

ON Semiconductor®



DATASHEET

AX-SIGFOX

**Ultra-Low Power, AT Command
Controlled, Sigfox Compliant
Transceiver IC for Up-Link and
Down-Link**

Revision 2



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1. Overview

1.1. Circuit description

AX-Sigfox is an ultra-low power single chip solution for a node on the Sigfox network with both up- and down-link functionality. The **AX-Sigfox** chip is delivered fully ready for operation and contains all the necessary firmware to transmit and receive data from the Sigfox network in Europe. It connects to the customer product using a logic level RS232 UART. AT commands are used to send frames and configure radio parameters.

1.2. Features

Functionality and Ecosystem

- **Sigfox up-link and down-link functionality controlled by AT commands**
- **The AX-Sigfox IC is part of a whole development and product ecosystem available from AXSEM for any Sigfox requirement. Other parts of the ecosystem include**
 - **Ready to go AX-Sigfox development kit with fully functional AX-Sigfox module including Sigfox subscription**
 - **Sigfox Ready certified reference design for the AX-Sigfox IC**
 - **PIOX by AXSEM Sigfox modules with SMA connector or chip antenna**
 - **AX-Sigfox-API IC for customers wishing to write their own application software based on the AXSEM Sigfox Library**

General Features

- **QFN40 4mm x 5mm package**
- **Supply range 1.8V - 3.6V**
- **-40°C to 85°C**
- **Temperature sensor**
- **Supply voltage measurements**
- **10 GPIO pins**
 - **4 GPIO pins with selectable voltage measure functionality, differential**

(1V or 10V range) or single ended (1V range) with 10 bit resolution

- **2 GPIO pins with selectable sigma delta DAC output functionality**
- **2 GPIO pins with selectable output clock**
- **3 GPIO pins selectable as SPI master interface**
- **Integrated RX/TX switching with differential antenna pins**

Power Consumption

- **Ultra-low power consumption:**
 - **Charge required to send a Sigfox OOB packet at 14dBm output power: 0.28 C**
 - **Deepsleep mode current: 100 nA**
 - **Sleep mode current: 1.3 µA**
 - **Standby mode current: 0.5 mA**
 - **Continuous radio RX-mode at 869.525 MHz : 10 mA**
 - **Continuous radio TX-mode at 868.130 MHz**
19 mA @ 0 dBm
49 mA @ 14 dBm

High performance narrow-band Sigfox RF transceiver

- **Receiver**
 - **Carrier frequency 869.525 MHz**
 - **Data-rate 600 bps**
 - **Sensitivity**
-126 dBm @ 600bps, 869.525MHz, GFSK
 - **0 dBm maximum input power**
- **Transmitter**
 - **Carrier frequency 868.13 MHz**
 - **Data-rate 100 bps**
 - **High efficiency, high linearity integrated power amplifier**
 - **Maximum output power 14 dBm**
 - **Power level programmable in 1dBm steps**



1.3. Applications

Sigfox networks up-link and down-link.

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2. Block Diagram

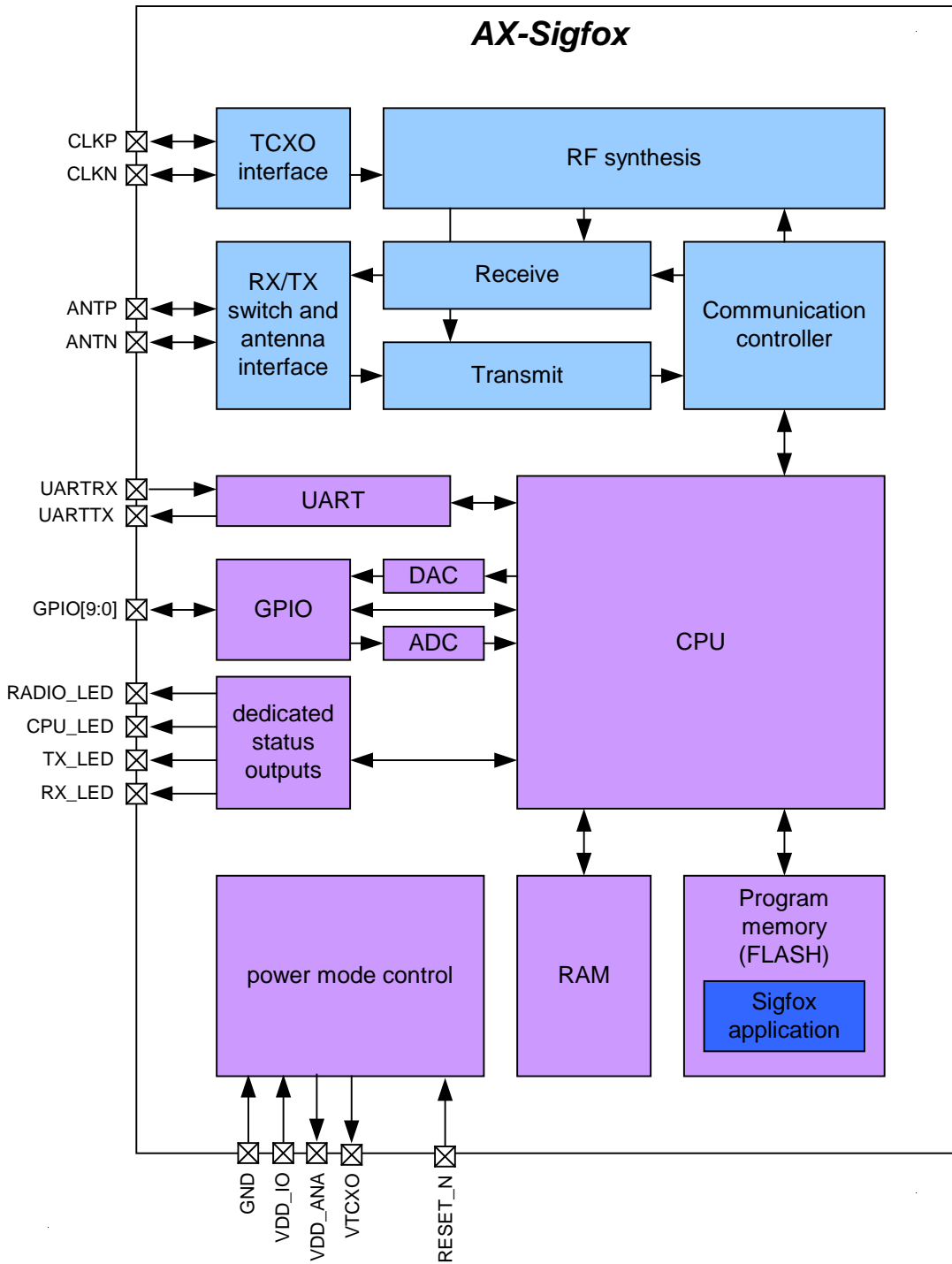


Figure 1 Functional block diagram of the AX-Sigfox



3. Pin Function Descriptions

| Symbol | Pin(s) | Type | Description |
|-----------|--------|----------|---|
| VDD_ANA | 1 | P | Analog power output, decouple to neighboring GND |
| GND | 2 | P | Ground, decouple to neighboring VDD_ANA |
| ANTP | 3 | A | Differential antenna input/output |
| ANTN | 4 | A | Differential antenna input/output |
| NC | 5 | N | Do not connect |
| GND | 6 | P | Ground, decouple to neighboring VDD_ANA |
| VDD_ANA | 7 | P | Analog power output, decouple to neighboring GND |
| GND | 8 | P | Ground |
| FILT | 9 | A | Synthesizer filter |
| NC | 10 | A | Must be connected to pin 11 |
| NC | 11 | A | Must be connected to pin 10 |
| NC | 12 | N | Do not connect |
| GPIO8 | 13 | I/O/PU | General purpose IO |
| GPIO7 | 14 | I/O/PU | General purpose IO, selectable SPI functionality (MISO) |
| GPIO6 | 15 | I/O/PU | General purpose IO, selectable SPI functionality (MOSI) |
| GPIO5 | 16 | I/O/PU | General purpose IO, selectable SPI functionality (SCK) |
| GPIO4 | 17 | I/O/PU | General purpose IO, selectable $\Sigma\Delta$ DAC functionality, selectable clock functionality |
| CPU_LED | 18 | O | CPU activity indicator |
| RADIO_LED | 19 | O | Radio activity indicator |
| VTCXO | 20 | O | TCXO power |
| GPIO9 | 21 | I/O/PU | General purpose IO, wakeup from deep sleep |
| UARTTX | 22 | O | UART transmit |
| UARTRX | 23 | I/PU | UART receive |
| RX_LED | 24 | O | Receive activity indicator |
| TX_LED | 25 | O | Transmit activity indicator |
| NC | 26 | PD | Do not connect |
| RESET_N | 27 | I/PU | Optional reset pin Internal pull-up resistor is permanently enabled, nevertheless it is recommended to connect this pin to VDD_IO if it is not used. |
| GND | 28 | P | Ground |
| VDD_IO | 29 | P | Unregulated power supply |
| GPIO0 | 30 | I/O/A/PU | General purpose IO, selectable ADC functionality, selectable $\Sigma\Delta$ DAC functionality, selectable clock functionality |
| GPIO1 | 31 | I/O/A/PU | General purpose IO, selectable ADC functionality |
| GPIO2 | 32 | I/O/A/PU | General purpose IO, selectable ADC functionality |
| NC | 33 | N | Do not connect |
| NC | 34 | N | Do not connect |



| Symbol | Pin(s) | Type | Description |
|--------|------------|----------|--|
| GPIO3 | 35 | I/O/A/PU | General purpose IO, selectable ADC functionality |
| VDD_IO | 36 | P | Unregulated power supply |
| NC | 37 | N | Connect to Ground |
| NC | 38 | N | Connect to Ground |
| CLKN | 39 | A | TCXO interface |
| CLKP | 40 | A | TCXO interface |
| GND | Center pad | P | Ground on center pad of QFN, must be connected |

A = analog signal

I = digital input signal

O = digital output signal

PU = pull-up

I/O = digital input/output signal

N = not to be connected

P = power or ground

PD = pull-down

All digital inputs are Schmitt trigger inputs, digital input and output levels are LVCMOS/LVTTL compatible. Pins GPIO[3:0] must not be driven above VDD_IO, all other digital inputs are 5V tolerant. All GPIO pins and UARTRX start up as input with pull-up.

| Pin | Possible GPIO modes |
|-------|---------------------|
| GPIO0 | 0,1,Z,U,A,T |
| GPIO1 | 0,1,Z,U,A |
| GPIO2 | 0,1,Z,U,A |
| GPIO3 | 0,1,Z,U,A |
| GPIO4 | 0,1,Z,U,T |
| GPIO5 | 0,1,Z,U |
| GPIO0 | 0,1,Z,U |
| GPIO1 | 0,1,Z,U |
| GPIO2 | 0,1,Z,U |
| GPIO3 | 0,1,Z,U |

0 = pin drives

1 = not to be connected

Z = pin is high impedance input

U = pin is input with pull-up

A = pin is analog input

T = pin is driven by clock or DAC



3.1. Pinout Drawing

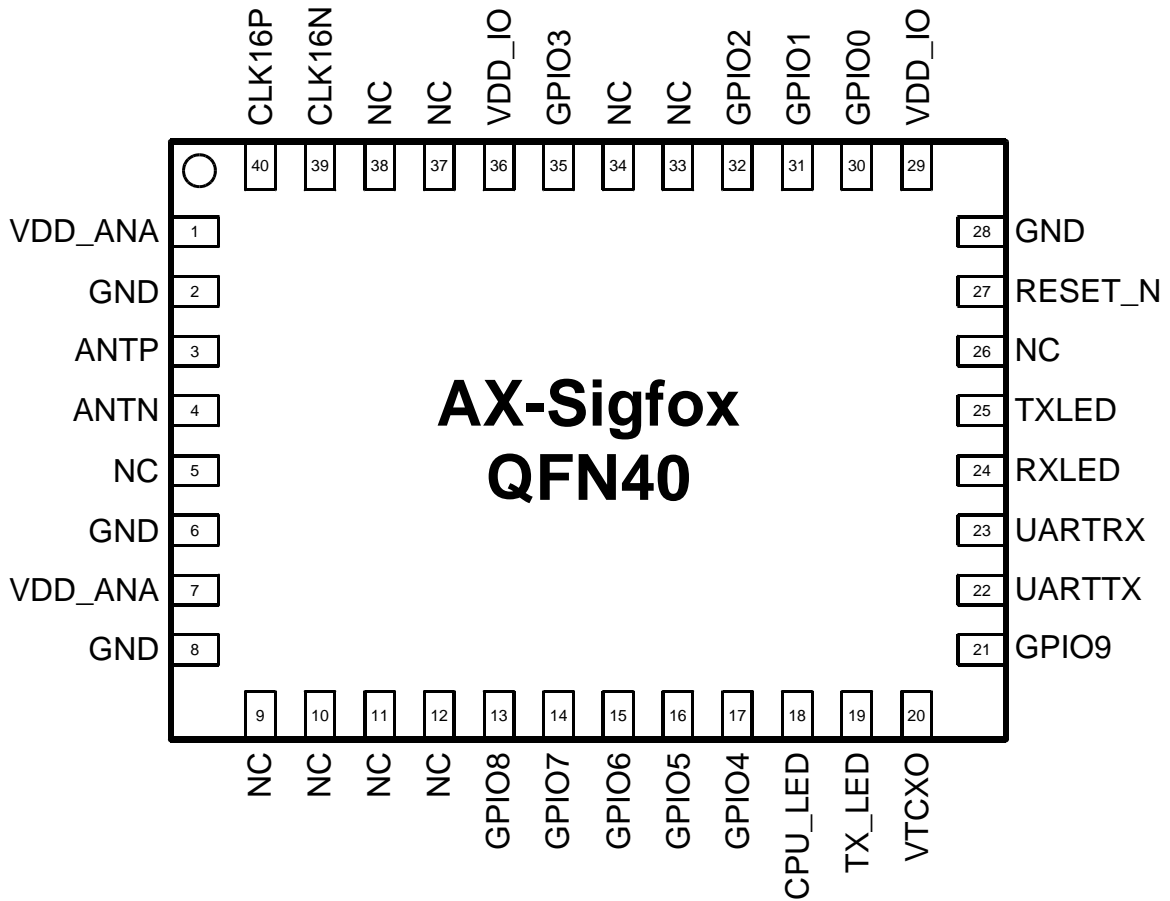


Figure 2 Pinout drawing (Top view)



4. Specifications

4.1. Absolute Maximum Ratings

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device.

This is a stress rating only; functional operation of the device at these or any other conditions above those listed in the operational sections of this specification is not implied.

Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

| SYMBOL | DESCRIPTION | CONDITION | MIN | MAX | UNIT |
|------------------|--|-------------------------------|-------|------|------|
| VDD_IO | Supply voltage | | -0.5 | 5.5 | V |
| IDD | Supply current | | | 200 | mA |
| P _{tot} | Total power consumption | | | 800 | mW |
| P _i | Absolute maximum input power at receiver input | ANTP and ANTN pins in RX mode | | 10 | dBm |
| I _{I1} | DC current into any pin except ANTP, ANTN | | -10 | 10 | mA |
| I _{I2} | DC current into pins ANTP, ANTN | | -100 | 100 | mA |
| I _o | Output Current | | | 40 | mA |
| V _{ia} | Input voltage ANTP, ANTN pins | | -0.5 | 5.5 | V |
| | Input voltage digital pins | | -0.5 | 5.5 | V |
| V _{es} | Electrostatic handling | HBM | -2000 | 2000 | V |
| T _{amb} | Operating temperature | | -40 | 85 | °C |
| T _{stg} | Storage temperature | | -65 | 150 | °C |
| T _j | Junction Temperature | | | 150 | °C |



4.2. DC Characteristics

Supplies

| SYM | DESCRIPTION | CONDITION | MIN | TYP | MAX | UNIT |
|--|---|-------------------------------------|-----|------|-----|------|
| Conditions for all current and energy values unless otherwise specified are for the hardware configuration described in the AX-Sigfox Application Note: Sigfox Compliant Reference Design. | | | | | | |
| T _{AMB} | Operational ambient temperature | | -40 | 27 | 85 | °C |
| VDD _{IO} | I/O and voltage regulator supply voltage | | 1.8 | 3.0 | 3.6 | V |
| VDD _{IO,R1} | I/O voltage ramp for reset activation; Note 1 | Ramp starts at VDD_IO ≤ 0.1V | 0.1 | | | V/ms |
| VDD _{IO,R2} | I/O voltage ramp for reset activation; Note 1 | Ramp starts at 0.1V < VDD_IO < 0.7V | 3.3 | | | V/ms |
| I _{DS} | Deep sleep mode current | AT\$P=2 | | 100 | | nA |
| I _{SLP} | Sleep mode current | AT\$P=1 | | 1.3 | | μA |
| I _{STDBY} | Standby mode current | | | 0.5 | | mA |
| I _{RX,CONT} | Current consumption continuous RX | AT\$SR=1,1,-1 | | 10 | | mA |
| Q _{SFX_OOB_0} | Energy to send a Sigfox out of band message, 0dBm | AT\$S0 | | 0.12 | | C |
| Q _{SFX_BIT_0} | Energy to send a bit, 0dBm | AT\$SB=0 | | 0.08 | | C |
| Q _{SFX_BITDL_0} | Energy to send a bit with downlink receive, 0dBm | AT\$SB=0,1 | | 0.14 | | C |
| Q _{SFX_LFR_0} | Energy to send the longest possible Sigfox frame (12 byte) , 0dBm | AT\$SF=00112233445566778899aabb | | 0.27 | | C |
| Q _{SFX_LFRDL_0} | Energy to send the longest possible Sigfox frame (12 byte) with downlink receive, 0dBm | AT\$SF=00112233445566778899aabb,1 | | 0.27 | | C |
| Q _{SFX_OOB_14} | Energy to send a Sigfox out of band message, 14dBm | AT\$S0 | | 0.28 | | C |
| Q _{SFX_BIT_14} | Energy to send a bit, 14dBm | AT\$SB=0 | | 0.20 | | C |
| Q _{SFX_BITDL_14} | Energy to send a bit with downlink receive, 14dBm | AT\$SB=0,1 | | 0.35 | | C |
| Q _{SFX_LFR_14} | Energy to send the longest possible Sigfox frame (12 byte) , 14dBm | AT\$SF=00112233445566778899aabb | | 0.39 | | C |
| Q _{SFX_LFRDL_14} | Energy to send the longest possible Sigfox frame (12 byte) with downlink receive, 14dBm | AT\$SF=00112233445566778899aabb,1 | | 0.46 | | C |
| I _{TXMOD0AVG} | Modulated Transmitter Current, Notes 3, 4 | Pout=0 dBm; average | | 19.0 | | mA |
| I _{TXMOD14AVG} | Modulated Transmitter Current, Notes 3, 4 | Pout=14 dBm; average | | 49.0 | | mA |

Notes :

1. If VDD_IO ramps cannot be guaranteed, an external reset circuit is recommended, see the AX8052 Application Note: Power On Reset
2. Digital circuitry is functional down to typically 1 V.
3. The output power of the AX-Sigfox can be programmed in 1 dB steps from 0 dBm – 14 dBm. Current consumption values are given for a matching network that is optimized for 14 dBm output. 0 dBm transmission with typically 10 mA can be achieved with other networks that are optimized for 0 dBm operation.
4. Values in dBm are typical, the matching network is optimized for 14 dBm



Typical Current Waveform

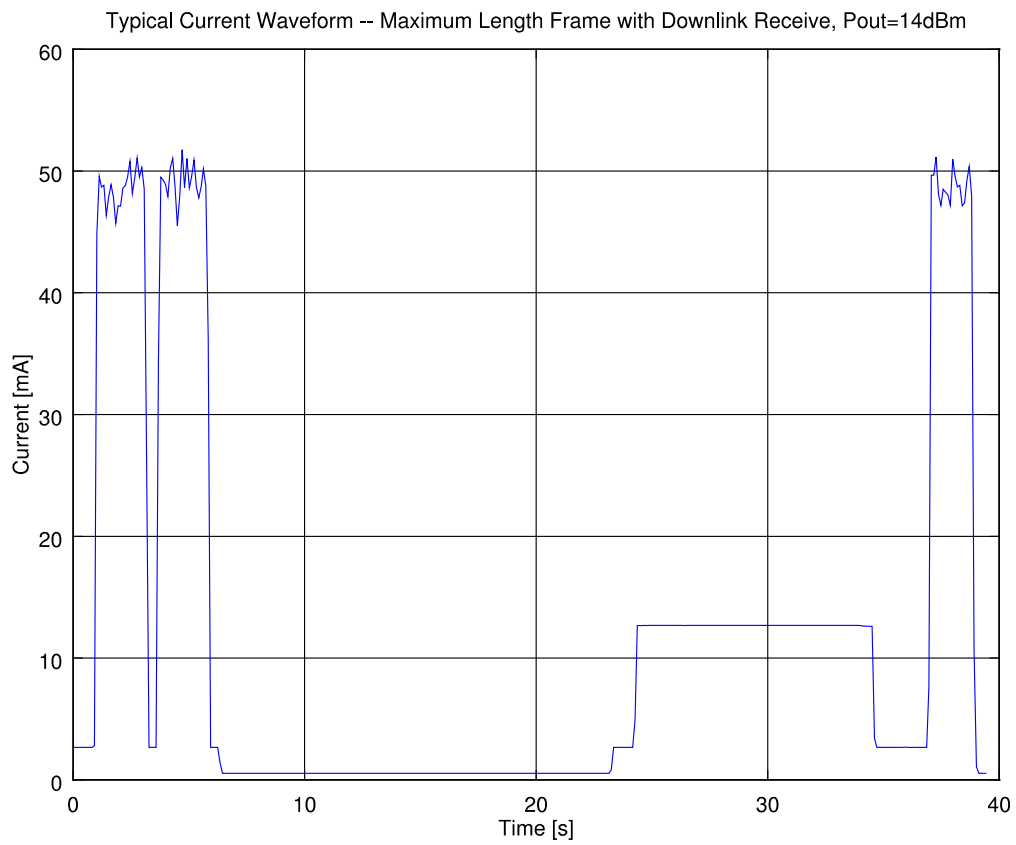


Figure 3 Typical current waveform for a maximum length frame with downlink receive at 14 dBm output power



Battery Life Examples

Scenario 1:

- CR2032 coin cell battery
- One OOB frame transmitter per day at Pout=0 dBm
- Device in Sleep
- Neglecting battery self discharge

| | | |
|--------------------------|----------------------|------------|
| CR2032 capacity | 225 mAh * 3600 s/h | 810 C |
| Sleep charge per day | 1.3 μ A * 86400s | 0.11 C/day |
| OOB frame transmission | | 0.12 C/day |
| Total Charge consumption | | 0.23 C/day |
| Battery life | | 9.6 Years |

Scenario 2:

- 2 AAA Alkaline batteries in series
- One OOB frame transmitter per day at Pout=14 dBm
- Four maximum length frames with downlink receive per day at Pout=14 dBm
- Device in Sleep
- Neglecting battery self discharge

| | | |
|----------------------------------|----------------------|------------|
| 2 AAA alkaline capacity | 1500 mAh * 3600 s/h | 5400 C |
| Sleep charge per day | 1.3 μ A * 86400s | 0.11 C/day |
| OOB frame transmission | | 0.28 C/day |
| Frame transmission with downlink | 4 * 0.46 C/day | 1.84 C/day |
| Total Charge consumption | | 2.26 C/day |
| Battery life | | 6.5 Years |



Logic

| SYMBOL | DESCRIPTION | CONDITION | MIN | TYP | MAX | UNIT |
|------------------------|---|---------------------|------|------|--------------|-----------|
| DIGITAL INPUTS | | | | | | |
| V_{T+} | Schmitt trigger low to high threshold point | $V_{DD_IO} = 3.3V$ | | 1.55 | | V |
| V_{T-} | Schmitt trigger high to low threshold point | | | 1.25 | | V |
| V_{IL} | Input voltage, low | | | | 0.8 | V |
| V_{IH} | Input voltage, high | | 2.0 | | | V |
| V_{IPA} | Input voltage range, GPIO[3:0] | | -0.5 | | V_{DD_IO} | V |
| V_{IPBC} | Input voltage range, GPIO[9:4], UARTRX | | -0.5 | | 5.5 | V |
| I_L | Input leakage current | | -10 | | 10 | μA |
| R_{PU} | Programmable Pull-Up Resistance | | | 65 | | $k\Omega$ |
| DIGITAL OUTPUTS | | | | | | |
| I_{OH} | Output Current, high Ports GPIO[9:0], UARTTX, TXLED, RXLED, TXLED, CPULED | $V_{OH} = 2.4V$ | 8 | | | mA |
| I_{OL} | Output Current, low GPIO[9:0], UARTTX, TXLED, RXLED, TXLED, CPULED | $V_{OL} = 0.4V$ | 8 | | | mA |
| I_{OZ} | Tri-state output leakage current | | -10 | | 10 | μA |

4.3. AC Characteristics

TCXO Reference Input

| SYMBOL | DESCRIPTION | CONDITION | MIN | TYP | MAX | UNIT |
|------------|----------------|---|-----|-----|-----|------|
| f_{TCXO} | TCXO frequency | <p>A passive network between the TCXO output and the pins CLKP and CLKN is required.</p> <p>For detailed TCXO network recommendations depending on the TCXO output swing refer to the AX5043 Application Note: Use with a TCXO Reference Clock.</p> <p>For TCXO recommendations see the Ax-Sigfox Application Note: Sigfox Compliant Reference Design</p> | | 48 | | MHz |



Transmitter

| SYMBOL | DESCRIPTION | CONDITION | MIN | TYP | MAX | UNIT |
|--|---|-----------------------|-----|---------|-----|------|
| Conditions for transmitter specifications unless otherwise specified with the antenna network from AX-Sigfox Application Note: Sigfox Compliant Reference Design and at 868.130 MHz. | | | | | | |
| SBR | Signal bit rate | | | 100 | | bps |
| PTX _{min} | Lowest Transmitter output power | AT\$CW=868130000,1,0 | | 0 | | dBm |
| PTX _{max} | Highest Transmitter output power | AT\$CW=868130000,1,14 | | 14 | | |
| PTX _{step} | Programming step size output power | | | 1 | | dB |
| dTX _{temp} | Transmitter power variation vs. temperature | -40 °C to +85 °C | | +/- 0.5 | | dB |
| dTX _{Vdd} | Transmitter power variation vs. VDD_IO | 1.8 to 3.6 V | | +/- 0.5 | | dB |
| PTX _{harm2} | Emission @ 2 nd harmonic | | | -51 | | dBc |
| PTX _{harm3} | Emission @ 3 rd harmonic | | | -63 | | |
| PTX _{harm4} | Emission @ 4 th harmonic | | | -84 | | |

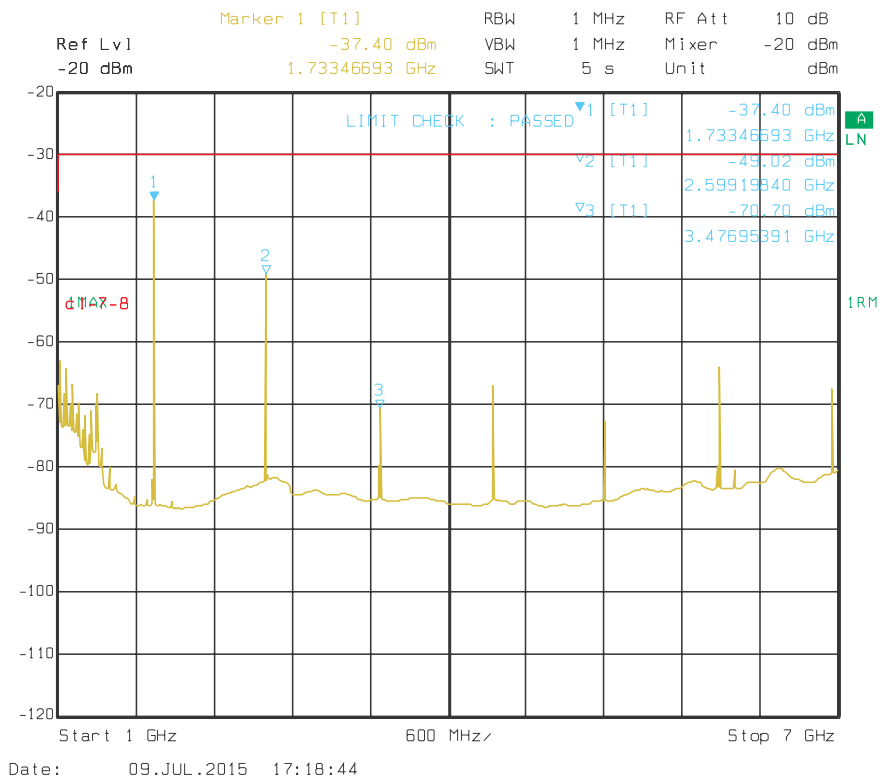


Figure 4 Typical spectrum with harmonics at 14 dBm output power



Receiver

| SYM | DESCRIPTION | CONDITION | MIN | TYP | MAX | UNIT |
|--|------------------------------|---|-----|------|-----|------|
| Conditions for transmitter specifications unless otherwise specified with the antenna network from AX-Sigfox Application Note: Sigfox Compliant Reference Design and at 869.525 MHz. | | | | | | |
| SBR | Signal bit rate | | | 600 | | bps |
| IS _{BER868} | | AT\$SB=x,1, AT\$SF=x,1, AT\$SR PER < 0.1 | | -126 | | dBm |
| BLK ₈₆₈ | Blocking at +/- 10MHz offset | Channel/Blocker @ PER = 0.1, wanted signal level is +3 dB above the typical sensitivity, the blocker signal is CW | | 78 | | dB |

ADC / Temperature Sensor

| SYMBOL | DESCRIPTION | CONDITION | MIN | TYP | MAX | UNIT |
|---------------------------------|--|-----------|------|-------|--------|------|
| ADCRES | ADC resolution | | | 10 | | Bits |
| V _{ADCREf} | ADC reference voltage | | 0.95 | 1 | 1.05 | V |
| Z _{ADCO0} | Input capacitance | | | | 2.5 | pF |
| DNL | Differential nonlinearity | | | +/- 1 | | LSB |
| INL | Integral non inearity | | | +/- 1 | | LSB |
| OFF | Offset | | | 3 | | LSB |
| GAIN_ERR | Gain error | | | 0.8 | | % |
| ADC in Differential Mode | | | | | | |
| V _{ABS_DIFF} | Absolute voltages & common mode voltage in differential mode at each input | | 0 | | VDD_IO | V |
| V _{FS_DIFF01} | Full swing input for differential signals | Gain x1 | -500 | | 500 | mV |
| V _{FS_DIFF10} | | Gain x10 | -50 | | 50 | mV |
| ADC in Single Ended Mode | | | | | | |
| V _{MID_SE} | Mid code input voltage in single ended mode | | | 0.5 | | V |
| V _{IN_SE00} | Input voltage in single ended mode | | 0 | | VDD_IO | V |
| V _{FS_SE01} | Full swing input for single ended signals | Gain x1 | 0 | | 1 | V |
| Temperature Sensor | | | | | | |
| T _{RNG} | Temperature range | AT\$T? | -40 | | 85 | °C |
| T _{ERR_CAL} | Temperature error | AT\$T? | -2 | | +2 | °C |

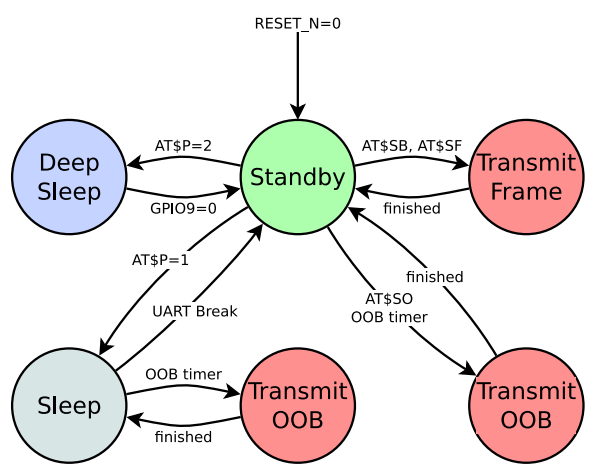


5. Command Interface

5.1. Serial Parameters: 9600,8,N,1

The **AX-Sigfox** uses the UART (pins UARTTX, UARTRX) to communicate with a host and uses a bitrate of **9600 baud**, no parity, 8 data bits and one stop bit.

5.2. Power Modes



Standby

After Power-Up and after finishing a SIGFOX transmission, **AX-Sigfox** enters Standby mode. In Standby mode, **AX-Sigfox** listens on the UART for commands from the host. Also, OOB frames are transmitted whenever the OOB timer fires. To conserve power, the **AX-Sigfox** can be put into Sleep or turned off (Deep Sleep) completely.

Sleep

The command **AT\$P=1** is used to put the **AX-Sigfox** into Sleep mode. In this mode, only the wakeup timer for out-of-band messages is still running. To wake the **AX-Sigfox** up from Sleep mode toggle the serial UARTRX pin, e.g. by sending a break (break is an RS232 framing violation, i.e. at least 10 bit durations low). When an Out of Band (OOB) message is due, **AX-Sigfox** automatically wakes up to transmit the message, and then returns to Sleep mode.

Deep Sleep

In Deep Sleep mode, the **AX-Sigfox** is completely turned off and only draws negligible leakage current. Deep Sleep mode can be activated with **AT\$P=2**. To wake-up from Deep Sleep mode, GPIO9 is pulled to GND.



When using Deep Sleep mode, keep two things in mind: Everything is turned off, timers are not running at all and all settings will be lost (use **AT\$WR** to save settings to flash before entering Deep Sleep mode). Out-of-band messages will therefore not be sent. The pins states are frozen in Deep Sleep mode. The user must ensure that this will not result in condition which would draw a lot of current.

5.3. AT Commands

Numerical Syntax

```

hexdigit ::= [0-9A-Fa-f]
hexnum  ::= "0x" hexdigit+
decnum  ::= "0" | [1-9] [0-9]*
octnum  ::= "0" [0-7]+
binnum  ::= "0b" [01]+
bit     ::= [01]
optnum  ::= "-1"
frame   ::= (hexdigit hexdigit)+
uint    ::= hexnum | decnum | octnum | binnum
uint_opt ::= uint | optnum

```

Command Syntax

A command starts with 'AT' (everything is case sensitive!), continues with the actual command followed by parameters (if any) and ends with any kind of whitespace (space, tab, newline etc.)

If incorrect syntax is detected ("parsing error") all input is ignored up until the next whitespace character.

Also note that any number can be entered in any format (Hexadecimal, Decimal, Octal and binary) by adding the corresponding prefix ('0x', '0', '0b'). The only exception is the 'Send Frame' command (**AT\$SF**) which expects a list of hexadecimal digits without any prefix.

Return Codes

A successful command execution is indicated by sending 'OK'. If a command returns a value (e.g. by querying a register) only the value is returned.

Examples

Bold text is sent to **AX-Sigfox**.

```

AT$I=0
AXSEM AT Command Interface

```

Here, we execute command 'I' to query some general information.

```

AT$SF=aabb1234
OK

```



This sends a Sigfox frame containing { 0x00 : 0x11 : 0x22 : 0x33 : 0x44 }, then waits for a downlink response telegram, which in this example contains { 0xAA : 0xBB : 0xCC : 0xDD }.

```
AT$SF=0011223344,1
OK
RX=AA BB CC DD
```

This sends a Sigfox frame containing { 0xAA : 0xBB : 0x12 : 0x34 } without waiting for a response telegram.

```
AT$CB=0xAA,1
OK
```

The 'CB' command sends out a continuous pattern of bits, in this case 0xAA = 0b10101010.

```
AT$P=1
OK
```

This transitions the device into sleep mode. Out-of-band transmissions will still be triggered. The UART is powered down. The device can be woken up by a low level on the UART signal, i.e. by sending break.

Commands

| Command | Name | Description |
|--------------------|-----------------------------------|--|
| AT | Dummy command | Just returns 'OK' and does nothing else. Can be used to check communication. |
| AT\$SB=bit[,bit] | Send bit | Send a bit status (0 or 1). Optional bit flag indicates if AX-Sigfox should receive a downlink frame. |
| AT\$SF=frame[,bit] | Send frame | Send payload data, 1 to 12 bytes. Optional bit flag indicates if AX-Sigfox should receive a downlink frame. |
| AT\$SO | Manually send out of band message | Send the out-of-band message. |
| AT\$uint? | Get register | Query a specific configuration register's value. See Chapter "Registers" for a list of registers. |
| AT\$uint=uint | Set register | Change a configuration register. |
| AT\$IF=uint | Set TX frequency | Set the output carrier macro channel for Sigfox frames. |
| AT\$IF? | Get TX frequency | Get the currently chosen TX frequency. |
| AT\$DR=uint | Set RX frequency | Set the reception carrier macro channel for Sigfox frames. |
| AT\$DR? | Get RX frequency | Get the currently chosen RX frequency. |



| Command | Name | Description | | | | | | | | | | | | | | | | |
|---|--------------------------------|---|---------|-------|-------------|---------|-----------|--------------------------|--|--|------|------|--------------------------------------|--|-------|------|---------------|----|
| AT\$CW= <i>uint,bit</i> <i>[,uint_opt]</i> | Continuous wave | <p>To run emission tests for Sigfox certification it is necessary to send a continuous wave, i.e. just the base frequency without any modulation.</p> <p>Parameters:</p> <table border="1"> <thead> <tr> <th>Name</th> <th>Range</th> <th>Description</th> <th>Default</th> </tr> </thead> <tbody> <tr> <td>frequency</td> <td>800000000 – 999999999, 0</td> <td>Continuous wave frequency in Hz. Use 868130000 for Sigfox or 0 to keep previous frequency.</td> <td></td> </tr> <tr> <td>mode</td> <td>0, 1</td> <td>Enable or disable carrier wave.</td> <td></td> </tr> <tr> <td>power</td> <td>0-14</td> <td>dBm of signal</td> <td>14</td> </tr> </tbody> </table> | Name | Range | Description | Default | frequency | 800000000 – 999999999, 0 | Continuous wave frequency in Hz. Use 868130000 for Sigfox or 0 to keep previous frequency. | | mode | 0, 1 | Enable or disable carrier wave. | | power | 0-14 | dBm of signal | 14 |
| Name | Range | Description | Default | | | | | | | | | | | | | | | |
| frequency | 800000000 – 999999999, 0 | Continuous wave frequency in Hz. Use 868130000 for Sigfox or 0 to keep previous frequency. | | | | | | | | | | | | | | | | |
| mode | 0, 1 | Enable or disable carrier wave. | | | | | | | | | | | | | | | | |
| power | 0-14 | dBm of signal | 14 | | | | | | | | | | | | | | | |
| AT\$CB= <i>uint_opt,bit</i> | Test mode: TX constant byte | <p>For emission testing it is useful to send a specific bit pattern. The first parameter specifies the byte to send. Use '-1' for a (pseudo-) random pattern.</p> <p>Parameters:</p> <table border="1"> <thead> <tr> <th>Name</th> <th>Range</th> <th>Description</th> <th>Default</th> </tr> </thead> <tbody> <tr> <td>pattern</td> <td>0-255, -1</td> <td>Byte to send. Use '-1' for a (pseudo-) random pattern</td> <td></td> </tr> <tr> <td>mode</td> <td>0, 1</td> <td>Enable or disable pattern test mode.</td> <td></td> </tr> </tbody> </table> | Name | Range | Description | Default | pattern | 0-255, -1 | Byte to send. Use '-1' for a (pseudo-) random pattern | | mode | 0, 1 | Enable or disable pattern test mode. | | | | | |
| Name | Range | Description | Default | | | | | | | | | | | | | | | |
| pattern | 0-255, -1 | Byte to send. Use '-1' for a (pseudo-) random pattern | | | | | | | | | | | | | | | | |
| mode | 0, 1 | Enable or disable pattern test mode. | | | | | | | | | | | | | | | | |
| AT\$T? | Get temperature | Measure internal temperature and return it in 1/10 th of a degree Celsius. | | | | | | | | | | | | | | | | |
| AT\$V? | Get voltages | Return current voltage and voltage measured during the last transmission in mV. | | | | | | | | | | | | | | | | |



| Command | Name | Description |
|-------------------------|----------------|---|
| <code>AT\$I=uint</code> | Information | <p>Display various product information:</p> <ul style="list-style-type: none"> 0: Software Name & Version Example Response: AX-Sigfox 1.0.6-ETSI 1: Contact Details Example Response: support@axsem.com 2: Silicon revision lower byte Example Response: 8F 3: Silicon revision upper byte Example Response: 00 4: Major Firmware Version Example Response: 1 5: Minor Firmware Version Example Response: 0 6: Firmware Revision Example Response: 3 7: Firmware Variant (Frequency Band etc. (EU/US)) Example Response: ETSI 8: Firmware VCS Version Example Response: v1.0.2-36 9: SIGFOX Library Version Example Response: DL0-1.4 10: Device ID Example Response: 00012345 11: PAC Example Response: 0123456789ABCDEF |
| <code>AT\$P=uint</code> | Set power mode | <p>To conserve power, the AX-Sigfox can be put to sleep manually. Depending on power mode, you will be responsible for waking up the AX-Sigfox again!</p> <ul style="list-style-type: none"> 0: software reset (settings will be reset to values in flash) 1: sleep (send a break to wake up) 2: deep sleep (toggle GPIO9 or RESET_N pin to wake up; the AX-Sigfox is not running and all settings will be reset!) |
| <code>AT\$WR</code> | Save config | <p>Write all settings to flash (RX/TX frequencies, registers) so that they survive reset/deep sleep or loss of power.</p> <p>Use <code>AT\$P=0</code> to reset the AX-Sigfox and load settings from flash.</p> |



| Command | Name | Description | | | | | | | | | | | | | | | | | | | | | | |
|-----------------------------------|---|--|------|-------------|----|----------------|----|-----------------|----|-----------------------------|----|---------------------------|----|---|----|---|----|---------|----|---------|----|---------|----|---------|
| AT:Pn? | Get GPIO pin | <p>Return the setting of the GPIO pin n; n can range from 0 to 9. A character string is returned describing the mode of the pin, followed by the actual value. If the pin is configured as analog pin, then the voltage (range 0...1 V) is returned. The mode characters have the following meaning:</p> <table border="1"> <thead> <tr> <th>Mode</th> <th>Description</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>Pin drives low</td> </tr> <tr> <td>1</td> <td>Pin drives high</td> </tr> <tr> <td>Z</td> <td>Pin is high impedance input</td> </tr> <tr> <td>U</td> <td>Pin is input with pull-up</td> </tr> <tr> <td>A</td> <td>Pin is analog input (GPIO pin 0...3 only)</td> </tr> <tr> <td>T</td> <td>Pin is driven by clock or DAC (GPIO pin 0 and 4 only)</td> </tr> </tbody> </table> <p>The default mode after exiting reset is U on all GPIO pins.</p> | Mode | Description | 0 | Pin drives low | 1 | Pin drives high | Z | Pin is high impedance input | U | Pin is input with pull-up | A | Pin is analog input (GPIO pin 0...3 only) | T | Pin is driven by clock or DAC (GPIO pin 0 and 4 only) | | | | | | | | |
| Mode | Description | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | Pin drives low | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Pin drives high | | | | | | | | | | | | | | | | | | | | | | | |
| Z | Pin is high impedance input | | | | | | | | | | | | | | | | | | | | | | | |
| U | Pin is input with pull-up | | | | | | | | | | | | | | | | | | | | | | | |
| A | Pin is analog input (GPIO pin 0...3 only) | | | | | | | | | | | | | | | | | | | | | | | |
| T | Pin is driven by clock or DAC (GPIO pin 0 and 4 only) | | | | | | | | | | | | | | | | | | | | | | | |
| AT:Pn=? | Get GPIO pin range | <p>Print a list of possible modes for a pin. The table below lists the response.</p> <table border="1"> <thead> <tr> <th>Pin</th> <th>Modes</th> </tr> </thead> <tbody> <tr> <td>P0</td> <td>0,1,Z,U,A,T</td> </tr> <tr> <td>P1</td> <td>0,1,Z,U,A</td> </tr> <tr> <td>P2</td> <td>0,1,Z,U,A</td> </tr> <tr> <td>P3</td> <td>0,1,Z,U,A</td> </tr> <tr> <td>P4</td> <td>0,1,Z,U,T</td> </tr> <tr> <td>P5</td> <td>0,1,Z,U</td> </tr> <tr> <td>P6</td> <td>0,1,Z,U</td> </tr> <tr> <td>P7</td> <td>0,1,Z,U</td> </tr> <tr> <td>P8</td> <td>0,1,Z,U</td> </tr> <tr> <td>P9</td> <td>0,1,Z,U</td> </tr> </tbody> </table> | Pin | Modes | P0 | 0,1,Z,U,A,T | P1 | 0,1,Z,U,A | P2 | 0,1,Z,U,A | P3 | 0,1,Z,U,A | P4 | 0,1,Z,U,T | P5 | 0,1,Z,U | P6 | 0,1,Z,U | P7 | 0,1,Z,U | P8 | 0,1,Z,U | P9 | 0,1,Z,U |
| Pin | Modes | | | | | | | | | | | | | | | | | | | | | | | |
| P0 | 0,1,Z,U,A,T | | | | | | | | | | | | | | | | | | | | | | | |
| P1 | 0,1,Z,U,A | | | | | | | | | | | | | | | | | | | | | | | |
| P2 | 0,1,Z,U,A | | | | | | | | | | | | | | | | | | | | | | | |
| P3 | 0,1,Z,U,A | | | | | | | | | | | | | | | | | | | | | | | |
| P4 | 0,1,Z,U,T | | | | | | | | | | | | | | | | | | | | | | | |
| P5 | 0,1,Z,U | | | | | | | | | | | | | | | | | | | | | | | |
| P6 | 0,1,Z,U | | | | | | | | | | | | | | | | | | | | | | | |
| P7 | 0,1,Z,U | | | | | | | | | | | | | | | | | | | | | | | |
| P8 | 0,1,Z,U | | | | | | | | | | | | | | | | | | | | | | | |
| P9 | 0,1,Z,U | | | | | | | | | | | | | | | | | | | | | | | |
| AT:Pn=mode | Set GPIO pin | <p>Set the GPIO pin mode. For a list of the modes see the command AT:Pn?</p> | | | | | | | | | | | | | | | | | | | | | | |
| AT:ADC Pn[-Pn[(1V 10V)]]? | Get GPIO pin analog voltage | <p>Measure the voltage applied to a GPIO pin. The command also allows measurement of the voltage difference across two GPIO pins. In differential mode, the full scale range may also be specified as 1 V or 10 V. Note however that the pin input voltages must not exceed the range 0..VDD_IO. The command returns the result as fraction of the full scale range (1V if none is specified). The GPIO pins referenced should be initialized to analog mode before issuing this command.</p> | | | | | | | | | | | | | | | | | | | | | | |



| Command | Name | Description | | | | | | | | | | | | | | | |
|---|-----------------------------|--|------|-----------------|-------------|---|--------|--------|---|--------|-----------|---|----------|--------|---|----------|-----------|
| AT:SPI [(A B C D)] = <i>bytes</i> | SPI transaction | <p>This command clocks out <i>bytes</i> on the SPI port. The clock frequency is 312.5kHz. The command returns the bytes read on MISO during output. Optionally the clocking mode may be specified (default is A):</p> <table border="1"> <thead> <tr> <th>Mode</th> <th>Clock Inversion</th> <th>Clock Phase</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>normal</td> <td>normal</td> </tr> <tr> <td>B</td> <td>normal</td> <td>alternate</td> </tr> <tr> <td>C</td> <td>inverted</td> <td>normal</td> </tr> <tr> <td>D</td> <td>inverted</td> <td>alternate</td> </tr> </tbody> </table> <p>Note that SEL, if needed, is not generated by this command, and must instead be driven using standard GPIO commands (AT:Pn=0 1).</p> | Mode | Clock Inversion | Clock Phase | A | normal | normal | B | normal | alternate | C | inverted | normal | D | inverted | alternate |
| Mode | Clock Inversion | Clock Phase | | | | | | | | | | | | | | | |
| A | normal | normal | | | | | | | | | | | | | | | |
| B | normal | alternate | | | | | | | | | | | | | | | |
| C | inverted | normal | | | | | | | | | | | | | | | |
| D | inverted | alternate | | | | | | | | | | | | | | | |
| AT:CLK=freq, reffreq | Set clock generator | <p>Output a square wave on the pin(s) set to T mode. The frequency of the square wave is $\frac{freq}{2^{16}} \times reffreq$. Possible values for reffreq are 20000000, 10000000, 5000000, 2500000, 1250000, 625000, 312500, 156250. Possible values if freq are 0...65535.</p> | | | | | | | | | | | | | | | |
| AT:CLK=OFF | Turn off clock generator | Switch off the clock generator. | | | | | | | | | | | | | | | |
| AT:CLK? | Get clock generator | Return the settings of the clock generator. Two numbers are returned, freq and reffreq. | | | | | | | | | | | | | | | |
| AT:DAC=value | Set $\Sigma\Delta$ DAC | <p>Output a $\Sigma\Delta$ DAC value on the pin(s) set to T mode. Parameter value may be in the range $-32768..32767$. The average output voltage is $(\frac{1}{2} + \frac{value}{2^{17}}) \times VDD$.</p> <p>An external low pass filter is needed to get smooth output voltages. The modulation frequency is 20 MHz. A possible low pass filter choice is a simple RC low pass filter with R=10kΩ and C=1μF</p> | | | | | | | | | | | | | | | |
| AT:DAC=OFF | Turn off $\Sigma\Delta$ DAC | Switch off the DAC. | | | | | | | | | | | | | | | |
| AT:DAC? | Get $\Sigma\Delta$ DAC | Return the DAC value. | | | | | | | | | | | | | | | |



Registers

| Number | Name | Description | Default | Range | Unit |
|--------|--------------------|---|---------|-------|-------|
| 300 | Out of band period | AX-Sigfox sends periodic static messages to indicate that they are alive. Set to 0 to disable. | 24 | 0-24 | hours |
| 302 | Power level | The output power of the radio. | 14 | 0-14 | dBm |



6. Application Information

6.1. Typical Application Diagrams

Typical Sigfox Application Diagram

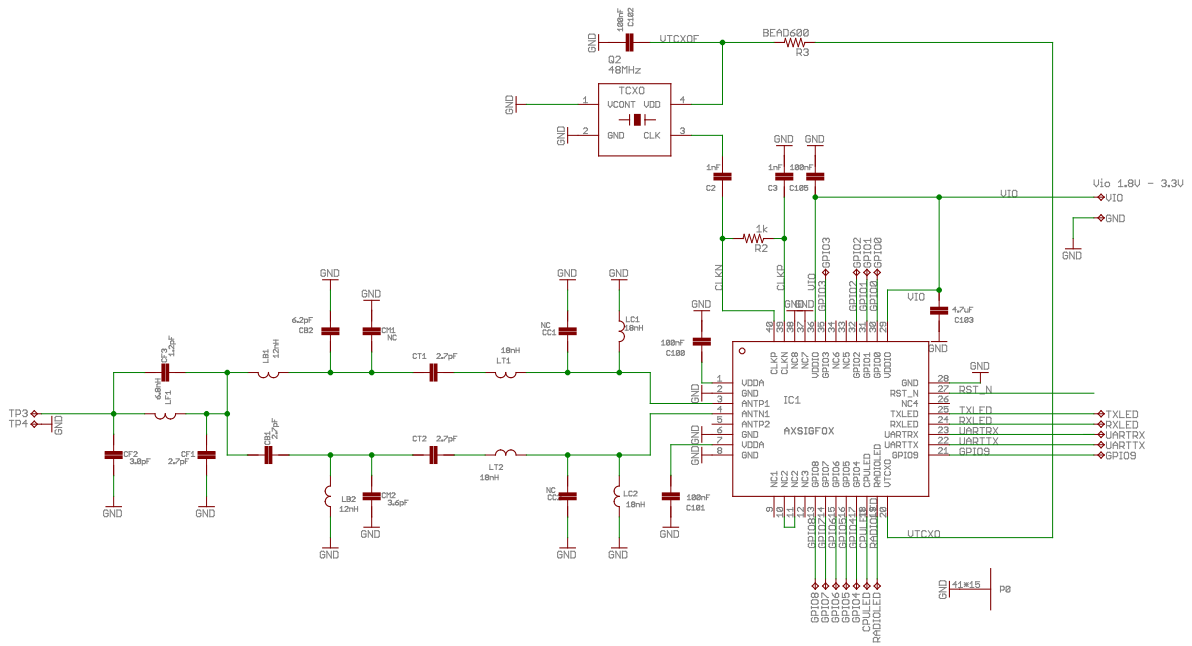


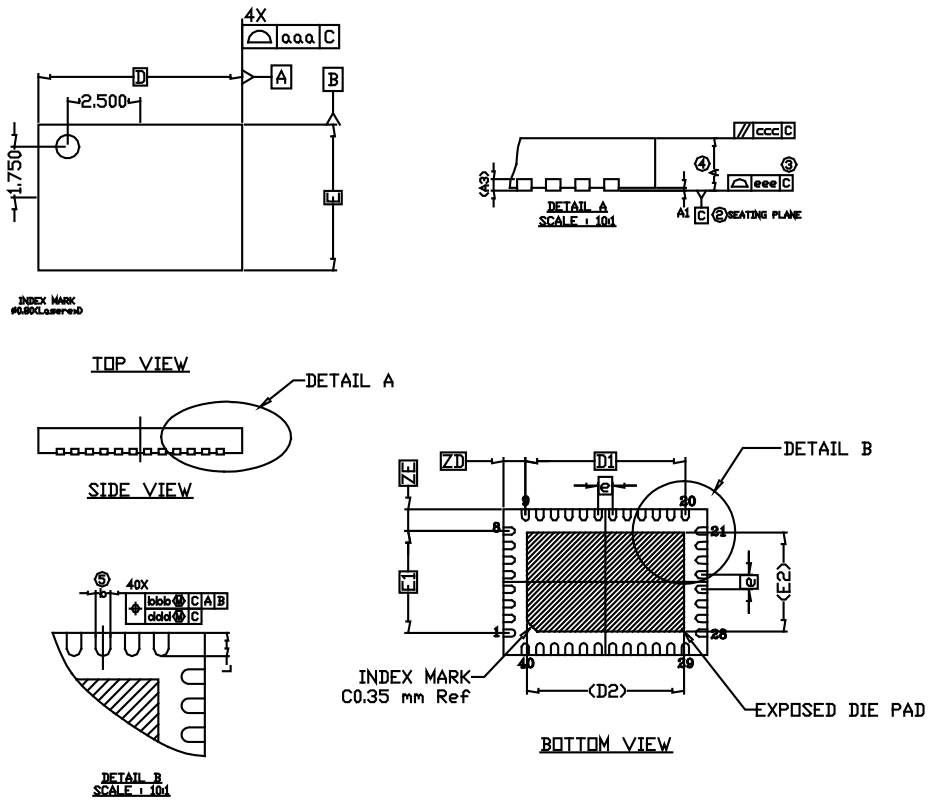
Figure 5 Typical application diagram

For detailed application configuration and BOM see the AX-Sigfox Application Note: Sigfox Compliant Reference Design.



7. QFN40 Package Information

7.1. Package Outline QFN40 5x7mm



| DIMENSIONAL REFERENCES | | | |
|------------------------|----------|------|------|
| REF. | Min. | Nom. | Max. |
| A | 0.80 | 0.90 | 1.00 |
| A1 | 0 | 0.02 | 0.05 |
| A3 | 0.20 Ref | | |
| D | 7.00 BSC | | |
| D1 | 5.50 BSC | | |
| E | 5.00 BSC | | |
| E1 | 3.50 BSC | | |
| e | 0.50 BSC | | |
| ZD | 0.75 BSC | | |
| ZE | 0.75 BSC | | |

| TOLERANCE OF FORM AND POSITION | |
|--------------------------------|------|
| aaa | 0.15 |
| bbb | 0.10 |
| ccc | 0.10 |
| ddd | 0.05 |
| eee | 0.08 |

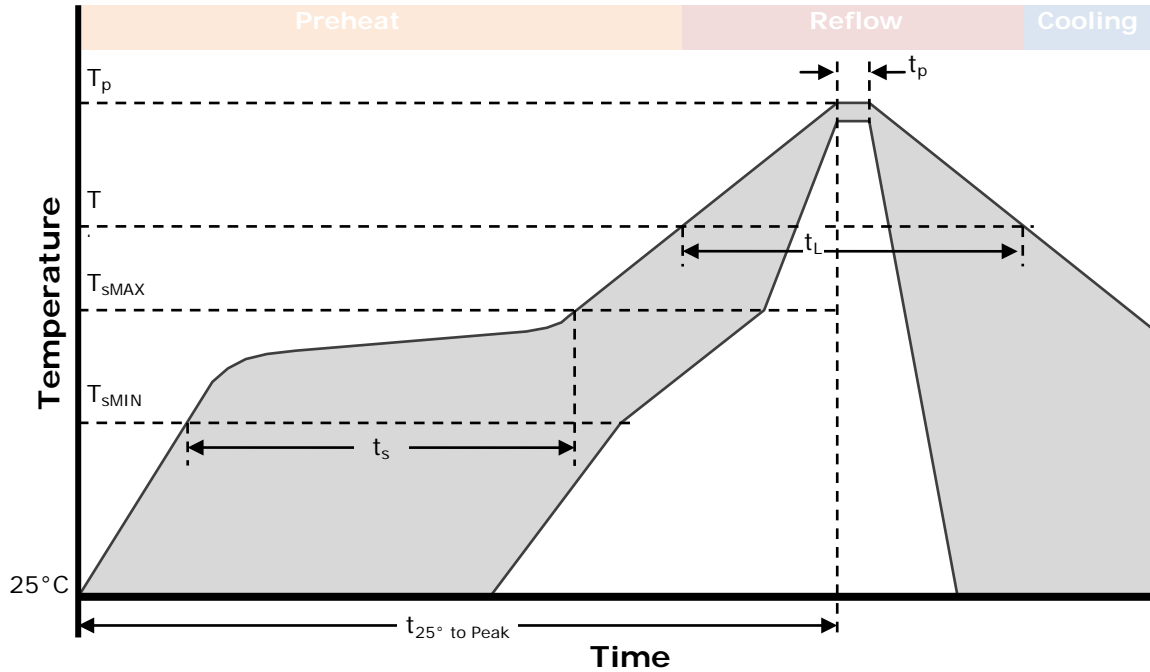
| TOLERANCE OF FORM AND POSITION | | | | |
|--------------------------------|--------|------|------|------|
| LF REF#. | Symbol | Min | Nom | Max |
| FR9020 | b | 0.18 | 0.25 | 0.30 |
| | L | 0.30 | 0.40 | 0.50 |
| | D2 | 5.30 | 5.40 | 5.50 |
| | E2 | 3.30 | 3.40 | 3.50 |

Notes

- 'e' represents the basic terminal pitch
- Datum 'C' is the mounting surface with which the package is in contact.
- '3' specifies the vertical shift of the flat part of each terminal from the mounting surface.
- Dimension 'A' includes package warpage.
- Dimension 'b' applies to the metallised terminal and is measured between 0.15 to 0.30 mm from the terminal tip. If the terminal has the optional radius on the other end of the terminal, the dimension 'b' should not be measured in the radius arc
- Package dimension take reference from JEDEC MO-220
- RoHS



7.2. QFN40 Soldering Profile



| Profile Feature | | Pb-Free Process |
|--|--------------------------|-----------------|
| Average Ramp-Up Rate | | 3 °C/sec max. |
| Preheat Preheat | | |
| Temperature Min | T _{sMIN} | 150°C |
| Temperature Max | T _{sMAX} | 200°C |
| Time (T _{sMIN} to T _{sMAX}) | t _s | 60 – 180 sec |
| Time 25°C to Peak Temperature | T _{25° to Peak} | 8 min max. |
| Reflow Phase | | |
| Liquidus Temperature | T _L | 217°C |
| Time over Liquidus Temperature | t _L | 60 – 150 sec |
| Peak Temperature | t _p | 260°C |
| Time within 5°C of actual Peak Temperature | T _p | 20 – 40 sec |
| Cooling Phase | | |
| Ramp-down rate | | 6°C/sec max. |

Notes:

All temperatures refer to the top side of the package, measured on the package body surface.



7.3. QFN40 Recommended Pad Layout

1. PCB land and solder masking recommendations are shown in Figure 6.

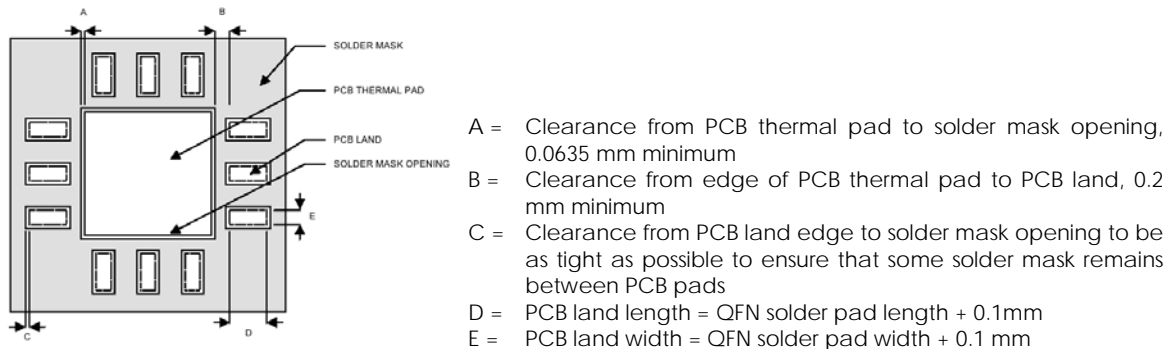


Figure 6 PCB land and solder mask recommendations

2. Thermal vias should be used on the PCB thermal pad (middle ground pad) to improve thermal conductivity from the device to a copper ground plane area on the reverse side of the printed circuit board. The number of vias depends on the package thermal requirements, as determined by thermal simulation or actual testing.
3. Increasing the number of vias through the printed circuit board will improve the thermal conductivity to the reverse side ground plane and external heat sink. In general, adding more metal through the PCB under the IC will improve operational heat transfer, but will require careful attention to uniform heating of the board during assembly.

7.4. Assembly Process

Stencil Design & Solder Paste Application

1. Stainless steel stencils are recommended for solder paste application.
2. A stencil thickness of 0.125 – 0.150 mm (5 – 6 mils) is recommended for screening.
3. For the PCB thermal pad, solder paste should be printed on the PCB by designing a stencil with an array of smaller openings that sum to 50% of the QFN exposed pad area. Solder paste should be applied through an array of squares (or circles) as shown in Figure 7.
4. The aperture opening for the signal pads should be between 50-80% of the QFN pad area as shown in Figure 8.
5. Optionally, for better solder paste release, the aperture walls should be trapezoidal and the corners rounded.
6. The fine pitch of the IC leads requires accurate alignment of the stencil and the printed circuit board. The stencil and printed circuit assembly should be aligned to within + 1 mil prior to application of the solder paste.
7. No-clean flux is recommended since flux from underneath the thermal pad will be difficult to clean if water-soluble flux is used.

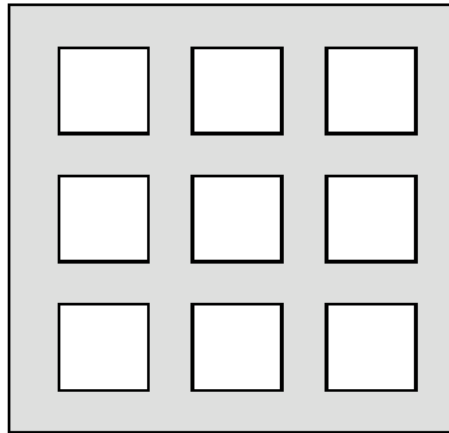


Figure 7 Solder paste application on exposed pad

Minimum
50% coverage

62% coverage

Maximum
80% coverage

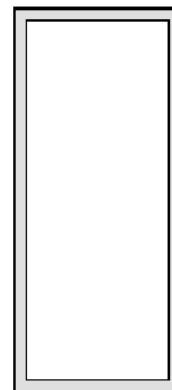
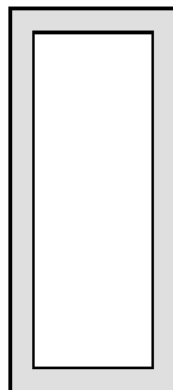
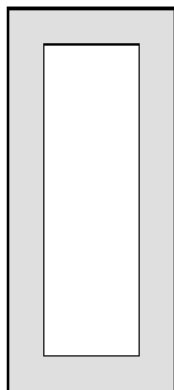


Figure 8 Solder paste application on pins



8. Device Versions

| Version | Device Marking | AT\$I=0 | AT\$I=2 | AT\$I=3 |
|---------|-----------------------------------|----------------------|---------|---------|
| 1 | AX-Sigfox-1 or AX8052F143-2 | AX-Sigfox 1.0.6-ETSI | 0x8F | 0x51 |

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