NXP Semiconductors, Inc.
User's Guide

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IoT Low Power Sensor Node Reference Design Board

User's Guide

1. Introduction

This manual describes the NXP reference design board IoT Low Power Sensor Node. The IoT Low Power Sensor Node circuit board provides a diverse reference design with all necessary I/O connections to use as a self-contained board or for connection to an external application.

The IoT Low Power Sensor Node board is built around the NXP MKW24D512. The MKW24D512 wireless MCU is a 2.4 GHz Industrial, Scientific, and Medical (ISM) single-chip device intended for the IEEE® Std. 802.15.4, including Thread©, ZigBee Pro, ZigBee RF4CE, and IPv6/6loWPAN protocols.

The IoT Low Power Sensor Node board contains the MKW24D512 transceiver that works in conjunction with a software stack to implement an IEEE Std. 802.15.4 platform solution.

1.1. Audience

This manual is intended for system designers and system engineers.

Contents

2. Board overview and description

The IoT Low Power Sensor Node board is based on the NXP MKW24D512 transceiver (MKW24); it incorporates a complete low-power IEEE Std. 802.15.4, 2.4 GHz radio frequency transceiver.

The IoT Low Power Sensor Node platform contains the MKW24D512 device with 32 MHz reference oscillator crystal, RF circuitry including antenna, a 6-axis sensor with integrated linear accelerometer and magnetometer, and supporting circuitry in a reduced form factor board. The board is a standalone and supports applications development with the NXP IEEE Std. 802.15.4 protocol stack.

2.1. Board features

The IoT Low Power Sensor Node reference design board contains the MKW24D512 device and is used to demonstrate and evaluate the available features of the MKW24D512 in a reduced form factor board with a specific application taking advantage of the MKW24D512 low-power capabilities powered by a 3V-1200 mAh battery.

0 shows the IoT Low Power Sensor Node reference design board.

Figure 1. IoT Low Power Sensor Node reference design board

The IoT Low Power Sensor Node reference design board includes the following features:

- The NXP low-power Kinetis MKW24D512 transceiver
- Full IEEE Std. 802.15.4 compliant wireless node; ZigBee and Thread capable
- Reference design area with small footprint, low-cost RF node
  - RF circuitry includes a Balun to convert the differential I/O pin of the MKW24D512 transceiver to single-ended for on-board signal routing
  - Low off-chip component count
  - Programmable output power from -35 dBm to +8 dBm
  - Receiver sensitivity: -102 dBm, typical (@1% PER for 20 byte payload packet)
- Integrated PCB meander horizontal antenna
- 32 MHz reference oscillator
- 32 kHz clock oscillator
- 2.4 GHz frequency operation (ISM Band)
- Cortex 10-pin (0.05 inch) JTAG/SWD debug port for target MCU
- 1 RGB LED indicator
- 2 interrupt push button switches
- 1 FXOS87000CQ combo sensor
- 1 battery (1/2 AA) 3.6V 1200 mAh
- 1 On/Off switch

0 shows the main board features of the NXP IoT Low Power Sensor Node board.

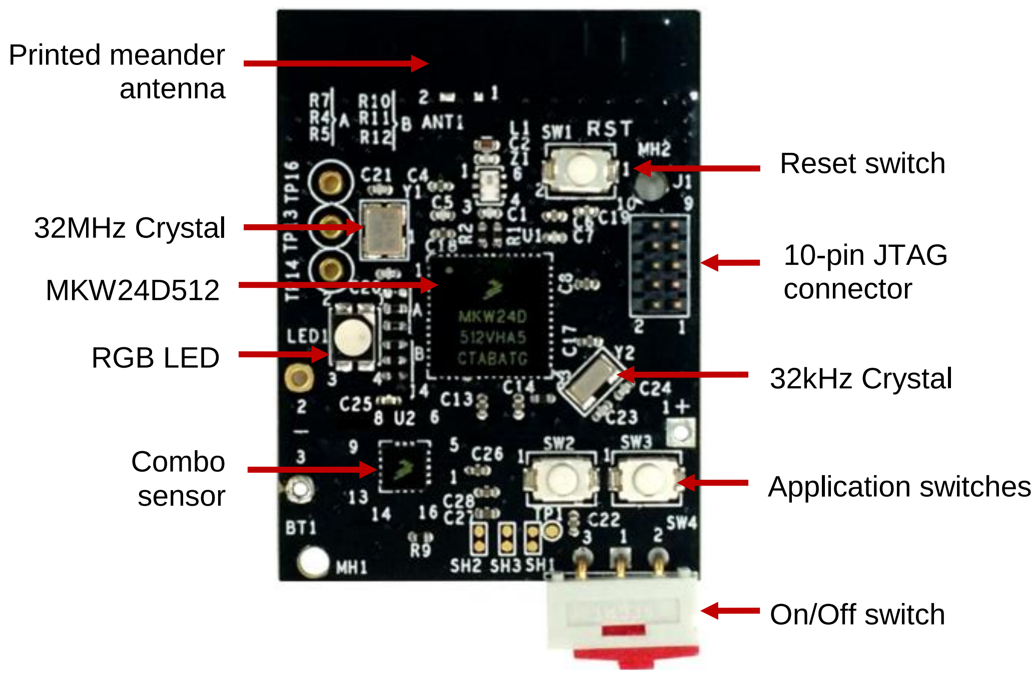

Figure 2. IoT Low Power Sensor Node reference design components

3. IoT Low Power Sensor Node reference design board

The IoT Low Power Sensor Node board is a reference design based on the NXP MKW24D512 transceiver. The core device is accompanied by a 32 MHz reference oscillator crystal, RF circuitry including a PCB antenna (and supporting circuitry), accelerometer/magnetometer sensor, and RGB LED in a small form factor battery-operated board. 0 shows a simple block diagram.

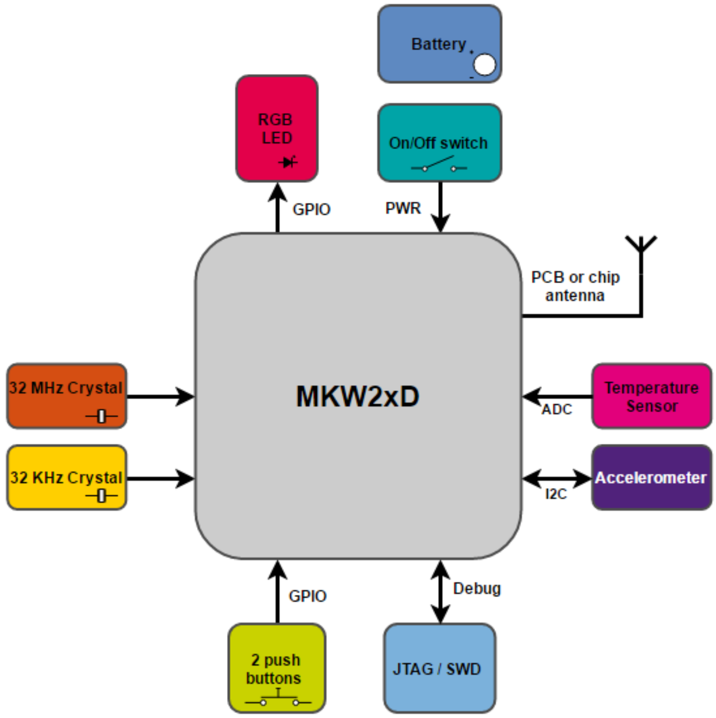

Figure 3. IoT Low Power Sensor Node block diagram

3.1. PCB Features

The IoT Low Power Sensor Node board provides the following features:

- 2-layer metal, 0.062 inch thick FR4 board
- LGA footprint and power supply bypass
- Printed metal meander antenna
- 32 MHz reference oscillator crystal
- 32.768 kHz crystal provided for optional timing oscillator
- Combo sensor, 6-axis sensor with integrated linear accelerometer and magnetometer
- 1 battery (1/2 AA) 3.6 V 1200 mAh
- 1 on/off switch
- 2 application switches
- Small RF footprint

3.2. Functional description

The IoT Low Power Sensor Node board is built around the NXP MKW24D512 transceiver in a 63-pin (56-pin usable) LGA package. The MKW24D512 device features an IEEE Std. 802.15.4 radio frequency transceiver and a Kinetis family low-power, mixed-signal ARM® Cortex®-M4 MCU in a single package. This two-layer board is intended as a reference design platform and/or as a building block for application development. The principal purpose of the reference design board is to demonstrate some of the available features of the MKW24D512 transceiver in a reduced form factor board with a specific application taking advantage of the MKW24D512 transceiver’s low-power capabilities powered by a 3V-1200 mAh battery.

3.2.1. RF performance and considerations

The IoT Low Power Sensor Node reference design board includes a 1 mW nominal output PA with internal voltage controlled oscillator (VCO), integrated transmit/receive switch, on-board power supply regulation, and full spread-spectrum encoding and decoding. Key specifications for the MKW24D512 transceiver are:

- Programmable output power from -35 dBm to +8 dBm MCU output pins
- Typical sensitivity is -102 dBm (@1% PER for 20 byte payload packet)
- Frequency range is 2360 MHz to 2480 MHz
- Differential bidirectional RF I/O port with integrated transmit/receive switch
- Meander horizontal printed metal antenna for a small footprint, low-cost design
- The board features a low component count RF matching network with off-chip 1:1 Balun

The layout has provision for out-of-band signal suppression (components L1 and C2) if required. 0 shows the typical topology for the RF circuitry.

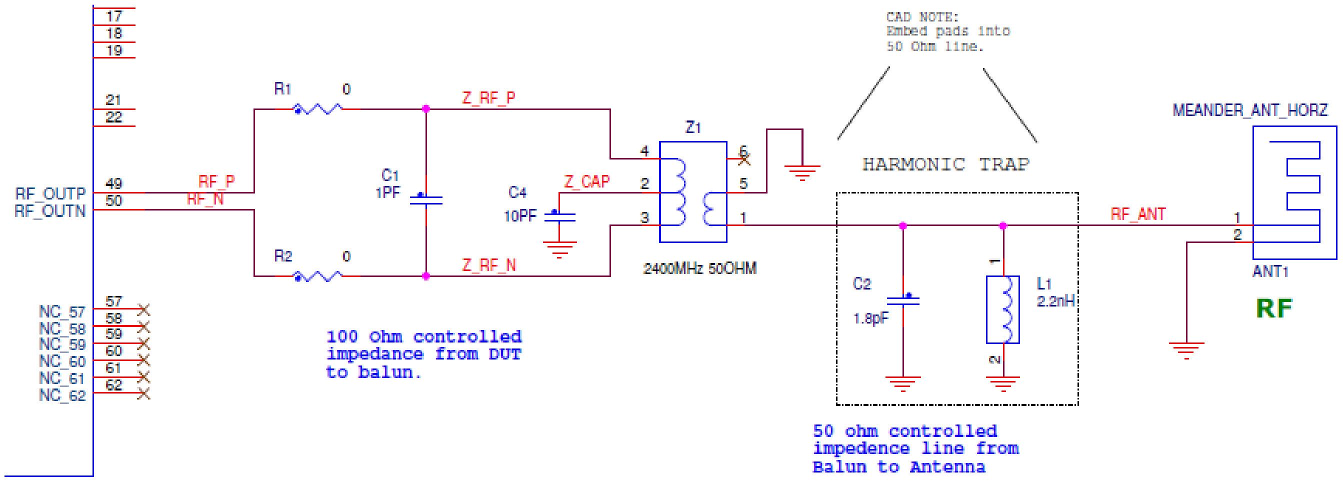

Figure 4. IoT Low Power Sensor Node RF circuitry

3.2.2. Clocks

The IoT Low Power Sensor Node has two clocks:

- 32 MHz Reference Oscillator: 0 shows the external 32 MHz external crystal Y1. This mounted crystal must meet the specifications outlined in the AN3251 application note. The IEEE Std. 802.15.4 requires that the frequency be accurate to less than ±40 ppm.
  - Capacitors C20 and C21 provide the bulk of the crystal load capacitance. At 25 °C it is desired to have the frequency accurate to ±10 ppm or less to allow for temperature variation.
  - To measure the 32 MHz oscillator frequency, signal CLKOUT (PTA18/CLK_OUT) can optionally be programmed to provide a buffered output clock signal.
- Optional 32.768 kHz Crystal Oscillator: Provision is also made for a secondary 32.768 kHz crystal Y2 (see 0). This oscillator can be used for a low power accurate time base.
  - The module comes provided with this Y2 crystal and its load capacitors C23 and C24.
  - Load capacitors C23 and C24 provide the entire crystal load capacitance; there is no onboard trim capacitance.
  - The 32 kHz oscillator components are supplied.

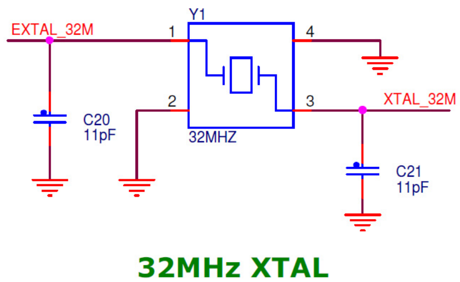

Figure 5. IoT Low Power Sensor Node 32 MHz reference oscillator circuit

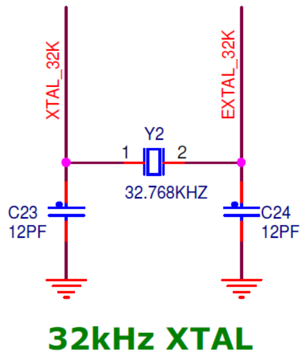

Figure 6. IoT Low Power Sensor Node 32.768 kHz optional oscillator circuit

3.2.3. Power management

The IoT Low Power Sensor Node power management circuit is shown in 0.

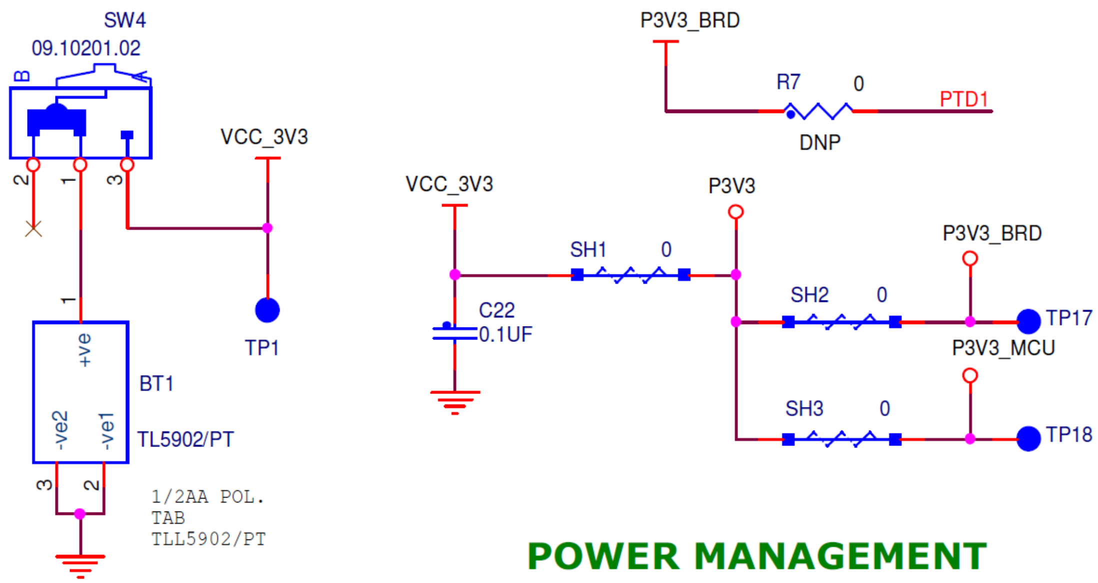

Figure 7. IoT Low Power Sensor Node power management circuit

3.2.4. IoT Low Power Sensor Node peripheral functions - combo sensor (I^2C interface)

Component U2 is a Freescale sensor, FXOS8700C, a 6-axis sensor with integrated linear accelerometer and magnetometer, very low power consumption, I^2C selectable. Figure 8 shows the sensor circuit.

- Sensor power supply is P3V3_BRD
- Discrete pull-up resistors for the I^2C port are provided
- Two interrupt signals

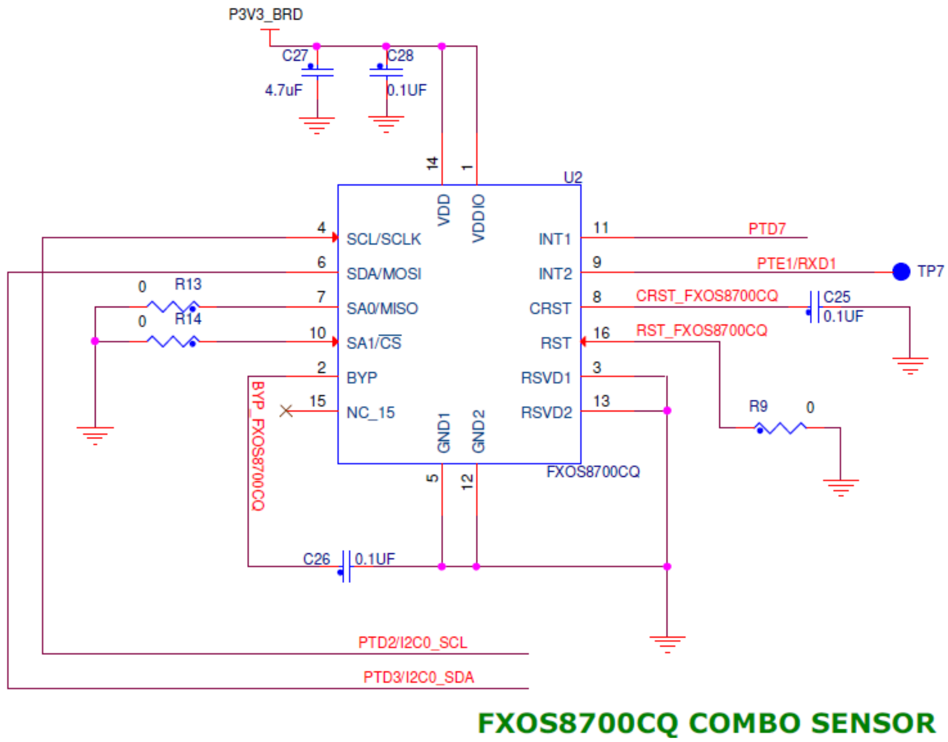

Figure 8. FXOS8700CQ combo sensor

3.3. Schematic, board layout, and bill of material

3.3.1. Schematic

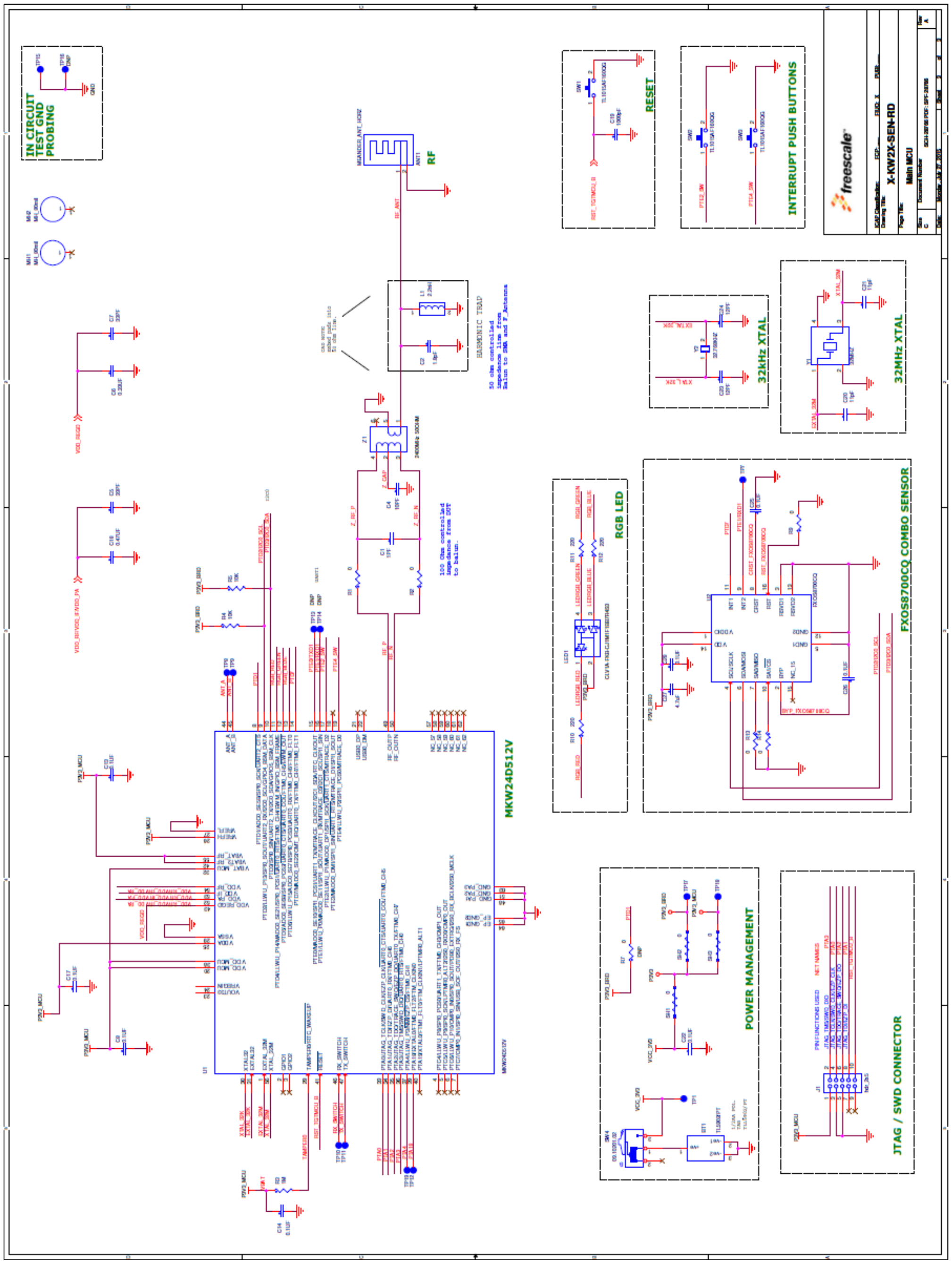

Figure 9. IoT Low Power Sensor Node schematic Rev. A

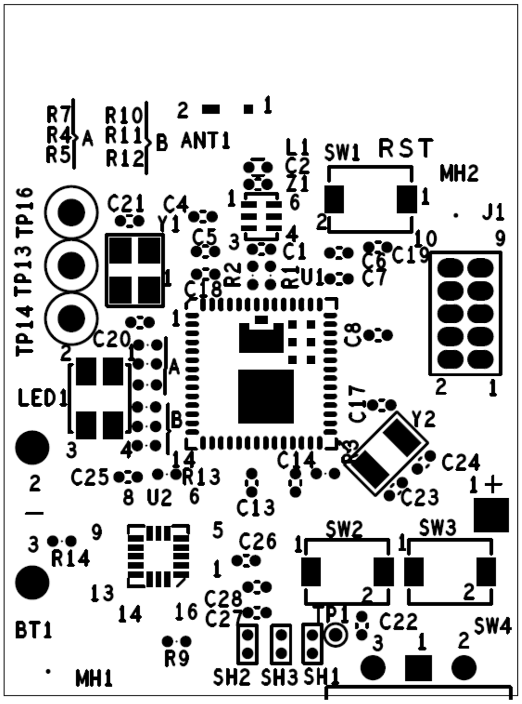

Figure 10. IoT Low Power Sensor Node board component location (top view)

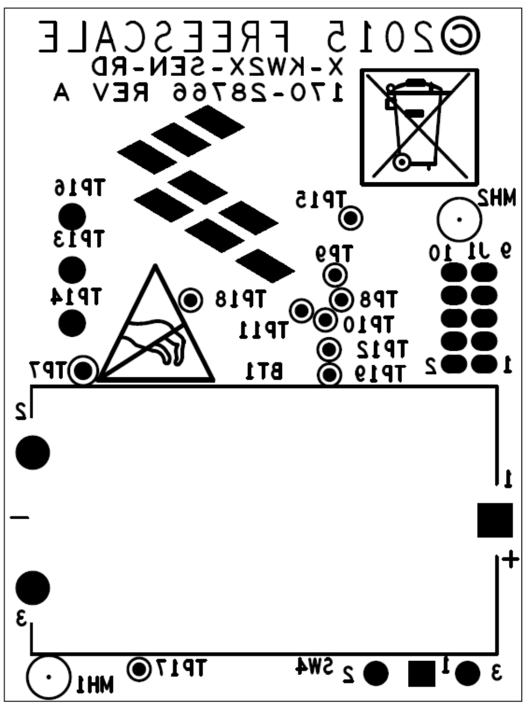

Figure 11. IoT Low Power Sensor Node board test points

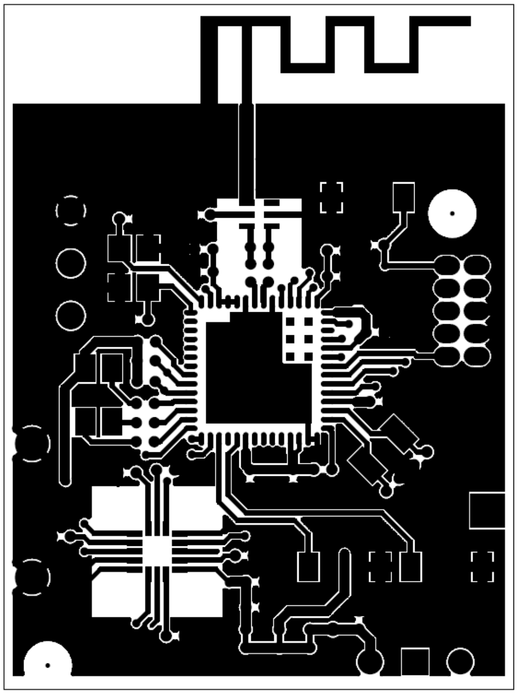

Figure 12. IoT Low Power Sensor Node board layout (top view)

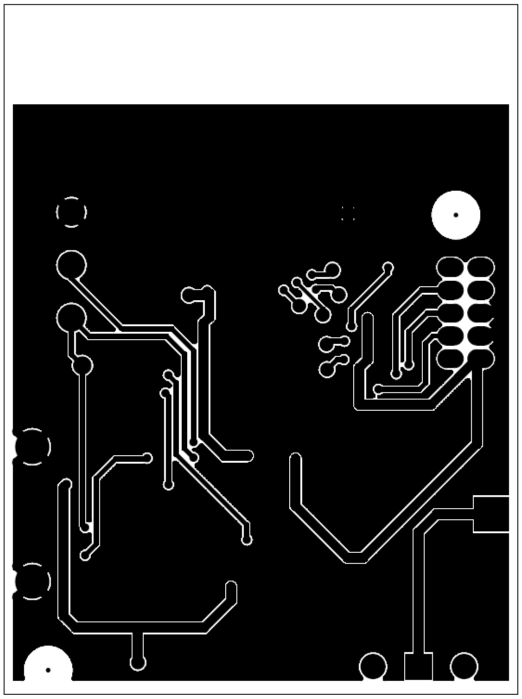

Figure 13. IoT Low Power Sensor Node board layout (bottom view)

3.3.2. Bill of Materials

Table 1. Bill of materials (common parts for all frequency bands)

Item	Qty	Reference	Value	Description	Mfg. Name	Mfg. Part Number
1	1	ANT1	MEANDER_ANT_HORZ	PCB MEANDER ANTENNA HORIZONTAL, NO PART TO ORDER	NO PART TO ORDER	NO PART TO ORDER
2	1	BT1	TL5902/PT	BATTERY 1/2AA LI-SOCI2 3.6V 1200MAH	TADIRAN BATTERIES	TL5902/PT
3	1	C1	1PF	CAP CER 1PF 50V 5% C0G 0402	MURATA	GRM1555C1H1R0CA01B
4	1	C2	1.8pF	CAP CER 1.8PF 50V 0.25PF C0G 0402	MURATA	GRM1555C1H1R8CA01D
5	1	C4	10PF	CAP CER 10PF 50V 5% C0G 0402	AVX	04025A100JAT2A
6	2	C5,C7	33PF	CAP CER 33PF 50V 5% C0G 0402	VENKEL COMPANY	C0402C0G500-330JNE
7	1	C6	0.33UF	CAP CER 0.33UF 6.3V 10% X5R 0402	MURATA	GRM155R60J334KE01D
8	5	C8,C13,C14,C17, C22	0.1UF	CAP CER 0.1UF 16V 10% X7R 0402	KEMET	C0402C104K4RAC
9	1	C18	0.47UF	CAP CER 0.47UF 6.3V 10% X5R 0402	Murata	GRM155R60J474KE19D
10	1	C19	1000pF	CAP CER 1000PF 50V 5% C0G 0402	MURATA	GRM1555C1H102JA01D
11	2	C20,C21	11pF	CAP CER 11pF 50V 1% C0G 0402	AVX	04025U110FAT2A
12	2	C23,C24	12PF	CAP CER 12PF 50V 5% C0G 0402	MURATA	GRM1555C1H120JZ01D
13	3	C25,C26,C28	0.1UF	CAP CER 0.1UF 10V 10% X5R 0402	KEMET	C0402C104K8PAC
14	1	C27	4.7uF	CAP CER 4.7UF 6.3V 20% X5R 0402	VENKEL COMPANY	C0402X5R6R3-475MNP
15	1	J1	hdr_2x5	HDR 2X5 TH 50MIL CTR 254H AU 91L	SAMTEC	FTSH-105-04-F-D
16	1	LED1	CLV1A-FKB-CJ1M1F1BB7R4S3	LED RED BL GRN SGL 50/25/25mA SMT	CREE, INC	CLV1A-FKB-CJ1M1F1BB7R4S3
17	1	L1	2.2nH	IND -- 2.2NH@500MHZ 220mA 4% 0402	MURATA	LQP15MN2N2B02
18	2	MH1,MH2	MH_80mil	MOUNTING HOLE NON-PLATED 80MIL TH NO PART TO ORDER	NA	Mounting Hole - 80Mil drill NPTH
19	5	R1,R2,R9,R13, R14	0	RES MF ZERO OHM 1/16W 5% 0402	ROHM	MCR01MZPJ000
20	1	R3	1M	RES MF 1.0M 1/10W 5% 0402	PANASONIC	ERJ-2GEJ105X
21	2	R4,R5	10K	RES MF 10K 1/16W 5% 0402	VISHAY INTERTECHNOLOGY	CRCW040210K0JNED
22	1	R7 DNP	0	RES MF ZERO OHM 1/16W 5% 0402	ROHM	MCR01MZPJ000
23	3	R10,R11,R12	220	RES MF 220 OHM 1/16W 5% 0402	KOA SPEER	RK73B1ETTP221J
24	3	SH1,SH2,SH3	0	ZERO OHM CUT TRACE 0402 PADS; NO PART TO ORDER	LAYOUT ELEMENT ONLY	LAYOUT ELEMENT ONLY
25	3	SW1,SW2,SW3	TL1015AF160QG	SW SPST PB 50MA 12V SMT	E SWITCH	TL1015AF160QG
26	1	SW4	09.10201.02	SW SPDT RA SLD 12V 500MA TH	EAO SWITCH	09-10201-02
27	10	TP1,TP8,TP9, TP10,TP11,TP12, TP15,TP17, TP18,TP19	TPAD_030	TEST POINT PAD 30MIL DIA SMT, NO PART TO ORDER	NOTACOMPONENT	NOTACOMPONENT
28	1	TP7	TPAD_040	TEST POINT PAD 40MIL DIA SMT, NO PART TO ORDER	NOTACOMPONENT	NOTACOMPONENT
29	3	TP13,TP14,TP16 DNP	TEST POINT WHITE	TEST POINT WHITE 40 MIL DRILL 180 MIL TH 109L	COMPONENTS CORPORATION	TP-105-01-09
30	1	U1	MKW24D512V	IC MCU XCVR 2.4GHZ 64KB RAM 512KB FLASH - USB 1.8-3.6V LGA63	Freescale Semiconductor	MKW24D512VHA5
31	1	U2	FXOS8700CQ	IC ACCELEROMETER AND MAGNETOMETER SENSOR 3-AXIS 2.5V QFN16	Freescale Semiconductor	FXOS8700CQ
32	1	Y1	32MHZ	XTAL 32MHZ 9PF -- SMT 3.2X2.5MM	NDK	EXS00A-CS02368
33	1	Y2	32.768KHZ	XTAL 32.768KHZ SMT ROHS COMPLIANT	EPSON ELECTRONICS	FC-135 32.7680KA-A3
34	1	Z1	2400MHz 50OHM	XFMR BALUN 2400 +/-100MHZ SMT	MURATA	LDB212G4005C-001

4. PCB manufacturing specifications

This section provides the specifications used to manufacture the IoT Low Power Sensor Node development printed circuit board (PCB) described in this guide.

The IoT Low Power Sensor Node development platform PCBs must comply with the following:

- The PCB must comply with Perfag1D/3C (www.perfag.dk/en/)
- The PCB manufacturer's logo is required
- The PCB production week and year code is required
  - The manufacturer's logo and week/year code must be stamped on the back of the PCB solder mask
  - The PCB manufacturer cannot insert text on the PCB either in copper or in silkscreen without written permission from NXP Semiconductors.
- The required Underwriter's Laboratory (UL) Flammability Rating
  - The level is 94V-0 (http://ulstandards.ul.com/standard/?id=94)
  - The UL information must be stamped on the back of the PCB solder mask

NOTE

- A complete set of design files is available for the IoT Low Power Sensor Node transceiver at the NXP website (KW2xD) under "Software and Tools." These reference designs should be used as a starting point for a custom application.
- The *Freescale IEEE 802.15.4 / ZigBee Package and Hardware Layout Considerations Reference Manual*, (ZHDCRM) is also available at the same web site to provide additional design guidance.

4.1. Single PCB construction

This section describes individual PCB construction details.

- The IoT Low Power Sensor Node PCBs are two-layer, multi-layer designs
- The PCBs contain no blind, buried, or micro vias
- PCB data:
  - IoT Low Power Sensor Node board's size: approximately 28.7 x 38.35 mm (1.13 x 1.51 inches)
  - IoT Low Power Sensor Node board's final thickness (Cu/Cu): 1.57 mm (0.62 inches) ±10% (excluding solder mask)

Error! Reference source not found. defines some of the layers of the completed PCB. The artwork identification refers to the name of the layer in commonly used terms.

Table 2. IoT Low Power Sensor Node layer by layer overview

Layer	Artwork Identification	File Name
1	Silkscreen Top	PSS.art
2	Top Layer Metal	L1_PS.art
3	Bottom Layer Metal	L2_SS.art
4	Silkscreen Bottom	SSS.art

CAUTION:

The IoT Low Power Sensor Node reference design board contains high frequency 2.4 GHz RF circuitry. As a result, RF component placement, line geometries and layout, and spacing to the ground plane are critical parameters. As a result, BOARD STACKUP GEOMETRY IS CRITICAL.

Dielectric and copper thicknesses and spacing must not be changed; follow the stackup (see Figure 14) information provided with the reference design.

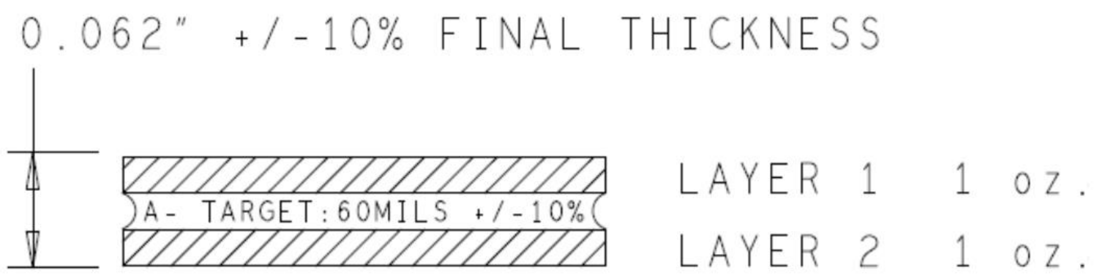

Figure 14. IoT Low Power Sensor Node FXOS8700CQ combo sensor

- Solder mask is required
- Silk screen is required

4.2. Panelization

The panel size can be negotiated depending on production volume.

4.3. Materials

The PCB composite materials must meet the following requirements:

- Laminate: the base material (laminate) must be FR4. If the laminate material is changed, the RF electrical characteristics may change and degrade RF performance.
- Copper foil:
  - Top and Bottom copper layers must be 1 oz. copper
- Plating: All pad plating must be Hot Air Leveling (HAL).

4.4. Solder mask

The solder mask must meet the following requirements:

- Solder mask type: Liquid Film Electra EMP110 or equivalent
- Solder mask thickness: 10–30 µm.

4.5. Silk screen

The silk screen must meet the following requirements:

- Silk screen color: White
- Silk screen must be applied after application of solder mask if solder mask is required
- The silk screen ink must not extend into any plated-thru-holes
- The silk screen must be clipped back to the line of resistance.

4.6. Electrical PCB testing

- All PCBs must be 100% tested for opens and shorts
- Impedance measurement: An impedance measurement report is not mandatory.

4.7. Packaging

Packaging for the PCBs must meet the following requirements:

- Finished PCBs must remain in panel
- Finished PCBs must be packed in plastic bags that do not contain silicones or sulphur materials. These materials can degrade solderability.

4.8. Hole specification/tool table

See the *ncdrill-1-4.tap* file included with the Gerber files and the *FAB-28766* file.

4.9. File description

Files included with the download include Design, Gerber, and PDF files. Gerber files are RS-274x format. Not all files included with the Gerber files are for PCB manufacturing.

PDF files included are:

- *FAB-28766.pdf*— board fabrication drawing
- *GRB-28766.zip*— metal layers, solder mask, solder paste and silk screen
- *SPF-28766.pdf*— schematic diagram

Design files are in Allegro format with OrCAD schematic capture.

5. Revision history

Revision number	Date	Substantive changes
1	02/2017	Initial release