requirements..... | 12 | 6.8.4 | DSPI switching specifications (low-speed mode)..... | 55 |
| 5.1.3 | Voltage and current operating behaviors..... | 13 | 6.8.5 | DSPI switching specifications (high-speed mode)..... | 56 |
| 5.1.4 | Power mode transition operating behaviors..... | 13 | 6.8.6 | I2C switching specifications..... | 58 |
| 5.1.5 | Power consumption operating behaviors..... | 14 | 6.8.7 | UART switching specifications..... | 58 |
| 5.1.6 | EMC radiated emissions operating behaviors..... | 17 | 6.8.8 | SDHC specifications..... | 58 |
| 5.1.7 | Designing with radiated emissions in mind..... | 18 | 6.8.9 | I2S switching specifications..... | 59 |
| 5.1.8 | Capacitance attributes..... | 18 | 6.9 | Human-machine interfaces (HMI)..... | 61 |
| 5.2 | Switching specifications..... | 18 | 6.9.1 | TSI electrical specifications..... | 61 |
| 5.2.1 | Device clock specifications..... | 18 | 6.9.2 | LCD electrical characteristics..... | 62 |
| 5.2.2 | General switching specifications..... | 19 | 7 | Dimensions..... | 63 |
| 5.3 | Thermal specifications..... | 20 | 7.1 | Obtaining package dimensions..... | 63 |
| 5.3.1 | Thermal operating requirements..... | 20 | 8 | Pinout..... | 64 |
| 5.3.2 | Thermal attributes..... | 20 | 8.1 | K51 Signal Multiplexing and Pin Assignments..... | 64 |
| 6 | Peripheral operating requirements and behaviors..... | 20 | | | |

1 Ordering parts

1.1 Determining valid orderable parts

Valid orderable part numbers are provided on the web. To determine the orderable part numbers for this device, go to <http://www.freescale.com> and perform a part number search for the following device numbers: PK51 and MK51.

2 Part identification

2.1 Description

Part numbers for the chip have fields that identify the specific part. You can use the values of these fields to determine the specific part you have received.

2.2 Format

Part numbers for this device have the following format:

Q K## M FFF T PP CCC N

2.3 Fields

This table lists the possible values for each field in the part number (not all combinations are valid):

| Field | Description | Values |
|-------|----------------------|--|
| Q | Qualification status | <ul style="list-style-type: none"> M = Fully qualified, general market flow P = Prequalification |
| K## | Kinetis family | <ul style="list-style-type: none"> K51 |
| M | Flash memory type | <ul style="list-style-type: none"> N = Program flash only X = Program flash and FlexMemory |

Table continues on the next page...

| Field | Description | Values |
|-------|-----------------------------|---|
| FFF | Program flash memory size | <ul style="list-style-type: none"> • 32 = 32 KB • 64 = 64 KB • 128 = 128 KB • 256 = 256 KB • 512 = 512 KB • 1M0 = 1 MB |
| T | Temperature range (°C) | <ul style="list-style-type: none"> • V = -40 to 105 • C = -40 to 85 |
| PP | Package identifier | <ul style="list-style-type: none"> • FM = 32 QFN (5 mm x 5 mm) • FT = 48 QFN (7 mm x 7 mm) • LF = 48 LQFP (7 mm x 7 mm) • EX = 64 QFN (9 mm x 9 mm) • LH = 64 LQFP (10 mm x 10 mm) • LK = 80 LQFP (12 mm x 12 mm) • MB = 81 MAPBGA (8 mm x 8 mm) • LL = 100 LQFP (14 mm x 14 mm) • MC = 121 MAPBGA (8 mm x 8 mm) • LQ = 144 LQFP (20 mm x 20 mm) • MD = 144 MAPBGA (13 mm x 13 mm) • MF = 196 MAPBGA (15 mm x 15 mm) • MJ = 256 MAPBGA (17 mm x 17 mm) |
| CCC | Maximum CPU frequency (MHz) | <ul style="list-style-type: none"> • 50 = 50 MHz • 72 = 72 MHz • 100 = 100 MHz • 120 = 120 MHz • 150 = 150 MHz |
| N | Packaging type | <ul style="list-style-type: none"> • R = Tape and reel • (Blank) = Trays |

2.4 Example

This is an example part number:

MK51N512VMD100

3 Terminology and guidelines

3.1 Definition: Operating requirement

An *operating requirement* is a specified value or range of values for a technical characteristic that you must guarantee during operation to avoid incorrect operation and possibly decreasing the useful life of the chip.

3.1.1 Example

This is an example of an operating requirement, which you must meet for the accompanying operating behaviors to be guaranteed:

| Symbol | Description | Min. | Max. | Unit |
|-----------------|---------------------------|------|------|------|
| V _{DD} | 1.0 V core supply voltage | 0.9 | 1.1 | V |

3.2 Definition: Operating behavior

An *operating behavior* is a specified value or range of values for a technical characteristic that are guaranteed during operation if you meet the operating requirements and any other specified conditions.

3.2.1 Example

This is an example of an operating behavior, which is guaranteed if you meet the accompanying operating requirements:

| Symbol | Description | Min. | Max. | Unit |
|-----------------|--|------|------|------|
| I _{WP} | Digital I/O weak pullup/pulldown current | 10 | 130 | μA |

3.3 Definition: Attribute

An *attribute* is a specified value or range of values for a technical characteristic that are guaranteed, regardless of whether you meet the operating requirements.

3.3.1 Example

This is an example of an attribute:

| Symbol | Description | Min. | Max. | Unit |
|--------|---------------------------------|------|------|------|
| CIN_D | Input capacitance: digital pins | — | 7 | pF |

3.4 Definition: Rating

A *rating* is a minimum or maximum value of a technical characteristic that, if exceeded, may cause permanent chip failure:

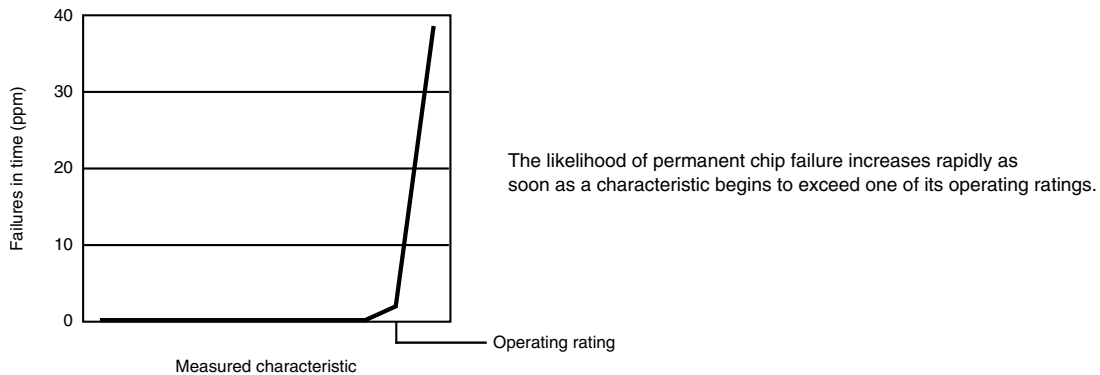
- *Operating ratings* apply during operation of the chip.
- *Handling ratings* apply when the chip is not powered.

3.4.1 Example

This is an example of an operating rating:

| Symbol | Description | Min. | Max. | Unit |
|-----------------|---------------------------|------|------|------|
| V _{DD} | 1.0 V core supply voltage | -0.3 | 1.2 | V |

3.5 Result of exceeding a rating



3.6 Relationship between ratings and operating requirements

| | | | | | | | |
|--|---|--|---|--|--|-------------------------------------|--|
| Operating or handling rating (min.) | | Operating requirement (min.) | | Operating requirement (max.) | | Operating or handling rating (max.) | |
| Fatal range - Probable permanent failure | Limited operating range - No permanent failure - Possible decreased life - Possible incorrect operation | Normal operating range - No permanent failure - Correct operation | Limited operating range - No permanent failure - Possible decreased life - Possible incorrect operation | Fatal range - Probable permanent failure | | | |
| Handling range - No permanent failure | | | | | | | |

3.7 Guidelines for ratings and operating requirements

Follow these guidelines for ratings and operating requirements:

- Never exceed any of the chip’s ratings.
- During normal operation, don’t exceed any of the chip’s operating requirements.
- If you must exceed an operating requirement at times other than during normal operation (for example, during power sequencing), limit the duration as much as possible.

3.8 Definition: Typical value

A *typical value* is a specified value for a technical characteristic that:

- Lies within the range of values specified by the operating behavior
- Given the typical manufacturing process, is representative of that characteristic during operation when you meet the typical-value conditions or other specified conditions

Typical values are provided as design guidelines and are neither tested nor guaranteed.

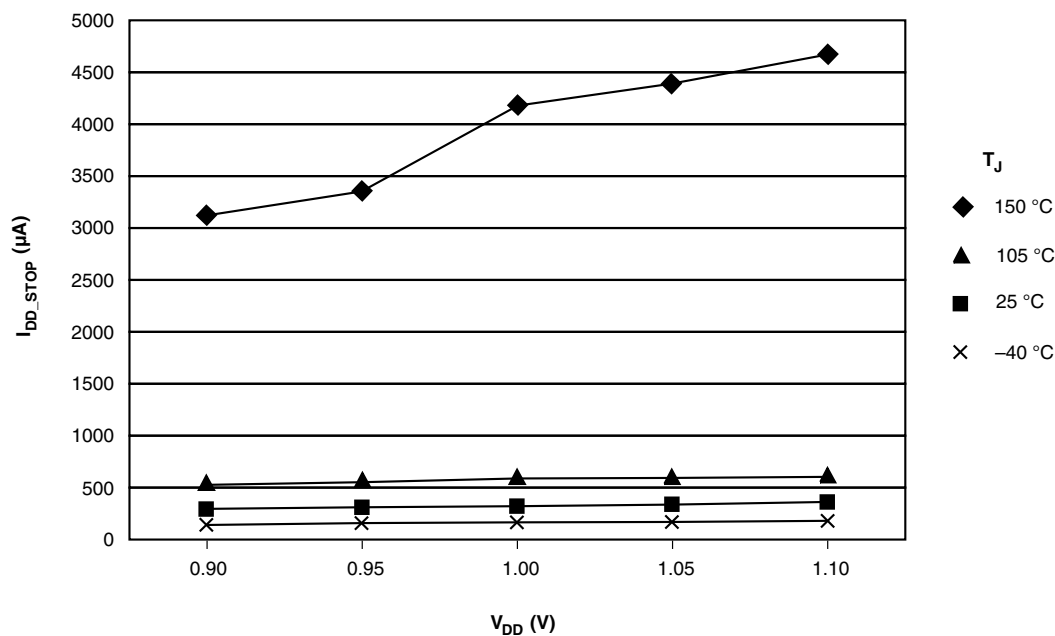
3.8.1 Example 1

This is an example of an operating behavior that includes a typical value:

| Symbol | Description | Min. | Typ. | Max. | Unit |
|----------|--|------|------|------|---------------|
| I_{WP} | Digital I/O weak pullup/pulldown current | 10 | 70 | 130 | μA |

3.8.2 Example 2

This is an example of a chart that shows typical values for various voltage and temperature conditions:



3.9 Typical value conditions

Typical values assume you meet the following conditions (or other conditions as specified):

| Symbol | Description | Value | Unit |
|----------|----------------------|-------|--------------------|
| T_A | Ambient temperature | 25 | $^{\circ}\text{C}$ |
| V_{DD} | 3.3 V supply voltage | 3.3 | V |

4 Ratings

4.1 Thermal handling ratings

| Symbol | Description | Min. | Max. | Unit | Notes |
|------------------|-------------------------------|------|------|------|-------|
| T _{STG} | Storage temperature | -55 | 150 | °C | 1 |
| T _{SDR} | Solder temperature, lead-free | — | 260 | °C | 2 |
| | Solder temperature, leaded | — | 245 | | |

1. Determined according to JEDEC Standard JESD22-A103, *High Temperature Storage Life*.
2. Determined according to IPC/JEDEC Standard J-STD-020, *Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices*.

4.2 Moisture handling ratings

| Symbol | Description | Min. | Max. | Unit | Notes |
|--------|----------------------------|------|------|------|-------|
| MSL | Moisture sensitivity level | — | 3 | — | 1 |

1. Determined according to IPC/JEDEC Standard J-STD-020, *Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices*.

4.3 ESD handling ratings

| Symbol | Description | Min. | Max. | Unit | Notes |
|------------------|---|-------|-------|------|-------|
| V _{HBM} | Electrostatic discharge voltage, human body model | -2000 | +2000 | V | 1 |
| V _{CDM} | Electrostatic discharge voltage, charged-device model | -500 | +500 | V | 2 |
| I _{LAT} | Latch-up current at ambient temperature of 85°C | -100 | +100 | mA | |

1. Determined according to JEDEC Standard JESD22-A114, *Electrostatic Discharge (ESD) Sensitivity Testing Human Body Model (HBM)*.
2. Determined according to JEDEC Standard JESD22-C101, *Field-Induced Charged-Device Model Test Method for Electrostatic-Discharge-Withstand Thresholds of Microelectronic Components*.

4.4 Voltage and current operating ratings

| Symbol | Description | Min. | Max. | Unit |
|------------------|---|------|------|------|
| V _{DD} | Digital supply voltage | -0.3 | 3.8 | V |
| I _{DD} | Digital supply current | — | 185 | mA |
| V _{DIO} | Digital input voltage (except RESET, EXTAL, and XTAL) | -0.3 | 5.5 | V |

Table continues on the next page...

| Symbol | Description | Min. | Max. | Unit |
|---------------------|---|-----------------------|-----------------------|------|
| V _{AIO} | Analog, RESET, EXTAL, and XTAL input voltage | -0.3 | V _{DD} + 0.3 | V |
| I _D | Instantaneous maximum current single pin limit (applies to all port pins) | -25 | 25 | mA |
| V _{DDA} | Analog supply voltage | V _{DD} - 0.3 | V _{DD} + 0.3 | V |
| V _{USB_DP} | USB_DP input voltage | -0.3 | 3.63 | V |
| V _{USB_DM} | USB_DM input voltage | -0.3 | 3.63 | V |
| V _{REGIN} | USB regulator input | -0.3 | 6.0 | V |
| V _{BAT} | RTC battery supply voltage | -0.3 | 3.8 | V |

5 General

5.1 Nonswitching electrical specifications

5.1.1 Voltage and current operating requirements

Table 1. Voltage and current operating requirements

| Symbol | Description | Min. | Max. | Unit | Notes |
|------------------------------------|--|------------------------|------------------------|------|-------|
| V _{DD} | Supply voltage | 1.71 | 3.6 | V | |
| V _{DDA} | Analog supply voltage | 1.71 | 3.6 | V | |
| V _{DD} - V _{DDA} | V _{DD} -to-V _{DDA} differential voltage | -0.1 | 0.1 | V | |
| V _{SS} - V _{SSA} | V _{SS} -to-V _{SSA} differential voltage | -0.1 | 0.1 | V | |
| V _{BAT} | RTC battery supply voltage | 1.71 | 3.6 | V | |
| V _{IH} | Input high voltage <ul style="list-style-type: none"> • 2.7 V ≤ V_{DD} ≤ 3.6 V • 1.7 V ≤ V_{DD} ≤ 2.7 V | 0.7 × V _{DD} | — | V | |
| | | 0.75 × V _{DD} | — | V | |
| V _{IL} | Input low voltage <ul style="list-style-type: none"> • 2.7 V ≤ V_{DD} ≤ 3.6 V • 1.7 V ≤ V_{DD} ≤ 2.7 V | — | 0.35 × V _{DD} | V | |
| | | — | 0.3 × V _{DD} | V | |
| V _{HYS} | Input hysteresis | 0.06 × V _{DD} | — | V | |

Table continues on the next page...

Table 1. Voltage and current operating requirements (continued)

| Symbol | Description | Min. | Max. | Unit | Notes |
|--------------|--|------|------|------|-------|
| I_{IC} | DC injection current — single pin • $V_{IN} < V_{SS}$ | 0 | -0.2 | mA | 1 |
| | DC injection current — total MCU limit, includes sum of all stressed pins • $V_{IN} < V_{SS}$ | 0 | -5 | mA | 1 |
| V_{RAM} | V_{DD} voltage required to retain RAM | 1.2 | — | V | |
| V_{RFVBAT} | V_{BAT} voltage required to retain the VBAT register file | TBD | — | V | |

1. All functional non-supply pins are internally clamped to V_{SS} , and induce an injection current when V_{IN} is less than V_{SS} . The I_{IC} maximum operating requirement should not be exceeded. If this requirement cannot be met, the input must be current limited to the value specified.

5.1.2 LVD and POR operating requirements

Table 2. V_{DD} supply LVD and POR operating requirements

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|--|---|------|------|------|---------|-------|
| V_{POR} | Falling VDD POR detect voltage | TBD | 1.1 | TBD | V | |
| V_{LVDH} | Falling low-voltage detect threshold — high range (LVDV=01) | TBD | 2.56 | TBD | V | |
| V_{LW1H} V_{LW2H} V_{LW3H} V_{LW4H} | Low-voltage warning thresholds — high range | | | | | 1 |
| | • Level 1 falling (LVWV=00) | TBD | 2.70 | TBD | V | |
| | • Level 2 falling (LVWV=01) | TBD | 2.80 | TBD | V | |
| | • Level 3 falling (LVWV=10) | TBD | 2.90 | TBD | V | |
| | • Level 4 falling (LVWV=11) | TBD | 3.00 | TBD | V | |
| V_{HYSH} | Low-voltage inhibit reset/recover hysteresis — high range | | 60 | | mV | |
| V_{LVDL} | Falling low-voltage detect threshold — low range (LVDV=00) | TBD | 1.60 | TBD | V | |
| V_{LW1L} V_{LW2L} V_{LW3L} V_{LW4L} | Low-voltage warning thresholds — low range | | | | | 1 |
| | • Level 1 falling (LVWV=00) | TBD | 1.80 | TBD | V | |
| | • Level 2 falling (LVWV=01) | TBD | 1.90 | TBD | V | |
| | • Level 3 falling (LVWV=10) | TBD | 2.00 | TBD | V | |
| | • Level 4 falling (LVWV=11) | TBD | 2.10 | TBD | V | |
| V_{HYSL} | Low-voltage inhibit reset/recover hysteresis — low range | | 40 | | mV | |
| V_{BG} | Bandgap voltage reference | TBD | 1.00 | TBD | V | |
| t_{LPO} | Internal low power oscillator period factory trimmed | TBD | 1000 | TBD | μ s | |

1. Rising thresholds are falling threshold + hysteresis voltage

Table 3. VBAT power operating requirements

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|-----------------------|--|------|------|------|------|-------|
| V _{POR_VBAT} | Falling VBAT supply POR detect voltage | TBD | 1.1 | TBD | V | |

5.1.3 Voltage and current operating behaviors

Table 4. Voltage and current operating behaviors

| Symbol | Description | Min. | Max. | Unit | Notes |
|---------------------|---|-----------------------|------|------|-------|
| V _{OH} | Output high voltage — high drive strength | | | | |
| | • 2.7 V ≤ V _{DD} ≤ 3.6 V, I _{OH} = -10mA | V _{DD} - 0.5 | — | V | |
| | • 1.71 V ≤ V _{DD} ≤ 2.7 V, I _{OH} = -3mA | V _{DD} - 0.5 | — | V | |
| | Output high voltage — low drive strength | | | | |
| V _{OL} | Output low voltage — high drive strength | | | | |
| | • 2.7 V ≤ V _{DD} ≤ 3.6 V, I _{OL} = 10mA | — | 0.5 | V | |
| | • 1.71 V ≤ V _{DD} ≤ 2.7 V, I _{OL} = 3mA | — | 0.5 | V | |
| | Output low voltage — low drive strength | | | | |
| I _{OHT} | Output high current total for all ports | — | 100 | mA | |
| | Output low voltage — high drive strength | | | | |
| | • 2.7 V ≤ V _{DD} ≤ 3.6 V, I _{OL} = 2mA | — | 0.5 | V | |
| | • 1.71 V ≤ V _{DD} ≤ 2.7 V, I _{OL} = 0.6mA | — | 0.5 | V | |
| I _{OLT} | Output low current total for all ports | — | 100 | mA | |
| I _{IN} | Input leakage current (per pin) except TRI0_DM, TRI0_DP, TRI1_DM, TRI1_DP | — | 1 | μA | 1 |
| I _{ILKG_A} | Input leakage current (per pin) for TRI0_DM, TRI0_DP, TRI1_DM, TRI1_DP | — | 1 | nA | 1 |
| I _{OZ} | Hi-Z (off-state) leakage current (per pin) | — | 1 | μA | |
| R _{PU} | Internal pullup resistors | 30 | 50 | kΩ | 2 |
| R _{PD} | Internal pulldown resistors | 30 | 50 | kΩ | 3 |

1. Measured at V_{DD}=3.6V
2. Measured at V_{DD} supply voltage = V_{DD} min and V_{input} = V_{SS}
3. Measured at V_{DD} supply voltage = V_{DD} min and V_{input} = V_{DD}

5.1.4 Power mode transition operating behaviors

All specifications except t_{POR} , and $VLLSx \rightarrow RUN$ recovery times in the following table assume this clock configuration:

- CPU and system clocks = 100 MHz
- Bus clock = 50 MHz
- Flash clock = 25 MHz

Table 5. Power mode transition operating behaviors

| Symbol | Description | Min. | Max. | Unit | Notes |
|-----------|--|------|-------|---------|-------|
| t_{POR} | After a POR event, amount of time from the point V_{DD} reaches 1.8V to execution of the first instruction across the operating temperature range of the chip. | — | 300 | μs | 1 |
| | RUN \rightarrow VLLS1 \rightarrow RUN <ul style="list-style-type: none"> • RUN \rightarrow VLLS1 • VLLS1 \rightarrow RUN | — | 4.1 | μs | |
| | | — | 123.8 | μs | |
| | RUN \rightarrow VLLS2 \rightarrow RUN <ul style="list-style-type: none"> • RUN \rightarrow VLLS2 • VLLS2 \rightarrow RUN | — | 4.1 | μs | |
| | | — | 49.3 | μs | |
| | RUN \rightarrow VLLS3 \rightarrow RUN <ul style="list-style-type: none"> • RUN \rightarrow VLLS3 • VLLS3 \rightarrow RUN | — | 4.1 | μs | |
| | | — | 49.2 | μs | |
| | RUN \rightarrow LLS \rightarrow RUN <ul style="list-style-type: none"> • RUN \rightarrow LLS • LLS \rightarrow RUN | — | 4.1 | μs | |
| | | — | 5.9 | μs | |
| | RUN \rightarrow STOP \rightarrow RUN <ul style="list-style-type: none"> • RUN \rightarrow STOP • STOP \rightarrow RUN | — | 4.1 | μs | |
| | | — | 4.2 | μs | |
| | RUN \rightarrow VLPS \rightarrow RUN <ul style="list-style-type: none"> • RUN \rightarrow VLPS • VLPS \rightarrow RUN | — | 4.1 | μs | |
| | | — | 5.8 | μs | |

1. Normal boot (FTFL_OPT[LPBOOT]=1)

5.1.5 Power consumption operating behaviors

Table 6. Power consumption operating behaviors

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|------------------------------|--|------|------|------|------|-------|
| I _{DDA} | Analog supply current | — | — | TBD | mA | 1 |
| I _{DD_RUN} | Run mode current — all peripheral clocks disabled, code executing from flash | — | 40 | TBD | mA | 2 |
| | | — | 42 | TBD | mA | |
| I _{DD_RUN} | Run mode current — all peripheral clocks enabled, code executing from flash | — | 55 | TBD | mA | 3 |
| | | — | 56 | TBD | mA | |
| I _{DD_RUN_M AX} | Run mode current — all peripheral clocks enabled and peripherals active, code executing from flash | — | 85 | TBD | mA | 4 |
| | | — | 85 | TBD | mA | |
| I _{DD_WAIT} | Wait mode high frequency current at 3.0 V — all peripheral clocks disabled | — | 35 | TBD | mA | 2 |
| I _{DD_WAIT} | Wait mode reduced frequency current at 3.0 V — all peripheral clocks disabled | — | 15 | TBD | mA | 5 |
| I _{DD_STOP} | Stop mode current at 3.0 V | — | 0.4 | TBD | mA | |
| I _{DD_VLPR} | Very-low-power run mode current at 3.0 V — all peripheral clocks disabled | — | 1.25 | TBD | mA | 6 |
| I _{DD_VLPR} | Very-low-power run mode current at 3.0 V — all peripheral clocks enabled | — | TBD | TBD | mA | 7 |
| I _{DD_VLPW} | Very-low-power wait mode current at 3.0 V | — | 1.05 | TBD | mA | 8 |
| I _{DD_VLPS} | Very-low-power stop mode current at 3.0 V | — | 50 | TBD | μA | |
| I _{DD_LLS} | Low leakage stop mode current at 3.0 V | — | 12 | TBD | μA | |
| I _{DD_VLLS3} | Very low-leakage stop mode 3 current at 3.0 V | | | | | |
| I _{DD_VLLS2} | Very low-leakage stop mode 2 current at 3.0 V | — | 4 | TBD | μA | |
| I _{DD_VLLS1} | Very low-leakage stop mode 1 current at 3.0 V | — | 2 | TBD | μA | |
| I _{DD_VBAT} | Average current when CPU is not accessing RTC registers at 3.0 V | — | 550 | TBD | nA | 9 |

1. The analog supply current is the sum of the active or disabled current for each of the analog modules on the device. See each module's specification for its supply current.
2. 100MHz core and system clock, 50MHz bus clock, and 25MHz flash clock. MCG configured for FEI mode. All peripheral clocks disabled.
3. 100MHz core and system clock, 50MHz bus clock, and 25MHz flash clock. MCG configured for FEI mode. All peripheral clocks enabled, but peripherals are not in active operation.
4. 100MHz core and system clock, 50MHz bus clock, and 25MHz flash clock. MCG configured for FEI mode. All peripheral clocks enabled, and peripherals are in active operation.
5. 25MHz core and system clock, 25MHz bus clock, and 12.5MHz flash clock. MCG configured for FEI mode.

General

- 2 MHz core, system, and bus clock and 1MHz flash clock. MCG configured for fast IRCLK mode. All peripheral clocks disabled. Code executing from flash.
- 2 MHz core, system, and bus clock and 1MHz flash clock. MCG configured for fast IRCLK mode. All peripheral clocks enabled but peripherals are not in active operation. Code executing from flash.
- 2 MHz core, system, and bus clock and 1MHz flash clock. MCG configured for fast IRCLK mode. All peripheral clocks disabled.
- Includes 32kHz oscillator current and RTC operation.

5.1.5.1 Diagram: Typical IDD_RUN operating behavior

The following data was measured under these conditions:

- MCG in FEI mode (39.0625 kHz IRC), except for 1 MHz core (FBE)
- All peripheral clocks disabled except FTFL
- LVD disabled, USB regulator disabled
- No GPIOs toggled
- Code execution from flash

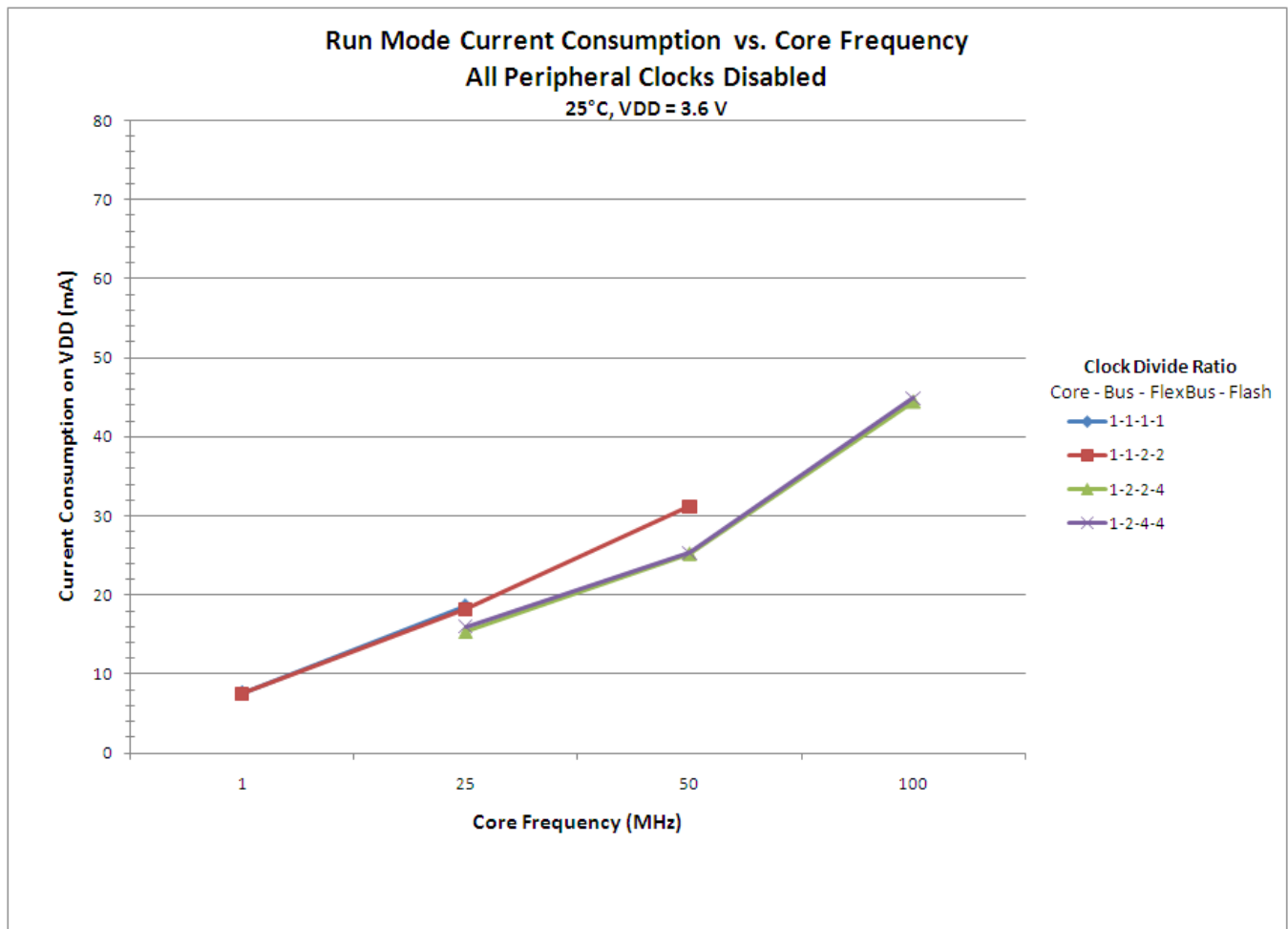


Figure 1. Run mode supply current vs. core frequency — all peripheral clocks disabled

The following data was measured under these conditions:

- MCG in FEI mode (39.0625 kHz IRC), except for 1 MHz core (FBE)
- All peripheral clocks enabled but peripherals are not in active operation
- LVD disabled, USB regulator disabled
- No GPIOs toggled
- Code execution from flash

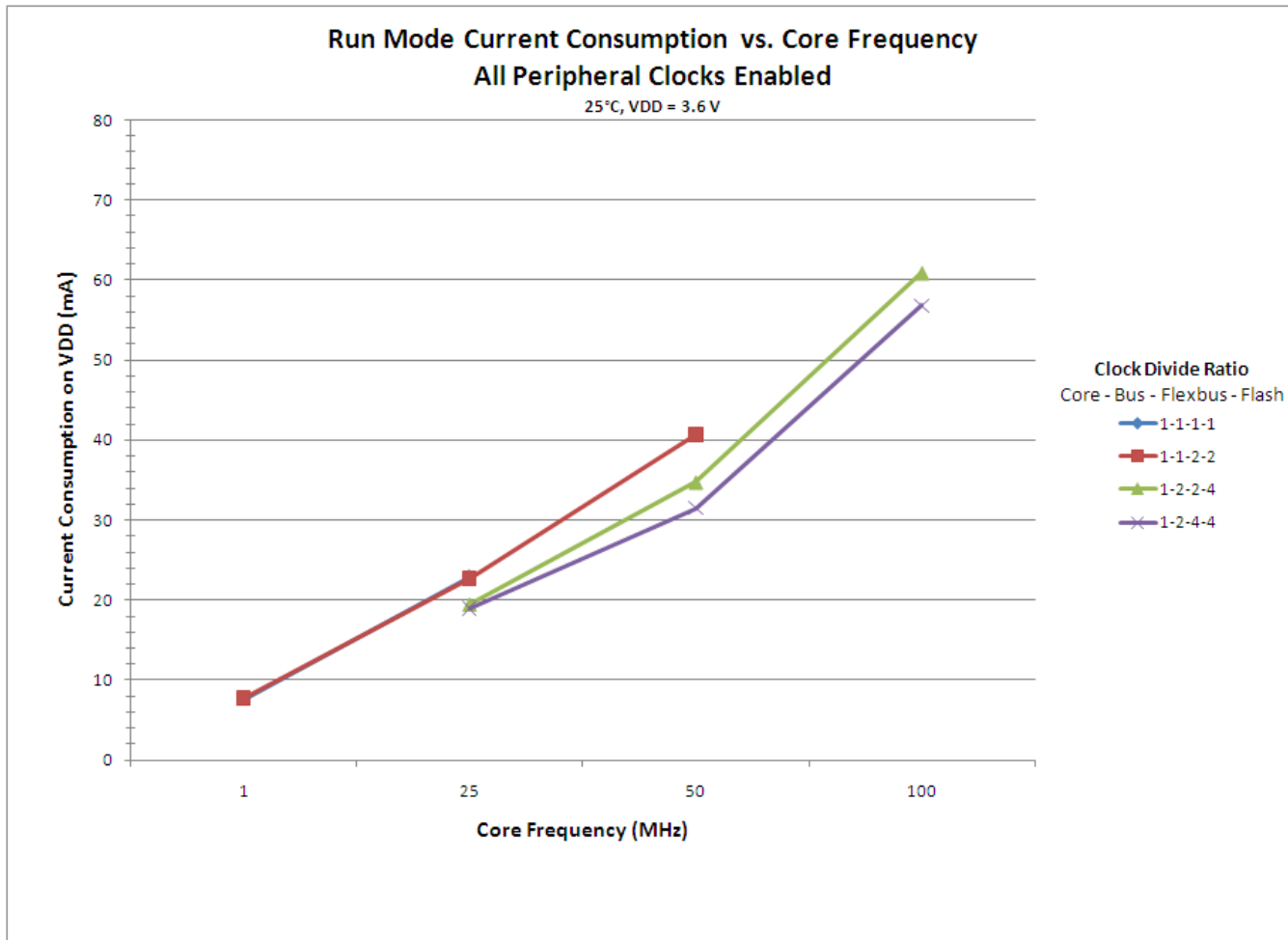


Figure 2. Run mode supply current vs. core frequency — all peripheral clocks enabled

5.1.6 EMC radiated emissions operating behaviors

Table 7. EMC radiated emissions operating behaviors

| Symbol | Description | Frequency band (MHz) | Typ. | Unit | Notes |
|-------------------------|------------------------------------|----------------------|------|------------|-------|
| V _{RE1} | Radiated emissions voltage, band 1 | 0.15–50 | TBD | dB μ V | 1, 2 |
| V _{RE2} | Radiated emissions voltage, band 2 | 50–150 | TBD | | |
| V _{RE3} | Radiated emissions voltage, band 3 | 150–500 | TBD | | |
| V _{RE4} | Radiated emissions voltage, band 4 | 500–1000 | TBD | | |
| V _{RE_IEC_SAE} | IEC and SAE level | 0.15–1000 | TBD | — | 2, 3 |

1. Determined according to IEC Standard 61967-1, *Integrated Circuits - Measurement of Electromagnetic Emissions, 150 kHz to 1 GHz Part 1: General Conditions and Definitions*, IEC Standard 61967-2, *Integrated Circuits - Measurement of Electromagnetic Emissions, 150 kHz to 1 GHz Part 2: Measurement of Radiated Emissions—TEM Cell and Wideband TEM Cell Method*, and SAE Standard J1752-3, *Measurement of Radiated Emissions from Integrated Circuits—TEM/Wideband TEM (GTEM) Cell Method*.
2. V_{DD} = 3 V, T_A = 25 °C, f_{OSC} = 12 MHz (crystal), f_{SYS} = 96 MHz
3. Specified according to Annex D of IEC Standard 61967-2, *Measurement of Radiated Emissions—TEM Cell and Wideband TEM Cell Method*, and Appendix D of SAE Standard J1752-3, *Measurement of Radiated Emissions from Integrated Circuits—TEM/Wideband TEM (GTEM) Cell Method*.

5.1.7 Designing with radiated emissions in mind

To find application notes that provide guidance on designing your system to minimize interference from radiated emissions:

1. Go to <http://www.freescale.com>.
2. Perform a keyword search for “EMC design.”

5.1.8 Capacitance attributes

Table 8. Capacitance attributes

| Symbol | Description | Min. | Max. | Unit |
|-------------------|---------------------------------|------|------|------|
| C _{IN_A} | Input capacitance: analog pins | — | 7 | pF |
| C _{IN_D} | Input capacitance: digital pins | — | 7 | pF |

5.2 Switching specifications

5.2.1 Device clock specifications

| Symbol | Description | Min. | Max. | Unit | Notes |
|-----------------|---|------|------|------|-------|
| Normal run mode | | | | | |
| f_{SYS} | System and core clock | — | 100 | MHz | |
| f_{SYS_USB} | System and core clock when USB in operation | 20 | — | MHz | |
| f_{BUS} | Bus clock | — | 50 | MHz | |
| f_{FLASH} | Flash clock | — | 25 | MHz | |
| VLPR mode | | | | | |
| f_{SYS} | System and core clock | — | 2 | MHz | |
| f_{BUS} | Bus clock | — | 2 | MHz | |
| f_{FLASH} | Flash clock | — | 1 | MHz | |

5.2.2 General switching specifications

These general purpose specifications apply to all signals configured for GPIO, UART, CMT, and I²C signals.

| Symbol | Description | Min. | Max. | Unit | Notes |
|--------|---|--------|----------|------------------|-------|
| | GPIO pin interrupt pulse width (digital glitch filter disabled) — Synchronous path | 1.5 | — | Bus clock cycles | 1 |
| | GPIO pin interrupt pulse width (digital glitch filter disabled, analog filter enabled) — Asynchronous path | 100 | — | ns | 2 |
| | GPIO pin interrupt pulse width (digital glitch filter disabled, analog filter disabled) — Asynchronous path | 16 | — | ns | 2 |
| | External reset pulse width (digital glitch filter disabled) | TBD | — | | |
| | Mode select (EZP_CS) hold time after reset deassertion | 2 | — | Bus clock cycles | |
| | Port rise and fall time (high drive strength) | | | | 3 |
| | <ul style="list-style-type: none"> • Slew disabled • Slew enabled | — — | 12 36 | ns ns | |
| | Port rise and fall time (low drive strength) | | | | 4 |
| | <ul style="list-style-type: none"> • Slew disabled • Slew enabled | — — | 32 36 | ns ns | |

1. The greater synchronous and asynchronous timing must be met.
2. This is the shortest pulse that is guaranteed to be recognized.
3. 75pF load
4. 15pF load

5.3 Thermal specifications

5.3.1 Thermal operating requirements

Table 9. Thermal operating requirements

| Symbol | Description | Min. | Max. | Unit |
|--------|--------------------------|------|------|------|
| T_J | Die junction temperature | -40 | 125 | °C |
| T_A | Ambient temperature | -40 | 85 | °C |

5.3.2 Thermal attributes

| Board type | Symbol | Description | 121 MAPBGA | Unit | Notes |
|-------------------|------------------|---|------------|------|-------|
| Single-layer (1s) | $R_{\theta JA}$ | Thermal resistance, junction to ambient (natural convection) | TBD | °C/W | 1 |
| Four-layer (2s2p) | $R_{\theta JA}$ | Thermal resistance, junction to ambient (natural convection) | TBD | °C/W | 1 |
| Single-layer (1s) | $R_{\theta JMA}$ | Thermal resistance, junction to ambient (200 ft./min. air speed) | TBD | °C/W | 1 |
| Four-layer (2s2p) | $R_{\theta JMA}$ | Thermal resistance, junction to ambient (200 ft./min. air speed) | TBD | °C/W | 1 |
| — | $R_{\theta JB}$ | Thermal resistance, junction to board | TBD | °C/W | 2 |
| — | $R_{\theta JC}$ | Thermal resistance, junction to case | TBD | °C/W | 3 |
| — | Ψ_{JT} | Thermal characterization parameter, junction to package top outside center (natural convection) | TBD | °C/W | 4 |

1. Determined according to JEDEC Standard JESD51-2, *Integrated Circuits Thermal Test Method Environmental Conditions—Natural Convection (Still Air)*, or EIA/JEDEC Standard JESD51-6, *Integrated Circuit Thermal Test Method Environmental Conditions—Forced Convection (Moving Air)*.

6 Peripheral operating requirements and behaviors

All digital I/O switching characteristics assume:

- output pins
 - have $C_L=30\text{pF}$ loads,
 - are configured for fast slew rate ($\text{PORTx_PCRn[SRE]}=0$), and
 - are configured for high drive strength ($\text{PORTx_PCRn[DSE]}=1$)
- input pins

- have their passive filter disabled (PORTx_PCRn[PFE]=0)

6.1 Core modules

6.1.1 Debug trace timing specifications

Table 10. Debug trace operating behaviors

| Symbol | Description | Min. | Max. | Unit |
|-----------|--------------------------|---------------------|------|------|
| T_{cyc} | Clock period | Frequency dependent | | MHz |
| T_{wl} | Low pulse width | 2 | — | ns |
| T_{wh} | High pulse width | 2 | — | ns |
| T_r | Clock and data rise time | — | 3 | ns |
| T_f | Clock and data fall time | — | 3 | ns |
| T_s | Data setup | 3 | — | ns |
| T_h | Data hold | 2 | — | ns |

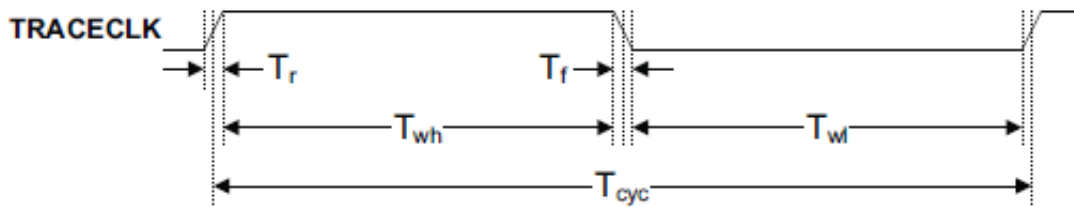


Figure 3. TRACE_CLKOUT specifications

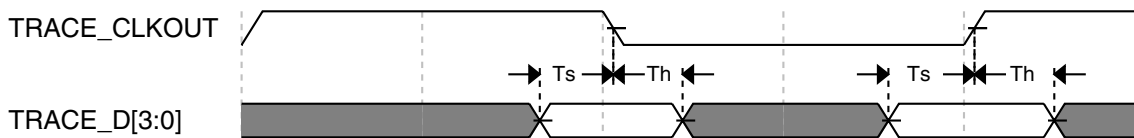


Figure 4. Trace data specifications

6.1.2 JTAG electricals

Table 11. JTAG limited voltage range electricals

| Symbol | Description | Min. | Max. | Unit |
|--------|--|----------------|----------------|------|
| | Operating voltage | 2.7 | 3.6 | V |
| J1 | TCLK frequency of operation <ul style="list-style-type: none"> • Boundary Scan • JTAG and CJTAG • Serial Wire Debug | 0 0 0 | 10 25 50 | MHz |
| J2 | TCLK cycle period | 1/J1 | — | ns |
| J3 | TCLK clock pulse width <ul style="list-style-type: none"> • Boundary Scan • JTAG and CJTAG • Serial Wire Debug | 50 20 10 | — — | ns |
| J4 | TCLK rise and fall times | — | 3 | ns |
| J5 | Boundary scan input data setup time to TCLK rise | 20 | — | ns |
| J6 | Boundary scan input data hold time after TCLK rise | 0 | — | ns |
| J7 | TCLK low to boundary scan output data valid | — | 25 | ns |
| J8 | TCLK low to boundary scan output high-Z | — | 25 | ns |
| J9 | TMS, TDI input data setup time to TCLK rise | 8 | — | ns |
| J10 | TMS, TDI input data hold time after TCLK rise | 1 | — | ns |
| J11 | TCLK low to TDO data valid | — | 17 | ns |
| J12 | TCLK low to TDO high-Z | — | 17 | ns |
| J13 | TRST assert time | 100 | — | ns |
| J14 | TRST setup time (negation) to TCLK high | 8 | — | ns |

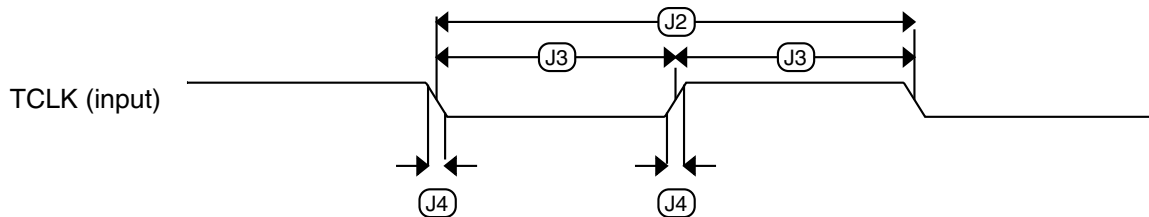
Table 12. JTAG full voltage range electricals

| Symbol | Description | Min. | Max. | Unit |
|--------|--|-------------|----------------|------|
| | Operating voltage | 1.71 | 3.6 | V |
| J1 | TCLK frequency of operation <ul style="list-style-type: none"> • Boundary Scan • JTAG and CJTAG • Serial Wire Debug | 0 0 0 | 10 20 40 | MHz |
| J2 | TCLK cycle period | 1/J1 | — | ns |

Table continues on the next page...

Table 12. JTAG full voltage range electricals (continued)

| Symbol | Description | Min. | Max. | Unit |
|--------|---|------------------|------|------|
| J3 | TCLK clock pulse width <ul style="list-style-type: none"> Boundary Scan JTAG and CJTAG Serial Wire Debug | 50 25 12.5 | — | ns |
| J4 | TCLK rise and fall times | — | 3 | ns |
| J5 | Boundary scan input data setup time to TCLK rise | 20 | — | ns |
| J6 | Boundary scan input data hold time after TCLK rise | 0 | — | ns |
| J7 | TCLK low to boundary scan output data valid | — | 25 | ns |
| J8 | TCLK low to boundary scan output high-Z | — | 25 | ns |
| J9 | TMS, TDI input data setup time to TCLK rise | 8 | — | ns |
| J10 | TMS, TDI input data hold time after TCLK rise | 1.4 | — | ns |
| J11 | TCLK low to TDO data valid | — | 22.1 | ns |
| J12 | TCLK low to TDO high-Z | — | 22.1 | ns |
| J13 | TRST assert time | 100 | — | ns |
| J14 | TRST setup time (negation) to TCLK high | 8 | — | ns |

**Figure 5. Test clock input timing**

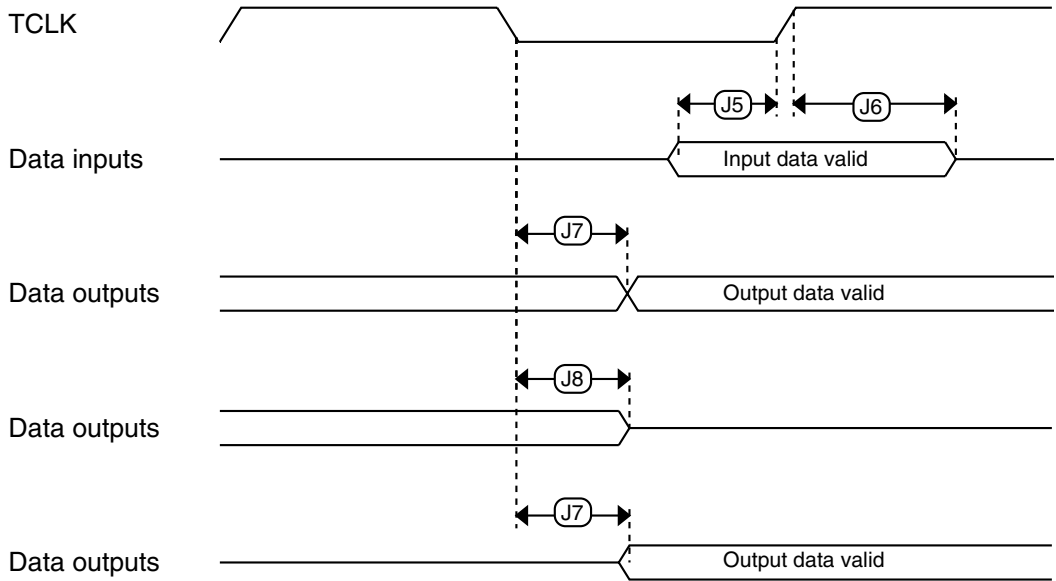


Figure 6. Boundary scan (JTAG) timing

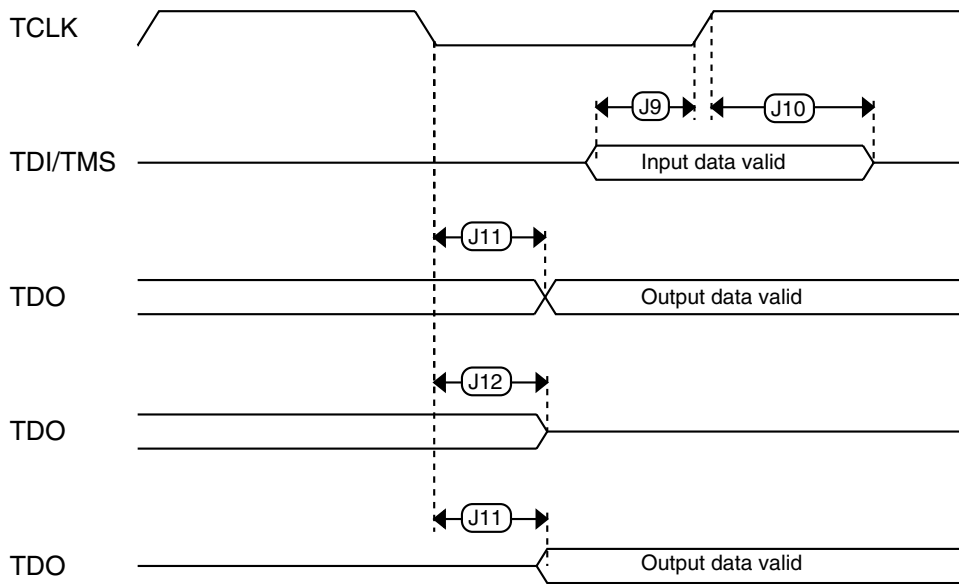


Figure 7. Test Access Port timing

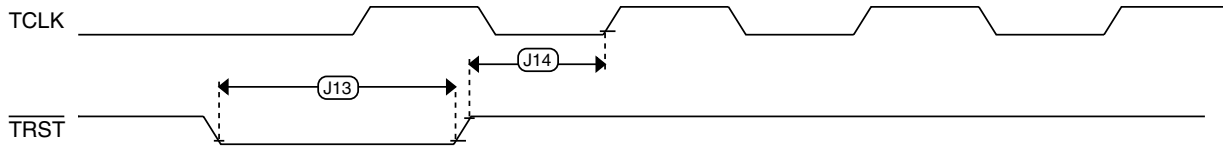


Figure 8. TRST timing

6.2 System modules

There are no specifications necessary for the device's system modules.

6.3 Clock modules

6.3.1 MCG specifications

Table 13. MCG specifications

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|---------------------------------|--|-------|----------------|---------|--------------------|-------|
| $f_{\text{ints_ft}}$ | Internal reference frequency (slow clock) — factory trimmed at nominal VDD and 25°C | — | 32.768 | — | kHz | |
| $f_{\text{ints_t}}$ | Internal reference frequency (slow clock) — user trimmed | 31.25 | — | 39.0625 | kHz | |
| I_{ints} | Internal reference (slow clock) current | — | TBD | — | μA | |
| t_{refsts} | Internal reference (slow clock) startup time | — | TBD | 4 | μs | |
| $\Delta f_{\text{dco_res_t}}$ | Resolution of trimmed DCO output frequency at fixed voltage and temperature — using SCTRIM and SCFTRIM | — | ± 0.1 | ± 0.3 | % f_{dco} | 1 |
| $\Delta f_{\text{dco_res_t}}$ | Resolution of trimmed DCO output frequency at fixed voltage and temperature — using SCTRIM only | — | ± 0.2 | ± 0.5 | % f_{dco} | 1 |
| $\Delta f_{\text{dco_t}}$ | Total deviation of trimmed average DCO output frequency over voltage and temperature | — | + 0.5 - 1.0 | ± 3.5 | % f_{dco} | 1 |
| $\Delta f_{\text{dco_t}}$ | Total deviation of trimmed average DCO output frequency over fixed voltage and temperature range of 0–70°C | — | ± 0.5 | ± TBD | % f_{dco} | 1 |
| $f_{\text{intf_ft}}$ | Internal reference frequency (fast clock) — factory trimmed at nominal VDD and 25°C | 3.4 | — | 4 | MHz | |
| $f_{\text{intf_t}}$ | Internal reference frequency (fast clock) — user trimmed | 3 | — | 5 | MHz | |

Table continues on the next page...

Table 13. MCG specifications (continued)

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes | |
|-------------------------|--|---|------|---------|---------------|-------|------|
| I_{intf} | Internal reference (fast clock) current | — | TBD | — | μA | | |
| $t_{irefstf}$ | Internal reference startup time (fast clock) | — | TBD | TBD | μs | | |
| f_{loc_low} | Loss of external clock minimum frequency — RANGE = 00 | $(3/5) \times f_{ints_t}$ | — | — | kHz | | |
| f_{loc_high} | Loss of external clock minimum frequency — RANGE = 01, 10, or 11 | $(16/5) \times f_{ints_t}$ | — | — | kHz | | |
| FLL | | | | | | | |
| f_{fll_ref} | FLL reference frequency range | 31.25 | — | 39.0625 | kHz | | |
| f_{dco} | DCO output frequency range | Low range (DRS=00) $640 \times f_{fll_ref}$ | 20 | 20.97 | 25 | MHz | 2, 3 |
| | | Mid range (DRS=01) $1280 \times f_{fll_ref}$ | 40 | 41.94 | 50 | MHz | |
| | | Mid-high range (DRS=10) $1920 \times f_{fll_ref}$ | 60 | 62.91 | 75 | MHz | |
| | | High range (DRS=11) $2560 \times f_{fll_ref}$ | 80 | 83.89 | 100 | MHz | |
| $f_{dco_t_DMX3}$ 2 | DCO output frequency | Low range (DRS=00) $732 \times f_{fll_ref}$ | — | 23.99 | — | MHz | 4, 5 |
| | | Mid range (DRS=01) $1464 \times f_{fll_ref}$ | — | 47.97 | — | MHz | |
| | | Mid-high range (DRS=10) $2197 \times f_{fll_ref}$ | — | 71.99 | — | MHz | |
| | | High range (DRS=11) $2929 \times f_{fll_ref}$ | — | 95.98 | — | MHz | |
| J_{cyc_fll} | FLL period jitter | — | TBD | TBD | ps | 6 | |
| J_{acc_fll} | FLL accumulated jitter of DCO output over a 1 μs time window | — | TBD | TBD | ps | 6 | |
| $t_{fll_acquire}$ | FLL target frequency acquisition time | — | — | 1 | ms | 7 | |
| PLL | | | | | | | |
| f_{vco} | VCO operating frequency | 48.0 | — | 100 | MHz | | |
| I_{pll} | PLL operating current • PLL @ 96 MHz ($f_{osc_hi_1}$ =8MHz, f_{pll_ref} =2MHz, VDIV multiplier=48) | — | 950 | — | μA | 8 | |
| f_{pll_ref} | PLL reference frequency range | 2.0 | — | 4.0 | MHz | | |
| J_{cyc_pll} | PLL period jitter | — | 400 | — | ps | 9, 10 | |
| J_{acc_pll} | PLL accumulated jitter over 1 μs window | — | TBD | — | ps | 9, 10 | |

Table continues on the next page...

Table 13. MCG specifications (continued)

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|-----------------|--------------------------------|------------|------|-------------------------------|------|-------|
| D_{lock} | Lock entry frequency tolerance | ± 1.49 | — | ± 2.98 | % | |
| D_{unl} | Lock exit frequency tolerance | ± 4.47 | — | ± 5.97 | % | |
| t_{pll_lock} | Lock detector detection time | — | — | $0.15 + 1075(1/f_{pll_ref})$ | ms | 11 |

1. This parameter is measured with the internal reference (slow clock) being used as a reference to the FLL (FEI clock mode).
2. These typical values listed are with the slow internal reference clock (FEI) using factory trim and DMX32=0.
3. The resulting system clock frequencies should not exceed their maximum specified values. The DCO frequency deviation (Δf_{dco_t}) over voltage and temperature should be considered.
4. These typical values listed are with the slow internal reference clock (FEI) using factory trim and DMX32=1.
5. The resulting clock frequency must not exceed the maximum specified clock frequency of the device.
6. This specification was obtained at TBD frequency.
7. This specification applies to any time the FLL reference source or reference divider is changed, trim value is changed, DMX32 bit is changed, DRS bits are changed, or changing from FLL disabled (BLPE, BLPI) to FLL enabled (FEI, FEE, FBE, FBI). If a crystal/resonator is being used as the reference, this specification assumes it is already running.
8. Excludes any oscillator currents that are also consuming power while PLL is in operation.
9. This specification was obtained using a Freescale developed PCB. PLL jitter is dependent on the noise characteristics of each PCB and results will vary.
10. This specification was obtained at internal frequency of TBD.
11. This specification applies to any time the PLL VCO divider or reference divider is changed, or changing from PLL disabled (BLPE, BLPI) to PLL enabled (PBE, PEE). If a crystal/resonator is being used as the reference, this specification assumes it is already running.

6.3.2 Oscillator electrical specifications

This section provides the electrical characteristics of the module.

6.3.2.1 Oscillator DC electrical specifications

Table 14. Oscillator DC electrical specifications

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|-------------|---|------|------|------|---------|-------|
| V_{DD} | Supply voltage | 1.71 | — | 3.6 | V | |
| I_{DDOSC} | Supply current — low-power mode (HGO=0) | | | | | 1 |
| | • 32 kHz | — | 500 | — | nA | |
| | • 4 MHz | — | 200 | — | μ A | |
| | • 8 MHz | — | 300 | — | μ A | |
| | • 16 MHz | — | 700 | — | μ A | |
| | • 24 MHz | — | 1.2 | — | mA | |
| | • 32 MHz | — | 1.5 | — | mA | |

Table continues on the next page...

Table 14. Oscillator DC electrical specifications (continued)

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|------------------------------|--|------|-----------------|------|------|-------|
| I _{DDOSC} | Supply current — high gain mode (HGO=1) | | | | | 1 |
| | • 32 kHz | — | 25 | — | μA | |
| | • 4 MHz | — | 400 | — | μA | |
| | • 8 MHz | — | 800 | — | μA | |
| | • 16 MHz | — | 1.5 | — | mA | |
| | • 24 MHz | — | 3 | — | mA | |
| • 32 MHz | — | 4 | — | mA | | |
| C _x | EXTAL load capacitance | — | — | — | | 2, 3 |
| C _y | XTAL load capacitance | — | — | — | | 2, 3 |
| R _F | Feedback resistor — low-frequency, low-power mode (HGO=0) | — | — | — | MΩ | 2, 4 |
| | Feedback resistor — low-frequency, high-gain mode (HGO=1) | — | 10 | — | MΩ | |
| | Feedback resistor — high-frequency, low-power mode (HGO=0) | — | — | — | MΩ | |
| | Feedback resistor — high-frequency, high-gain mode (HGO=1) | — | 1 | — | MΩ | |
| R _S | Series resistor — low-frequency, low-power mode (HGO=0) | — | — | — | kΩ | |
| | Series resistor — low-frequency, high-gain mode (HGO=1) | — | 200 | — | kΩ | |
| | Series resistor — high-frequency, low-power mode (HGO=0) | — | — | — | kΩ | |
| | Series resistor — high-frequency, high-gain mode (HGO=1) | — | 0 | — | kΩ | |
| V _{pp} ⁵ | Peak-to-peak amplitude of oscillation (oscillator mode) — low-frequency, low-power mode (HGO=0) | — | 0.6 | — | V | |
| | Peak-to-peak amplitude of oscillation (oscillator mode) — low-frequency, high-gain mode (HGO=1) | — | V _{DD} | — | V | |
| | Peak-to-peak amplitude of oscillation (oscillator mode) — high-frequency, low-power mode (HGO=0) | — | 0.6 | — | V | |
| | Peak-to-peak amplitude of oscillation (oscillator mode) — high-frequency, high-gain mode (HGO=1) | — | V _{DD} | — | V | |

1. V_{DD}=3.3 V, Temperature =25 °C
2. See crystal or resonator manufacturer's recommendation
3. C_x,C_y can be provided by using either the integrated capacitors or by using external components.
4. When low power mode is selected, R_F is integrated and must not be attached externally.

5. The EXTAL and XTAL pins should only be connected to required oscillator components and must not be connected to any other devices.

6.3.2.2 Oscillator frequency specifications

Table 15. Oscillator frequency specifications

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|------------------|---|------|------|------|------|-------|
| f_{osc_lo} | Oscillator crystal or resonator frequency — low frequency mode (MCG_C2[RANGE]=00) | 32 | — | 40 | kHz | |
| $f_{osc_hi_1}$ | Oscillator crystal or resonator frequency — high frequency mode (low range) (MCG_C2[RANGE]=01) | 3 | — | 8 | MHz | |
| $f_{osc_hi_2}$ | Oscillator crystal or resonator frequency — high frequency mode (high range) (MCG_C2[RANGE]=1x) | 8 | — | 32 | MHz | |
| f_{ec_extal} | Input clock frequency (external clock mode) | — | — | 50 | MHz | 1 |
| t_{dc_extal} | Input clock duty cycle (external clock mode) | 40 | 50 | 60 | % | |
| t_{cst} | Crystal startup time — 32 kHz low-frequency, low-power mode (HGO=0) | — | TBD | — | ms | 2, 3 |
| | Crystal startup time — 32 kHz low-frequency, high-gain mode (HGO=1) | — | 800 | — | ms | |
| | Crystal startup time — 8 MHz high-frequency (MCG_C2[RANGE]=01), low-power mode (HGO=0) | — | 4 | — | ms | |
| | Crystal startup time — 8 MHz high-frequency (MCG_C2[RANGE]=01), high-gain mode (HGO=1) | — | 3 | — | ms | |

1. Other frequency limits may apply when external clock is being used as a reference for the FLL or PLL.
2. Proper PC board layout procedures must be followed to achieve specifications.
3. Crystal startup time is defined as the time between the oscillator being enabled and the OSCINIT bit in the MCG_S register being set.

6.3.3 32kHz Oscillator Electrical Characteristics

This section describes the module electrical characteristics.

6.3.3.1 32kHz oscillator DC electrical specifications

Table 16. 32kHz oscillator DC electrical specifications

| Symbol | Description | Min. | Typ. | Max. | Unit |
|------------|---|------|------|------|------------|
| V_{BAT} | Supply voltage | 1.71 | — | 3.6 | V |
| R_F | Internal feedback resistor | — | 100 | — | M Ω |
| C_{para} | Parasitical capacitance of EXTAL32 and XTAL32 | — | 2.5 | — | pF |

Table continues on the next page...

Table 16. 32kHz oscillator DC electrical specifications (continued)

| Symbol | Description | Min. | Typ. | Max. | Unit |
|------------|--|------|------|------|------|
| C_{load} | Internal load capacitance (programmable) | — | 15 | — | pF |
| V_{pp} | Peak-to-peak amplitude of oscillation | — | 0.6 | — | V |

6.3.3.2 32kHz oscillator frequency specifications

Table 17. 32kHz oscillator frequency specifications

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|---------------|-----------------------|------|------|------|------|-------|
| f_{osc_lo} | Oscillator crystal | — | 32 | — | kHz | |
| t_{start} | Crystal start-up time | — | 1000 | — | ms | 1 |

1. Proper PC board layout procedures must be followed to achieve specifications.

6.4 Memories and memory interfaces

6.4.1 Flash (FTFL) electrical specifications

This section describes the electrical characteristics of the FTFL module.

6.4.1.1 Flash timing specifications — program and erase

The following specifications represent the amount of time the internal charge pumps are active and do not include command overhead.

Table 18. NVM program/erase timing specifications

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|--------------------|--|------|------|------|---------|-------|
| t_{hvpgm4} | Longword Program high-voltage time | — | 20 | TBD | μ s | |
| $t_{hversscr}$ | Sector Erase high-voltage time | — | 20 | 100 | ms | 1 |
| $t_{hversblk256k}$ | Erase Block high-voltage time for 256 KB | — | 160 | 800 | ms | 1 |

1. Maximum time based on expectations at cycling end-of-life.

6.4.1.2 Flash timing specifications — commands

Table 19. Flash command timing specifications

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|--|---|------|------|------|---------|-------|
| $t_{rd1blk256k}$ | Read 1s Block execution time • 256 KB data flash | — | — | 1.4 | ms | |
| $t_{rd1sec2k}$ | Read 1s Section execution time (flash sector) | — | — | 40 | μ s | 1 |
| t_{pgmchk} | Program Check execution time | — | — | 35 | μ s | 1 |
| t_{rdsrc} | Read Resource execution time | — | — | 35 | μ s | 1 |
| t_{pgm4} | Program Longword execution time | — | 50 | TBD | μ s | |
| $t_{ersblk256k}$ | Erase Flash Block execution time • 256 KB data flash | — | 160 | 800 | ms | 2 |
| t_{ersscr} | Erase Flash Sector execution time | — | 20 | 100 | ms | 2 |
| $t_{pgmsec512}$ | Program Section execution time • 512 B flash | — | TBD | TBD | ms | |
| $t_{pgmsec1k}$ | • 1 KB flash | — | TBD | TBD | ms | |
| $t_{pgmsec2k}$ | • 2 KB flash | — | TBD | TBD | ms | |
| t_{rd1all} | Read 1s All Blocks execution time | — | — | 2.8 | ms | |
| t_{rdonce} | Read Once execution time | — | — | 35 | μ s | 1 |
| $t_{pgmonce}$ | Program Once execution time | — | 50 | TBD | μ s | |
| t_{ersall} | Erase All Blocks execution time | — | 320 | 1600 | ms | 2 |
| t_{vfykey} | Verify Backdoor Access Key execution time | — | — | 35 | μ s | 1 |
| $t_{pgmpart256k}$ | Program Partition for EEPROM execution time • 256 KB FlexNVM | — | 175 | TBD | ms | |
| $t_{setram32k}$ | Set FlexRAM Function execution time: • 32 KB EEPROM backup | — | TBD | TBD | ms | |
| $t_{setram256k}$ | • 256 KB EEPROM backup | — | TBD | TBD | ms | |
| Byte-write to FlexRAM for EEPROM operation | | | | | | |
| $t_{eerw8bers}$ | Byte-write to erased FlexRAM location execution time | — | 100 | TBD | μ s | 3 |
| $t_{eerw8b32k}$ | Byte-write to FlexRAM execution time: • 32 KB EEPROM backup | — | TBD | TBD | ms | |
| $t_{eerw8b64k}$ | • 64 KB EEPROM backup | — | TBD | 1.5 | ms | |
| $t_{eerw8b128k}$ | • 128 KB EEPROM backup | — | TBD | TBD | ms | |
| $t_{eerw8b256k}$ | • 256 KB EEPROM backup | — | TBD | 2.5 | ms | |
| Word-write to FlexRAM for EEPROM operation | | | | | | |

Table continues on the next page...

Table 19. Flash command timing specifications (continued)

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|--|---|------|------|------|---------------|-------|
| $t_{\text{eewr16bers}}$ | Word-write to erased FlexRAM location execution time | — | 100 | TBD | μs | |
| $t_{\text{eewr16b32k}}$ | Word-write to FlexRAM execution time: <ul style="list-style-type: none"> • 32 KB EEPROM backup • 64 KB EEPROM backup • 128 KB EEPROM backup • 256 KB EEPROM backup | — | TBD | TBD | ms | |
| $t_{\text{eewr16b64k}}$ | | — | TBD | 1.5 | ms | |
| $t_{\text{eewr16b128k}}$ | | — | TBD | TBD | ms | |
| $t_{\text{eewr16b256k}}$ | | — | TBD | 2.5 | ms | |
| Longword-write to FlexRAM for EEPROM operation | | | | | | |
| $t_{\text{eewr32bers}}$ | Longword-write to erased FlexRAM location execution time | — | 200 | TBD | μs | |
| $t_{\text{eewr32b32k}}$ | Longword-write to FlexRAM execution time: <ul style="list-style-type: none"> • 32 KB EEPROM backup • 64 KB EEPROM backup • 128 KB EEPROM backup • 256 KB EEPROM backup | — | TBD | TBD | ms | |
| $t_{\text{eewr32b64k}}$ | | — | TBD | 2.7 | ms | |
| $t_{\text{eewr32b128k}}$ | | — | TBD | TBD | ms | |
| $t_{\text{eewr32b256k}}$ | | — | TBD | 3.7 | ms | |

1. Assumes 25MHz flash clock frequency.
2. Maximum times for erase parameters based on expectations at cycling end-of-life.
3. For byte-writes to an erased FlexRAM location, the aligned word containing the byte must be erased.

6.4.1.3 Flash (FTFL) current and power specifications

Table 20. Flash (FTFL) current and power specifications

| Symbol | Description | Typ. | Unit |
|----------------------|---|------|------|
| $I_{\text{DD_PGM}}$ | Worst case programming current in program flash | 10 | mA |

6.4.1.4 Reliability specifications

Table 21. NVM reliability specifications

| Symbol | Description | Min. | Typ. ¹ | Max. | Unit | Notes |
|--------------------------|--|------|-------------------|------|--------|-------|
| Program Flash | | | | | | |
| $t_{\text{nv mretp10k}}$ | Data retention after up to 10 K cycles | 5 | TBD | — | years | 2 |
| $t_{\text{nv mretp1k}}$ | Data retention after up to 1 K cycles | 10 | TBD | — | years | 2 |
| $t_{\text{nv mretp100}}$ | Data retention after up to 100 cycles | 15 | TBD | — | years | 2 |
| $n_{\text{nv mcycp}}$ | Cycling endurance | 10 K | TBD | — | cycles | 3 |
| Data Flash | | | | | | |
| $t_{\text{nv mretd10k}}$ | Data retention after up to 10 K cycles | 5 | TBD | — | years | 2 |

Table continues on the next page...

Table 21. NVM reliability specifications (continued)

| Symbol | Description | Min. | Typ. ¹ | Max. | Unit | Notes |
|-------------------|--|--------|-------------------|------|--------|-------|
| $t_{nvmretd1k}$ | Data retention after up to 1 K cycles | 10 | TBD | — | years | 2 |
| $t_{nvmretd100}$ | Data retention after up to 100 cycles | 15 | TBD | — | years | 2 |
| n_{nvmcyd} | Cycling endurance | 10 K | TBD | — | cycles | 3 |
| FlexRAM as EEPROM | | | | | | |
| $t_{nvmretee100}$ | Data retention up to 100% of write endurance | 5 | TBD | — | years | 2 |
| $t_{nvmretee10}$ | Data retention up to 10% of write endurance | 10 | TBD | — | years | 2 |
| $t_{nvmretee1}$ | Data retention up to 1% of write endurance | 15 | TBD | — | years | 2 |
| | Write endurance | | | | | 4 |
| $n_{nvmwree16}$ | • EEPROM backup to FlexRAM ratio = 16 | 35 K | TBD | — | writes | |
| $n_{nvmwree128}$ | • EEPROM backup to FlexRAM ratio = 128 | 315 K | TBD | — | writes | |
| $n_{nvmwree512}$ | • EEPROM backup to FlexRAM ratio = 512 | 1.27 M | TBD | — | writes | |
| $n_{nvmwree4k}$ | • EEPROM backup to FlexRAM ratio = 4096 | 10 M | TBD | — | writes | |
| $n_{nvmwree32k}$ | • EEPROM backup to FlexRAM ratio = 32,768 | 80 M | TBD | — | writes | |

1. Typical data retention values are based on intrinsic capability of the technology measured at high temperature derated to 25°C. For additional information on how Freescale defines typical data retention, please refer to Engineering Bulletin EB618.
2. Data retention is based on $T_{javg} = 55^\circ\text{C}$ (temperature profile over the lifetime of the application).
3. Cycling endurance represents number of program/erase cycles at $-40^\circ\text{C} \leq T_j \leq 125^\circ\text{C}$.
4. Write endurance represents the number of writes to each FlexRAM location at $-40^\circ\text{C} \leq T_j \leq 125^\circ\text{C}$ influenced by the cycling endurance of the FlexNVM (same value as data flash) and the allocated EEPROM backup per subsystem. Minimum value assumes all byte-writes to FlexRAM.

6.4.1.5 Write endurance to FlexRAM for EEPROM

When the FlexNVM partition code is not set to full data flash, the EEPROM data set size can be set to any of several non-zero values.

The bytes not assigned to data flash via the FlexNVM partition code are used by the FTFL to obtain an effective endurance increase for the EEPROM data. The built-in EEPROM record management system raises the number of program/erase cycles that can be attained prior to device wear-out by cycling the EEPROM data through a larger EEPROM NVM storage space.

While different partitions of the FlexNVM are available, the intention is that a single choice for the FlexNVM partition code and EEPROM data set size is used throughout the entire lifetime of a given application. The EEPROM endurance equation and graph shown below assume that only one configuration is ever used.

$$\text{Writes}_{\text{subsystem}} = \frac{\text{EEPROM} - 2 \times \text{EEESPLIT} \times \text{EEESIZE}}{\text{EEESPLIT} \times \text{EEESIZE}} \times \text{Write}_{\text{efficiency}} \times n_{nvmcyd}$$

where

- Writes_subsystem — minimum number of writes to each FlexRAM location for subsystem (each subsystem can have different endurance)
- EEPROM — allocated FlexNVM for each EEPROM subsystem based on DEPART; entered with Program Partition command
- EEESPLIT — FlexRAM split factor for subsystem; entered with the Program Partition command
- EEESIZE — allocated FlexRAM based on DEPART; entered with Program Partition command
- Write_efficiency —
 - 0.25 for 8-bit writes to FlexRAM
 - 0.50 for 16-bit or 32-bit writes to FlexRAM
- n_{nvmcycd} — data flash cycling endurance

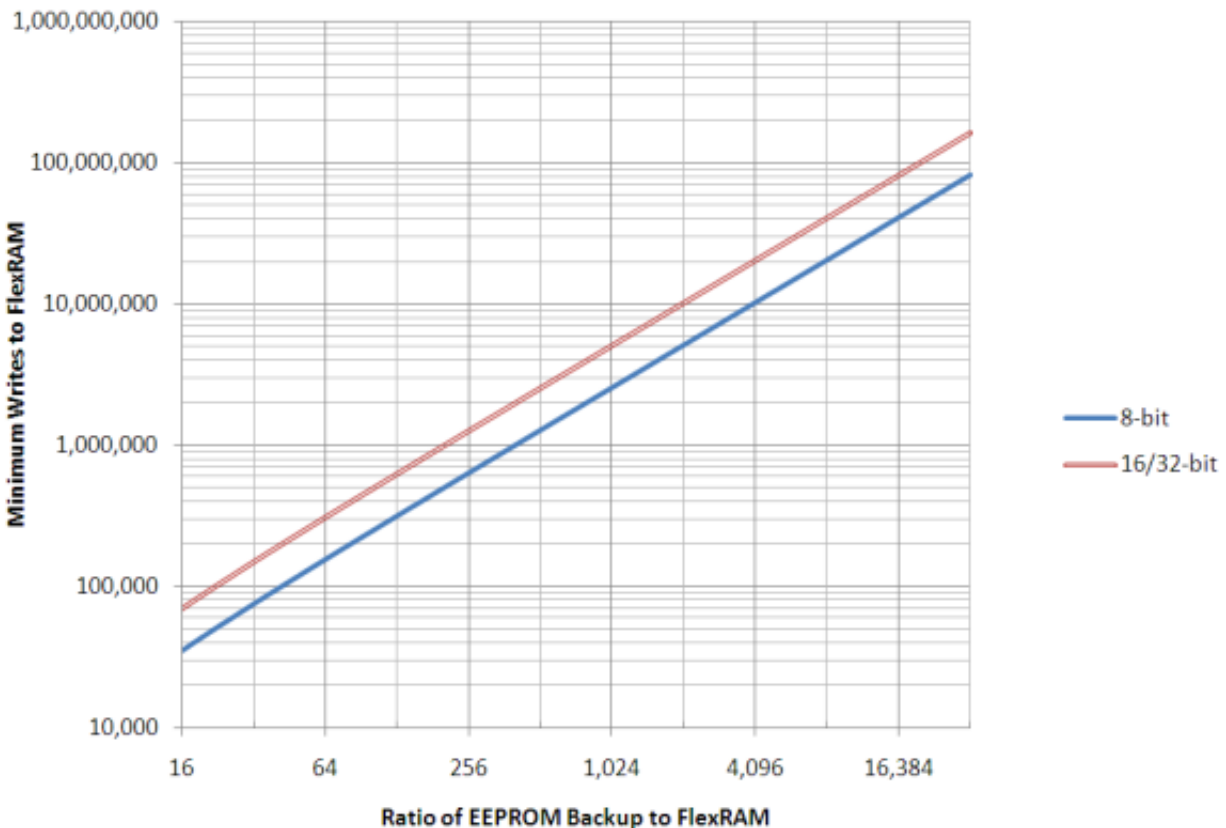


Figure 9. EEPROM backup writes to FlexRAM

6.4.2 EzPort Switching Specifications

Table 22. EzPort switching specifications

| Num | Description | Min. | Max. | Unit |
|------|--|------------------------|-------------|------|
| | Operating voltage | 2.7 | 3.6 | V |
| EP1 | EZP_CK frequency of operation (all commands except READ) | — | $f_{SYS}/2$ | MHz |
| EP1a | EZP_CK frequency of operation (READ command) | — | $f_{SYS}/8$ | MHz |
| EP2 | $\overline{EZP_CS}$ negation to next $\overline{EZP_CS}$ assertion | $2 \times t_{EZP_CK}$ | — | ns |
| EP3 | $\overline{EZP_CS}$ input valid to EZP_CK high (setup) | 5 | — | ns |
| EP4 | EZP_CK high to $\overline{EZP_CS}$ input invalid (hold) | 5 | — | ns |
| EP5 | EZP_D input valid to EZP_CK high (setup) | 2 | — | ns |
| EP6 | EZP_CK high to EZP_D input invalid (hold) | 5 | — | ns |
| EP7 | EZP_CK low to EZP_Q output valid (setup) | — | 12 | ns |
| EP8 | EZP_CK low to EZP_Q output invalid (hold) | 0 | — | ns |
| EP9 | $\overline{EZP_CS}$ negation to EZP_Q tri-state | — | 12 | ns |

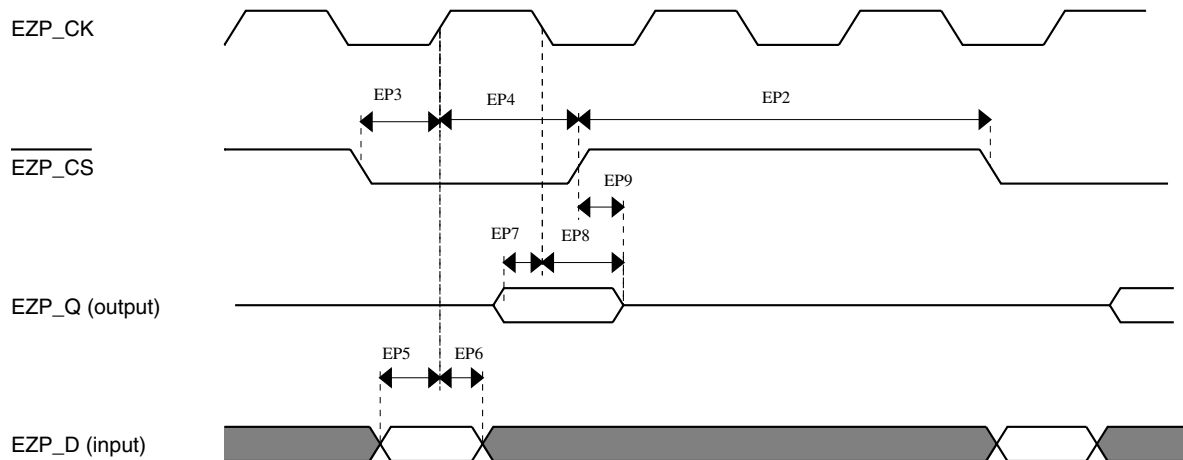


Figure 10. EzPort Timing Diagram

6.5 Security and integrity modules

There are no specifications necessary for the device's security and integrity modules.

6.6 Analog

6.6.1 ADC electrical specifications

The 16-bit accuracy specifications listed in [Table 23](#) and [Table 24](#) are achievable on the differential pins ADCx_DP0, ADCx_DM0, ADCx_DP1, ADCx_DM1, ADCx_DP3, and ADCx_DP3.

The ADCx_DP2 and ADCx_DM2 ADC inputs are used as the PGA inputs and are not direct device pins. Accuracy specifications for these pins are defined in [Table 25](#) and [Table 26](#).

All other ADC channels meet the 13-bit differential/12-bit single-ended accuracy specifications.

6.6.1.1 16-bit ADC operating conditions

Table 23. 16-bit ADC operating conditions

| Symbol | Description | Conditions | Min. | Typ. ¹ | Max. | Unit | Notes |
|-------------------|--------------------------------|---|-------------------|-------------------|-------------------|------|-------------------|
| V _{DDA} | Supply voltage | Absolute | 1.71 | — | 3.6 | V | |
| ΔV _{DDA} | Supply voltage | Delta to V _{DD} (V _{DD} -V _{DDA}) | -100 | 0 | +100 | mV | 2 |
| ΔV _{SSA} | Ground voltage | Delta to V _{SS} (V _{SS} -V _{SSA}) | -100 | 0 | +100 | mV | 2 |
| V _{REFH} | ADC reference voltage high | | 1.13 | V _{DDA} | V _{DDA} | V | |
| V _{REFL} | Reference voltage low | | V _{SSA} | V _{SSA} | V _{SSA} | V | |
| V _{ADIN} | Input voltage | | V _{REFL} | — | V _{REFH} | V | |
| C _{ADIN} | Input capacitance | <ul style="list-style-type: none"> 16 bit modes 8/10/12 bit modes | — | 8 | 10 | pF | |
| R _{ADIN} | Input resistance | | — | 2 | 5 | kΩ | |
| R _{AS} | Analog source resistance | 13/12 bit modes f _{ADCK} < 4MHz | — | — | 5 | kΩ | 3 |
| f _{ADCK} | ADC conversion clock frequency | ≤13 bit modes | 1.0 | — | 18.0 | MHz | 4 |
| f _{ADCK} | ADC conversion clock frequency | 16 bit modes | 2.0 | — | 12.0 | MHz | 5 |

Table continues on the next page...

Table 23. 16-bit ADC operating conditions (continued)

| Symbol | Description | Conditions | Min. | Typ. ¹ | Max. | Unit | Notes |
|------------|---------------------|---|--------|-------------------|---------|------|-------|
| C_{rate} | ADC conversion rate | ≤ 13 bit modes No ADC hardware averaging Continuous conversions enabled Peripheral clock = 50MHz | 18.484 | — | 818.330 | Ksps | 6 |
| C_{rate} | ADC conversion rate | 16 bit modes No ADC hardware averaging Continuous conversions enabled Peripheral clock = 50MHz | 37.037 | — | 361.402 | Ksps | 7 |

1. Typical values assume $V_{DDA} = 3.0$ V, Temp = 25°C, $f_{ADCK} = 1.0$ MHz unless otherwise stated. Typical values are for reference only and are not tested in production.
2. DC potential difference.
3. This resistance is external to MCU. The analog source resistance should be kept as low as possible in order to achieve the best results. The results in this datasheet were derived from a system which has $<8 \Omega$ analog source resistance. The R_{AS}/C_{AS} time constant should be kept to <1 ns.
4. In order to use the maximum ADC conversion clock frequency ADHSC bit should be set and the ADLPC should be clear.
5. In order to use the maximum ADC conversion clock frequency ADHSC bit should be set and the ADLPC should be clear.
6. For guidelines and examples of conversion rate calculation please download the ADC calculator tool http://cache.freescale.com/files/soft_dev_tools/software/app_software/converters/ADC_CALCULATOR_CNV.zip?fpsp=1
7. For guidelines and examples of conversion rate calculation please download the ADC calculator tool http://cache.freescale.com/files/soft_dev_tools/software/app_software/converters/ADC_CALCULATOR_CNV.zip?fpsp=1

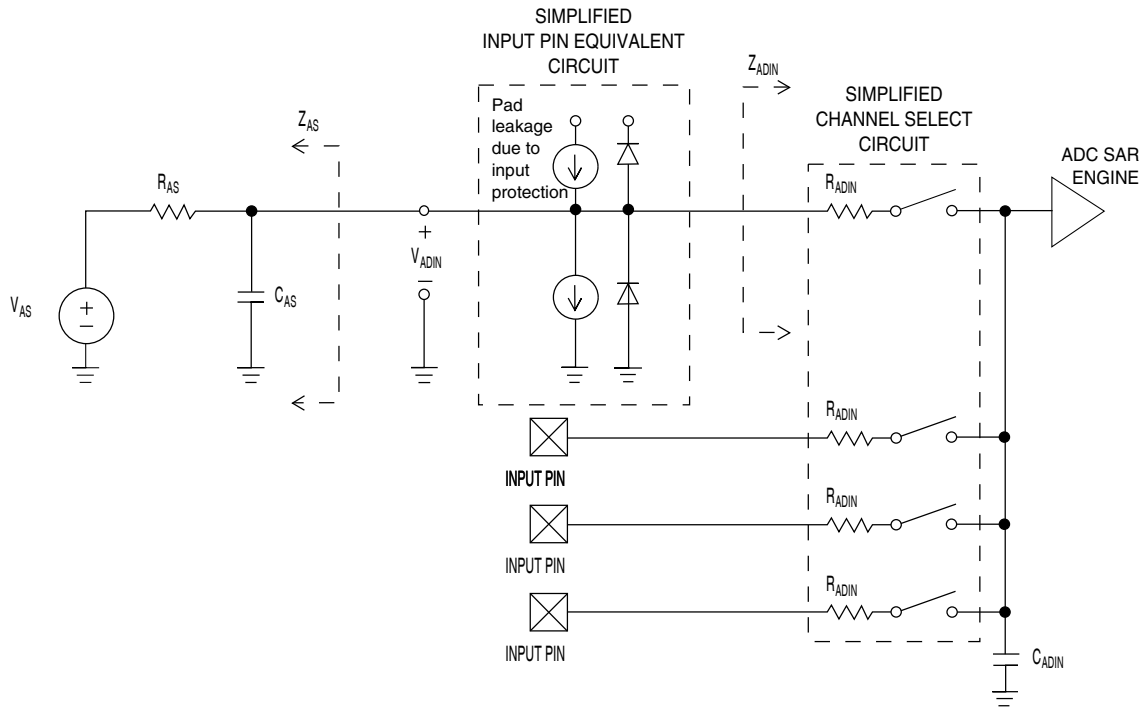


Figure 11. ADC input impedance equivalency diagram

6.6.1.2 16-bit ADC electrical characteristics

Table 24. 16-bit ADC characteristics ($V_{REFH} = V_{DDA}$, $V_{REFL} = V_{SSA}$)

| Symbol | Description | Conditions ¹ | Min. | Typ. ² | Max. | Unit | Notes |
|-------------|-------------------------------|---|-------|-------------------|------|------------------|---|
| I_{DDA} | Supply current | | 0.215 | — | 1.7 | mA | 3 |
| f_{ADACK} | ADC asynchronous clock source | <ul style="list-style-type: none"> ADLPC=1, ADHSC=0 ADLPC=1, ADHSC=1 ADLPC=0, ADHSC=0 ADLPC=0, ADHSC=1 | — | 2.4 | — | MHz | $t_{ADACK} = 1/f_{ADACK}$ |
| | | | — | 4.0 | — | MHz | |
| | | | — | 5.2 | — | MHz | |
| | | | — | 6.2 | — | MHz | |
| | Sample Time | See Reference Manual chapter for sample times | | | | | |
| | Conversion Time | The ADC calculator tool can be used to determine ADC conversion times for different ADC configurations: http://cache.freescale.com/files/soft_dev_tools/software/app_software/converters/ADC_CALCULATOR_CNV.zip?fp=1 | | | | | |
| TUE | Total unadjusted error | <ul style="list-style-type: none"> ≤13 bit modes <12 bit modes | | ±0.8 | ±TBD | LSB ⁴ | ADC conversion clock <12MHz, Max hardware averaging (AVGE = %1, AVGS = %11) |
| | | | | ±0.5 | ±1 | | |

Table continues on the next page...

Table 24. 16-bit ADC characteristics ($V_{REFH} = V_{DDA}$, $V_{REFL} = V_{SSA}$) (continued)

| Symbol | Description | Conditions ¹ | Min. | Typ. ² | Max. | Unit | Notes |
|----------|---------------------------------|---|----------------------------------|----------------------------|--------------------------------------|------------------------------|--|
| DNL | Differential non-linearity | <ul style="list-style-type: none"> • ≤ 13 bit modes • < 12 bit modes | | ± 0.7 ± 0.2 | $\pm \text{TBD}$ ± 0.5 | LSB ⁴ | ADC conversion clock $< 12\text{MHz}$, Max hardware averaging (AVGE = %1, AVGS = %11) |
| INL | Integral non-linearity | <ul style="list-style-type: none"> • ≤ 13 bit modes • < 12 bit modes | — | ± 1.0 ± 0.5 | $\pm \text{TBD}$ $\pm \text{TBD}$ | LSB ⁴ | Max averaging |
| E_{FS} | Full-scale error | <ul style="list-style-type: none"> • ≤ 13 bit modes • < 12 bit modes | — | ± 0.4 ± 1.0 | $\pm \text{TBD}$ $\pm \text{TBD}$ | LSB ⁴ | $V_{ADIN} = V_{DDA}$ |
| E_Q | Quantization error | <ul style="list-style-type: none"> • 16 bit modes • ≤ 13 bit modes | — | -1 to 0 — | — ± 0.5 | LSB ⁴ | |
| ENOB | Effective number of bits | 16 bit differential mode <ul style="list-style-type: none"> • Avg=32 • Avg=1 16 bit single-ended mode <ul style="list-style-type: none"> • Avg=32 • Avg=1 | TBD TBD TBD TBD | 13.6 13.2 TBD TBD | TBD TBD TBD TBD | bits bits bits bits | 5 |
| SINAD | Signal-to-noise plus distortion | See ENOB | $6.02 \times \text{ENOB} + 1.76$ | | | dB | |
| THD | Total harmonic distortion | 16 bit differential mode <ul style="list-style-type: none"> • Avg=32 16 bit single-ended mode <ul style="list-style-type: none"> • Avg=32 | — | -94 TBD | TBD TBD | dB dB | 5 |
| SFDR | Spurious free dynamic range | 16 bit differential mode <ul style="list-style-type: none"> • Avg=32 16 bit single-ended mode <ul style="list-style-type: none"> • Avg=32 | TBD TBD | 95 TBD | — — | dB dB | 5 |

Table continues on the next page...

Table 24. 16-bit ADC characteristics ($V_{REFH} = V_{DDA}$, $V_{REFL} = V_{SSA}$) (continued)

| Symbol | Description | Conditions ¹ | Min. | Typ. ² | Max. | Unit | Notes |
|--------------|---------------------|--|------------------------|-------------------|------|------------------------|--|
| E_{IL} | Input leakage error | | $I_{in} \times R_{AS}$ | | | mV | I_{in} = leakage current (refer to the MCU's voltage and current operating ratings) |
| | Temp sensor slope | <ul style="list-style-type: none"> • -40°C to 25°C • 25°C to 105°C | — | TBD | — | mV/ $^{\circ}\text{C}$ | |
| V_{TEMP25} | Temp sensor voltage | 25°C | — | TBD | — | mV | |

1. All accuracy numbers assume the ADC is calibrated with $V_{REFH} = V_{DDA}$
2. Typical values assume $V_{DDA} = 3.0\text{ V}$, Temp = 25°C , $f_{ADCK} = 2.0\text{ MHz}$ unless otherwise stated. Typical values are for reference only and are not tested in production.
3. The ADC supply current depends on the ADC conversion clock speed, conversion rate and the ADLPC bit (low power). For lowest power operation the ADLPC bit should be set, the HSC bit should be clear with 1MHz ADC conversion clock speed.
4. $1\text{ LSB} = (V_{REFH} - V_{REFL})/2^N$
5. Input data is 1 kHz sine wave.

FIGURE TBD

Figure 12. Typical TUE vs. ADC conversion rate 12-bit single-ended mode

FIGURE TBD

Figure 13. Typical ENOB vs. Averaging for 16-bit differential and 16-bit single-ended modes

6.6.1.3 16-bit ADC with PGA operating conditions

Table 25. 16-bit ADC with PGA operating conditions

| Symbol | Description | Conditions | Min. | Typ. ¹ | Max. | Unit | Notes |
|--------------|-------------------------|------------|--------------|-------------------|--------------|------|-------|
| V_{DDA} | Supply voltage | Absolute | 1.71 | — | 3.6 | V | |
| V_{REFPGA} | PGA ref voltage | | V_{REFOUT} | V_{REFOUT} | V_{REFOUT} | V | 2, 3 |
| V_{ADIN} | Input voltage | | V_{SSA} | — | V_{DDA} | V | |
| V_{CM} | Input Common Mode range | | V_{SSA} | — | V_{DDA} | V | |

Table continues on the next page...

Table 25. 16-bit ADC with PGA operating conditions (continued)

| Symbol | Description | Conditions | Min. | Typ. ¹ | Max. | Unit | Notes |
|-------------------|------------------------------|---|------|-------------------|------|------|-------------------------|
| R _{PGAD} | Differential input impedance | Gain = 1, 2, 4, 8 Gain = 16, 32 Gain = 64 | — | 128 64 32 | — | kΩ | IN+ to IN- ⁴ |
| R _{AS} | Analog source resistance | | — | 100 | — | Ω | 5 |
| T _S | ADC sampling time | | 1.25 | — | — | μs | 6 |

1. Typical values assume V_{DDA} = 3.0 V, Temp = 25°C, f_{ADCK} = 6 MHz unless otherwise stated. Typical values are for reference only and are not tested in production.
2. ADC must be configured to use the internal voltage reference (VREFOUT)
3. PGA reference connected to the VREFOUT pin. If the user wishes to drive VREFOUT with a voltage other than the output of the VREF module, the VREF module must be disabled.
4. For single ended configurations the input impedance of the driven input is 1/2.
5. The analog source resistance (R_{AS}), external to MCU, should be kept as minimum as possible. Increased R_{AS} causes drop in PGA gain without affecting other performances. This is not dependent on ADC clock frequency.
6. The minimum sampling time is dependent on input signal frequency and ADC mode of operation. A minimum of 1.25μs time should be allowed for F_{in}=4 kHz at 16-bit differential mode. Recommended ADC setting is: ADLSMP=1, ADLSTS=2 at 8 MHz ADC clock.

6.6.1.4 16-bit ADC with PGA characteristics

Table 26. 16-bit ADC with PGA characteristics

| Symbol | Description | Conditions | Min. | Typ. ¹ | Max. | Unit | Notes |
|----------------------|-------------------------------|--|---|-------------------|------|------|---|
| I _{DDA_PGA} | Supply current | | — | 590 | TBD | μA | |
| I _{DC_PGA} | Input DC current | | $\frac{2}{R_{PGAD}} \left(\frac{(V_{REFPGA} \times 0.583) - V_{CM}}{(Gain+1)} \right)$ | | | A | 2 |
| I _{ILKG} | Input Leakage current | PGA disabled | — | TBD | TBD | μA | 3 |
| G | Gain ⁴ | <ul style="list-style-type: none"> • PGAG=0 • PGAG=1 • PGAG=2 • PGAG=3 • PGAG=4 • PGAG=5 • PGAG=6 | TBD | 0.98 | TBD | | R _{AS} < 100Ω |
| BW | Input signal bandwidth | <ul style="list-style-type: none"> • 16-bit modes • < 16-bit modes | — | — | 4 | kHz | |
| PSRR | Power supply rejection ration | Gain=1 | TBD | TBD | — | dB | V _{DDA} = 3V ±100mV, f _{VDDA} = 50Hz, 60Hz |

Table continues on the next page...

Table 26. 16-bit ADC with PGA characteristics (continued)

| Symbol | Description | Conditions | Min. | Typ. ¹ | Max. | Unit | Notes |
|-----------------------|---|---|--|-------------------|------|--------|---|
| CMRR | Common mode rejection ratio | <ul style="list-style-type: none"> Gain=1 Gain=64 | TBD | TBD | — | dB | V _{CM} =500mV _{pp} , f _{VCM} =50Hz, 100Hz |
| | | | TBD | TBD | — | dB | |
| V _{OFS} | Input offset voltage | | — | 0.2 | TBD | mV | Gain=1, ADC Averaging=32 |
| T _{GSW} | Gain switching settling time | | — | — | 10 | μs | 5 |
| dG/dT | Gain drift over temperature | <ul style="list-style-type: none"> Gain=1 Gain=64 | — | TBD | TBD | ppm/°C | 0 to 50°C |
| | | | — | TBD | TBD | ppm/°C | |
| dV _{OFS} /dT | Offset drift over temperature | Gain=1 | — | TBD | TBD | ppm/°C | 0 to 50°C, ADC Averaging=32 |
| dG/dV _{DDA} | Gain drift over supply voltage | <ul style="list-style-type: none"> Gain=1 Gain=64 | — | TBD | TBD | %/V | V _{DDA} from 1.71 to 3.6V |
| | | | — | TBD | TBD | %/V | |
| E _{IL} | Input leakage error | All modes | I _{in} × R _{AS} | | | mV | I _{in} = leakage current (refer to the MCU's voltage and current operating ratings) |
| V _{PP,DIFF} | Maximum differential input signal swing | | $\left(\frac{(\min(V_X, V_{DDA} - V_X) - 0.2) \times 4}{\text{Gain}} \right)$ | | | V | 6 |
| | | | where V _X = V _{REFPGA} × 0.583 | | | | |
| SNR | Signal-to-noise ratio | <ul style="list-style-type: none"> Gain=1 Gain=64 | TBD | 83.0 | — | dB | 16-bit differential mode, Average=32 |
| | | | TBD | 57.5 | — | dB | |
| THD | Total harmonic distortion | <ul style="list-style-type: none"> Gain=1 Gain=64 | TBD | 89.4 | — | dB | 16-bit differential mode, Average=32, f _{in} =500Hz |
| | | | TBD | 90.0 | — | dB | |
| SFDR | Spurious free dynamic range | <ul style="list-style-type: none"> Gain=1 Gain=64 | TBD | 90.9 | — | dB | 16-bit differential mode, Average=32, f _{in} =500Hz |
| | | | TBD | 77.0 | — | dB | |

Table continues on the next page...

Table 26. 16-bit ADC with PGA characteristics (continued)

| Symbol | Description | Conditions | Min. | Typ. ¹ | Max. | Unit | Notes |
|--------|---------------------------------------|-----------------------|--------------------|-------------------|------|------|---|
| ENOB | Effective number of bits | • Gain=1, Average=4 | TBD | 12.3 | — | bits | 16-bit differential mode, $f_{in}=500\text{Hz}$ |
| | | • Gain=1, Average=8 | TBD | 12.7 | — | bits | |
| | | • Gain=64, Average=4 | TBD | 8.4 | — | bits | |
| | | • Gain=64, Average=8 | TBD | 8.7 | — | bits | |
| | | • Gain=1, Average=32 | TBD | 13.3 | — | bits | |
| | | • Gain=2, Average=32 | TBD | 13.1 | — | bits | |
| | | • Gain=4, Average=32 | TBD | 12.5 | — | bits | |
| | | • Gain=8, Average=32 | TBD | 11.8 | — | bits | |
| | | • Gain=16, Average=32 | TBD | 11.1 | — | bits | |
| | | • Gain=32, Average=32 | TBD | 10.2 | — | bits | |
| | | • Gain=64, Average=32 | TBD | 9.3 | — | bits | |
| SINAD | Signal-to-noise plus distortion ratio | See ENOB | 6.02 × ENOB + 1.76 | | | dB | |

1. Typical values assume $V_{DDA}=3.0\text{V}$, $\text{Temp}=25^{\circ}\text{C}$, $f_{ADCK}=6\text{MHz}$ unless otherwise stated.
2. Between IN+ and IN-. The PGA draws a DC current from the input terminals. The magnitude of the DC current is a strong function of input common mode voltage (V_{CM}) and the PGA gain.
3. This is the input leakage current of the module in addition to the PAD leakage current.
4. $\text{Gain} = 2^{\text{PGAG}}$
5. When the PGA gain is changed, it takes some time to settle the output for the ADC to work properly. During a gain switching, a few ADC outputs should be discarded (minimum two data samples, may be more depending on ADC sampling rate and time of the switching).
6. Limit the input signal swing so that the PGA does not saturate during operation. Input signal swing is dependent on the PGA reference voltage and gain setting.

6.6.2 CMP and 6-bit DAC electrical specifications

Table 27. Comparator and 6-bit DAC electrical specifications

| Symbol | Description | Min. | Typ. | Max. | Unit |
|-------------|---|----------------|------|----------|---------------|
| V_{DD} | Supply voltage | 1.71 | — | 3.6 | V |
| I_{DDHS} | Supply current, High-speed mode (EN=1, PMODE=1) | — | — | 200 | μA |
| $I_{DDL S}$ | Supply current, low-speed mode (EN=1, PMODE=0) | — | — | 20 | μA |
| V_{AIN} | Analog input voltage | $V_{SS} - 0.3$ | — | V_{DD} | V |
| V_{AIO} | Analog input offset voltage | — | — | 20 | mV |

Table continues on the next page...

Table 27. Comparator and 6-bit DAC electrical specifications (continued)

| Symbol | Description | Min. | Typ. | Max. | Unit |
|-------------|---|----------------|------|------|------------------|
| V_H | Analog comparator hysteresis ¹ | | | | |
| | • CR0[HYSTCTR] = 00 | — | 5 | — | mV |
| | • CR0[HYSTCTR] = 01 | — | 10 | — | mV |
| | • CR0[HYSTCTR] = 10 | — | 20 | — | mV |
| | • CR0[HYSTCTR] = 11 | — | 30 | — | mV |
| V_{CMPOH} | Output high | $V_{DD} - 0.5$ | — | — | V |
| V_{CMPOI} | Output low | — | — | 0.5 | V |
| t_{DHS} | Propagation delay, high-speed mode (EN=1, PMODE=1) | 20 | 50 | 200 | ns |
| t_{DLS} | Propagation delay, low-speed mode (EN=1, PMODE=0) | 120 | 250 | 600 | ns |
| | Analog comparator initialization delay ² | — | — | TBD | ns |
| I_{DAC6b} | 6-bit DAC current adder (enabled) | — | 7 | — | μ A |
| INL | 6-bit DAC integral non-linearity | -0.5 | — | 0.5 | LSB ³ |
| DNL | 6-bit DAC differential non-linearity | -0.3 | — | 0.3 | LSB |

1. Typical hysteresis is measured with input voltage range limited to 0.6 to $V_{DD}-0.6V$.
2. Comparator initialization delay is defined as the time between software writes to change control inputs (Writes to DACEN, VRSEL, PSEL, MSEL, VOSEL) and the comparator output settling to a stable level.
3. 1 LSB = $V_{reference}/64$

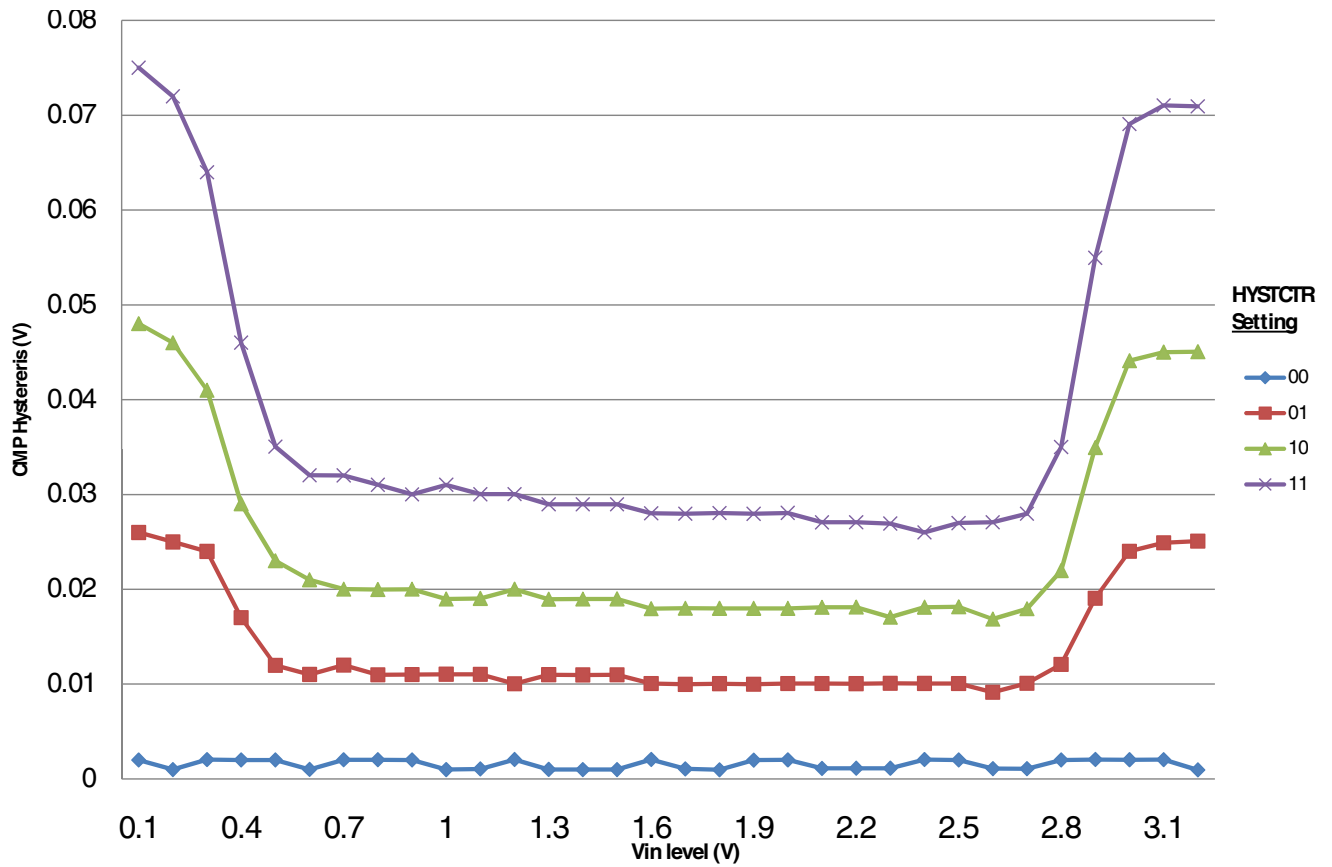


Figure 14. Typical hysteresis vs. Vin level (VDD=3.3V, PMODE=0)

Peripheral operating requirements and behaviors

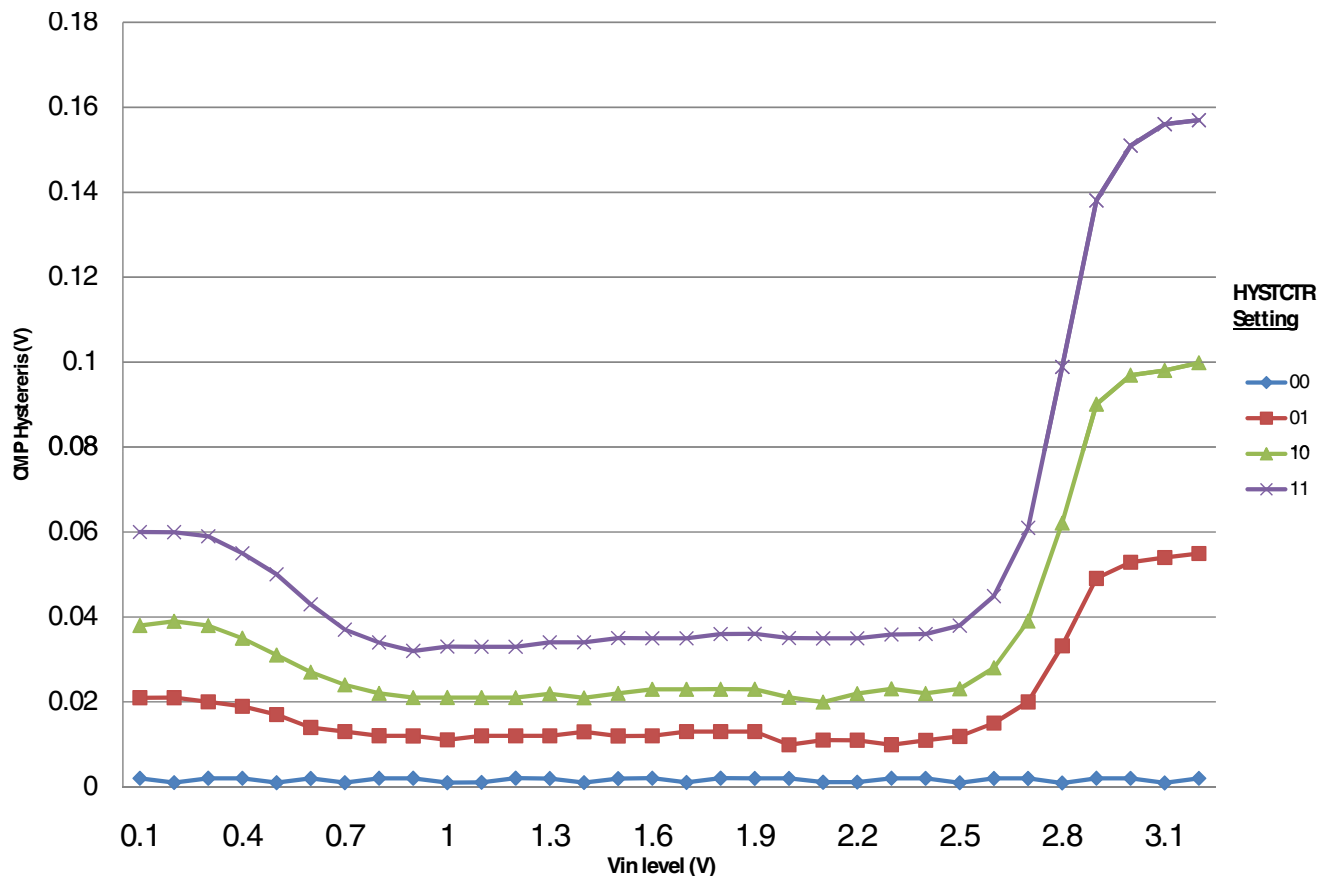


Figure 15. Typical hysteresis vs. Vin level (VDD=3.3V, PMODE=1)

6.6.3 12-bit DAC electrical characteristics

6.6.3.1 12-bit DAC operating requirements

Table 28. 12-bit DAC operating requirements

| Symbol | Description | Min. | Max. | Unit | Notes |
|------------|-------------------------|------|------|------|-------|
| V_{DDA} | Supply voltage | 1.71 | 3.6 | V | |
| V_{DACR} | Reference voltage | 1.13 | 3.6 | V | 1 |
| T_A | Temperature | -40 | 105 | °C | |
| C_L | Output load capacitance | — | 100 | pF | 2 |
| I_L | Output load current | — | 1 | mA | |

1. The DAC reference can be selected to be VDDA or the voltage output of the VREF module (VREFO)
2. A small load capacitance (47 pF) can improve the bandwidth performance of the DAC

6.6.3.2 12-bit DAC operating behaviors

Table 29. 12-bit DAC operating behaviors

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|------------------|---|------------------|-------------|------------|-------------------------|-------|
| I_{DDA_DACLP} | Supply current — low-power mode | — | — | 150 | μA | |
| I_{DDA_DACHP} | Supply current — high-speed mode | — | — | 700 | μA | |
| t_{DACLP} | Full-scale settling time (0x080 to 0xF7F) — low-power mode | — | 100 | 200 | μs | 1 |
| t_{DACHP} | Full-scale settling time (0x080 to 0xF7F) — high-power mode | — | 15 | 30 | μs | 1 |
| $t_{CCDACLP}$ | Code-to-code settling time (0xBF8 to 0xC08) — low-power mode | — | — | 5 | μs | 1 |
| $t_{CCDACHP}$ | Code-to-code settling time (0xBF8 to 0xC08) — high-speed mode | 1 | TBD | — | μs | 1 |
| $V_{dacoutl}$ | DAC output voltage range low — high-speed mode, no load, DAC set to 0x000 | — | 100 | TBD | mV | |
| $V_{dacouth}$ | DAC output voltage range high — high-speed mode, no load, DAC set to 0xFFFF | $V_{DACR} - 100$ | — | V_{DACR} | mV | |
| INL | Integral non-linearity error — high speed mode | — | — | ± 8 | LSB | 2 |
| DNL | Differential non-linearity error — $V_{DACR} > 2\text{ V}$ | — | — | ± 1 | LSB | 3 |
| DNL | Differential non-linearity error — $V_{DACR} = V_{REFO}$ (1.15 V) | — | — | ± 1 | LSB | 4 |
| V_{OFFSET} | Offset error | ± 0.4 | — | ± 0.8 | %FSR | 5 |
| E_G | Gain error | ± 0.1 | — | ± 0.6 | %FSR | 5 |
| PSRR | Power supply rejection ratio, $V_{DDA} \geq 2.4\text{ V}$ | 60 | — | 90 | dB | |
| T_{CO} | Temperature coefficient offset voltage | — | TBD | — | $\mu\text{V}/\text{C}$ | |
| T_{GE} | Temperature coefficient gain error | — | TBD | — | ppm of FSR/C | |
| A_C | Offset aging coefficient | — | — | TBD | $\mu\text{V}/\text{yr}$ | |
| R_{op} | Output resistance load = 3 k Ω | — | — | 250 | Ω | |
| SR | Slew rate -80h → F7Fh → 80h <ul style="list-style-type: none"> High power (SP_{HP}) Low power (SP_{LP}) | 1.2 0.05 | 1.7 0.12 | — — | V/ μs | |
| CT | Channel to channel cross talk | — | — | -80 | dB | |
| BW | 3dB bandwidth <ul style="list-style-type: none"> High power (SP_{HP}) Low power (SP_{LP}) | 550 40 | — — | — — | kHz | |

1. Settling within ± 1 LSB
2. The INL is measured for 0+100mV to $V_{DACR} - 100\text{ mV}$
3. The DNL is measured for 0+100 mV to $V_{DACR} - 100\text{ mV}$
4. The DNL is measured for 0+100mV to $V_{DACR} - 100\text{ mV}$ with $V_{DDA} > 2.4\text{V}$

Peripheral operating requirements and behaviors

5. Calculated by a best fit curve from $V_{SS}+100$ mV to $V_{REF}-100$ mV

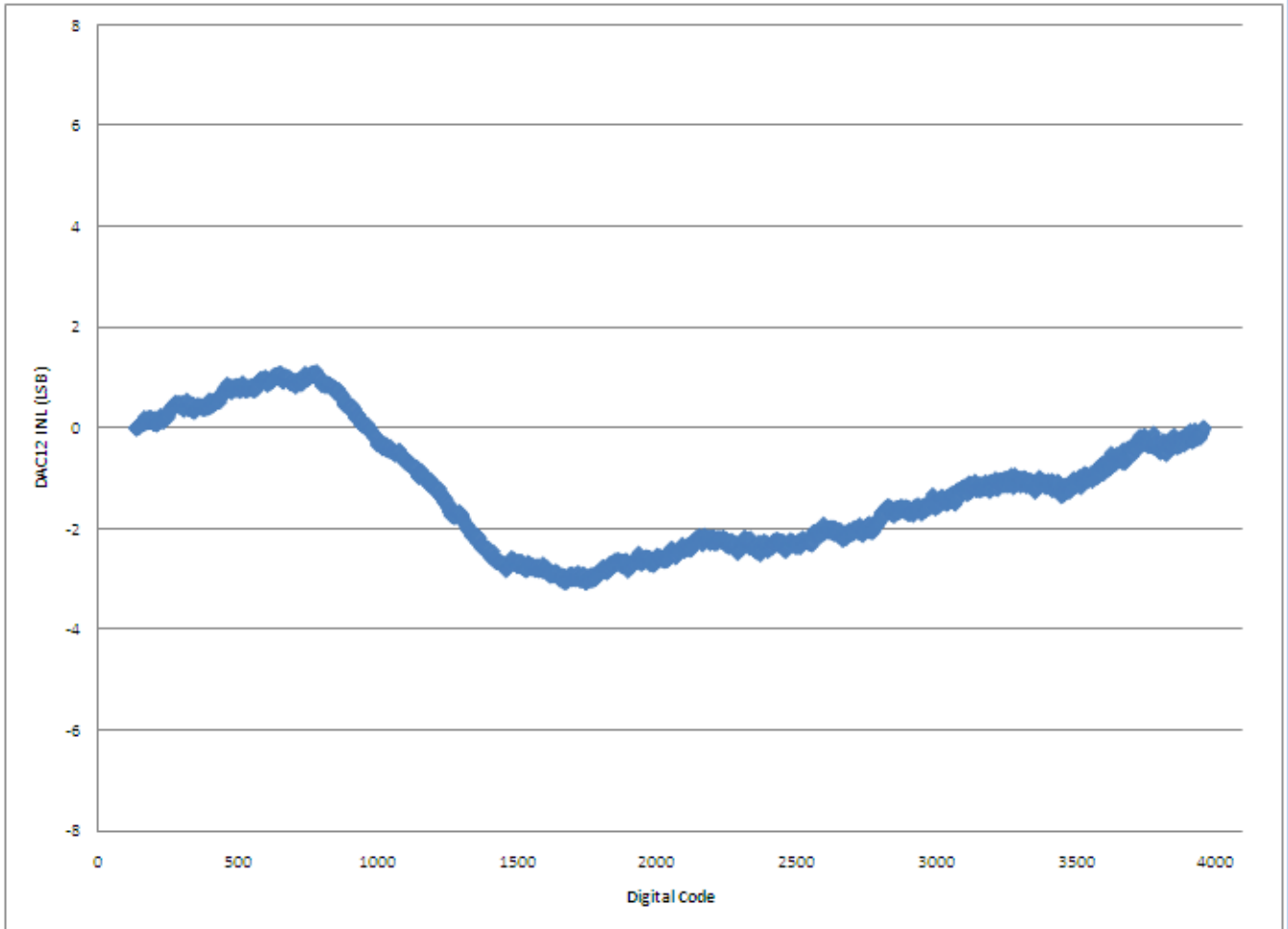


Figure 16. Typical INL error vs. digital code



Figure 17. Offset at half scale vs. temperature

6.6.4 Op-amp electrical specifications

Table 30. Op-amp electrical specifications

| Symbol | Description | Min. | Typ. | Max. | Unit |
|----------------|--|------|-----------|------|-----------|
| V_{DD} | Operating voltage | 1.71 | — | 3.6 | V |
| I_{SUPPLY} | Supply current ($I_{OUT}=0mA$, $CL=0$), low-power mode | — | 70 | TBD | μA |
| I_{SUPPLY} | Supply current ($I_{OUT}=0mA$, $CL=0$), high-speed mode | — | 500 | TBD | μA |
| V_{OS} | Input offset voltage | — | ± 3 | TBD | mV |
| α_{VOS} | Input offset voltage temperature coefficient | — | 10 | — | $\mu V/C$ |
| I_{OS} | Input offset current (0~50°C) | — | ± 300 | — | pA |
| I_{OS} | Input offset current (-40~105°C) | — | TBD | — | pA |
| I_{BIAS} | Input bias current (0~50°C) | — | ± 300 | — | pA |

Table continues on the next page...

Table 30. Op-amp electrical specifications (continued)

| Symbol | Description | Min. | Typ. | Max. | Unit |
|---------------------|--|------|------|------|--------|
| I _{BIAS} | Input bias current (0~105°C) | — | TBD | — | pA |
| V _{CML} | Input common mode voltage low | 0 | — | — | V |
| V _{CMH} | Input common mode voltage high | — | — | VDD | V |
| R _{IN} | Input resistance | 500 | — | — | MΩ |
| C _{IN} | Input capacitance | — | — | TBD | pF |
| X _{IN} | AC input impedance (f _{IN} =100kHz) | — | 50 | — | MΩ |
| CMRR | Input common mode rejection ratio | 60 | — | — | dB |
| PSRR | Power supply rejection ratio | 60 | — | — | dB |
| SR | Slew rate (ΔV _{IN} =100mV), low-power mode | 0.1 | — | — | V/μs |
| SR | Slew rate (ΔV _{IN} =100mV), high-speed mode | 1 | — | — | V/μs |
| GBW | Unity gain bandwidth, low-power mode | 0.15 | — | — | MHz |
| GBW | Unity gain bandwidth, high-speed mode | 1 | — | — | MHz |
| A _V | DC open-loop voltage gain | 80 | 90 | — | dB |
| CL(max) | Load capacitance driving capability | — | — | TBD | pF |
| R _{OUT} | Output resistance | — | — | TBD | Ω |
| V _{OUT} | Output voltage range | 0.1 | — | TBD | V |
| I _{OUT} | Output load current | — | ±0.5 | — | mA |
| GM | Gain margin | — | 20 | — | dB |
| PM | Phase margin | 45 | 56 | — | deg |
| T _{settle} | Settling time (Buffer mode, low-power mode) (T _o <0.1%, V _{in} =2Vp-p, CL=25pF, RL=100k) | — | TBD | — | μs |
| T _{settle} | Settling time (Buffer mode, high-speed mode) (T _o <0.1%, V _{in} =2Vp-p, CL=25pF, RL=100k) | — | TBD | — | μs |
| V _n | Voltage noise density (noise floor) 1kHz | — | 350 | TBD | nV/√Hz |
| V _n | Voltage noise density (noise floor) 10kHz | — | 90 | TBD | nV/√Hz |

6.6.5 Transimpedance amplifier electrical specifications — full range

Table 31. TRIAMP full range operating requirements

| Symbol | Description | Min. | Max. | Unit | Notes |
|------------------|-------------------------|------|-----------------------|------|-------|
| V _{DDA} | Supply voltage | 1.71 | 3.6 | V | |
| V _{IN} | Input voltage range | -0.2 | V _{DDA} -1.4 | V | |
| C _L | Output load capacitance | | 100 | pf | |
| R _{OUT} | Output resistance | | 1500 | Ω | |

Table 32. TRIAMP full range operating behaviors

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|---------------------|--|------|------|-----------------------|--------|-------|
| I _{SUPPLY} | Supply current (I _{OUT} =0mA, CL=0) — Low-power mode | — | 60 | — | μA | |
| I _{SUPPLY} | Supply current (I _{OUT} =0mA, CL=0) — High-speed mode | — | 280 | — | μA | |
| V _{OS} | Input offset voltage | — | ±3 | TBD | mV | |
| α _{VOS} | Input offset voltage temperature coefficient | — | 10 | TBD | μV/C | |
| I _{OS} | Input offset current | — | ±200 | TBD | pA | |
| I _{BIAS} | Input bias current | — | ±300 | TBD | pA | |
| R _{IN} | Input resistance | 500 | — | — | MΩ | |
| C _{IN} | Input capacitance | — | 17 | — | pF | |
| X _{IN} | AC input impedance (f _{IN} =100kHz) | — | TBD | — | MΩ | |
| CMRR | Input common mode rejection ratio | 60 | — | — | dB | |
| PSRR | Power supply rejection ratio | 60 | — | — | dB | |
| SR | Slew rate (ΔV _{IN} =100mV) — Low-power mode | 0.1 | — | — | V/μs | |
| SR | Slew rate (ΔV _{IN} =100mV) — High speed mode | 1 | — | — | V/μs | |
| GBW | Unity gain bandwidth — Low-power mode 50pF | 0.15 | — | — | MHz | |
| GBW | Unity gain bandwidth — High speed mode 50pF | 1 | — | — | MHz | |
| A _V | DC open-loop voltage gain | 80 | — | — | dB | |
| V _{OUT} | Output voltage range | 0.15 | — | V _{DD} -0.15 | V | |
| I _{OUT} | Output load current | — | ±0.5 | — | mA | |
| GM | Gain margin | — | 20 | — | dB | |
| PM | Phase margin | 50 | 60 | — | deg | |
| V _n | Voltage noise density (noise floor) 1kHz | — | 280 | — | nV/√Hz | |
| V _n | Voltage noise density (noise floor) 10kHz | — | 100 | — | nV/√Hz | |

Figure 18. Typical Open Loop Gain vs. Frequency [TBD]**Figure 19. Typical Phase vs. Frequency [TBD]**

6.6.6 Transimpedance amplifier electrical specifications — limited range

Table 33. TRIAMP limited range operating requirements

| Symbol | Description | Min. | Max. | Unit | Notes |
|------------------|-------------------------|------|-----------------------|------|-------|
| V _{DDA} | Supply voltage | 2.4 | 3.3 | V | |
| V _{IN} | Input voltage range | 0.1 | V _{DDA} -1.4 | V | |
| T _A | Temperature | 0 | 50 | C | |
| C _L | Output load capacitance | | 100 | pf | |
| R _{OUT} | Output resistance | | 1500 | Ω | |

Table 34. TRIAMP limited range operating behaviors

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|-------------------|---|------|------|------|------|-------|
| V _{OS} | Input offset voltage | — | ±3 | TBD | mV | |
| α _{VOS} | Input offset voltage temperature coefficient | — | 4 | TBD | μV/C | |
| I _{OS} | Input offset current | — | ±300 | TBD | pA | |
| I _{BIAS} | Input bias current | — | ±300 | TBD | pA | |
| X _{IN} | AC input impedance (f _{IN} =100kHz) | 500 | — | — | MΩ | |
| CMRR | Input common mode rejection ratio | — | 70 | — | dB | |
| PSRR | Power supply rejection ratio | — | 70 | — | dB | |
| SR | Slew rate (ΔV _{IN} =100mV) — Low-power mode | 0.1 | — | — | V/μs | |
| SR | Slew rate (ΔV _{IN} =100mV) — High speed mode | 1 | — | — | V/μs | |
| GBW | Unity gain bandwidth — Low-power mode 50pF | 0.15 | — | — | MHz | |
| GBW | Unity gain bandwidth — High speed mode 50pF | 1 | — | — | MHz | |
| A _V | DC open-loop voltage gain | 80 | — | — | dB | |
| GM | Gain margin | 30 | — | — | dB | |
| PM | Phase margin | 60 | 69 | — | deg | |

6.6.7 Voltage reference electrical specifications

Table 35. VREF full-range operating requirements

| Symbol | Description | Min. | Max. | Unit | Notes |
|------------------|-------------------------|------|------|------|-------|
| V _{DDA} | Supply voltage | 1.71 | 3.6 | V | |
| T _A | Temperature | -40 | 105 | °C | |
| C _L | Output load capacitance | — | 100 | nF | |

Table 36. VREF full-range operating behaviors

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|-------------|---|-------|------|-------|----------|-------------------------------|
| V_{out} | Voltage reference output with factory trim at nominal V_{DDA} and temperature=25C | TBD | 1.2 | TBD | V | |
| V_{out} | Voltage reference output with factory trim | TBD | — | TBD | V | |
| V_{out} | Voltage reference output user trim | 1.198 | — | 1.202 | V | |
| V_{step} | Voltage reference trim step | — | 0.5 | — | mV | |
| V_{drift} | Temperature drift ($V_{max} - V_{min}$ across the full temperature range) | — | — | 20 | mV | See Figure 20 |
| Ac | Aging coefficient | — | — | TBD | ppm/year | |
| I_{bg} | Bandgap only (MODE_LV = 00) current | — | — | TBD | μ A | |
| I_{tr} | Tight-regulation buffer (MODE_LV = 10) current | — | — | 1.1 | mA | |
| | Load regulation (MODE_LV = 10) current = ± 1.0 mA | — | — | TBD | V | |
| T_{stup} | Buffer startup time | — | — | 100 | μ s | |
| DC | Line regulation (power supply rejection) | — | — | TBD | mV | |
| | | -60 | — | TBD | dB | |

Table 37. VREF limited-range operating requirements

| Symbol | Description | Min. | Max. | Unit | Notes |
|--------|-------------|------|------|--------------|-------|
| T_A | Temperature | 0 | 50 | $^{\circ}$ C | |

Table 38. VREF limited-range operating behaviors

| Symbol | Description | Min. | Max. | Unit | Notes |
|-----------|--|------|------|------|-------|
| V_{out} | Voltage reference output with factory trim | TBD | TBD | V | |

TBD

Figure 20. Typical output vs. temperature

TBD

Figure 21. Typical output vs. VDD

6.7 Timers

See [General switching specifications](#).

6.8 Communication interfaces

6.8.1 USB electrical specifications

The USB electricals for the USB On-the-Go module conform to the standards documented by the Universal Serial Bus Implementers Forum. For the most up-to-date standards, visit <http://www.usb.org>.

6.8.2 USB DCD electrical specifications

Table 39. USB DCD electrical specifications

| Symbol | Description | Min. | Typ. | Max. | Unit |
|----------------------|--|-------|------|------|------------|
| V _{DP_SRC} | USB_DP source voltage (up to 250 μ A) | TBD | TBD | TBD | V |
| V _{LGC} | Threshold voltage for logic high | 0.8 | — | 2.0 | V |
| I _{DP_SRC} | USB_DP source current | 7 | 10 | 13 | μ A |
| I _{DM_SINK} | USB_DM sink current | 50 | 100 | 150 | μ A |
| R _{DM_DWN} | D- pulldown resistance for data pin contact detect | 14.25 | — | 24.8 | k Ω |
| V _{DAT_REF} | Data detect voltage | 0.25 | TBD | 0.4 | V |

6.8.3 USB VREG electrical specifications

Table 40. USB VREG electrical specifications

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|-----------------------|--|------|------|------|---------|-------|
| VREGIN | Input supply voltage | 2.7 | — | 5.5 | V | |
| I _{DDon} | Quiescent current — Run mode, load current equal zero, input supply (VREGIN) > 3.6 V | — | 120 | TBD | μ A | |
| I _{DDstby} | Quiescent current — Standby mode, load current equal zero | — | 1 | TBD | μ A | |
| I _{DDoff} | Quiescent current — Shutdown mode | — | 500 | — | nA | |
| | | — | — | TBD | μ A | |
| I _{LOADrun} | Maximum load current — Run mode | — | — | 120 | mA | |
| I _{LOADstby} | Maximum load current — Standby mode | — | — | 1 | mA | |

Table continues on the next page...

**Table 40. USB VREG electrical specifications
(continued)**

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|-----------------------|---|----------|------------|------------|------------------|-------|
| V_{Reg33out} | Regulator output voltage — Input supply (VREGIN) > 3.6 V <ul style="list-style-type: none"> Run mode Standby mode | 3 2.5 | 3.3 2.8 | 3.6 3.6 | V V | |
| V_{Reg33out} | Regulator output voltage — Input supply (VREGIN) < 3.6 V, pass-through mode | 2.3 | — | 3.6 | V | 1 |
| C_{OUT} | External output capacitor | 1.76 | 2.2 | 8.16 | μF | |
| ESR | External output capacitor equivalent series resistance | 1 | — | 100 | $\text{m}\Omega$ | |
| I_{LIM} | Current limitation threshold | 185 | 290 | 395 | mA | |

1. Operating in pass-through mode: regulator output voltage equal to the input voltage minus a drop proportional to I_{Load} .

6.8.4 DSPI switching specifications (low-speed mode)

The DMA Serial Peripheral Interface (DSPI) provides a synchronous serial bus with master and slave operations. Many of the transfer attributes are programmable. The tables below provides DSPI timing characteristics for classic SPI timing modes. Refer to the DSPI chapter of the Reference Manual for information on the modified transfer formats used for communicating with slower peripheral devices.

Table 41. Master mode DSPI timing (low-speed mode)

| Num | Description | Min. | Max. | Unit | Notes |
|-----|---------------------------------------|----------------------------|--------------------------|------|-------|
| | Operating voltage | 1.71 | 3.6 | V | 1 |
| | Frequency of operation | — | 12.5 | MHz | |
| DS1 | DSPI_SCK output cycle time | $4 \times t_{\text{BCLK}}$ | — | ns | |
| DS2 | DSPI_SCK output high/low time | $(t_{\text{SCK}/2}) - 4$ | $(t_{\text{SCK}/2}) + 4$ | ns | |
| DS3 | DSPI_PCS n to DSPI_SCK output valid | $(t_{\text{SCK}/2}) - 4$ | — | ns | |
| DS4 | DSPI_SCK to DSPI_PCS n output hold | $(t_{\text{SCK}/2}) - 4$ | — | ns | |
| DS5 | DSPI_SCK to DSPI_SOUT valid | — | 10 | ns | |
| DS6 | DSPI_SCK to DSPI_SOUT invalid | -2 | — | ns | |
| DS7 | DSPI_SIN to DSPI_SCK input setup | 15 | — | ns | |
| DS8 | DSPI_SCK to DSPI_SIN input hold | 0 | — | ns | |

1. The DSPI module can operate across the entire operating voltage for the processor, but to run across the full voltage range the maximum frequency of operation is reduced.

Peripheral operating requirements and behaviors

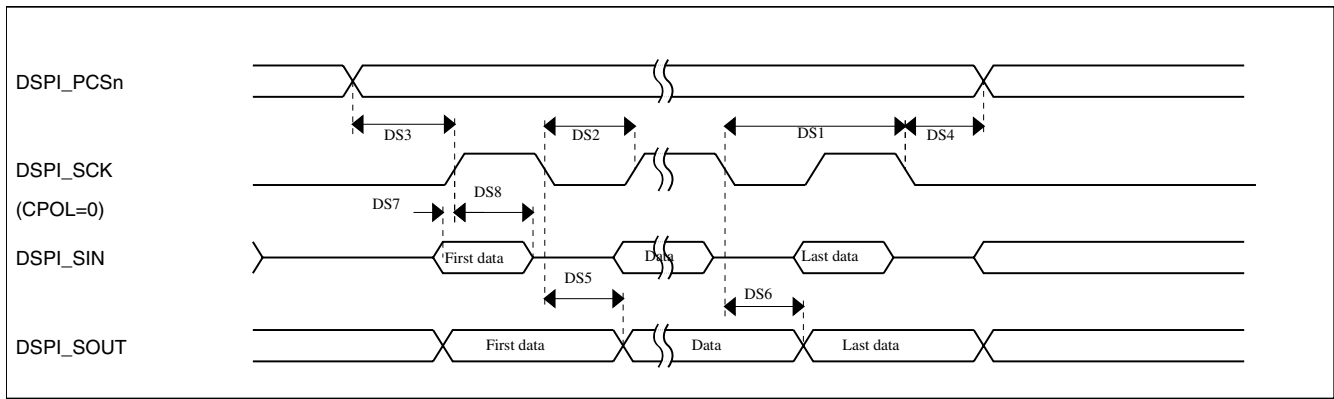


Figure 22. DSPI classic SPI timing — master mode

Table 42. Slave mode DSPI timing (low-speed mode)

| Num | Description | Min. | Max. | Unit |
|------|--|---------------------|-------------------|------|
| | Operating voltage | 1.71 | 3.6 | V |
| | Frequency of operation | — | 6.25 | MHz |
| DS9 | DSPI_SCK input cycle time | $8 \times t_{BCLK}$ | — | ns |
| DS10 | DSPI_SCK input high/low time | $(t_{SCK}/2) - 4$ | $(t_{SCK}/2) + 4$ | ns |
| DS11 | DSPI_SCK to DSPI_SOUT valid | — | 20 | ns |
| DS12 | DSPI_SCK to DSPI_SOUT invalid | 0 | — | ns |
| DS13 | DSPI_SIN to DSPI_SCK input setup | 5 | — | ns |
| DS14 | DSPI_SCK to DSPI_SIN input hold | 15 | — | ns |
| DS15 | $\overline{DSPI_SS}$ active to DSPI_SOUT driven | — | 15 | ns |
| DS16 | $\overline{DSPI_SS}$ inactive to DSPI_SOUT not driven | — | 15 | ns |

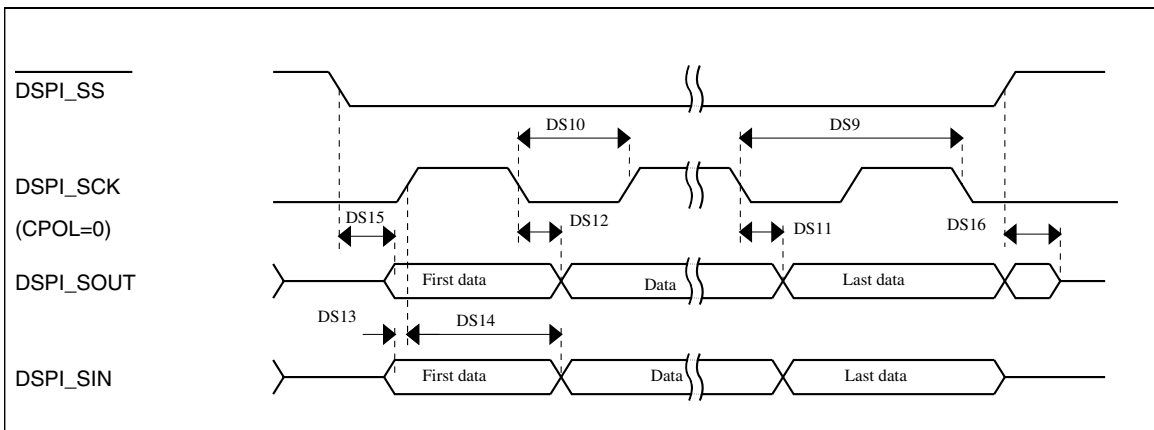


Figure 23. DSPI classic SPI timing — slave mode

6.8.5 DSPI switching specifications (high-speed mode)

The DMA Serial Peripheral Interface (DSPI) provides a synchronous serial bus with master and slave operations. Many of the transfer attributes are programmable. The tables below provide DSPI timing characteristics for classic SPI timing modes. Refer to the DSPI chapter of the Reference Manual for information on the modified transfer formats used for communicating with slower peripheral devices.

Table 43. Master mode DSPI timing (high-speed mode)

| Num | Description | Min. | Max. | Unit |
|-----|------------------------------------|---------------------|-------------------|------|
| | Operating voltage | 2.7 | 3.6 | V |
| | Frequency of operation | — | 25 | MHz |
| DS1 | DSPI_SCK output cycle time | $2 \times t_{BCLK}$ | — | ns |
| DS2 | DSPI_SCK output high/low time | $(t_{SCK}/2) - 2$ | $(t_{SCK}/2) + 2$ | ns |
| DS3 | DSPI_PCSn to DSPI_SCK output valid | $(t_{SCK}/2) - 2$ | — | ns |
| DS4 | DSPI_SCK to DSPI_PCSn output hold | $(t_{SCK}/2) - 2$ | — | ns |
| DS5 | DSPI_SCK to DSPI_SOUT valid | — | 8.5 | ns |
| DS6 | DSPI_SCK to DSPI_SOUT invalid | -2 | — | ns |
| DS7 | DSPI_SIN to DSPI_SCK input setup | TBD | — | ns |
| DS8 | DSPI_SCK to DSPI_SIN input hold | 0 | — | ns |

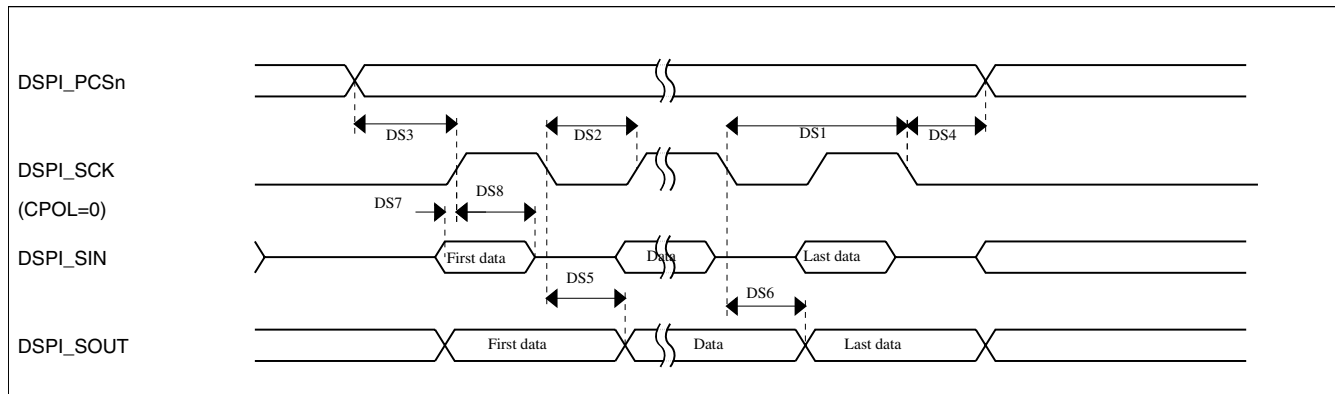


Figure 24. DSPI classic SPI timing — master mode

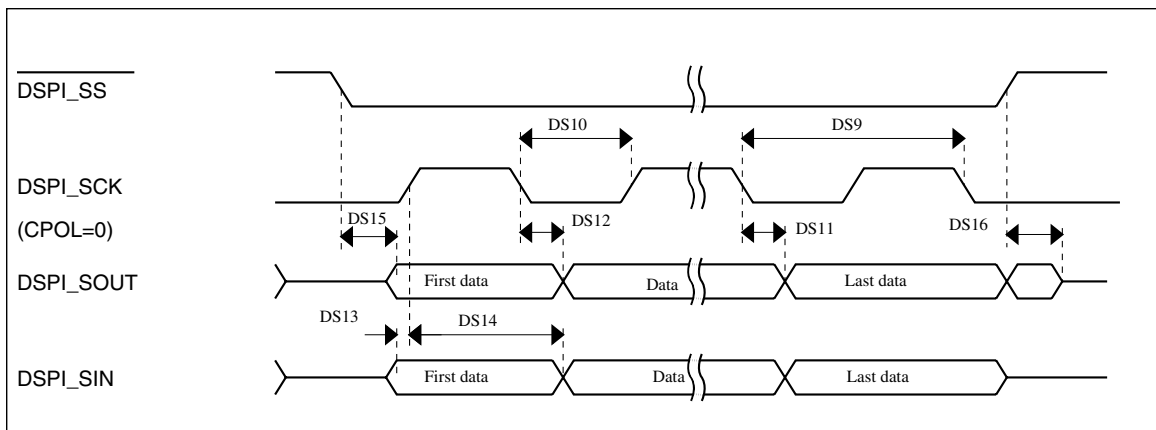
Table 44. Slave mode DSPI timing (high-speed mode)

| Num | Description | Min. | Max. | Unit |
|------|------------------------------|---------------------|-------------------|------|
| | Operating voltage | 2.7 | 3.6 | V |
| | Frequency of operation | | 12.5 | MHz |
| DS9 | DSPI_SCK input cycle time | $4 \times t_{BCLK}$ | — | ns |
| DS10 | DSPI_SCK input high/low time | $(t_{SCK}/2) - 2$ | $(t_{SCK}/2) + 2$ | ns |

Table continues on the next page...

Table 44. Slave mode DSPI timing (high-speed mode) (continued)

| Num | Description | Min. | Max. | Unit |
|------|---|------|------|------|
| DS11 | DSPI_SCK to DSPI_SOUT valid | — | TBD | ns |
| DS12 | DSPI_SCK to DSPI_SOUT invalid | 0 | — | ns |
| DS13 | DSPI_SIN to DSPI_SCK input setup | 2 | — | ns |
| DS14 | DSPI_SCK to DSPI_SIN input hold | 7 | — | ns |
| DS15 | $\overline{\text{DSPI_SS}}$ active to DSPI_SOUT driven | — | 14 | ns |
| DS16 | $\overline{\text{DSPI_SS}}$ inactive to DSPI_SOUT not driven | — | 14 | ns |

**Figure 25. DSPI classic SPI timing — slave mode**

6.8.6 I²C switching specifications

See [General switching specifications](#).

6.8.7 UART switching specifications

See [General switching specifications](#).

6.8.8 SDHC specifications

The following timing specs are defined at the chip I/O pin and must be translated appropriately to arrive at timing specs/constraints for the physical interface.

Table 45. SDHC switching specifications

| Num | Symbol | Description | Min. | Max. | Unit |
|---|------------------|---------------------------------------|------|------|------|
| | | Operating voltage | 2.7 | 3.6 | V |
| Card input clock | | | | | |
| SD1 | f _{pp} | Clock frequency (low speed) | 0 | 400 | kHz |
| | f _{pp} | Clock frequency (SD\SDIO full speed) | 0 | 25 | MHz |
| | f _{pp} | Clock frequency (MMC full speed) | 0 | 20 | MHz |
| | f _{OD} | Clock frequency (identification mode) | 0 | 400 | kHz |
| SD2 | t _{WL} | Clock low time | 7 | — | ns |
| SD3 | t _{WH} | Clock high time | 7 | — | ns |
| SD4 | t _{TLH} | Clock rise time | — | 3 | ns |
| SD5 | t _{THL} | Clock fall time | — | 3 | ns |
| SDHC output / card inputs SDHC_CMD, SDHC_DAT (reference to SDHC_CLK) | | | | | |
| SD6 | t _{OD} | SDHC output delay (output valid) | -5 | 6.5 | ns |
| SDHC input / card inputs SDHC_CMD, SDHC_DAT (reference to SDHC_CLK) | | | | | |
| SD7 | t _{THL} | SDHC input setup time | 5 | — | ns |
| SD8 | t _{THL} | SDHC input hold time | 0 | — | ns |

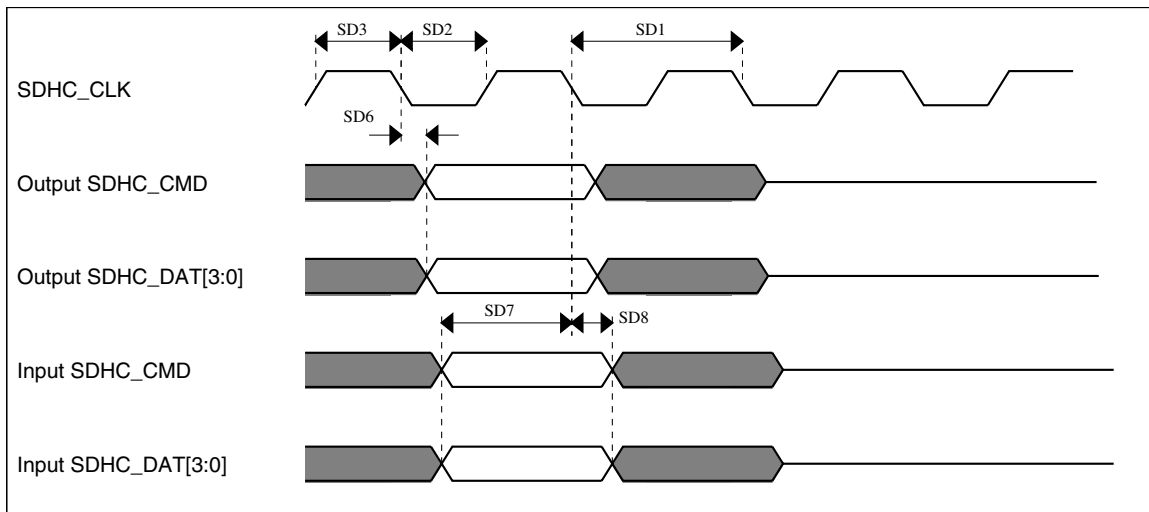


Figure 26. SDHC timing

6.8.9 I²S switching specifications

This section provides the AC timings for the I²S in master (clocks driven) and slave modes (clocks input). All timings are given for non-inverted serial clock polarity (TCR[TSCKP] = 0, RCR[RSCKP] = 0) and a non-inverted frame sync (TCR[TFSI] = 0, RCR[RFSI] = 0). If the polarity of the clock and/or the frame sync have been inverted, all the timings remain valid by inverting the clock signal (I2S_BCLK) and/or the frame sync (I2S_FS) shown in the figures below.

Table 46. I²S master mode timing

| Num | Description | Min. | Max. | Unit |
|-----|--|--------------------|------|-------------|
| | Operating voltage | 2.7 | 3.6 | V |
| S1 | I2S_MCLK cycle time | $2 \times t_{SYS}$ | | ns |
| S2 | I2S_MCLK pulse width high/low | 45% | 55% | MCLK period |
| S3 | I2S_BCLK cycle time | $5 \times t_{SYS}$ | — | ns |
| S4 | I2S_BCLK pulse width high/low | 45% | 55% | BCLK period |
| S5 | I2S_BCLK to I2S_FS output valid | — | 15 | ns |
| S6 | I2S_BCLK to I2S_FS output invalid | -2.5 | — | ns |
| S7 | I2S_BCLK to I2S_TXD valid | — | 15 | ns |
| S8 | I2S_BCLK to I2S_TXD invalid | -3 | — | ns |
| S9 | I2S_RXD/I2S_FS input setup before I2S_BCLK | 20 | — | ns |
| S10 | I2S_RXD/I2S_FS input hold after I2S_BCLK | 0 | — | ns |

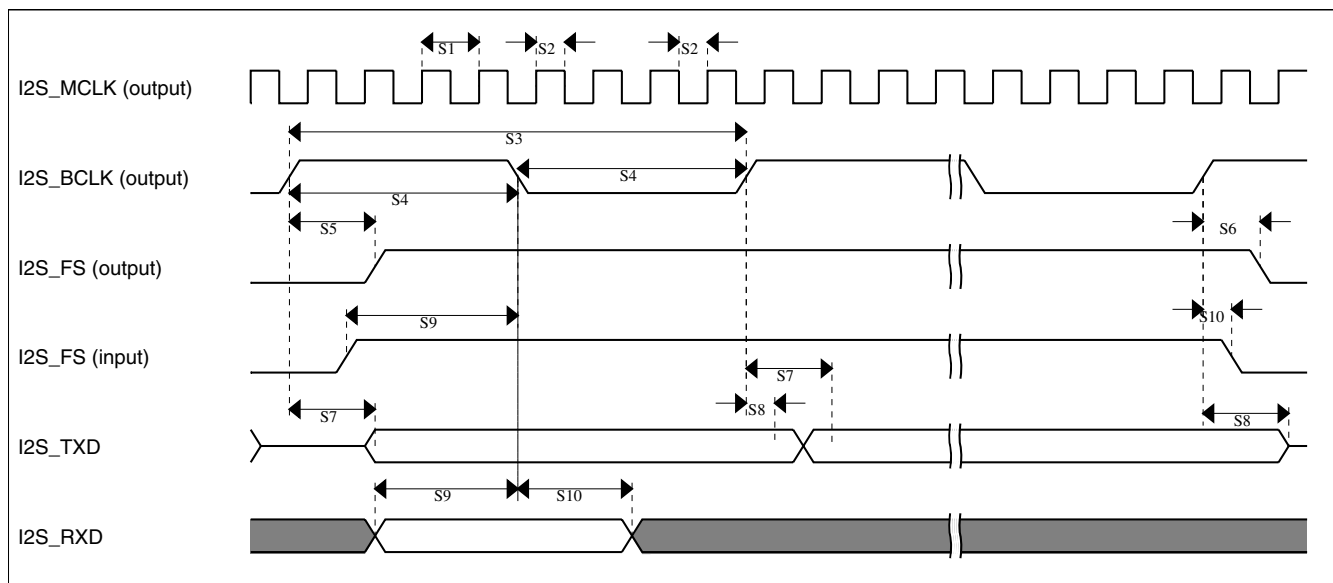
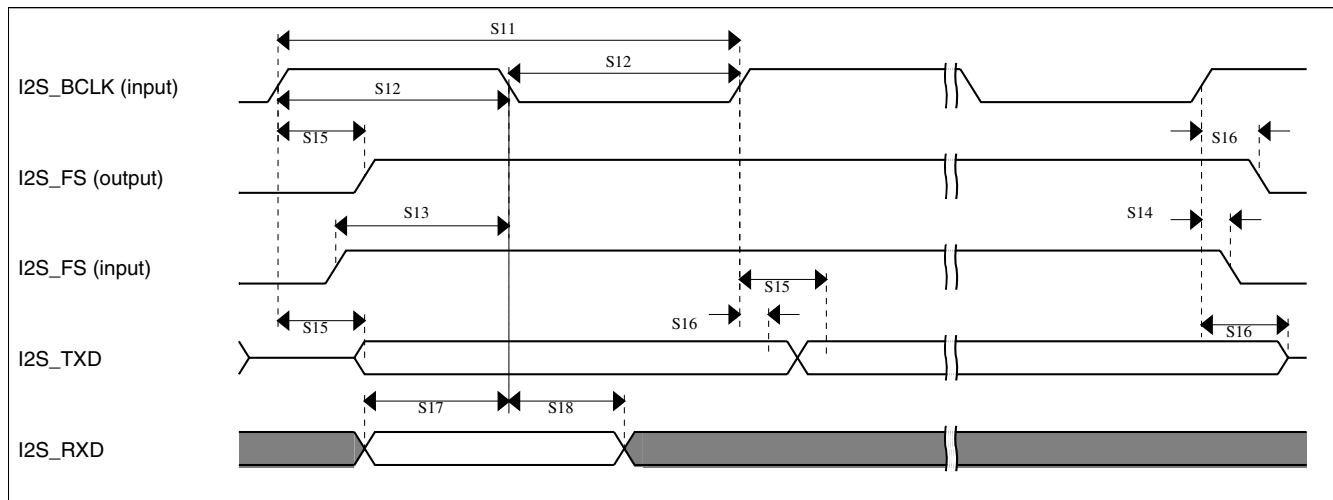


Figure 27. I²S timing — master mode

Table 47. I²S slave mode timing

| Num | Description | Min. | Max. | Unit |
|-----|---|----------------------|------|-------------|
| | Operating voltage | 2.7 | 3.6 | V |
| S11 | I2S_BCLK cycle time (input) | 8 x t _{sys} | — | ns |
| S12 | I2S_BCLK pulse width high/low (input) | 45% | 55% | MCLK period |
| S13 | I2S_FS input setup before I2S_BCLK | 10 | — | ns |
| S14 | I2S_FS input hold after I2S_BCLK | 3 | — | ns |
| S15 | I2S_BCLK to I2S_TXD/I2S_FS output valid | — | 20 | ns |
| S16 | I2S_BCLK to I2S_TXD/I2S_FS output invalid | 0 | — | ns |
| S17 | I2S_RXD setup before I2S_BCLK | 10 | — | ns |
| S18 | I2S_RXD hold after I2S_BCLK | 2 | — | ns |

**Figure 28. I²S timing — slave modes**

6.9 Human-machine interfaces (HMI)

6.9.1 TSI electrical specifications

Table 48. TSI electrical specifications

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|---------------------|------------------------------------|------|------|------|------|-------|
| V _{DDTSI} | Operating voltage | 1.71 | — | 3.6 | V | |
| C _{ELE} | Target electrode capacitance range | 1 | 20 | 500 | pF | 1 |
| f _{REFmax} | Reference oscillator frequency | — | 5.5 | TBD | MHz | |
| f _{ELEmax} | Electrode oscillator frequency | — | 0.5 | TBD | MHz | |

Table continues on the next page...

Table 48. TSI electrical specifications (continued)

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|----------------------|--|-------|------|------|----------|-------|
| C _{REF} | Internal reference capacitor | TBD | 1 | TBD | pF | |
| V _{DELTA} | Oscillator delta voltage | TBD | 600 | TBD | mV | |
| I _{REF} | Reference oscillator current source base current | TBD | 1 | TBD | μA | 2 |
| I _{ELE} | Electrode oscillator current source base current | TBD | 1 | TBD | μA | 2 |
| Pres5 | Electrode capacitance measurement precision | — | TBD | TBD | % | 3 |
| Pres20 | Electrode capacitance measurement precision | — | TBD | TBD | % | 4 |
| Pres100 | Electrode capacitance measurement precision | — | TBD | TBD | % | 5 |
| MaxSens20 | Maximum sensitivity @ 20 pF electrode | 0.003 | 0.25 | — | fF/count | 6 |
| MaxSens | Maximum sensitivity | 0.003 | — | — | fF/count | 7 |
| Res | Resolution | — | — | 16 | bits | |
| T _{Con20} | Response time @ 20 pF | 8 | 15 | 25 | μs | 8 |
| I _{TSI_RUN} | Current added in run mode | — | TBD | — | μA | |
| I _{TSI_LP} | Low power mode current adder | — | 1 | TBD | μA | |

1. The TSI module is functional with capacitance values outside this range. However, optimal performance is not guaranteed.
2. The programmable current source value is generated by multiplying the SCANC[REFCHRG] value and the base current.
3. Measured with a 5 pF electrode, reference oscillator frequency of 10 MHz, PS = 128, NSCN = 8; lext = 16.
4. Measured with a 20 pF electrode, reference oscillator frequency of 10 MHz, PS = 128, NSCN = 2; lext = 16.
5. Measured with a 20 pF electrode, reference oscillator frequency of 10 MHz, PS = 16, NSCN = 3; lext = 16.
6. Measured with a 20 pF electrode, reference oscillator frequency of ~5 MHz (I_{REF} = 5 μA, REFCHRG = 4), PS = 128, NSCN = 2; lext = 16 (EXTCHRG = 15).
7. Typical value depends on the configuration used.
8. Time to do one complete measurement of the electrode. Sensitivity resolution of 0.0133 pF, PS = 0, NSCN = 0, 1 electrode, DELVOL = 2, EXTCHRG = 15.

6.9.2 LCD electrical characteristics

Table 49. LCD electricals

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|--------------------|--|--------------|--------------|--------------|---------------------|-------|
| f _{Frame} | LCD frame frequency | 28 | 30 | 58 | Hz | |
| C _{LCD} | LCD charge pump capacitance — nominal value | — | 100 | — | nF | 1 |
| C _{BYLCD} | LCD bypass capacitance — nominal value | — | 100 | — | nF | 1 |
| C _{Glass} | LCD glass capacitance | — | 2000 | 8000 | pF | |
| V _{IREG} | V _{IREG} — HREFSEL = 0 <ul style="list-style-type: none"> • HREFSEL = 0 • HREFSEL = 1 | 0.89 1.49 | 1.00 1.67 | 1.15 1.85 | V V | 2 |
| Δ _{RTRIM} | V _{IREG} TRIM resolution | 3.0 | — | — | % V _{IREG} | |

Table continues on the next page...

Table 49. LCD electricals (continued)

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|--------------------|---|----------|------|------|------------------|-------|
| — | $V_{I\text{REG}}$ ripple <ul style="list-style-type: none"> HREFSEL = 0 HREFSEL = 1 | — | — | 30 | mV | |
| | | — | — | 50 | mV | |
| $I_{V\text{REG}}$ | $V_{I\text{REG}}$ current adder — RVEN = 1 | — | 1 | — | μA | 3 |
| $I_{R\text{BIAS}}$ | RBIAS current adder <ul style="list-style-type: none"> HREFSEL = 0 HREFSEL = 1 | — | 10 | — | μA | 3 |
| | | — | 1 | — | μA | |
| $R_{R\text{BIAS}}$ | RBIAS resistor values <ul style="list-style-type: none"> LADJ = 00 or 01 — Low load (LCD glass capacitance ≤ 2000 pF) LADJ = 10 or 11 — High load (LCD glass capacitance ≤ 8000 pF) | — | 0.28 | — | $\text{M}\Omega$ | |
| | | — | 2.98 | — | $\text{M}\Omega$ | |
| VLL2 | VLL2 voltage <ul style="list-style-type: none"> HREFSEL = 0 HREFSEL = 1 | 2.0 – 5% | 2.0 | — | V | |
| | | 3.3 – 5% | 3.3 | — | V | |
| VLL3 | VLL3 voltage <ul style="list-style-type: none"> HREFSEL = 0 HREFSEL = 1 | 3.0 – 5% | 3.0 | — | V | |
| | | 5 – 5% | 5 | — | V | |

1. The actual value used could vary with tolerance.
2. $V_{I\text{REG}}$ maximum should never be externally driven to any level other than $V_{DD} - 0.15$ V
3. 2000 pF load LCD, 32 Hz frame frequency

7 Dimensions

7.1 Obtaining package dimensions

Package dimensions are provided in package drawings.

To find a package drawing, go to <http://www.freescale.com> and perform a keyword search for the drawing's document number:

| If you want the drawing for this package | Then use this document number |
|--|-------------------------------|
| 121-pin MAPBGA | TBD |

8 Pinout

8.1 K51 Signal Multiplexing and Pin Assignments

The following table shows the signals available on each pin and the locations of these pins on the devices supported by this document. The Port Control Module is responsible for selecting which ALT functionality is available on each pin.

| 121 MAP BGA | Pin Name | Default | ALT0 | ALT1 | ALT2 | ALT3 | ALT4 | ALT5 | ALT6 | ALT7 | EzPort |
|-------------|-----------------------------------|-----------------------------------|-----------------------------------|------|-----------|-------------|------------|---|------------|------|--------|
| • | PTE0 | ADC1_SE4a | ADC1_SE4a | PTE0 | SPI1_PCS1 | UART1_TX | SDHC0_D1 | FB_AD27 | I2C1_SDA | | |
| • | PTE1 | ADC1_SE5a | ADC1_SE5a | PTE1 | SPI1_SOUT | UART1_RX | SDHC0_D0 | FB_AD26 | I2C1_SCL | | |
| • | PTE2 | ADC1_SE6a | ADC1_SE6a | PTE2 | SPI1_SCK | UART1_CTS_b | SDHC0_DCLK | FB_AD25 | | | |
| • | PTE3 | ADC1_SE7a | ADC1_SE7a | PTE3 | SPI1_SIN | UART1_RTS_b | SDHC0_CMD | FB_AD24 | | | |
| • | PTE4 | DISABLED | | PTE4 | SPI1_PCS0 | UART3_TX | SDHC0_D3 | FB_CS3_b/ FB_BE7_0_ BLS31_24_b | FB_TA_b | | |
| • | PTE5 | DISABLED | | PTE5 | SPI1_PCS2 | UART3_RX | SDHC0_D2 | FB_TBST_b/ FB_CS2_b/ FB_BE15_8_ BLS23_16_b | | | |
| • | PTE6 | DISABLED | | PTE6 | SPI1_PCS3 | UART3_CTS_b | I2S0_MCLK | FB_ALE/ FB_CS1_b/ FB_TS_b | I2S0_CLKIN | | |
| • | VDD | VDD | VDD | | | | | | | | |
| • | VSS | VSS | VSS | | | | | | | | |
| • | USB0_DP | USB0_DP | USB0_DP | | | | | | | | |
| • | USB0_DM | USB0_DM | USB0_DM | | | | | | | | |
| • | VOUT33 | VOUT33 | VOUT33 | | | | | | | | |
| • | VREGIN | VREGIN | VREGIN | | | | | | | | |
| • | ADC0_DP1/ OP0_DP0 | ADC0_DP1/ OP0_DP0 | ADC0_DP1/ OP0_DP0 | | | | | | | | |
| • | ADC0_DM1/ OP0_DM0 | ADC0_DM1/ OP0_DM0 | ADC0_DM1/ OP0_DM0 | | | | | | | | |
| • | ADC1_DP1/ OP1_DP0/ OP1_DM1 | ADC1_DP1/ OP1_DP0/ OP1_DM1 | ADC1_DP1/ OP1_DP0/ OP1_DM1 | | | | | | | | |
| • | ADC1_DM1/ OP1_DM0 | ADC1_DM1/ OP1_DM0 | ADC1_DM1/ OP1_DM0 | | | | | | | | |
| • | PGA0_DP/ ADC0_DP0/ ADC1_DP3 | PGA0_DP/ ADC0_DP0/ ADC1_DP3 | PGA0_DP/ ADC0_DP0/ ADC1_DP3 | | | | | | | | |

| 121 MAP BGA | Pin Name | Default | ALT0 | ALT1 | ALT2 | ALT3 | ALT4 | ALT5 | ALT6 | ALT7 | EzPort |
|-------------------|--|--|--|------|------|------|------|------|------|------|--------|
| • | PGA0_DM/ ADC0_DM0/ ADC1_DM3 | PGA0_DM/ ADC0_DM0/ ADC1_DM3 | PGA0_DM/ ADC0_DM0/ ADC1_DM3 | | | | | | | | |
| • | PGA1_DP/ ADC1_DP0/ ADC0_DP3 | PGA1_DP/ ADC1_DP0/ ADC0_DP3 | PGA1_DP/ ADC1_DP0/ ADC0_DP3 | | | | | | | | |
| • | PGA1_DM/ ADC1_DM0/ ADC0_DM3 | PGA1_DM/ ADC1_DM0/ ADC0_DM3 | PGA1_DM/ ADC1_DM0/ ADC0_DM3 | | | | | | | | |
| • | VDDA | VDDA | VDDA | | | | | | | | |
| • | VREFH | VREFH | VREFH | | | | | | | | |
| • | VREFL | VREFL | VREFL | | | | | | | | |
| • | VSSA | VSSA | VSSA | | | | | | | | |
| • | ADC1_SE16/ OP1_OUT/ CMP2_IN2/ ADC0_SE22/ OP0_DP2/ OP1_DP2 | ADC1_SE16/ OP1_OUT/ CMP2_IN2/ ADC0_SE22/ OP0_DP2/ OP1_DP2 | ADC1_SE16/ OP1_OUT/ CMP2_IN2/ ADC0_SE22/ OP0_DP2/ OP1_DP2 | | | | | | | | |
| • | ADC0_SE16/ OP0_OUT/ CMP1_IN2/ ADC0_SE21/ OP0_DP1/ OP1_DP1 | ADC0_SE16/ OP0_OUT/ CMP1_IN2/ ADC0_SE21/ OP0_DP1/ OP1_DP1 | ADC0_SE16/ OP0_OUT/ CMP1_IN2/ ADC0_SE21/ OP0_DP1/ OP1_DP1 | | | | | | | | |
| • | VREF_OUT/ CMP1_IN5/ CMP0_IN5/ ADC1_SE18 | VREF_OUT | VREF_OUT/ CMP1_IN5/ CMP0_IN5/ ADC1_SE18 | | | | | | | | |
| • | TRIO_OUT/ OP1_DM2 | TRIO_OUT/ OP1_DM2 | TRIO_OUT/ OP1_DM2 | | | | | | | | |
| • | TRIO_DM | TRIO_DM | TRIO_DM | | | | | | | | |
| • | TRIO_DP | TRIO_DP | TRIO_DP | | | | | | | | |
| • | TRI1_DM | TRI1_DM | TRI1_DM | | | | | | | | |
| • | TRI1_DP | TRI1_DP | TRI1_DP | | | | | | | | |
| • | TRI1_OUT/ CMP2_IN5/ ADC1_SE22 | TRI1_OUT | TRI1_OUT/ CMP2_IN5/ ADC1_SE22 | | | | | | | | |
| • | DAC0_OUT/ CMP1_IN3/ ADC0_SE23/ OP0_DP4/ OP1_DP4 | DAC0_OUT | DAC0_OUT/ CMP1_IN3/ ADC0_SE23/ OP0_DP4/ OP1_DP4 | | | | | | | | |
| • | DAC1_OUT/ CMP2_IN3/ ADC1_SE23/ OP0_DP5/ OP1_DP5 | DAC1_OUT | DAC1_OUT/ CMP2_IN3/ ADC1_SE23/ OP0_DP5/ OP1_DP5 | | | | | | | | |
| • | XTAL32 | XTAL32 | XTAL32 | | | | | | | | |

Pinout

| 121 MAP BGA | Pin Name | Default | ALT0 | ALT1 | ALT2 | ALT3 | ALT4 | ALT5 | ALT6 | ALT7 | EzPort |
|-------------------|----------|---|---|-------|-----------------|-----------|----------------|--|------------------|----------------------------|----------|
| • | EXTAL32 | EXTAL32 | EXTAL32 | | | | | | | | |
| • | VBAT | VBAT | VBAT | | | | | | | | |
| • | PTA0 | JTAG_TCLK/ SWD_CLK/ EZP_CLK | TSIO_CH1 | PTA0 | UART0_CTS _b | FTM0_CH5 | | | | JTAG_TCLK/ SWD_CLK | EZP_CLK |
| • | PTA1 | JTAG_TDI/ EZP_DI | TSIO_CH2 | PTA1 | UART0_RX | FTM0_CH6 | | | | JTAG_TDI | EZP_DI |
| • | PTA2 | JTAG_TDO/ TRACE_SW O/EZP_DO | TSIO_CH3 | PTA2 | UART0_TX | FTM0_CH7 | | | | JTAG_TDO/ TRACE_SW O | EZP_DO |
| • | PTA3 | JTAG_TMS/ SWD_DIO | TSIO_CH4 | PTA3 | UART0_RTS _b | FTM0_CH0 | | | | JTAG_TMS/ SWD_DIO | |
| • | PTA4 | NMI_b/ EZP_CS_b | TSIO_CH5 | PTA4 | | FTM0_CH1 | | | | NMI_b | EZP_CS_b |
| • | PTA12 | CMP2_IN0 | CMP2_IN0 | PTA12 | | FTM1_CH0 | | FB_CS5_b/ FB_TSIZ1/ FB_BE23_16 _BLS15_8_b | I2S0_TXD | FTM1_QD_P HA | |
| • | PTA13 | CMP2_IN1 | CMP2_IN1 | PTA13 | | FTM1_CH1 | | FB_CS4_b/ FB_TSIZ0/ FB_BE31_24 _BLS7_0_b | I2S0_TX_FS | FTM1_QD_P HB | |
| • | PTA14 | DISABLED | | PTA14 | SPI0_PCS0 | UART0_TX | | FB_AD31 | I2S0_TX_BC LK | | |
| • | PTA15 | DISABLED | | PTA15 | SPI0_SCK | UART0_RX | | FB_AD30 | I2S0_RXD | | |
| • | VDD | VDD | VDD | | | | | | | | |
| • | VSS | VSS | VSS | | | | | | | | |
| • | PTA18 | EXTAL | EXTAL | PTA18 | | FTM0_FLT2 | FTM_CLKIN 0 | | | | |
| • | PTA19 | XTAL | XTAL | PTA19 | | FTM1_FLT0 | FTM_CLKIN 1 | | LPT0_ALT1 | | |
| • | RESET_b | RESET_b | RESET_b | | | | | | | | |
| • | PTA24 | DISABLED | | PTA24 | | | | FB_AD14 | | | |
| • | PTA25 | DISABLED | | PTA25 | | | | FB_AD13 | | | |
| • | PTA26 | DISABLED | | PTA26 | | | | FB_AD12 | | | |
| • | PTA27 | DISABLED | | PTA27 | | | | FB_AD11 | | | |
| • | PTA28 | DISABLED | | PTA28 | | | | FB_AD10 | | | |
| • | PTA29 | DISABLED | | PTA29 | | | | FB_AD19 | | | |
| • | PTB0 | LCD_P0/ ADC0_SE8/ ADC1_SE8/ TSIO_CH0 | LCD_P0/ ADC0_SE8/ ADC1_SE8/ TSIO_CH0 | PTB0 | I2C0_SCL | FTM1_CH0 | | | FTM1_QD_P HA | LCD_P0 | |
| • | PTB1 | LCD_P1/ ADC0_SE9/ ADC1_SE9/ TSIO_CH6 | LCD_P1/ ADC0_SE9/ ADC1_SE9/ TSIO_CH6 | PTB1 | I2C0_SDA | FTM1_CH1 | | | FTM1_QD_P HB | LCD_P1 | |

| 121 MAP BGA | Pin Name | Default | ALT0 | ALT1 | ALT2 | ALT3 | ALT4 | ALT5 | ALT6 | ALT7 | EzPort |
|-------------------|----------|--|--|-------|-----------|-----------------|------------------|------|-----------------|---------|--------|
| • | PTB2 | LCD_P2/ ADC0_SE12/ TSIO_CH7 | LCD_P2/ ADC0_SE12/ TSIO_CH7 | PTB2 | I2C0_SCL | UART0_RTS _b | | | FTM0_FLT3 | LCD_P2 | |
| • | PTB3 | LCD_P3/ ADC0_SE13/ TSIO_CH8 | LCD_P3/ ADC0_SE13/ TSIO_CH8 | PTB3 | I2C0_SDA | UART0_CTS _b | | | FTM0_FLT0 | LCD_P3 | |
| • | PTB6 | LCD_P6/ ADC1_SE12 | LCD_P6/ ADC1_SE12 | PTB6 | | | | | | LCD_P6 | |
| • | PTB7 | LCD_P7/ ADC1_SE13 | LCD_P7/ ADC1_SE13 | PTB7 | | | | | | LCD_P7 | |
| • | PTB8 | LCD_P8 | LCD_P8 | PTB8 | | UART3_RTS _b | | | | LCD_P8 | |
| • | PTB9 | LCD_P9 | LCD_P9 | PTB9 | SPI1_PCS1 | UART3_CTS _b | | | | LCD_P9 | |
| • | PTB10 | LCD_P10/ ADC1_SE14 | LCD_P10/ ADC1_SE14 | PTB10 | SPI1_PCS0 | UART3_RX | | | FTM0_FLT1 | LCD_P10 | |
| • | PTB11 | LCD_P11/ ADC1_SE15 | LCD_P11/ ADC1_SE15 | PTB11 | SPI1_SCK | UART3_TX | | | FTM0_FLT2 | LCD_P11 | |
| • | PTB16 | LCD_P12/ TSIO_CH9 | LCD_P12/ TSIO_CH9 | PTB16 | SPI1_SOUT | UART0_RX | | | EWM_IN | LCD_P12 | |
| • | PTB17 | LCD_P13/ TSIO_CH10 | LCD_P13/ TSIO_CH10 | PTB17 | SPI1_SIN | UART0_TX | | | EWM_OUT_ b | LCD_P13 | |
| • | PTB18 | LCD_P14/ TSIO_CH11 | LCD_P14/ TSIO_CH11 | PTB18 | | FTM2_CH0 | I2S0_TX_BC LK | | FTM2_QD_P HA | LCD_P14 | |
| • | PTB19 | LCD_P15/ TSIO_CH12 | LCD_P15/ TSIO_CH12 | PTB19 | | FTM2_CH1 | I2S0_TX_FS | | FTM2_QD_P HB | LCD_P15 | |
| • | PTB20 | LCD_P16 | LCD_P16 | PTB20 | SPI2_PCS0 | | | | CMP0_OUT | LCD_P16 | |
| • | PTB21 | LCD_P17 | LCD_P17 | PTB21 | SPI2_SCK | | | | CMP1_OUT | LCD_P17 | |
| • | PTB22 | LCD_P18 | LCD_P18 | PTB22 | SPI2_SOUT | | | | CMP2_OUT | LCD_P18 | |
| • | PTB23 | LCD_P19 | LCD_P19 | PTB23 | SPI2_SIN | SPIO_PCS5 | | | | LCD_P19 | |
| • | PTC0 | LCD_P20/ ADC0_SE14/ TSIO_CH13 | LCD_P20/ ADC0_SE14/ TSIO_CH13 | PTC0 | SPI0_PCS4 | PDB0_EXTR G | I2S0_TXD | | | LCD_P20 | |
| • | PTC1 | LCD_P21/ ADC0_SE15/ TSIO_CH14 | LCD_P21/ ADC0_SE15/ TSIO_CH14 | PTC1 | SPI0_PCS3 | UART1_RTS _b | FTM0_CH0 | | | LCD_P21 | |
| • | PTC2 | LCD_P22/ ADC0_SE4b/ CMP1_IN0/ TSIO_CH15 | LCD_P22/ ADC0_SE4b/ CMP1_IN0/ TSIO_CH15 | PTC2 | SPI0_PCS2 | UART1_CTS _b | FTM0_CH1 | | | LCD_P22 | |
| • | PTC3 | LCD_P23/ CMP1_IN1 | LCD_P23/ CMP1_IN1 | PTC3 | SPI0_PCS1 | UART1_RX | FTM0_CH2 | | | LCD_P23 | |
| • | VSS | VSS | VSS | | | | | | | | |
| • | VLL3 | VLL3 | VLL3 | | | | | | | | |
| • | VLL2 | VLL2 | VLL2 | | | | | | | | |
| • | VLL1 | VLL1 | VLL1 | | | | | | | | |
| • | VCAP2 | VCAP2 | VCAP2 | | | | | | | | |

Pinout

| 121 MAP BGA | Pin Name | Default | ALT0 | ALT1 | ALT2 | ALT3 | ALT4 | ALT5 | ALT6 | ALT7 | EzPort |
|-------------------|----------|------------------------------------|------------------------------------|-------|-----------|-----------------|------------------|------|---------------|---------|--------|
| • | VCAP1 | VCAP1 | VCAP1 | | | | | | | | |
| • | PTC4 | LCD_P24 | LCD_P24 | PTC4 | SPI0_PCS0 | UART1_TX | FTM0_CH3 | | CMP1_OUT | LCD_P24 | |
| • | PTC5 | LCD_P25 | LCD_P25 | PTC5 | SPI0_SCK | | LPT0_ALT2 | | CMP0_OUT | LCD_P25 | |
| • | PTC6 | LCD_P26/ CMP0_IN0 | LCD_P26/ CMP0_IN0 | PTC6 | SPI0_SOUT | PDB0_EXTR G | | | | LCD_P26 | |
| • | PTC7 | LCD_P27/ CMP0_IN1 | LCD_P27/ CMP0_IN1 | PTC7 | SPI0_SIN | | | | | LCD_P27 | |
| • | PTC8 | LCD_P28/ ADC1_SE4b/ CMP0_IN2 | LCD_P28/ ADC1_SE4b/ CMP0_IN2 | PTC8 | | I2S0_MCLK | I2S0_CLKIN | | | LCD_P28 | |
| • | PTC9 | LCD_P29/ ADC1_SE5b/ CMP0_IN3 | LCD_P29/ ADC1_SE5b/ CMP0_IN3 | PTC9 | | | I2S0_RX_BC LK | | FTM2_FLT0 | LCD_P29 | |
| • | PTC10 | LCD_P30/ ADC1_SE6b/ CMP0_IN4 | LCD_P30/ ADC1_SE6b/ CMP0_IN4 | PTC10 | I2C1_SCL | | I2S0_RX_FS | | | LCD_P30 | |
| • | PTC11 | LCD_P31/ ADC1_SE7b | LCD_P31/ ADC1_SE7b | PTC11 | I2C1_SDA | | I2S0_RXD | | | LCD_P31 | |
| • | PTC12 | LCD_P32 | LCD_P32 | PTC12 | | UART4_RTS _b | | | | LCD_P32 | |
| • | PTC13 | LCD_P33 | LCD_P33 | PTC13 | | UART4_CTS _b | | | | LCD_P33 | |
| • | PTC14 | LCD_P34 | LCD_P34 | PTC14 | | UART4_RX | | | | LCD_P34 | |
| • | PTC15 | LCD_P35 | LCD_P35 | PTC15 | | UART4_TX | | | | LCD_P35 | |
| • | PTC16 | LCD_P36 | LCD_P36 | PTC16 | | UART3_RX | | | | LCD_P36 | |
| • | PTC17 | LCD_P37 | LCD_P37 | PTC17 | | UART3_TX | | | | LCD_P37 | |
| • | PTC18 | LCD_P38 | LCD_P38 | PTC18 | | UART3_RTS _b | | | | LCD_P38 | |
| • | PTC19 | LCD_P39 | LCD_P39 | PTC19 | | UART3_CTS _b | | | | LCD_P39 | |
| • | PTD0 | LCD_P40 | LCD_P40 | PTD0 | SPI0_PCS0 | UART2_RTS _b | | | | LCD_P40 | |
| • | PTD1 | LCD_P41/ ADC0_SE5b | LCD_P41/ ADC0_SE5b | PTD1 | SPI0_SCK | UART2_CTS _b | | | | LCD_P41 | |
| • | PTD2 | LCD_P42 | LCD_P42 | PTD2 | SPI0_SOUT | UART2_RX | | | | LCD_P42 | |
| • | PTD3 | LCD_P43 | LCD_P43 | PTD3 | SPI0_SIN | UART2_TX | | | | LCD_P43 | |
| • | PTD4 | LCD_P44 | LCD_P44 | PTD4 | SPI0_PCS1 | UART0_RTS _b | FTM0_CH4 | | EWM_IN | LCD_P44 | |
| • | PTD5 | LCD_P45/ ADC0_SE6b | LCD_P45/ ADC0_SE6b | PTD5 | SPI0_PCS2 | UART0_CTS _b | FTM0_CH5 | | EWM_OUT_ b | LCD_P45 | |
| • | PTD6 | LCD_P46/ ADC0_SE7b | LCD_P46/ ADC0_SE7b | PTD6 | SPI0_PCS3 | UART0_RX | FTM0_CH6 | | FTM0_FLT0 | LCD_P46 | |
| • | VSS | VSS | VSS | | | | | | | | |
| • | VDD | VDD | VDD | | | | | | | | |
| • | PTD7 | LCD_P47 | LCD_P47 | PTD7 | CMT_IRO | UART0_TX | FTM0_CH7 | | FTM0_FLT1 | LCD_P47 | |
| • | PTD8 | DISABLED | | PTD8 | I2C0_SCL | UART5_RX | | | | | |

| 121 MAP BGA | Pin Name | Default | ALT0 | ALT1 | ALT2 | ALT3 | ALT4 | ALT5 | ALT6 | ALT7 | EzPort |
|-------------------|----------|----------|------|-------|-----------|-------------|--------------|---------|------|------|--------|
| • | PTD9 | DISABLED | | PTD9 | I2C0_SDA | UART5_TX | | | | | |
| • | PTD10 | DISABLED | | PTD10 | | UART5_RTS_b | | FB_AD9 | | | |
| • | PTD11 | DISABLED | | PTD11 | SPI2_PCS0 | UART5_CTS_b | SDHC0_CLK_IN | FB_AD8 | | | |
| • | PTD12 | DISABLED | | PTD12 | SPI2_SCK | | SDHC0_D4 | FB_AD7 | | | |
| • | PTD13 | DISABLED | | PTD13 | SPI2_SOUT | | SDHC0_D5 | FB_AD6 | | | |
| • | PTD14 | DISABLED | | PTD14 | SPI2_SIN | | SDHC0_D6 | FB_AD5 | | | |
| • | PTD15 | DISABLED | | PTD15 | SPI2_PCS1 | | SDHC0_D7 | FB_RW_b | | | |

8.2 K51 Pinouts

The below figure shows the pinout diagram for the devices supported by this document. Many signals may be multiplexed onto a single pin. To determine what signals can be used on which pin, see the previous section.

NOTE

The 121 MAPBGA ballmap assignments are currently being developed.

9 Revision History

The following table provides a revision history for this document.

Table 50. Revision History

| Rev. No. | Date | Substantial Changes |
|----------|--------|---|
| 2 | 3/2011 | Initial public revision |
| 3 | 3/2011 | Added sections that were inadvertently removed in previous revision |
| 4 | 3/2011 | Reworded I _{IC} footnote in "Voltage and Current Operating Requirements" table. Added paragraph to "Peripheral operating requirements and behaviors" section. Added "JTAG full voltage range electricals" table to the "JTAG electricals" section. |

How to Reach Us:

Home Page:

www.freescale.com

Web Support:

<http://www.freescale.com/support>

USA/Europe or Locations Not Listed:

Freescale Semiconductor
Technical Information Center, EL516
2100 East Elliot Road
Tempe, Arizona 85284
+1-800-521-6274 or +1-480-768-2130
www.freescale.com/support

Europe, Middle East, and Africa:

Freescale Halbleiter Deutschland GmbH
Technical Information Center
Schatzbogen 7
81829 Muenchen, Germany
+44 1296 380 456 (English)
+46 8 52200080 (English)
+49 89 92103 559 (German)
+33 1 69 35 48 48 (French)
www.freescale.com/support

Japan:

Freescale Semiconductor Japan Ltd.
Headquarters
ARCO Tower 15F
1-8-1, Shimo-Meguro, Meguro-ku,
Tokyo 153-0064
Japan
0120 191014 or +81 3 5437 9125
support.japan@freescale.com

Asia/Pacific:

Freescale Semiconductor China Ltd.
Exchange Building 23F
No. 118 Jianguo Road
Chaoyang District
Beijing 100022
China
+86 10 5879 8000
support.asia@freescale.com

For Literature Requests Only:

Freescale Semiconductor Literature Distribution Center
1-800-441-2447 or +1-303-675-2140
Fax: +1-303-675-2150
LDCForFreescaleSemiconductor@hibbertgroup.com

Information in this document is provided solely to enable system and software implementers to use Freescale Semiconductors products. There are no express or implied copyright licenses granted hereunder to design or fabricate any integrated circuits or integrated circuits based on the information in this document.

Freescale Semiconductor reserves the right to make changes without further notice to any products herein. Freescale Semiconductor makes no warranty, representation, or guarantee regarding the suitability of its products for any particular purpose, nor does Freescale Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any liability, including without limitation consequential or incidental damages. "Typical" parameters that may be provided in Freescale Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals", must be validated for each customer application by customer's technical experts. Freescale Semiconductor does not convey any license under its patent rights nor the rights of others. Freescale Semiconductor products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which failure of the Freescale Semiconductor product could create a situation where personal injury or death may occur. Should Buyer purchase or use Freescale Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify Freescale Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claims alleges that Freescale Semiconductor was negligent regarding the design or manufacture of the part.

RoHS-compliant and/or Pb-free versions of Freescale products have the functionality and electrical characteristics as their non-RoHS-compliant and/or non-Pb-free counterparts. For further information, see <http://www.freescale.com> or contact your Freescale sales representative.

For information on Freescale's Environmental Products program, go to <http://www.freescale.com/epp>.

Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners.

© 2010–2011 Freescale Semiconductor, Inc.

