TI Designs

RF Sensor Node Development Platform for 6LoWPAN and 2.4 GHz Applications

TEXAS INSTRUMENTS

TI Designs

TI Designs are analog solutions created by TI's analog experts. Reference Designs offer the theory, component selection, and simulation of useful circuits. Circuit modifications that help to meet alternate design goals are also discussed.

Design Resources

RF Sensor Node	Tools Folder
CC2520	Product Folder
MSP430F5438A	Product Folder
TMP106	Product Folder
TPS22901	Product Folder
TPS72733	Product Folder
TPS60300	Product Folder
PTH08080W	Product Folder

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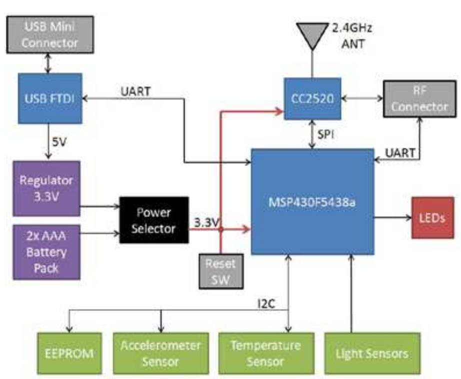
Design Features

- On-board 3-axis accelerometer, temperature, and light sensor allows for multiple parameter sensing
- Low-power MCU and RF Transceiver allows for longer battery life
- High-efficiency charge pump allows for low-power (1.2 V) operation
- USB and JTAG interface for on-board programming and debugging
- Small development platform for 2.4-GHz/6LoWPAN RF solutions

Featured Applications

- Home and Building Automation
- Internet of Things (IoT)
- Development Platform
- Wireless Sensor Networks



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1 System Description

The RF Sensor Node Platform is intended as a miniature development platform for 6LoWPAN and 2.4 GHz applications. The platform has three onboard sensors which includes a 3-axis accelerometer, a temperature sensor and two light sensors. The RF Sensor Node Platform can be a stand-alone sensor node or can be paired to an RF interface card and a power line communication (PLC) board, making a hybrid node. The RF node supports 2.4-GHz RF protocols which include 6LoWPAN or ZigBee.

Each sensor node communicates to a sink node or a gateway. The gateway is a Linux-based system that collects data from the various sensor nodes and hosts the information on a web server. From the web server, a user can interact with the consolidated data via a java-based Graphical User Interface (GUI).

The sensor nodes can send its measurement data back to the gateway through different pathways and nodes. This method is similar to a mesh network, but in this case the links can be either RF or PLC. Since the links between the nodes can be wired (PLC) or wireless (RF), hybrid networks offer better reliability and noise resistance than traditional nodes. If one communication node is noisy (for example, noise on the power lines makes it difficult to implement a PLC solution), RF can be used to reach the next node. This example only works for hybrid nodes where both options are available. Throughout the mesh-like network, the next node could have the same choice if it was a hybrid node. RF-only sensor nodes can only hop or communicate through the network via RF communications.

1.1 RF Sensor Node Development Platform

1.1.1 CC2520

The CC2520 device is the TI second-generation ZigBee or IEEE 802.15.4 RF transceiver for the 2.4-GHz, unlicensed ISM band. This chip enables industrial-grade applications by offering state-of-the-art selectivity and co-existence, excellent link budget, operation up to 125°C, and low-voltage operation. In addition, the CC2520 device provides extensive hardware support for frame handling, data buffering, burst transmissions, data encryption, data authentication, clear channel assessment, link-quality indication, and frame-timing information. These features reduce the load on the host controller. In a typical system, the CC2520 device will be used together with a microcontroller and a few additional passive components.

1.1.2 MSP430F5438A

The Texas Instruments MSP430 family of ultra-low-power microcontrollers consists of several devices, each featuring different sets of peripherals targeted for various applications. The architecture, combined with extensive low-power modes, is optimized to achieve extended battery-life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency. The digitally controlled oscillator (DCO) allows the device to wake up from low-power modes to active mode in 3.5 µs (typical).

The MSP430F543xA and MSP430F541xA series are microcontroller configurations with three 16-bit timers, a high-performance 12-bit analog-to-digital converter (ADC), up to four universal serial communication interfaces (USCIs), a hardware multiplier, DMA, a real-time clock module with alarm capabilities, and up to 87 I/O pins.

Typical applications for this device include analog and digital sensor systems, digital motor control, remote controls, thermostats, digital timers, and hand-held meters.

1.1.3 TMP106

The TMP106 device is a two-wire, serial output, temperature sensor available in a WCSP package. Requiring no external components, the TMP106 is capable of reading temperatures with a resolution of 0.0625°C.

The TMP106 device features a two-wire interface that is SMBus-compatible, with the TMP106 device allowing up to two devices on one bus. The TMP106 also features a SMBus Alert function.

The TMP106 is ideal for extended temperature measurement in a variety of communication, computer, consumer, environmental, industrial, and instrumentation applications.

1.1.4 TPS22901

TPS22901, TPS22902, and TPS22902B devices are ultra-small, low ON resistance (rON) load switches with controlled turn-on. The devices contain a P-channel MOSFET that operates over an input voltage range of 1.0 to 3.6 V. The switch is controlled by an on and off input (ON), which is capable of interfacing directly with low-voltage control signals. In the TPS22902 and in TPS22902B devices, a 120-Ω on-chip load resistor is added for output quick discharge when the switch is turned off.

TPS22901, TPS22902, and TPS22902B devices are available in a space-saving 4-terminal WCSP with 0.4-mm pitch (YFP). The devices are characterized for operation over the free-air temperature range of –40°C to 85°C.

1.1.5 TPS72733

The TPS727xx family of low-dropout (LDO), linear regulators are ultra-low, quiescent current LDOs with excellent line and ultra-fast load transient performance and are designed for power-sensitive applications. The LDO output voltage level is preset by the use of innovative factory EEPROM programming. A precision bandgap and error amplifier provides an overall 2% accuracy over load, line, and temperature extremes. The TPS727xx family is available in 1.5mm × 1.5mm SON and wafer chip-scale (WCSP) packages that make it ideal for handheld applications. This family of devices is fully specified over a temperature range of T_J = -40°C to +125°C.

1.1.6 TPS60300

The TPS6030x step-up, regulated charge pumps generate a 3-V ±4% or 3.3-V ±4% output voltage from a 0.9 to 1.8 V input voltage (one alkaline, NiCd, or NiMH battery).

Only five, small, 1-uF ceramic capacitors are required to build a complete, high efficiency, dc-dc charge pump converter. To achieve a high efficiency over a wide, input-voltage range, the charge pump automatically selects between a 3x or 4x conversion mode.

1.2 Interface Board

1.2.1 PTH08080W

The PTH08080W module is a highly-integrated, low-cost switching regulator module that delivers up to 2.25 A of output current. The PTH08080W module sources output current at a much higher efficiency than a TO-220 linear regulator IC, which eliminates the need for a heat sink. Its small size (0.5 × 0.6 in) and flexible operation creates value for a variety of applications.

The input voltage range of the PTH08080W module is 4.5 to 18 V, allowing operation from either a 5- or 12-V input bus. Using state-of-the-art, switched-mode, power-conversion technology, the PTH08080W module can step down to voltages as low as 0.9 V from a 5-V input bus, with less than 1 W of power dissipation. The output voltage can be adjusted to any voltage within the range, 0.9 V to 5.5 V, using a single external resistor. Operating features include an undervoltage lockout (UVLO), on and off inhibit, overcurrent protection, and overtemperature protection. Target applications include telecommunications, test and measurement applications, and high-end consumer products. This product is available in both through-hole and surface-mount package options, including tape and reel.

2 Block Diagrams

2.1 RF Sensor Node System Block Diagram

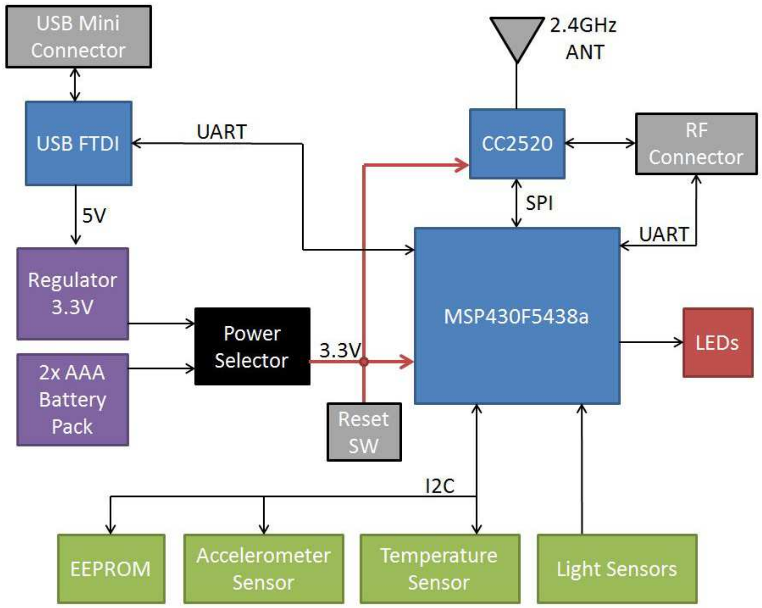


Figure 1. RF Sensor Node System Block Diagram

2.2 PLC Board, RF Sensor Node and Interface Board Functional Block Diagram

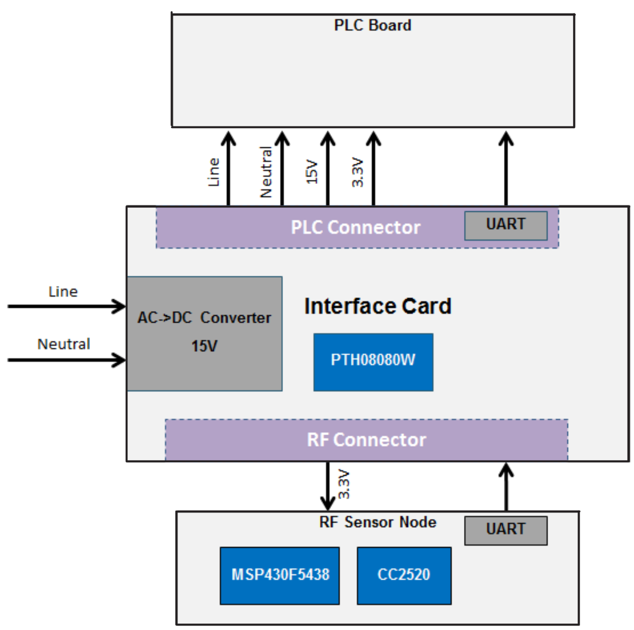


Figure 2. PLC Board, RF Sensor Node, and Interface Board Functional Block Diagram

2.3 CC2520 Functional Diagram

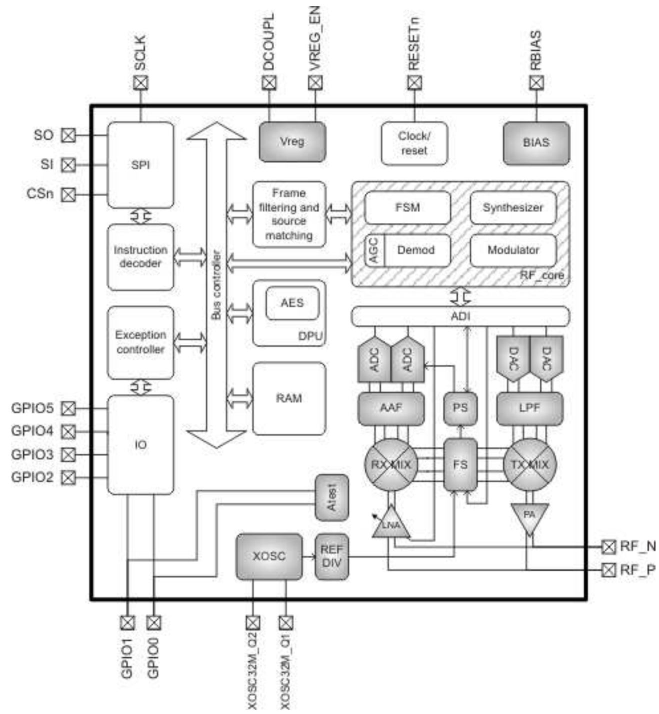


Figure 3. CC2520 Functional Diagram

2.4 MSP430F5438A Functional Diagram

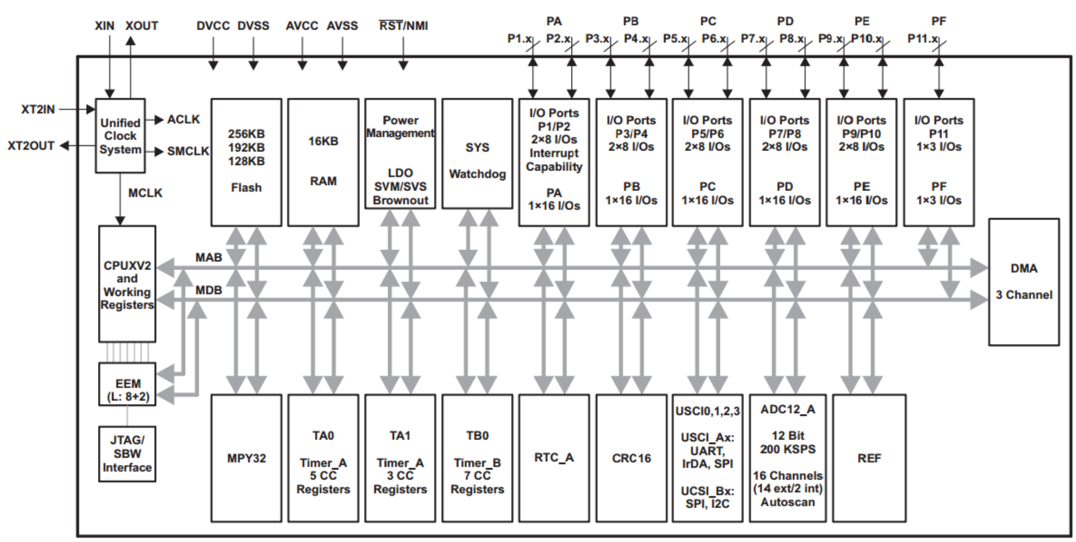


Figure 4. MSP430F5438A Functional Diagram

2.5 TMP106 Functional Diagram

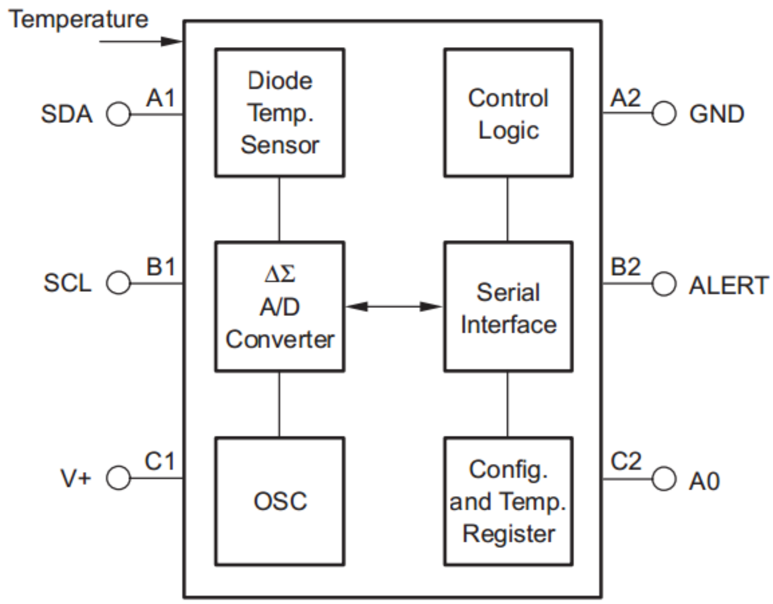


Figure 5. TMP106 Functional Diagram

2.6 TPS22901 Functional Diagram

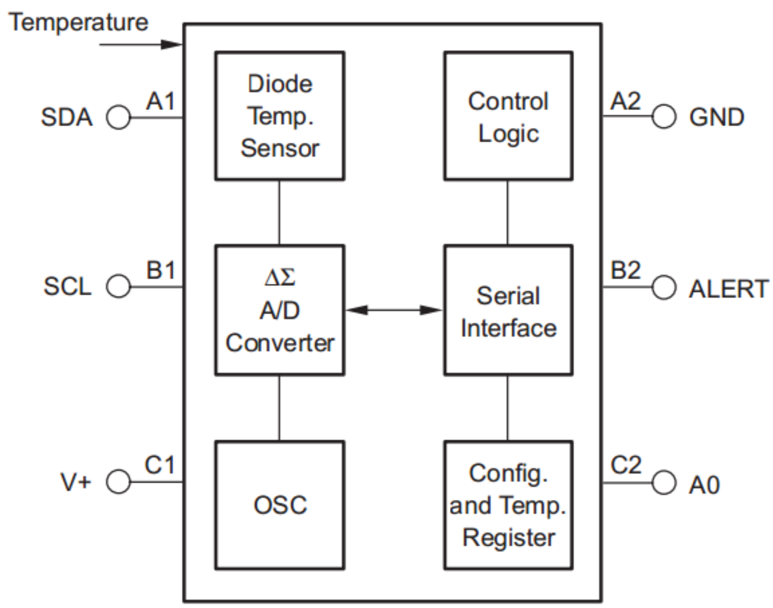


Figure 6. TPS22901 Functional Diagram

2.7 TPS72733 Functional Diagram

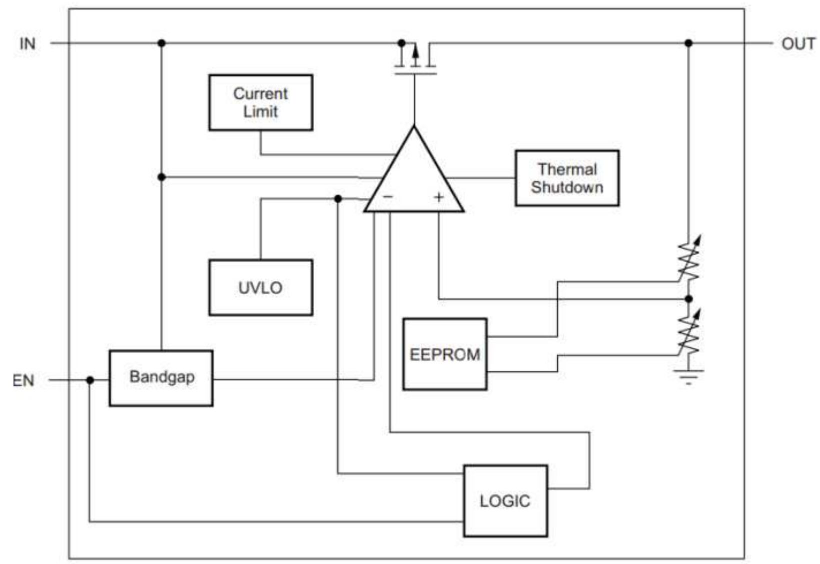


Figure 7. TPS72733 Functional Diagram

2.8 TPS60300 Functional Diagram

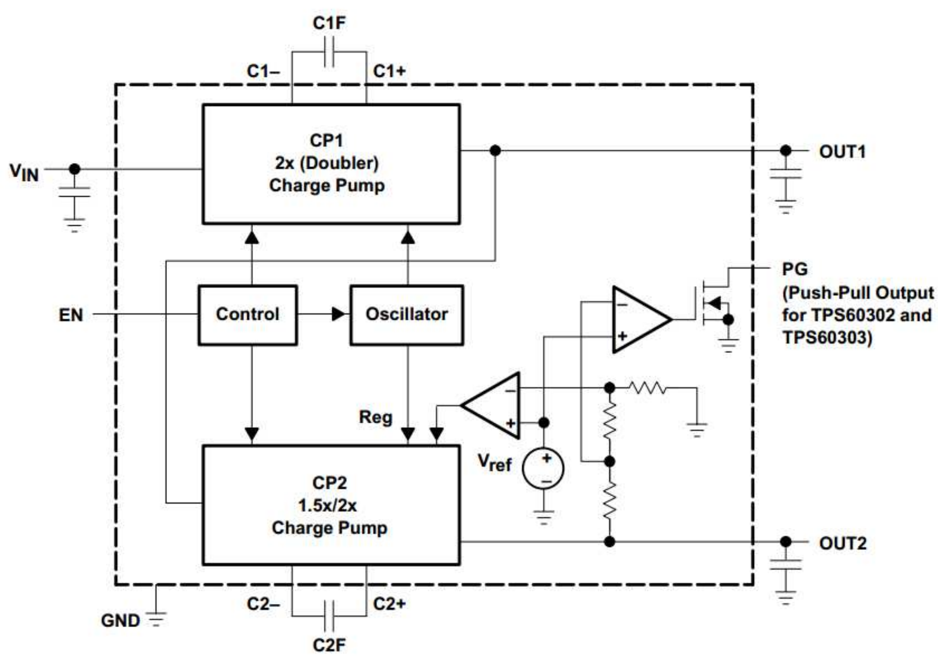


Figure 8. TPS60300 Functional Diagram

3 Component Selection

The components of this board were selected based on the following factors in mind:

- Power Efficiency
- Size
- General Availability

The *RF Sensor Node Reference Design* features the following devices:

- **CC2520:** Second-generation 2.4-GHz ZigBee/IEEE 802.15.4 RF transceiver
- **MSP430F5438A:** 16-Bit Ultra-Low-Power Microcontroller, 256KB Flash, 16KB RAM, 12-Bit ADC, 4 USCIs, 32-Bit HW Multi
- **TMP106:** Digital Temperature Sensor with Two-Wire Interface in Chip Scale Package
- **TPS22901:** Low Input Voltage, Ultra-Low r[DS(ON)] Load Switch
- **TPS72733:** 250-mA, Ultra-low IQ, Fast Transient Response, RF Low-Dropout Linear Regulator
- **TPS60300:** Single-Cell to 3.0-V/3.3-V, 20mA Dual Output, High-Efficiency Charge Pump

The Interface Card features the following device:

- **PTH08080W:** 2.25-A, 4.5-V to 18-V Input Wide Adjust Miniature Power Module

For more information on each of these devices, see the respective product folders at www.ti.com

3.1 CC2520 RF Radio

The CC2520 device is a 2.4-GHz, IEEE 802.15.4 and ZigBee® RF transceiver. The low-power modes fit well into the battery-powered, wireless application. The radio uses 18.5-mA receiving and 25.8- to 33.6-mA transmitting depending on TX mode. If the board enclosure is not shielded, then the 2.4-GHz antenna can be traced directly onto the PCB.

3.2 MSP430F5438A Microcontroller

The TI MSP430 device was selected for its low-power consumption, which is crucial for battery-powered sensor nodes. Battery life is essential for any wireless device and allows for more diverse product applications. A LQFP package was selected to decrease the footprint size on the PCB.

3.3 TMP106 Temperature Sensor

The TMP106 digital temperature sensor is a good fit for low-power, small-footprint applications. This I2C interface temperature sensor requires no external components, has less than 0.1°C resolution, and is ideal for extended temperature measurements.

3.4 TPS72733 Linear Regulator

The RF-only sensor node can be powered from a USB or a battery. The TI TPS72733 device low-dropout regulator is used for regulating 5- to 3.3-V from USB. When the node is running off batteries, two AAA batteries are used.

3.5 TPS60300 Charge Pump

The charge pump creates an output voltage of 3.3 V from as little as 0.9 V of input voltage. The true benefit of this charge pump is seen when the battery is in a low-power state. This allows the battery life to be extended, and can decrease the cost of ownership. The TPS60300 device works at up to 90% efficiency.

3.6 PTH08080W

The PTH08080W was chosen as a high-efficiency, switching regulator in a small package. The device only needs one external resistor to adjust the output voltage, which saves board space. The PTH08080W device has a much higher efficiency than a standard TO-220 linear regulator, which eliminates the need for a heat sink.

3.7 Debugging

An on-board USB FTDI enables debugging and programming via the mini USB port. A 10-pin JTAG connector is also included on the RF-only sensor node.

4 Theory of Operation

4.1 Hybrid Networks

Hybrid networks are made up of more than one type of communication medium. Examples include both wired and wireless. This RF sensor node reference design, when combined with the PLC card or interface card, can utilize both RF communications and power-line communications. Hybrid networks are more efficient than traditional networks because they determine the best links between nodes (RF link or PLC link) and the specific route to send information packets along the RF or PLC nodes.

Traditional networks can only utilize one type of communication medium. If an environment becomes unsuitable for RF communication, a traditional network cannot switch to a wired communication.

4.2 Hybrid Nodes

As mentioned in Section 4.1, a hybrid network contains nodes that may utilize both wired and wireless communication. Hybrid nodes can receive an RF or PLC message and then transmit an RF or PLC message independent of the original received message. This means a node can receive an RF message and then transmit either an RF message or a PLC message.

The hybrid nodes may allow the network to choose the best medium to send the message. If the power-line is noisy, the hybrid node can send a message via RF to the nearest node. On the other hand, if the RF frequency space is busy, the hybrid node can communicate via PLC. Multiple links between neighbor nodes are created because some nodes can transmit and receive on various mediums. The extra links allow the hybrid network to find the most efficient ways to communicate across the network, from the sensor node back to the gateway/sink node.

4.3 Unique Identification Process

Each RF, PLC, or hybrid sensor node is given a unique node identification number initialized at the time of compilation. This is done using the following line:

```
make TARGET=exp5438 udp-client.upload SC_NODE_TYPE=0 NODEID=20
```

The NODEID field is changed during the identification process for each node and the type of node is also selected in the NODE_TYPE field. Example steps are shown in the software setup section. The unique node ID's must be assigned manually because DHCP is not running on the RF network and therefore each node is not assigned a unique ID as it joins the network.

5 Software Description

The RF Sensor Node development platform can support many types of software such as Contiki. In the following sections, Contiki is being used for the tests and data monitoring.

The RF node is a flexible 2.4-GHz and 6LoWPAN development platform that supports various RF communication stacks. With Contiki running, the system is using an RPL routing algorithm native to Contiki OS. The RPL algorithm helps find neighboring nodes and selects the route. The neighboring nodes can communicate other details about the rest of the network. Some of these details include hops to the gateway and sink node and distance to another node. With these details each node can figure out the best routing for packets.

6 Test Setup

For the test setup, the PLC and RF hybrid nodes, PLC-only node, and the RF-only node were used in a Hybrid-sensor network. Nodes were placed in the following locations as shown in the map below. Some are PLC and RF hybrid boards and others are RF-only sensor nodes. Figure 9 shows a map of the node placement. The Java-based network controller with several nodes connected with approximate locations is shown in Figure 10. The red links represent RF links and the blue links represent the PLC links.

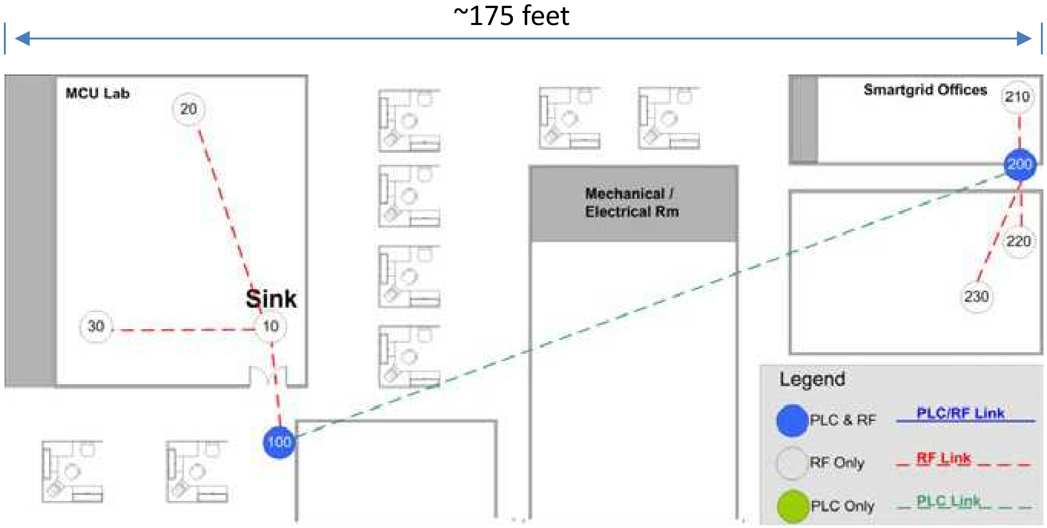


Figure 9. Node Placement Map

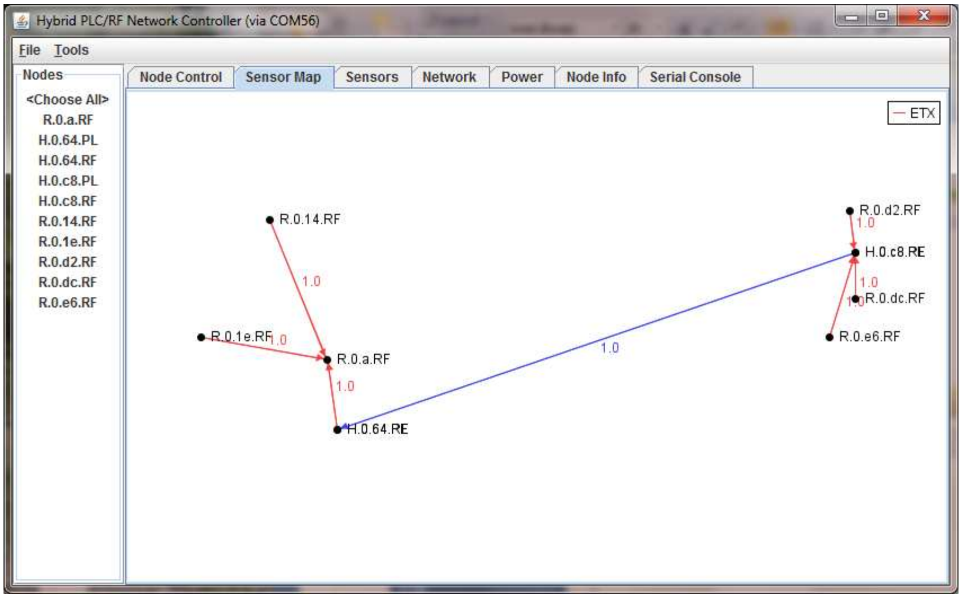


Figure 10. Network Controller Topology

7 Test Results

The RF Sensor Node measures various room and device parameters with its integrated accelerometer, temperature, and light sensors. Each sensor node is initialized with a unique ID which can be observed in the Contiki java GUI sidebar as shown in Figure 11, Figure 12, Figure 13, and Figure 14.

The measured data is sent back to the gateway node where the server can present the data through an internet browser or java based GUI. The messages are sent via the PLC link or the RF link. The Java-based GUI has numerous tabs which allows the user to monitor and control the various PLC, RF, or PLC and RF hybrid nodes within the network.

7.1 Temperature Sensor Readings

Figure 11 shows the temperature readings versus time for two RF sensor nodes and one PLC sensor node in a building application.

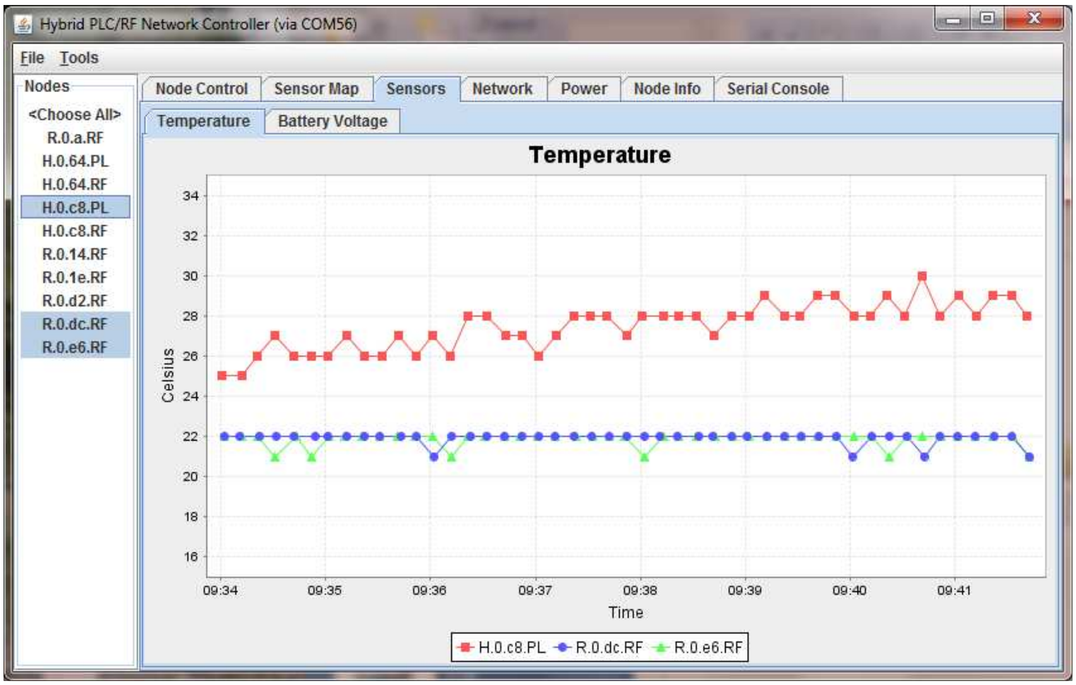


Figure 11. Temperature Sensor Readings

7.2 Node Power Readings

A gas-gauge feature is included in the battery-management system. This allows the GUI to show information on the average power consumption, power history, and other test data. Figure 12 and Figure 13 shows the average power consumption and the power history for various nodes in a building application.

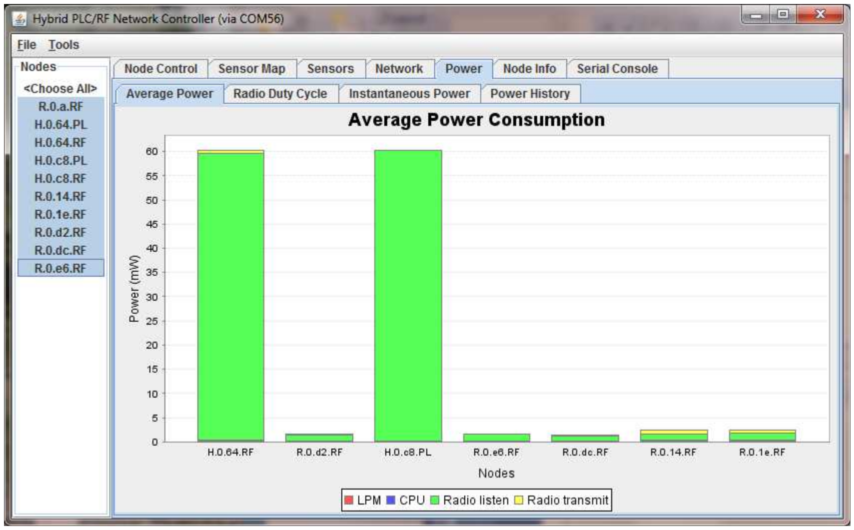


Figure 12. Average Power Consumption of Each Node

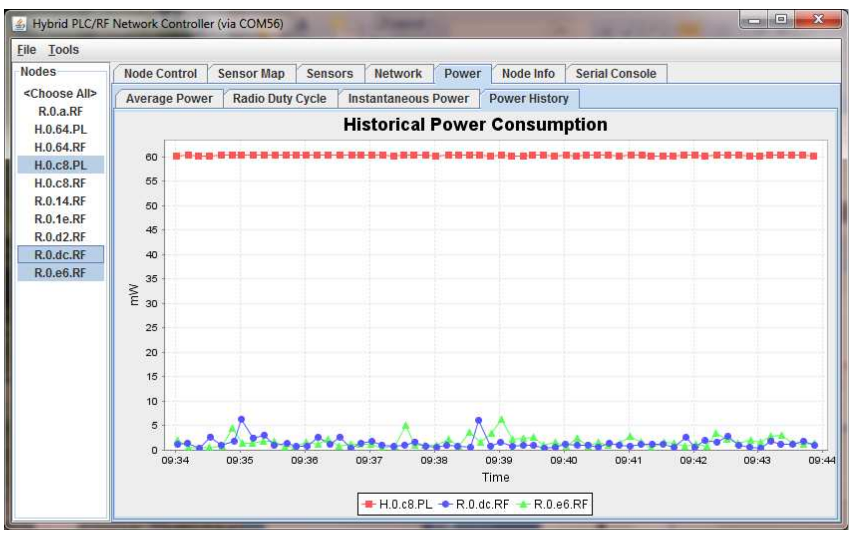


Figure 13. Past Power Consumption of the System

7.3 Network Statistics

Figure 14 shows the beacon interval graph for various sensor nodes. The network tab in the java-based GUI can also display other network related data such as network hops and latency.

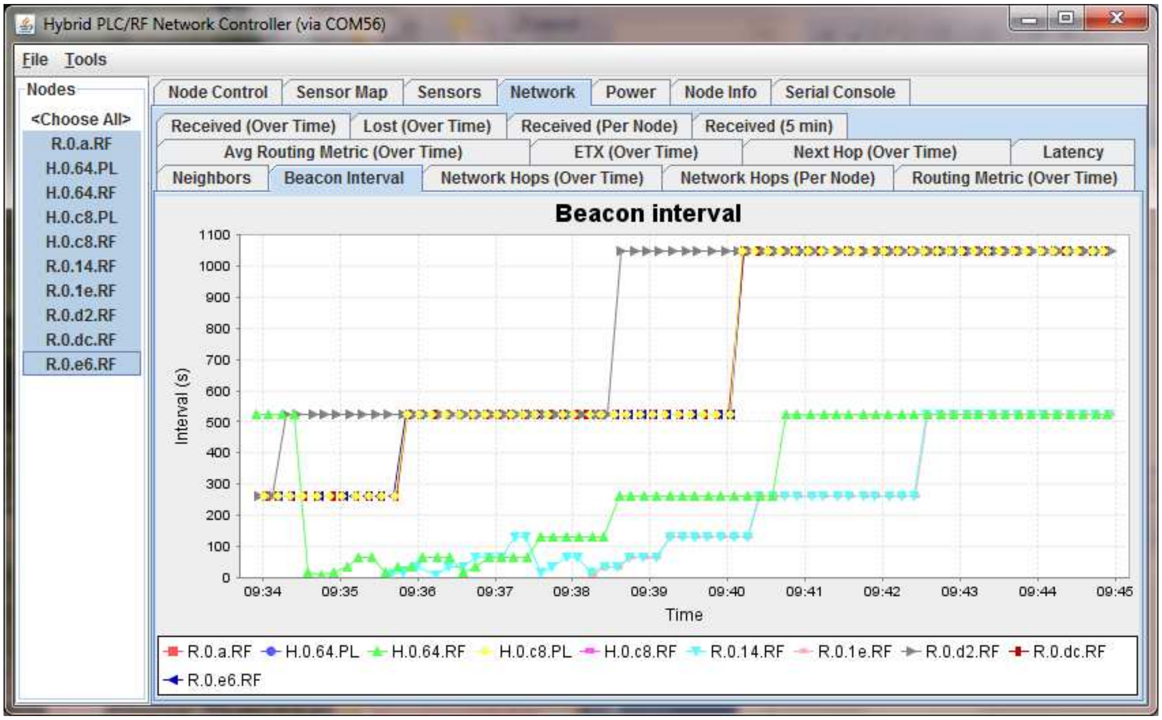


Figure 14. Network Statistics for Beacon Interval

8 Software Setup

8.1 Compile and Flash the RF Sensor Node

1. Install Cygwin
2. Install IAR
3. Add: "C:\[IAR_installation_dir]\430\bin" and "C:\[msp430flasher_dir]" to your PATH environment variable (in Windows). The Windows PATH variable will be reflected in Cygwin's $PATH variable.
4. Change directory to: "[contiki_dir]/examples/ipv6/sc_deployment_mvk"
5. Edit the "project-conf.h" files in both the "sc_deployment_mvk/" and "sc_deployment_mvk/udp-sink/" folder and uncomment the line:

   ```
   #define YJ_TOPO_CONTROL
   ```

6. Edit the file “[contiki_dir]/core/net/mac/yj-topology-control.c” and make sure the #else statement for the #ifdef RN_REMOTE_RESET looks like this:

   ```
   #else
   static uint8_t
   yj_accetable_neighbors[YJ_MAC_TOPOLOGY_CONTROL_ENTRY_COUNT][2+YJ_MAC_TOPOLOGY_CONTROL_MAC_NEIGH
   BOR_COUNT] = { \
           {10, 1, 100},
           {20, 1, 200},
           {100, 1, 10},
           {200, 1, 20}
   };
   #endif
   ```

7. Return to the directory “sc_deployment_mvk” and compile and flash the 3 client nodes (2 combo and 1 RF-only) using the commands:

   Combo node 1:

   ```
   make TARGET=exp5438 udp-client.upload SC_NODE_TYPE=2 NODEID=100
   ```

   Combo node 2:

   ```
   make TARGET=exp5438 udp-client.upload SC_NODE_TYPE=2 NODEID=200
   ```

   RF-only node:

   ```
   make TARGET=exp5438 udp-client.upload SC_NODE_TYPE=0 NODEID=20
   ```

8. 8) To compile and flash the sink node code onto the MVRK board, change directory to “[contiki_dir]/examples/ipv6/sc_deployment_mvk/udp-sink” use the command:

   ```
   make TARGET=exp5438 udp-sink.upload SC_NODE_TYPE=0 NODEID=10
   ```

8.2 Prepare the BeagleBone Gateway

1. Insert a flashed sink node MVRK board into the BeagleBone, via the RF header slot closest to the Ethernet port
2. Insert a microSD card, flashed with the demo image (see the “Flashing the microSD cards” tutorial)
3. Plug in the USB WiFi module (white w/long antenna)
4. Plug in the AC power adapter to the BeagleBone
5. Wait approximately 30 seconds for the BeagleBone to boot, connect to the WiFi network with SSID “Hybrid” (may take a minute to acquire an IP address)
6. Open up a browser window, and navigate to the address: http://192.168.1.1
7. Check the checkbox, “Start data acquisition”, and if there’s stored data you want to clear, also check the “clear all stored data” checkbox. then type the password “hybrid” and press Enter
8. Refresh the page, and you should see “STARTED” in green in the upper-left corner of the screen
9. As you turn on the combo and RF-only nodes, you should see them appear on the SC building map screen as long as their NODEID is listed in the mapConfig.php file (see the “Editing the map coordinates” tutorial)
10. You can now view one or more of the connected nodes sensor, network, or power data by:
    (a) First, clicking them to move them from the “available” box to the “selected” box on the left side navigation bar
    (b) Then, clicking one of the links in the left side navigation panel

9 Design Files

To see a complete collection of design files, please see http://www.ti.com/tool/TIDM-RF-SENSORNODE

9.1 Schematics

The schematics are presented in the following order:

1. The CC2520 Radio (see Figure 15)
2. MSP430 MCU and JTAG Interface (see Figure 16)
3. USB to UART/JTAG (see Figure 17)
4. Power Supply (see Figure 18)
5. RF Connector Interface (see Figure 19)
6. Sensors, I2C External Flash, Keypad, and LED’s (see Figure 20)
7. Interface Card (see Figure 21)

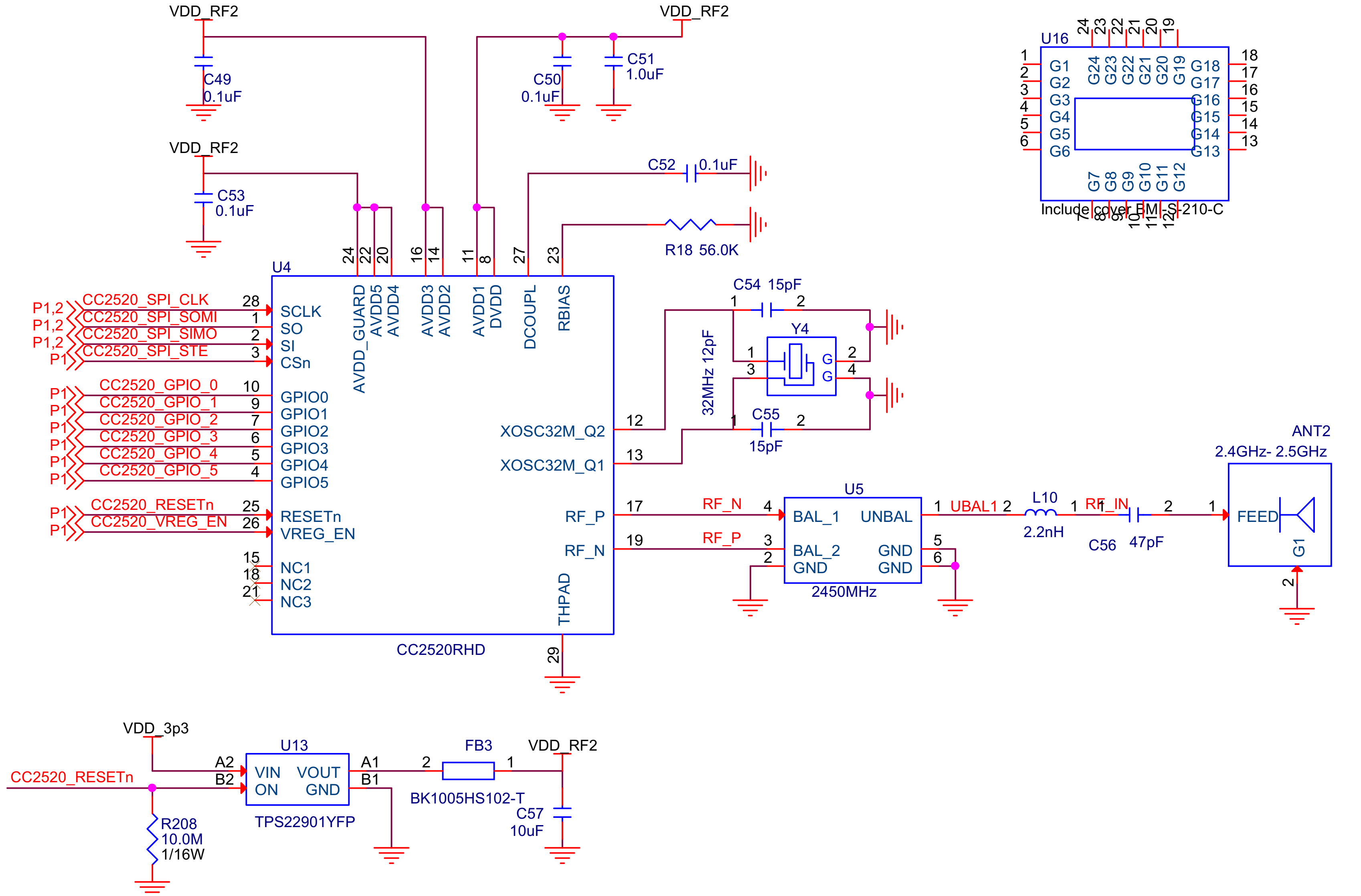


Figure 15. CC2520 Radio Schematic

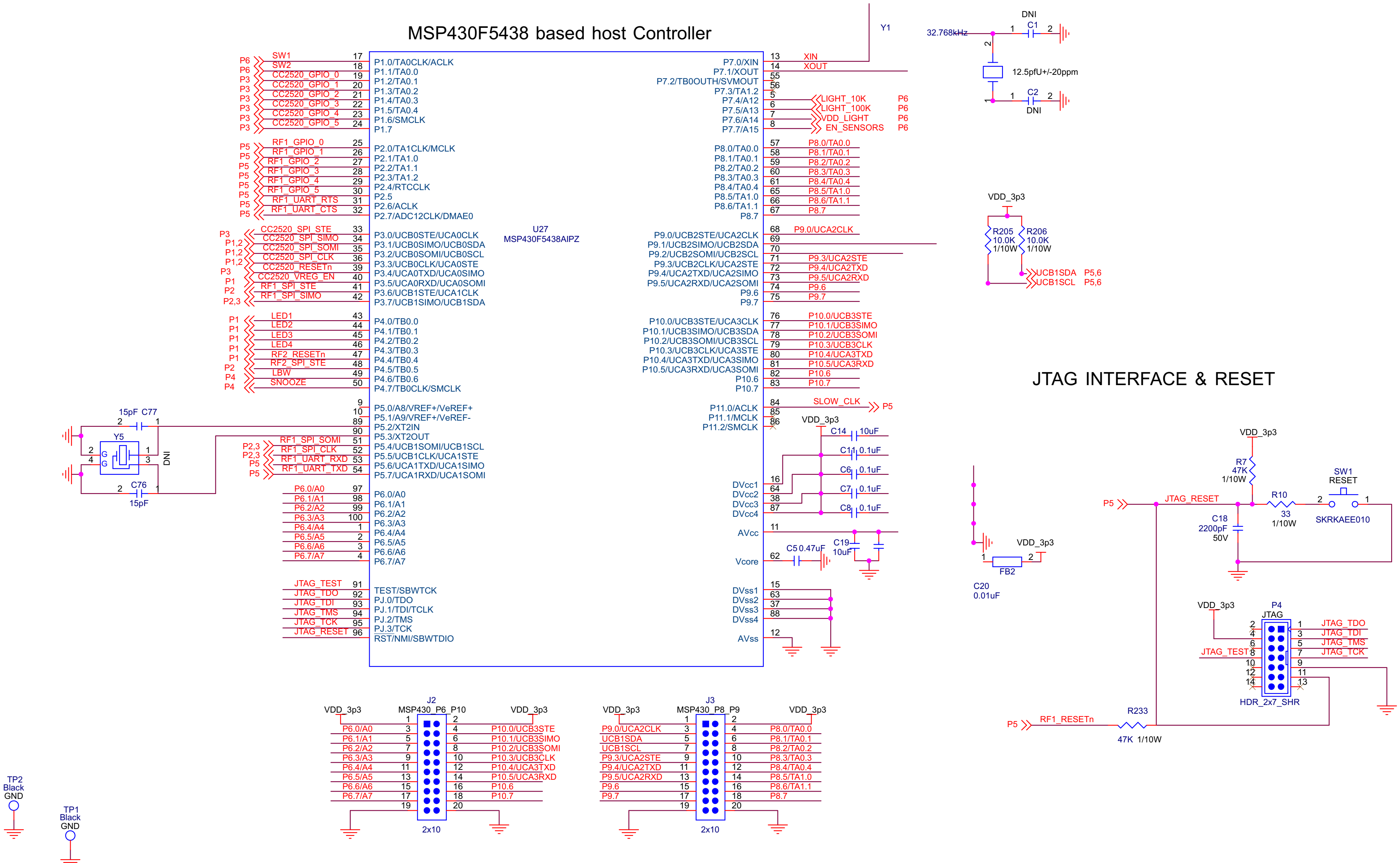
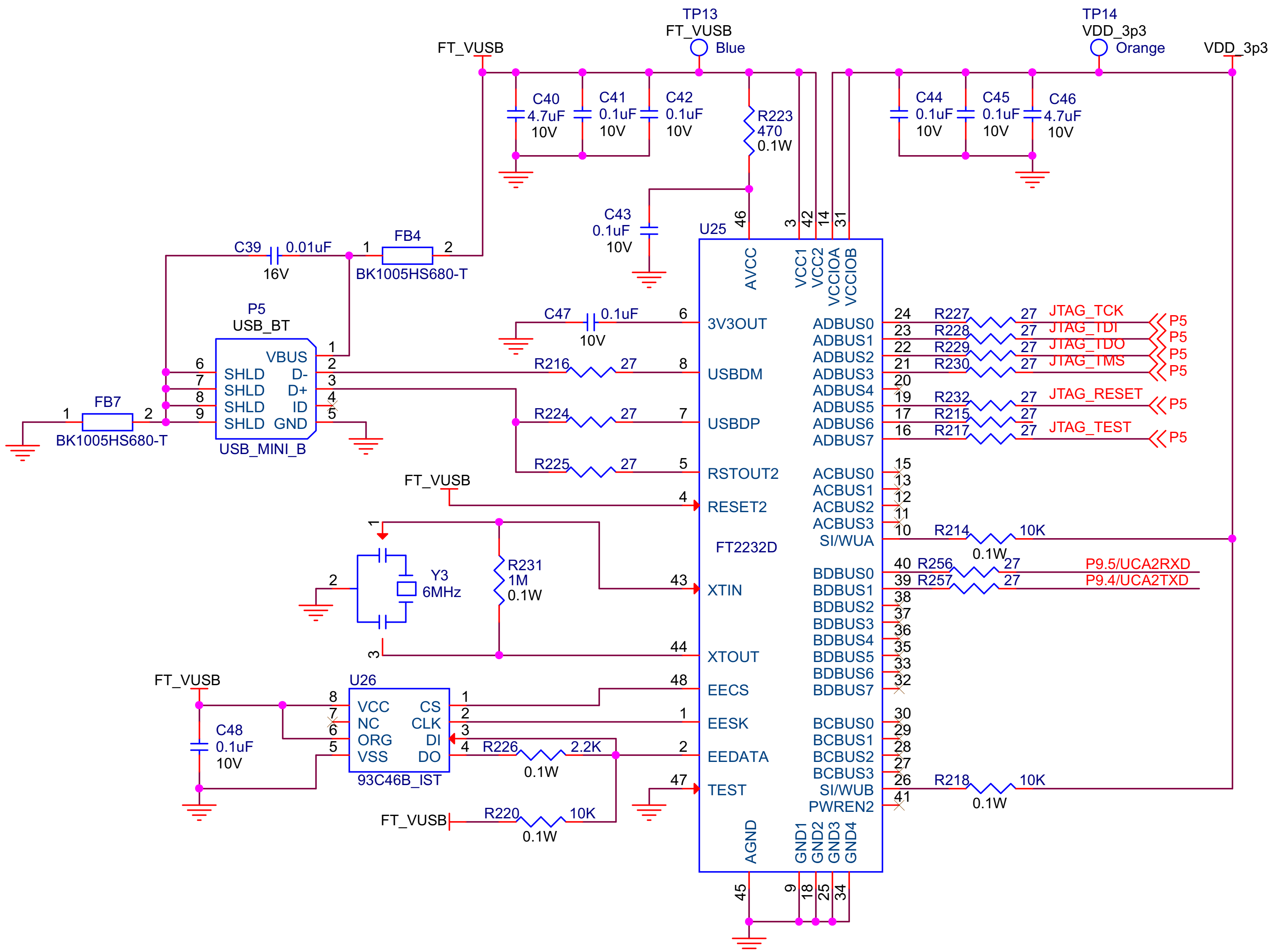
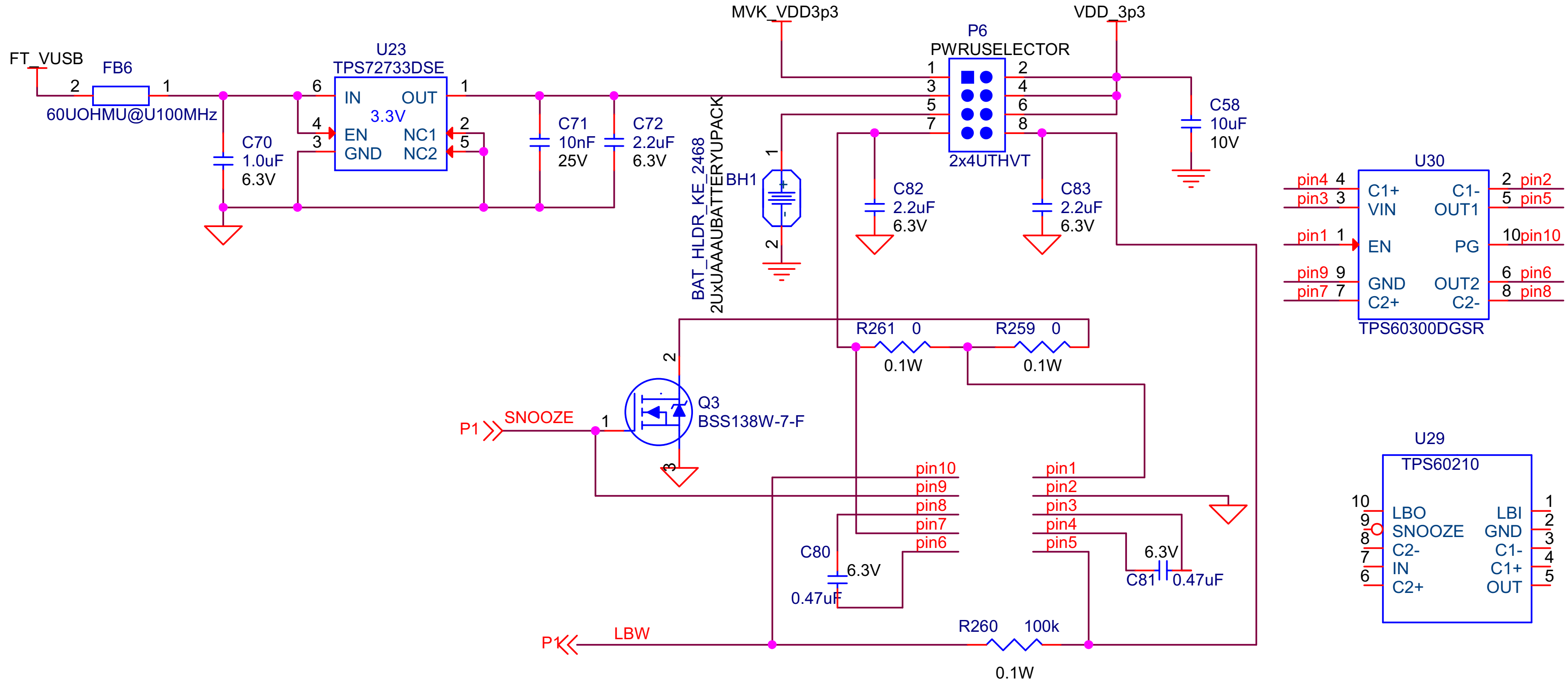


Figure 16. MSP430 MCU and JTAG Interface Schematic



A **Note:** All 27 Ohm resistors are 5%, 0.1W

Figure 17. USB to UART/JTAG Schematic



A Values of R261 and R259 have to be calculated. R260 is a pullup resistor in the 100kOhm to 1MOhm range. Refer to TPS60210 datasheet (literature number: SLVS296

B **Note:** U30 can be replaced with U29, if desired. Both U30 and U29 have the same footprint.

Figure 18. Power Supply Schematic

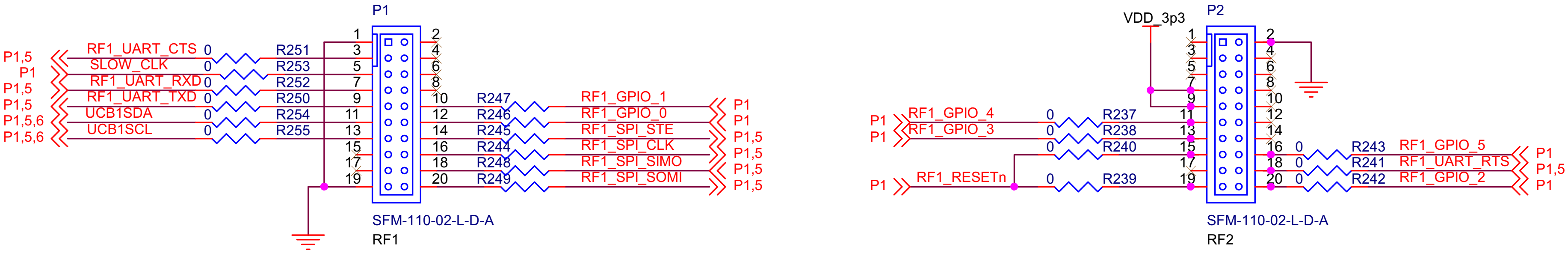


Figure 19. RF Connector Interface Schematic

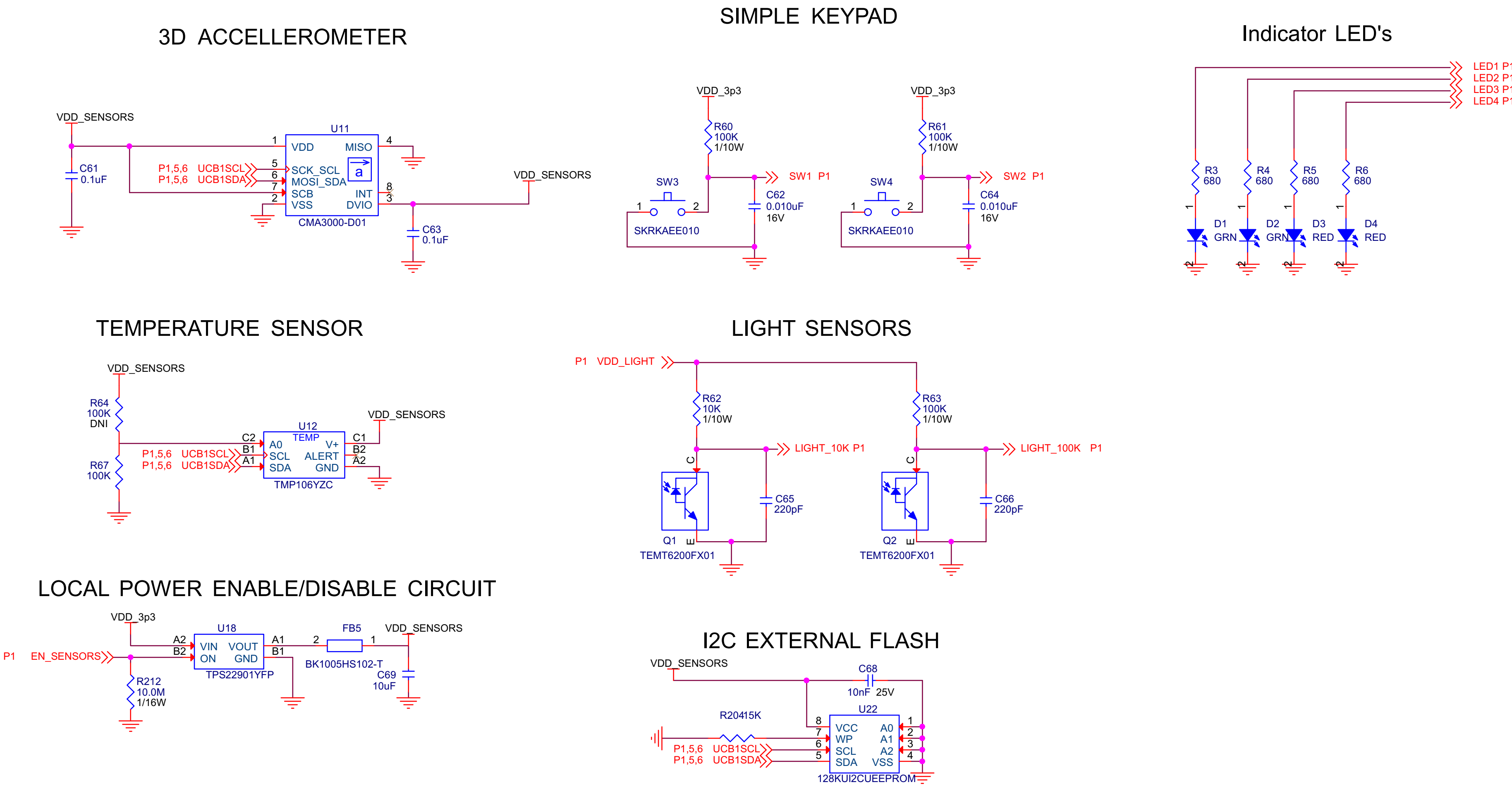


Figure 20. Sensors, I2C External Flash, Keypad, and LEDs Schematic

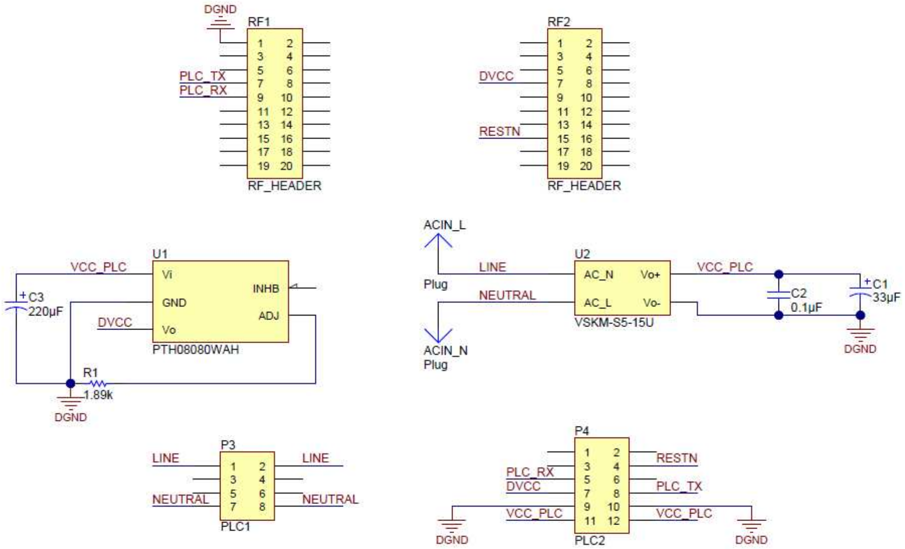


Figure 21. Interface Card Schematic

9.2 Bill of Materials

To download the bill of materials (BOM), see the design files at www.ti.com/tool/TIDM-RF-SENSORNODE. Table 1 shows the BOM for the RF sensor node and Table 2 shows the BOM for the interface Card.

Table 1. RF Sensor Node Bill of Materials

Item #	Quantity	Part Reference	Manufacturer	Manufacturer Part Number
1	1	ANT1	N/A	IIFA_CC2420
2	1	BH1	Keystone Electronics	2468
3	8	C1 C2 C100 C101 C80 C81 C82 C83	Taiyo Yuden	UMK105CG120JV-F
4	1	C5	Taiyo Yuden	LMK105BJ474KV-F
5	17	C6 C7 C8 C11 C41 C42 C43 C44 C45 C47 C48 C49 C50 C52 C53 C61 C63	Taiyo Yuden	LMK105BJ104KV-F
6	5	C14 C19 C57 C58 C69	Taiyo Yuden	LMK107BJ106MALTD
7	3	C20 C62 C64	Murata Electronics	GRM155R71C103KA01D
8	1	C39	Taiyo Yuden	EMK105B7103KV-F
9	2	C40 C46	TDK Corporation	C1608X5R1A475K
10	1	C51	Taiyo Yuden	LMK105BJ105KV-F
11	4	C54 C55 C76 C77	Murata	GRM1555C1H150JZ01D
12	1	C56	Taiyo Yuden	UMK105CG470JV-F
13	2	C65 C66	Taiyo Yuden	UMK105B7221KV-
14	3	C68 C71 C18	Taiyo Yuden	TMK105B7103KV-F
15	1	C70	Taiyo Yuden	JMK105BJ105KV-M
16	1	C72	Taiyo Yuden	JMK105BJ225MV-F
17	2	D1 D2	ROHM	SML-510MWT86
18	2	D3 D4	Lite-On Inc	LTST-C190KRKT
19	2	FB2 FB6	Taiyo Yuden	BK1608HS600-T
20	2	FB3 FB5	Taiyo Yuden	BK1005HS102-T
21	2	FB4 FB7	Taiyo Yuden	BK1005HS680-T
22	2	J2 J3	Samtec	HMTSW-110-07-G-D-230
23	1	L10	Johanson Technologies	L-07C2N2SV6T
24	2	P1 P2	SAMTEC	SFM-110-02-L-D-A
25	1	P4	Sullins	SBH11-PBPC-D07-ST-BK
26	1	P5	Hirose	UX60A-MB-5ST
27	1	P6	Samtec	HMTSW-104-07-G-D-230
28	2	Q1 Q2	Vishay	TEMT6200FX01
29	1	Q3	Diodes Inc	BSS138W-7-F
30	4	R3 R4 R5 R6	Panasonic-ECG	ERJ-2GE0R681X
31	2	R7 R233	Panasonic - ECG	ERJ-2GEJ473X
32	1	R18	Panasonic-ECG	ERJ-2RKF5602X
33	3	R60 R61 R67	Panasonic - ECG	ERJ-2GEJ104X
34	1	R62	Panasonic - ECG	ERJ-3EKF1002V
35	1	R63	Panasonic - ECG	ERJ-3GEYJ104V
36	11	R64 R227 R228 R229 R230 R232 R215 R216 R259 R260 R261	Panasonic-ECG	ERJ-2GEJ104X
37	1	R204	Panasonic - ECG	ERJ-2GEJ153X
38	2	R205 R206	Panasonic - ECG	ERJ-2RKF1002X
39	2	R208 R212	Vishay/Dale	CRCW040210M0FKED
40	3	R214 R218 R220	Panasonic - ECG	ERJ-2GEJ103X
41	5	R216 R224 R225 R256 R257	Panasonic - ECG	ERJ-2GEJ270X

Table 1. RF Sensor Node Bill of Materials (continued)

42	1	R223	Panasonic - ECG	ERJ-2GEJ471X
43	1	R226	Panasonic - ECG	ERJ-2GEJ222X
44	1	R231	Panasonic - ECG	ERJ-2GEJ105X
45	20	R237 R238 R239 R240 R241 R242 R243 R244 R245 R246 R247 R248 R249 R250 R251 R252 R253 R254 R255 R300	Panasonic-ECG	ERJ-2GE0R00X
46	3	SW1 SW3 SW4	Alps	SKRKAEE010
47	2	TP1 TP2	Components Corporation	TP-105-01-00
48	1	TP13	Components Corporation	TP-105-01-06
49	1	TP14	Components Corporation	TP-105-01-03
50	1	U4	TEXAS INSTRUMENTS	CC2520RHD
51	1	U5	Johanson Technology	2450BM15B0002
52	1	U11	VTI Technologies	CMA3000-D01
53	1	U12	Texas Instruments	TMP106YZC
54	2	U13 U18	Texas Instruments	TPS22901YFP
55	1	U16	Laird Technologies EMI	BMI-S-210-F
56	1	U22	ST Microelectronics	M24128-BWMN6TP
57	1	U23	Texas Instruments	TPS72733DSE
58	1	U25	Future Technology	FT2232D
59	1	U26	Microchip	93C46B-I/ST
60	1	U27	Texas Instruments	MSP430F5438AIPZ
61	1	U29	Texas Instruments	TPS60210
62	1	U30	Texas Instruments	TPS60300DGSR
63	1	Y1	Micro Crystal	CC7V-T1A 32.768kHz 12,5pF +/-20ppm
64	1	Y3	AVX	PBRC6.00MR50X000
65	1	Y4	Epson Toyocom	FA-128-32.000M-F10V-W3
66	1	Y5	Epson Toyocom	FA-128-32.000M-F10V-W3
67	1	R10	Panasonic - ECG	ERJ-2RKF1001X

Table 2. Interface Card Bill of Materials

Part	Value	Device	Package	Digikey Number
C1	33uF	CPOL-EUE2-5	E2-5	493-1059-ND
C2	0.1uF	C-EUC0603	C0603	311-1343-1-ND
C3	220uF	CPOL-EUE2-5	E2-5	493-1062-ND
CN1	MA04-2	MA04-2	con-lstb	S7107-ND (Not Needed if LSD board soldered directly on interface boardcard. This part makes the board less compact.)
CN2	MA06-2	MA06-2	con-lstb	S7109-ND (Not Needed if LSD board soldered directly on interface board. This part makes the board less compact.)
R1	1.91K	RES0805	R0805	311-1.91KCRCT-ND
U$1	RF_HEADER	RF_HEADER	TFM-110-02-SM-D-A-K	Must be ordered from Samtec
U$1	RF_HEADER	RF_HEADER	TFM-110-02-SM-D-A-K	Must be ordered from Samtec
U$2	VSK	VSK	VSK-S5-15	102-2518-ND
U9	PTH08080	PTH08080	PTH08080	296-20432-ND
Electric Plug				Q114-ND (Alternatively, a regular electric wire can be stripped for this part.

9.3 Layer Plots

To download the layer plots, see the design files at www.ti.com/tool/TIDM-RF-SENSORNODE. Figure 22 shows the layer plots for the RF sensor node.

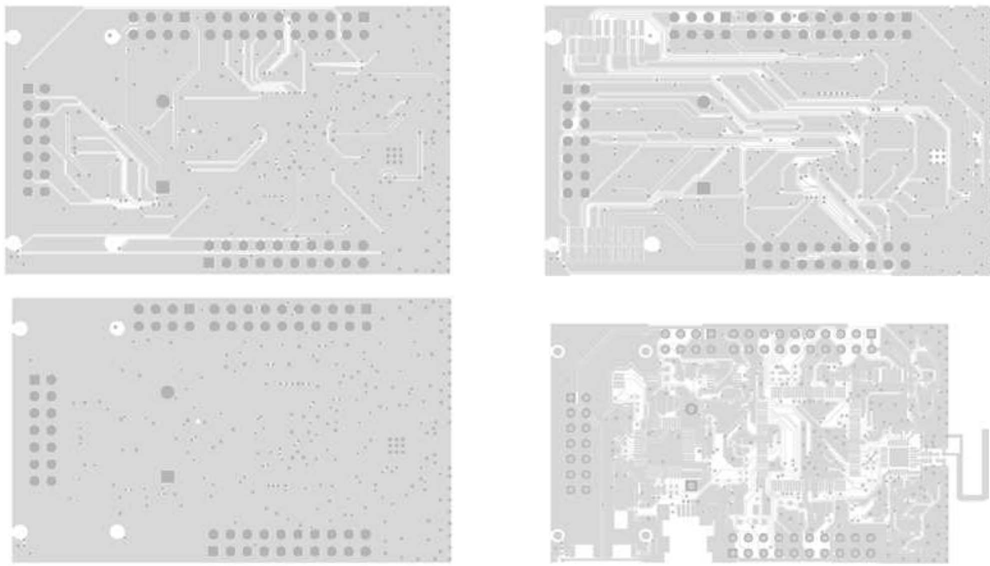


Figure 22. RF Sensor Node Layer Plots

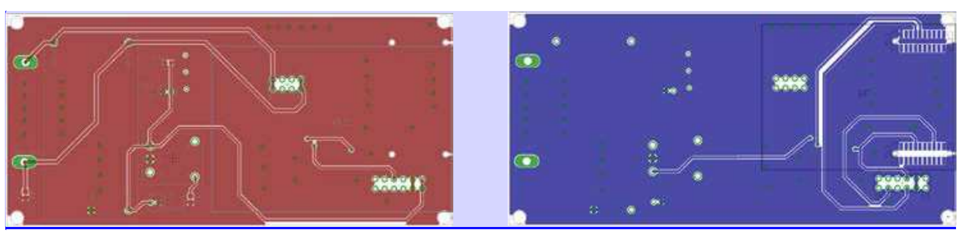


Figure 23. Interface Card Layer Plots

9.4 Eagle Project Files

To download the Eagle project files, see the design files at www.ti.com/tool/TIDM-RF-SENSORNODE.

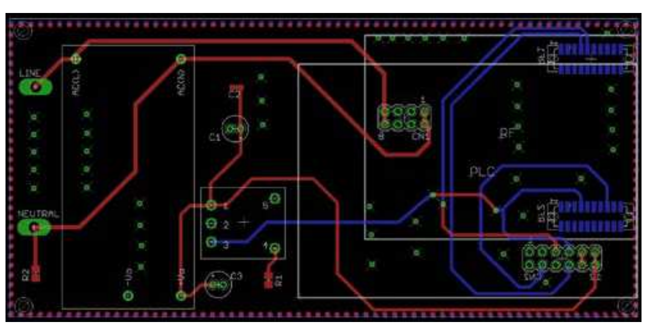


Figure 24. RF Sensor Node Layout

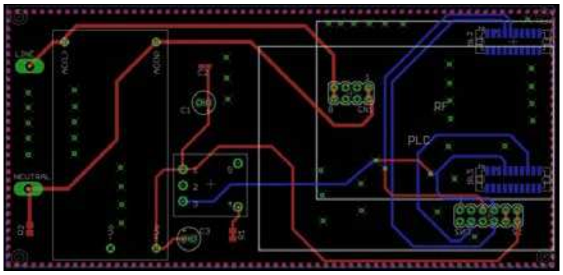


Figure 25. Interface Card Layout

9.5 Gerber Files

To download the Gerber files, see the design files at http://www.ti.com/tool/TIDM-RF-SENSORNODE.

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