

TI Designs Multiband wM-Bus RF Subsystem



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Design Resources

TIDC-Multiband-WMBUS	Design Folder
MSP430FR4133	Product Folder
CC1120	Product Folder
TPS62730	Product Folder
EM Adapter BoosterPack	Product Folder



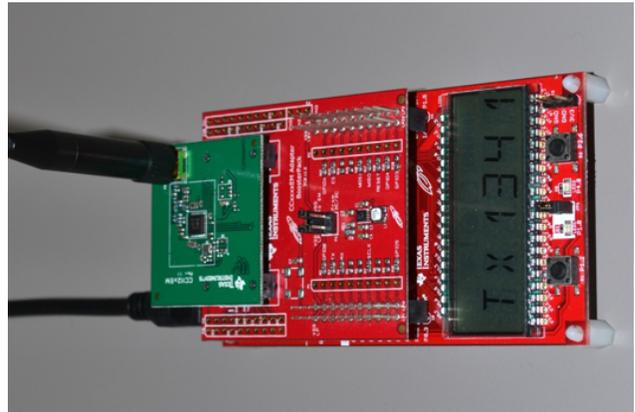
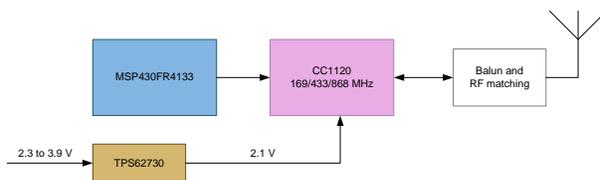
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Design Features

- Low-Power 169-, 433-, and 868-MHz wM-Bus RF Subsystem With 4-mux Segment LCD
- Example Source Code for wM-Bus Physical Layer in C, S, T, F, and N-Modes
- Market Leading RF Blocking, Selectivity, and RX Sensitivity Solution
- Ultra-Low-Power LCD Applications With RF Link
- Configuration Files for SmartRF™ Studio 7 for wM-Bus C, S, T, F, and N-Modes Receive Operation
- Supports Multiple Battery Technologies (for example, Li-SoCl₂, Li-MnO₂, and others)

Featured Applications

- Heat Cost Allocators with wM-Bus RF Link
- Smart Meters (Gas, Water, Heat, and Electricity) With wM-Bus at 169, 433, and 868 MHz
- In-Home Displays With wM-Bus
- Home Automation Applications With Proprietary RF Protocol Link



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1 Key System Specifications

The CC1120 operates from 2.0 to 3.6 V (3.9 V is the absolute maximum value allowed) and the transmit current for 15 dBm of TX power (conducted measurement) is typically 54 mA at a 3.3-V supply. The BOM of the CC1120EM has been optimized for the best RF performance on each frequency band, and there are no SAW filters or TCXO components used. Adding an external SAW component is possible and in many applications could be a good practice, especially when a GSM/GPRS or a 3G modem is being used as in some E-meters and data collectors.

In addition to low-cost XTAL devices, the CC1120 also supports TCXO components that are popular in narrow-band (< 25 kHz) RF applications. Narrow-band RF systems mandate the highest possible frequency accuracy over temperature and lifetime and are used in gas or water meters at 169 MHz, social alarms, and home alarm systems.

To achieve the lowest energy consumption with the CC1120, the TPS62730 with a fixed 2.1-V output is used. The input voltage range for this DC/DC converter is from 1.9 to 3.9 V, and a 30-nA (typ.) ultra-low-power bypass mode is integrated. The TPS62730 automatically enters bypass mode once the battery voltage falls below a defined transition threshold.

The DC/DC converter is available in a very small 1×1.5-mm², 6-pin QFN package, achieves up to 95% DC/DC efficiency, and can provide up to a 100-mA output current, using up to 3-MHz switching frequency. These 100-mA output currents have a sufficient margin to provide the total current required for the MCU and radio device.

The MSP430FR4133 operates between 1.8 and 3.6 V but can also handle up to 4.1 V (the absolute maximum rating). The operating ambient temperature for the MSP430FR4133, CC1120, and TPS62730 is $T_A = -40^{\circ}\text{C}$ to 85°C .

2 System Description

The CC1120 is targeted at systems with ETSI Category 1 Compliance in 169-MHz and 433-MHz bands and offers a high spectral efficiency (9.6 kbps in 12.5-kHz channel in compliance with the FCC Narrowbanding Mandate). The CC1120 delivers market leading blocking, selectivity, and sensitivity RF performance numbers in all supported wM-Bus modes below 1 GHz, which are:

- around 169.400 MHz (all N-modes)
- 433 MHz (F-mode)
- 868 MHz (S, T, and C1- and C2-modes)
 - R-mode is not considered here due to low popularity

Using a supply voltage of up to 3.6 V delivers excellent RF results but increases power loss in the internal LDOs of the CC1120. To reduce these power efficiency losses and extend the battery life in such an RF system, use the lowest possible supply voltage for both MCU and RF devices. Also consider that the supply voltage must be the same for both MSP430FR4133s running wM-Bus protocol example code and the CC1120 to avoid voltage level issues on the SPI and the control signals between those two devices. Therefore, the choice was made for the TPS62730 with a 2.1-V output (The TPS62733 with a 2.3-V fixed output is also available and could be used as an alternative if a 2.3-V supply is needed due to other system considerations).

To determine the most efficient power scheme for any radio and LCD system, it is required to calculate the so-called system power budget. The latter consists of LCD current consumption (which is usually quite constant), the RF current consumption (which varies in transmit, receive, or inactive modes), and the current for the rest of the application. Consider the leakage of the batteries (for battery operated systems) as well as the efficiency of the power supply (such as an LDO or DC/DC component) as well.

Depending on the application's duty cycle, for example how many transmit and receive operations per day are required, how long is the duration for each of these operations and which transmit power level is used, the RF energy consumption can typically contribute somewhere in the range of 30% to 60% of the total power budget. In wM-Bus-enabled water meters or heat cost allocators, the transmit operations can occur from every 10 seconds to every few minutes or even several hours, depending if a mobile or stationary reading of the RF data is being used. During inactivity the MSP430FR4133 should be in the lowest power mode with real-time clock (RTC) and the charge pump and LCD on of 0.94- μ A typical current at 3 V. For the CC1120 device, this duty cycle means either to shut down the device completely (power disconnect) or put it in sleep mode during the inactivity time. The power-up and initialization procedure of the CC1120 after shutdown takes a few milliseconds and is suitable for less frequent RF operations. In other cases with a higher duty cycle, using the CC1120 sleep mode with register retention (the latter has a typical value of only 0.12 μ A at 3-V supply) is the better option.

The combination of the TPS62730 + CC1120 + MSP430FR4133 radio delivers a market-leading solution in terms of both RF performance and ultra-low-power consumption, including "always-on" segment LCD operation. Using an LCD display is mandatory for most metering applications in EMEA and is often the second largest contributor to the system's power budget after the RF subsystem.

The RF solution described here meets and exceeds the requirements of all wM-Bus systems at 169-, 433-, and 868-MHz bands, which are becoming very popular in Europe for smart flow meters. Finally, the FR4133 ultra-low-power and cost-effective MCU enables very low-power LCD operation with its integrated LCD controller and handles the wM-Bus protocol. Adding the TPS62730 enables a longer battery lifetime, as both the CC1120 and MSP430™ can be operated with a higher power efficiency.

2.1 MSP430FR4133 — Ultra-Low-Power FRAM MCU

The MSP430FR4133 is a 16-bit embedded MCU with optimized low-power modes, an active current of 126 $\mu\text{A}/\text{MHz}$ and standby mode of 770 nA with an RTC counter and LCD running. It also provides a 15.5-KB ferroelectric RAM (FRAM) non-volatile memory and a built-in error correction code (ECC), configurable write protection, unified memory of program code, constants, and storage area. The FRAM memory has a 10^{15} write cycle endurance and is radiation resistant and nonmagnetic, which is a perfect fit for metering applications.

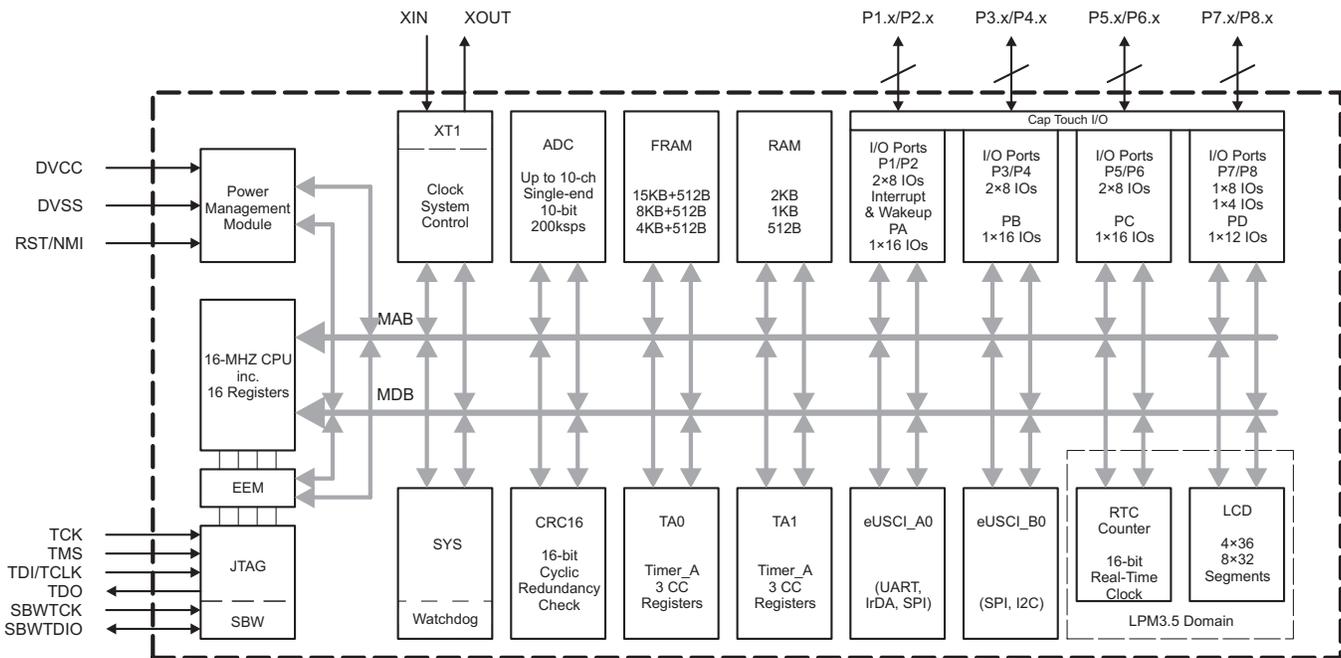


Figure 1. Functional Block Diagram of MSP430FR4133

2.2 CC1120 — High-Performance RF Transceiver for Narrow-Band Systems

The CC1120 transceiver features an adjacent channel selectivity of 64 dB at 12.5-kHz offset and blocking performance of 91 dB at 10-MHz offset in combination of excellent receiver sensitivity of -123 dBm at 1.2 kbps. In transmit mode, it transforms the wM-Bus data packets as per EN13757-4 [7], created by the example software code in the MSP430FR4133, into RF signal and passes it to the antenna. In receive mode, it receives RF signal from the antenna, detects the bit stream, and converts the bits into data bytes, which are then passed to the MSP430FR4133 over SPI for further wM-Bus protocol processing.

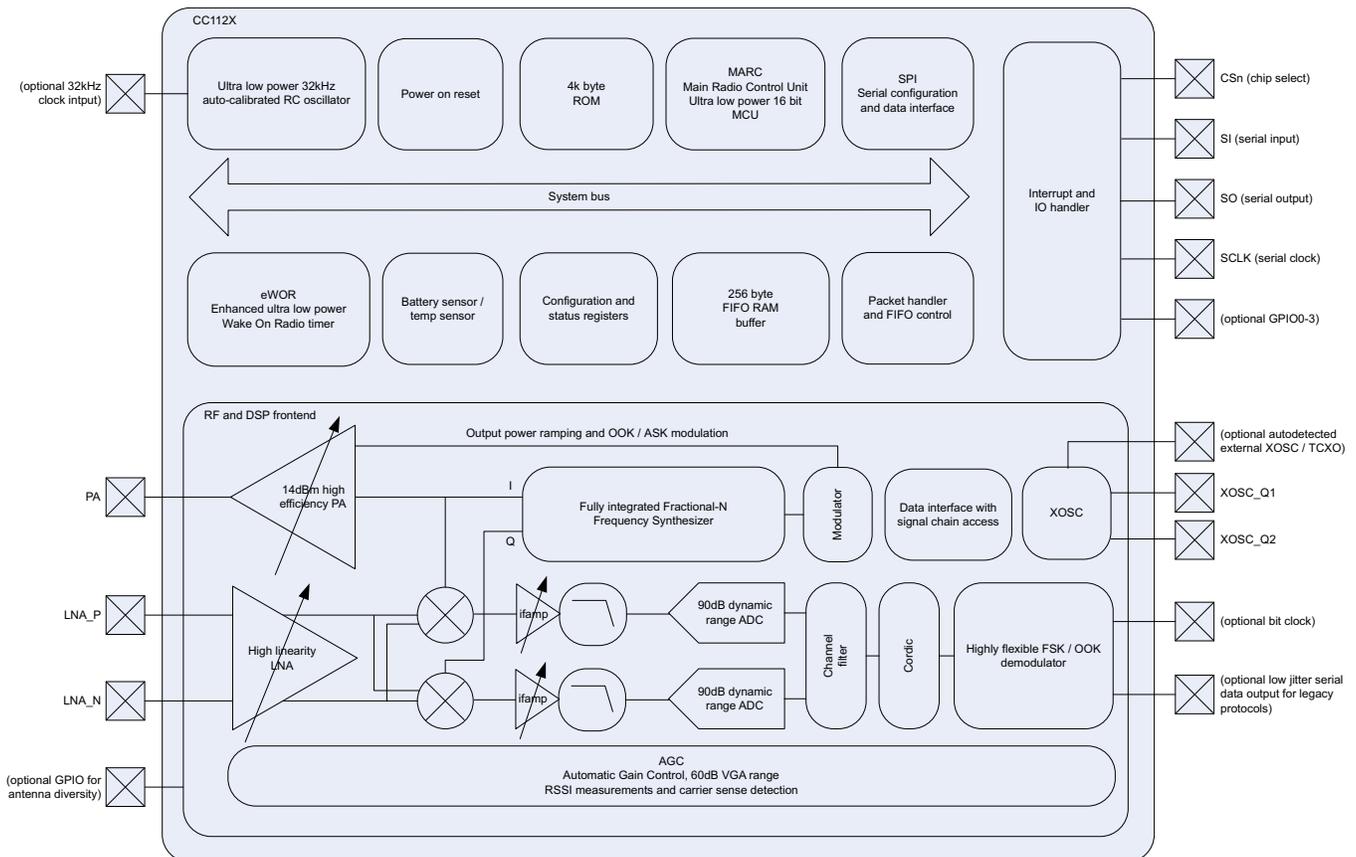


Figure 2. Functional Block Diagram of CC1120

2.3 TPS62730 — Step-Down Converter With Bypass Mode for Ultra-Low-Power Wireless Applications

The TPS62730 is a high-frequency synchronous step-down DC-DC converter optimized for ultra-low-power wireless applications, using TI's sub 1-GHz and 2.4-GHz RF transceivers and System-On-Chip solutions. The TPS62730 reduces the current consumption drawn from the battery during TX and RX mode, provides up to a 100-mA output current, and allows the use of tiny and low-cost chip inductors and capacitors. With an input voltage range of 1.9 to 3.9 V, the device supports Li-primary battery chemistries such as Li-SOCl₂, Li-SO₂, Li-MnO₂, and also two-cell alkaline batteries.

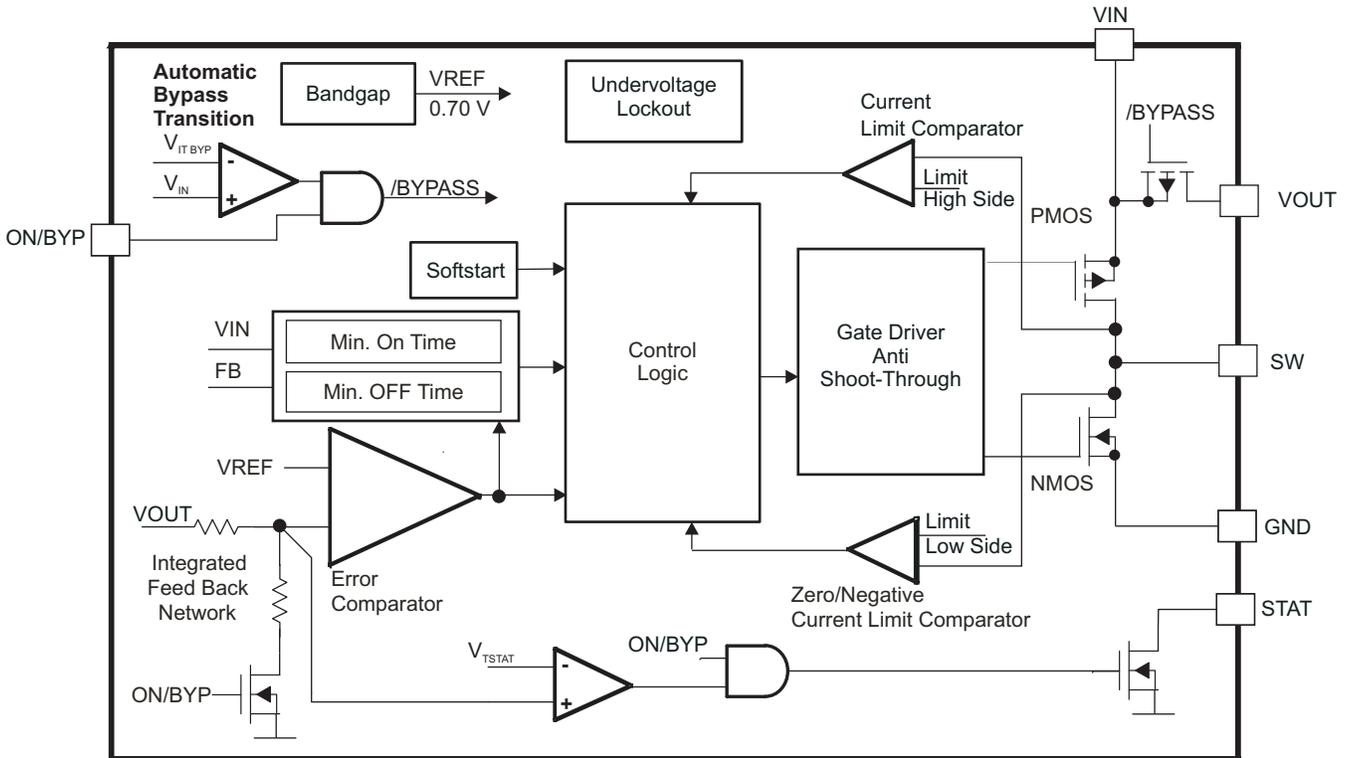


Figure 3. Block Diagram of TPS62730

3 Block Diagram

The system block diagram is shown in [Figure 4](#). The DC/DC converts the battery voltage to 2.1 V, which are delivered to both the MSP430 and CC1120 devices. The MCU uses a GPIO pin to enable the bypass function of TPS62730 if needed (for example, while the complete subsystem is in standby mode).

The radio has its Balun and matching network, built with discrete 0402-sized passive components, and an antenna connector (which is the 50-Ω RF feeding point).

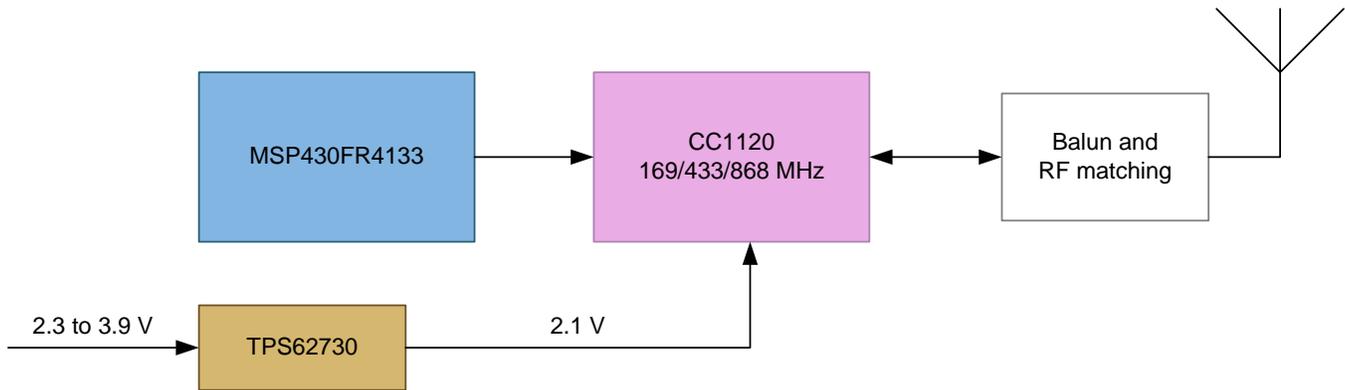


Figure 4. Block Diagram of Multiband wM-Bus RF Subsystem at 169, 433, and 868 MHz

3.1 Highlighted Products

3.1.1 MSP430FR4133

The MSP430FR4133 offers multiple differentiated features, which makes an excellent device for metering and RF applications, requiring both ultra-low power and cost-effective LCD functionality. This is typically the case in water or heat meters and heat cost allocators (HCA) with the wM-Bus RF subsystem. Further important features of MSP430FR4133 include:

- a digitally controlled oscillator (DCO) that allows the device to wake up from low-power modes to active mode in less than 10 μ s
- a functional RTC counter and LCD (in LPM3.5) while the rest of peripherals are off
- I/Os that can be configured as capacitive touch I/Os
- an extremely fast read and write access to FRAM memory

3.1.2 CC1120

The CC1120 device is a fully integrated single-chip radio transceiver designed for high performance at very low-power and low-voltage operation in wM-Bus enabled wireless systems. All filters are integrated, thus removing the need for costly external SAW and IF filters. The device supports the industrial, scientific, and medical (ISM) and short range device (SRD) frequency bands at 164 to 192 MHz, 274 to 320 MHz, 410 to 480 MHz, and 820 to 960 MHz, and is compatible with the wM-Bus standard, defined in the 169-, 433- and 868-MHz sub-bands.

The separate 128-B FIFOs in TX and RX direction inside the CC1120 enable an easy handling of the wM-Bus packets and sufficient time for handling the data bytes over SPI, avoiding FIFO over- or underflow conditions while transmitting or receiving data over the air. The Manchester hardware encoder and decoder are processing the S-mode and T2-mode (from other to meter direction) data packets automatically, eliminating the need of Manchester operations per the software in the MSP430FR4133. The main operating parameters of the CC1120 are controlled through a set of registers written or read out through an SPI directly connected to the MCU.

3.1.3 TPS62730

The TPS62730 combines a synchronous buck converter for a high-efficient voltage conversion and an integrated ultra-low-power bypass switch to support low-power modes of modern MCUs and RF ICs. The synchronous buck converter includes TI's DCS-Control™, an advanced regulation topology that combines the advantages of hysteretic and voltage mode control architectures. While a comparator stage provides excellent load transient response, an additional voltage feedback loop ensures high DC accuracy as well. The DCS-Control enables switch frequencies up to 3 MHz, excellent transient, AC load regulation, and operation with small and cost competitive external components.

4 System Design Theory

Several considerations were taken into account when defining this RF subsystem with the main focus on all of the following:

- Obtaining the best RF performance (RX sensitivity and blocking parameters) in all wM-Bus bands (169, 433, and 868 MHz)
- Lowest system cost with "always-on" ultra-low-power segment LCD support
- Highest power efficiency in any operating mode: power-down (or sleep), transmit, and receive

4.1 Power Efficiency

The TPS62730 is an "RF friendly" DC/DC device, meaning RF performance (such as RX sensitivity and blocking) of the CC1120 is not degraded to the switching frequency of the TPS62730. Further test data for the TPS62730 in combination with CC112x radio family is found in *The wM-Bus Standard* [7].

4.2 RF Performance at 169-, 433-, and 868-MHz Bands

The CC1120 meets the most stringent requirements in EM300220v2.4.1 for ETSI Category 1 receiver in both 169 MHz as well as 433 MHz and for ETSI Category 2 receiver in the 868-MHz band. The TIDC-Multiband-WMBUS reference design uses the same layout and PCB for all these ISM bands; only the values for a few L and C components are different, depending on the target operating frequency.

4.3 System Cost

In the high-volume deployment of wM-Bus systems in Europe, the total system cost (or BOM cost) is of utmost importance. Due to the CC1120's "Feedback to PLL" feature for automatic frequency compensation in the receiver, using a low-cost XTAL with ± 10 ppm is possible in all wM-Bus modes, even in the narrow-band N-modes. Achieving the ETSI Category 1 receiver performance is already quite challenging; however, doing so without an external TCXO and external SAW filter is even better. In summary, using the CC1120 high-performance radio is a cost-efficient solution, as costly external components like LNA, SAW-filter, and TCXO are not required in most wM-Bus applications.

5 Getting Started: Hardware

The hardware kit is comprised several boards:

- an MSP-EXP430FR4133 LaunchPad™
- a TIDC-Multiband-WMBUS board for the respective wM-Bus RF band
- a special adapter board, named EM Adapter Booster Pack, to convert the mechanical connection from LaunchPad pin rows to the TIDC-Multiband-WMBUS RF connectors

The TIDC-Multiband-WMBUS is available for purchase at TI's e-store (<https://store.ti.com/default.aspx>) in three different options:

1. [CC1120EMK-169](#)
2. [CC1120EMK-420-470](#)
3. [CC1120EMK-868](#)

In addition, the [TPS62730EVM-726](#) is also available for purchase at TI's website. This TPS62730EVM is added to prove the current reduction in RX and TX modes of the CC1120 while running the wM-Bus protocol.

5.1 Setting up the Hardware System

External power is delivered either through the USB cable from a PC to the MSP430 LaunchPad ([Figure 5](#)) or through the bench power supply, using J6 on the LaunchPad. When J6 is used, the jumper for 3.3 V at J101 of MSP-EXP430FR4133 has to be open.

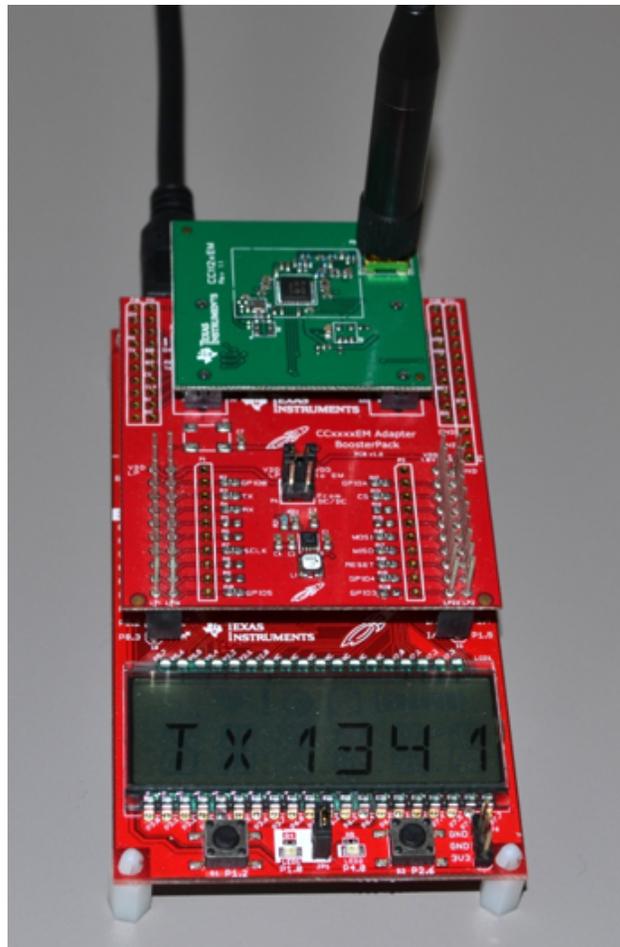


Figure 5. MSP-EXP430FR4133 With TIDC-Multiband-WMBUS (868-MHz Version) and EM Boost Adapter

The TPS62730EVM-726 board is connected through a HP E3631A DC power supply unit; the latter is set to 2.1, 3.0, or 3.6 V. When 2.1 V is used, the TPS62730 device automatically switches to bypass mode. Alternatively, the jumper JP1 is set to either ON or bypass settings. When JP1 is set to ON, the TPS62730 is active and regulates the input voltage to from 3.0 or 3.6 V down to a 2.1-V output.

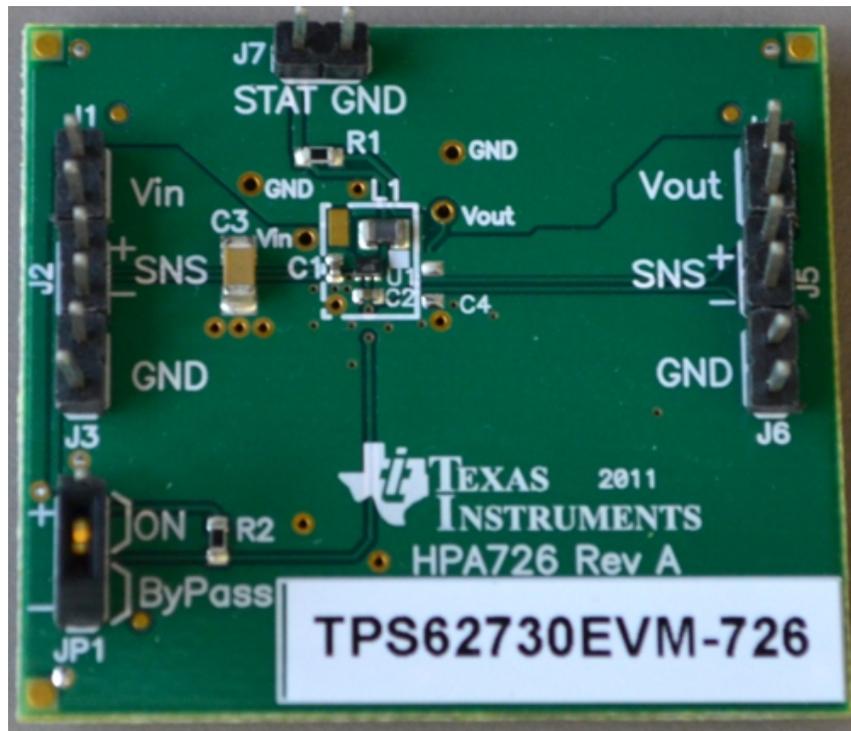


Figure 6. TPS62730 With Jumper Set to ON

5.2 Testing Conditions

All measurements were done at room temperature. The test frequencies were 169, 433, or 868 MHz, depending on the wM-Bus mode under test.

Power supply:

- HP E3631A bench supply to MSP-EXP430FR4133 ($V_{IN} = 3.6, 3.0, \text{ and } 2.1 \text{ V}$) or
- HP E3631A bench supply to TPS62730-726 EVM to MSP-EXP430FR4133 ($V_{IN} = 3.6, 3.0, \text{ and } 2.1 \text{ V}$)

NOTE: The HP E3631A unit has not been calibrated.

6 Getting Started: Firmware

There are two parts in any RF link, a transmitter and a receiver; both of these functionalities are provided in the example source code. This source code project can be compiled and debugged using Code Composer Studio™ (CCS) v6.0.1 or a later development tool where the MSP-EXP430FR4133 is connected to the PC over a USB cable.

For one set of the boards (see [Figure 7](#)), the TIDC-Multiband-WMBUS board will periodically transmit packets in the respective ISM band (for example, for 868 MHz that will be either S-, T-, C-, or C2OTHER-mode). The example code can be used for further modifications and improvements, as the focus of the code development has been to implement the wM-Bus protocol physical layer; therefore, no specific code optimizations for the MSP430 and CC1120 low-power modes have been done. There are multiple code examples for the CC1120 and MSP430FR4133 on TI's website that show how to obtain the lowest possible power consumption.

The second set of MSP-EXP430FR4133 and TIDC-Multiband-WMBUS board (with EM Boost Adapter in between) is used to receive and display the correctly decoded packets. In the receive part of the code, the wM-Bus packets are decoded and only a complete packet with CRC checked as correct will increment the count shown on the LCD while in RX mode of operation.

The software code examples are based on the TI wM-Bus example code [\[5\]](#), MSP-EXP430FR4133 out-of-box [\[9\]](#), and FRAM Water Meter TI design [\[10\]](#). To simplify, the maximal packet length is limited to 128 bytes, which is the FIFO depth of the CC1120.

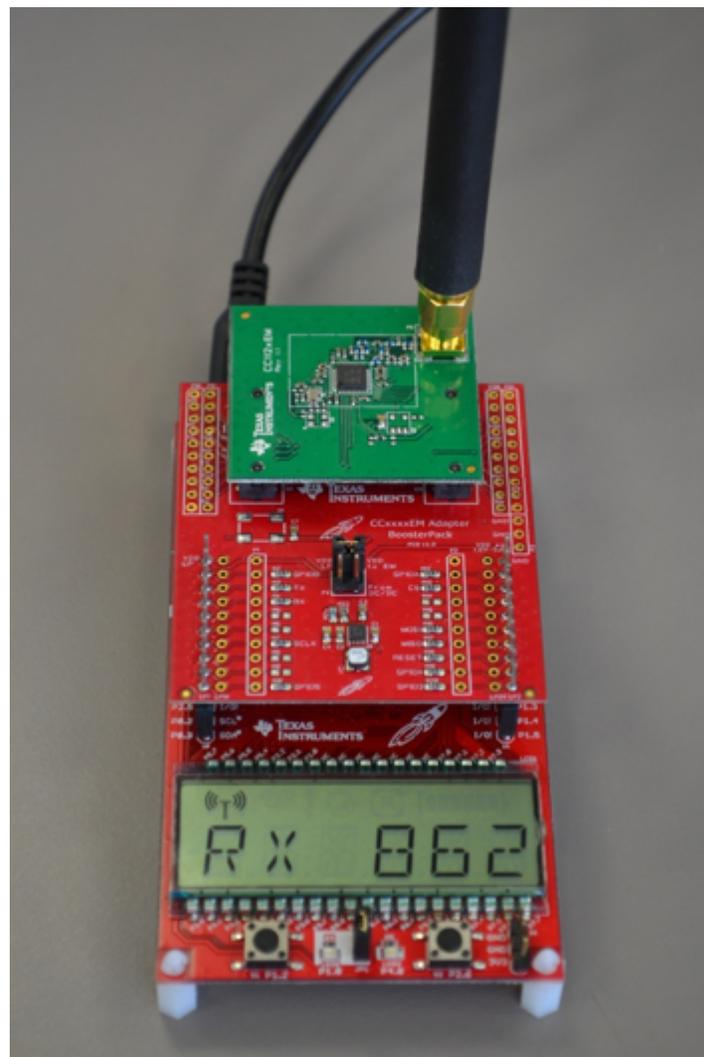


Figure 7. TIDC-Multiband-WMBUS in RX Mode

6.1 SmartRF Studio 7 Files

Eight XML configuration files for SmartRF Studio 7 have been tested and are provided as a reference, covering S-, T-, C1-, and C2-modes at 868 MHz, F-mode at 433 MHz, and Nabef, Ncd, and Ng modes at 169 MHz. In addition, the transmitted packets are captured by another piece of hardware, consisting of a TIDC-Multiband-WMBUS board mounted onto a TRXEB [12], connected to a Windows® PC running TI's SmartRF Studio 7 software [11].

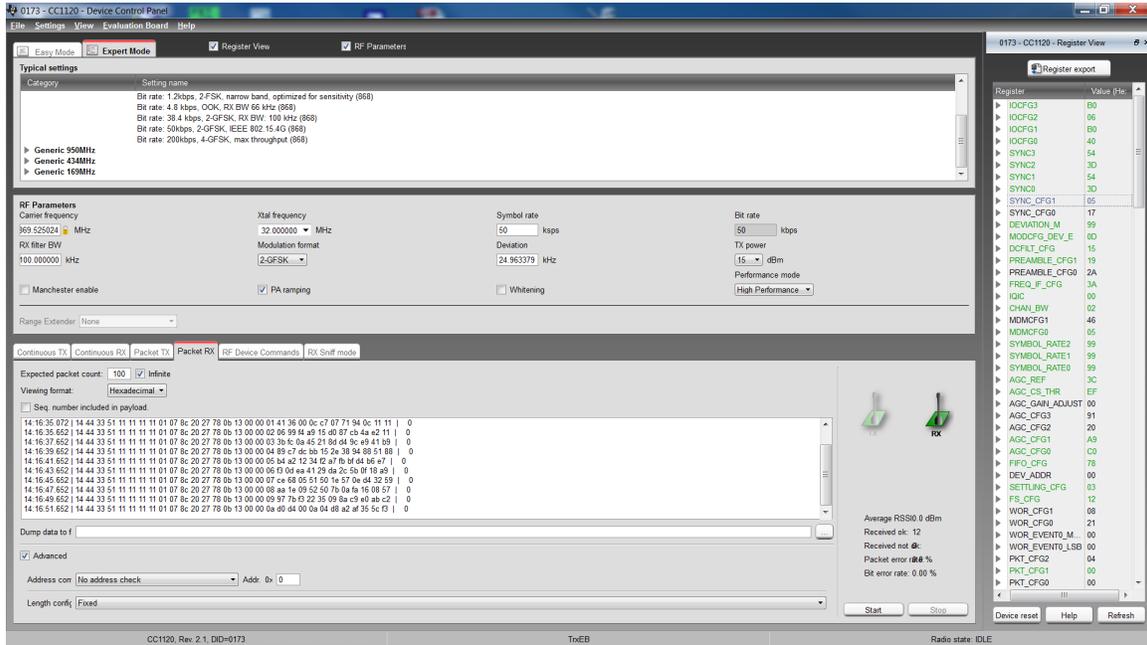


Figure 8. SmartRF Studio 7 With C2OTHER Configuration File Capturing wM-Bus Data Packets

All SRF7 configuration files use the "fixed" packet length setting, as the SmartRF Studio 7 is not able to decode and interpret the *Length* field due to 3-of-6 wM-Bus coding in T-mode or due to the exclusion of the subsequent CRC16 fields in *Format A* for S- and T-modes. As an example, testing the S-mode receive operation at 868.300 MHz requires that "TIDC_Multiband_WMBUS_Smode_RX.xml" is loaded into SRF7, using *File* → *Open Cfg F3* menu Item. Then SmartRF Studio 7 will receive the data packets and display them in HEX format, as shown in Figure 8.

6.2 wM-Bus Data Packets

The wM-Bus data packets transmitted are based on the example in the EN13757-4 document, as shown in Figure 9. The data packets in S- and T-modes use the "legacy" Format A, with multiple CRC16 fields in between each 16 data bytes and after the first data block of 9 bytes (excluding the L-field, which is always the first byte of any wM-Bus packet). The modes F, C and C2OTHER, and all N-modes use the newer packet Format B, which allows a maximum of two CRC16 fields per packet, thus minimizing the number of overhead bytes. In addition, NRZ coding is used (versus Manchester or 3-of-6 coding), which further reduces the number of bytes transmitted over the air.

Therefore, the new Format B brings a few important improvements:

1. Shorter transmission times, which leads to less energy drained from the battery
2. Reduced probability of RF interference that can disturb the reception of a data packet (due to shorter time over the air)
3. Neither 3-of-6 nor Manchester coding, achieving a higher effective data throughput
4. L-field also includes the CRC16 bytes, which simplify the length calculation of received packets. The CC1120 in-built packet engine is thus able to automatically recognize and decode the length of the wM-Bus data packet without any MCU intervention for length calculation and need for PKTLEN register reprogramming

Data format (as in EN13757-4):

```

Packet S2:  0F 44 AE 0C 78 56 34 12 01 07 44 47 78 0B 13 43 65 87 1E 6D
(20 Bytes) S- and T-Modes (Format A)
Packet C2:  14 44 AE 0C 78 56 34 12 01 07 8C 20 27 78 0B 13 43 65 87 7A C5
(21 Bytes) C1-, C2-, F- and all N-modes (Format B)
    
```

Figure 9. Byte Content of wM-Bus Data Packets (Format A or B)

The following modifications have been made:

1. Manufacturer ID of CEN (0xAE 0C) Bytes has been replaced with 0x5133 for Texas Instruments (Hong Kong) Ltd. (highlighted in yellow)
2. Manufacturer number 0x12345678, transmitted in reverse order is 0x11111111 (highlighted in gray)
3. The volume information 87 65 43 (in BCD) is replaced with a counter value, which starts with 0 and counts up for each data packet transmitted (highlighted in yellow)

NOTE: The highlighted green fields show the two CRC16 fields for a Frame Format A (Packet S2, shown in black) and the single CRC16 field for Format B (Packet C2, shown in blue).

```

Packet S2:  0F 44 33 51 11 11 11 11 01 07 ... 78 0B 13 00 00 01 ...
// (20 Bytes) S- and T-Modes (Format A)
Packet C2:  14 44 33 51 11 11 11 11 01 07 8C 20 27 78 0B 13 00 00 01 41 30
           14 44 33 51 11 11 11 11 01 07 8C 20 27 78 0B 13 00 00 02 06 03
...
(21 Bytes) C1-, C2-, F- and all N-modes (Format B)
    
```

Figure 10. Byte Content of wM-Bus Data Packets as Transmitted Over the Air (Format A and B)

These modifications represent an excellent software test as the CRC16 fields have to be recalculated for each packet.

6.3 C-Code Software Example

The source code CCS project combines both TX and RX functionality, which can be selected by pushing the button S1 and S2 on the MSP430FR4133LP board. The transmit unit sends periodically data packets based on an RTC timer in the MSP430FR4133, and the receiver unit decodes the received packets, increments a counter if the CRC16 fields are correct, and updates the LaunchPad's segment LCD. Optionally, the wM-Bus packets can be captured with the SmartRF Studio 7 as shown in Section 6.1 to visualize that they are transmitted and the packet content is correct.

7 Test Data

The RF performance of TIDC-Multiband-WMBUS for each wM-Bus mode has been extensively documented in the wM-Bus application note [4]. Additional RF performance measurements for the CC1120 in Nabef and Ncd modes and ETSI Category 1 requirements are found in the TIDC-WMBUS-169MHz user's guide (TIDU512).

7.1 TX Current

Measuring dynamic TX current is not simple due to the dynamically changing current levels while transmitting. In C2OTHER mode, the CC1120 is set to 15 dBm transmit power level and the current drawn is measured with a current probe with a 100-mV/1-A setting. The plot (shown in Figure 11) thus captures the current profile with 20 mA per square division, resulting in approximately a 54-mA peak current (as stated in the datasheet for 15 dBm at 868 MHz).

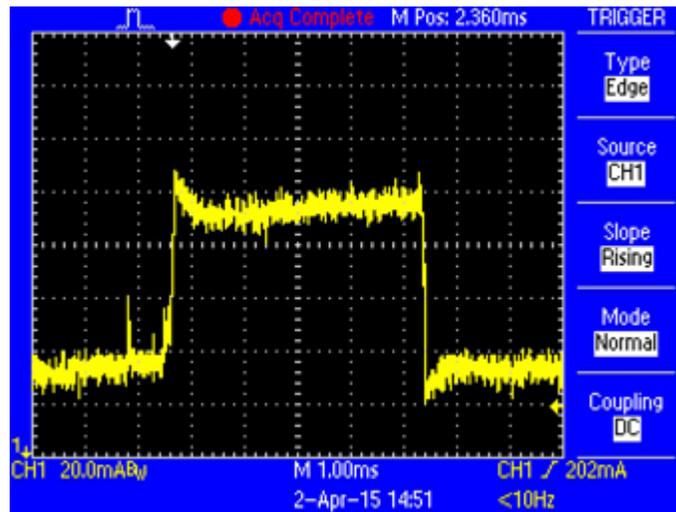


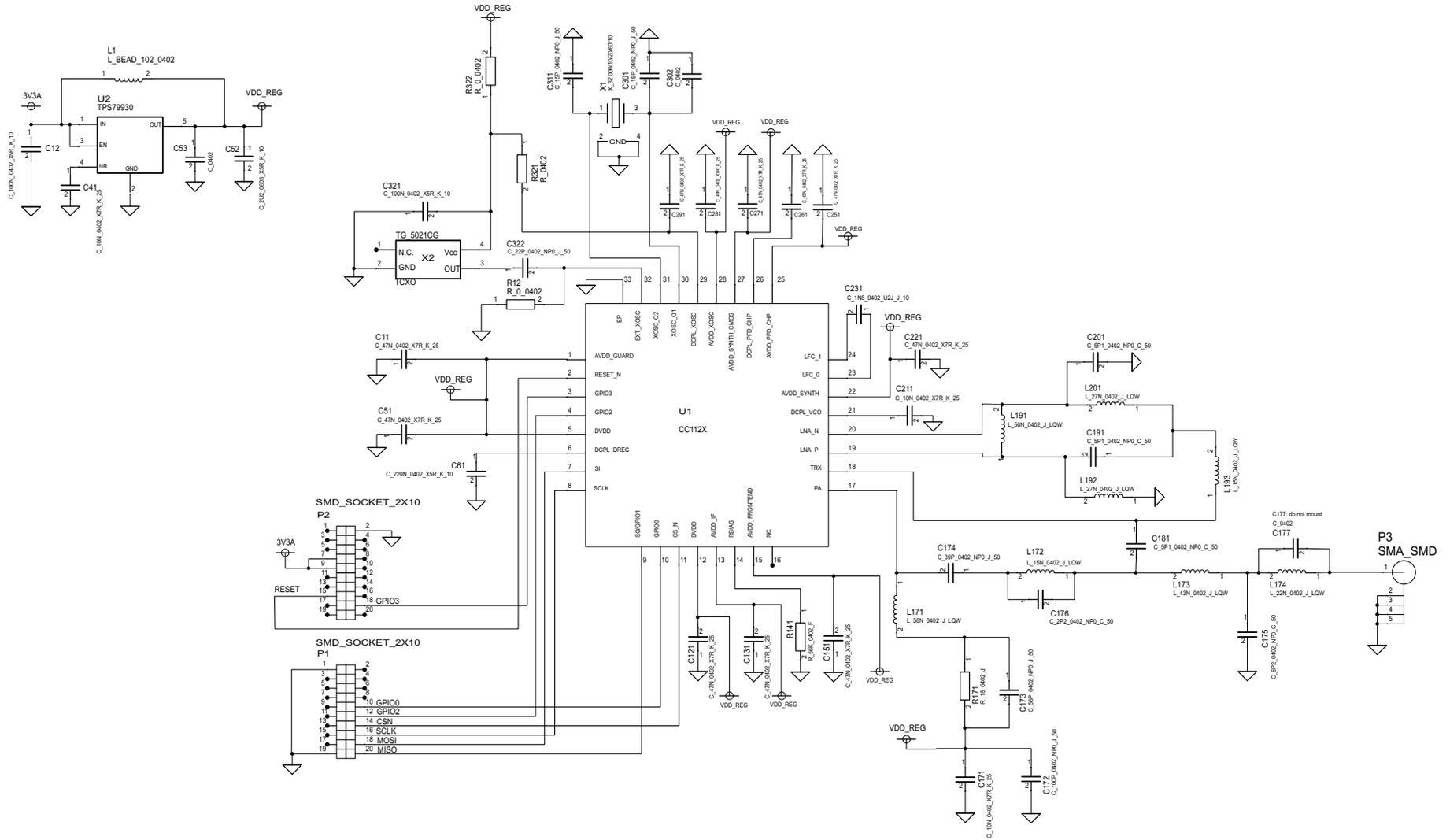
Figure 11. TX Current Plot for One Data Packet in C2OTHER Mode at 869.525 MHz

7.2 RX Current

When testing the RX current while the firmware was running in RX mode, C2OTHER wM-Bus mode equaled a 2-GFSK modulation at a 50-kbps datarate with Non-Return to Zero (NRZ) coding.

Table 1. Average RX Current Consumption With CC1120 Continuously in RX Mode

INPUT VOLTAGE	RX CURRENT (NO TPS62730)	TPS62730 IN BYPASS MODE	TPS62730 IN ACTIVE MODE	COMMENTS
2.1 V	23.5 mA	23.5 mA	23.5 mA	Average current
3.0 V	23.5 mA	23.5 mA	19 mA	Average current
3.6 V	23.5 mA	23.5 mA	16.5 mA	Average current



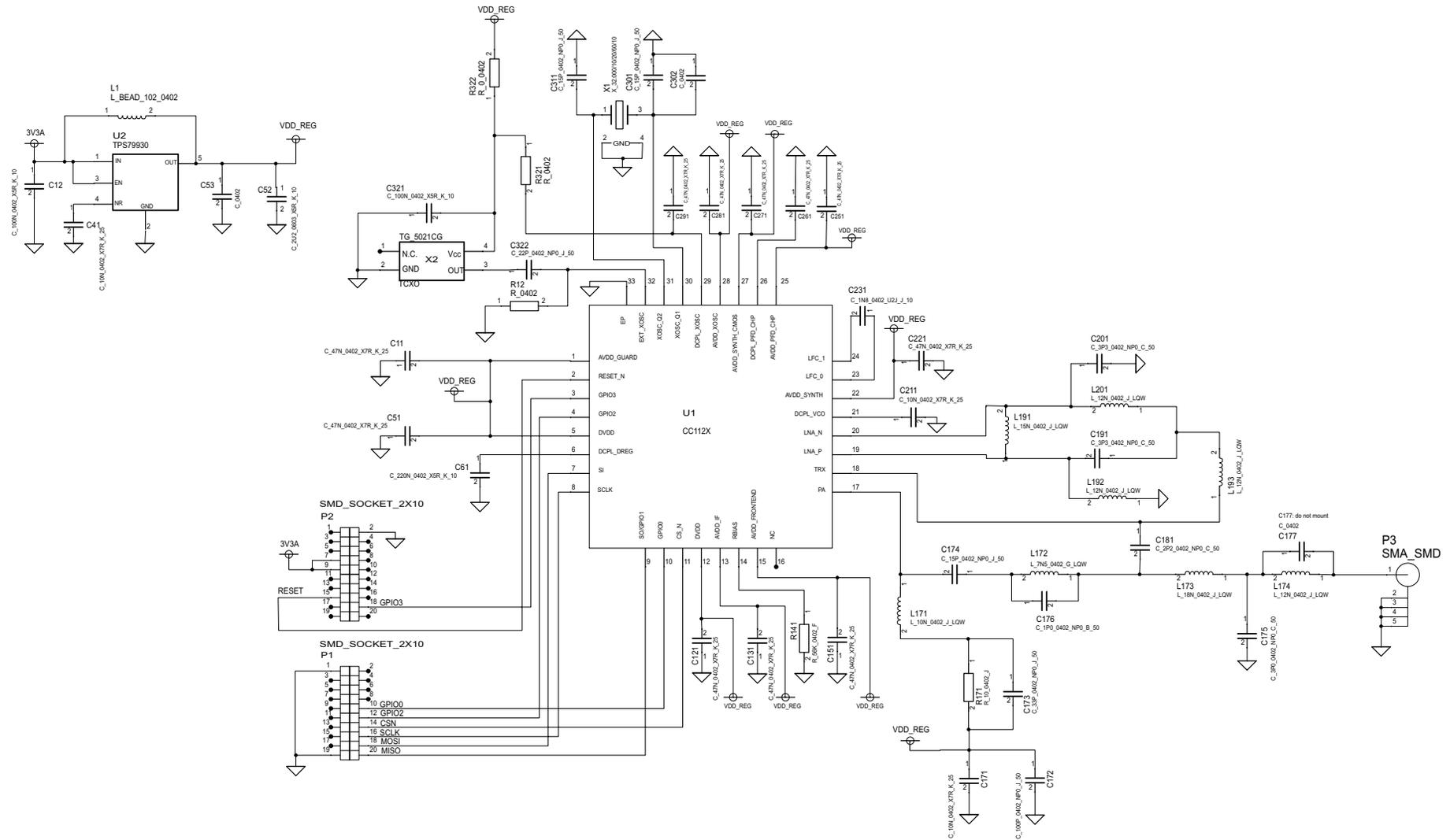


Figure 14. 868- to 915-MHz Frequency Band

8.2 **Bill of Materials**

To download the bill of materials (BOM), see the design files at [TIDC-Multiband-WMBUS](#).

8.3 **PCB Layout Recommendations**

Copy the layout exactly as shown in the Gerber files as it has been optimized for best RF performance; the RF subsystem is using a 4-layer PCB. Note that the PCB layout is identical for all RF bands (169, 433, and 868 MHz), only some of the component values for the RF Balun and the matching between the CC1120 and the antenna are different. Therefore, a TIDC-Multiband-WMBUS board can be populated for any of the wM-Bus frequency bands by using the respective passive L- and C-components (see BOM).

8.3.1 **Layer Plots**

To download the layer plots, see the design files at [TIDC-Multiband-WMBUS](#).

8.4 **CAD Files**

To download the CAD project files, see the design files at [TIDC-Multiband-WMBUS](#).

8.5 **Gerber Files**

To download the Gerber files, see the design files at [TIDC-Multiband-WMBUS](#).

8.6 **Assembly Drawings**

To download the assembly drawings, see the design files at [TIDC-Multiband-WMBUS](#).

9 Software Files

To download the software files, see the design files at [TIDC-Multiband-WMBUS](#).

10 References

1. Texas Instruments, *MSP430FR413x Mixed-Signal Microcontrollers*, MSP430FR4133 Datasheet ([SLAS865](#)).
2. Texas Instruments, *CC1120 High-Performance RF Transceiver for Narrowband Systems*, CC1120 Datasheet ([SWRS112](#)).
3. Texas Instruments, *Step Down Converter with Bypass Mode for Ultra Low Power Wireless Applications*, TPS62730 Datasheet ([SLVSAC3](#)).
4. Texas Instruments, *Wireless M-Bus Implementation with CC112x / CC120x High Performance Transceiver Family*, Application Note 121 ([SWRA423](#)).
5. Texas Instruments, *Wireless MBUS Implementation with CC1101 and MSP430*, Application Note 067 ([SWRA234](#)).
6. Texas Instruments, *Reduced Battery Current Using CC112x/CC1175/CC1200 with TPS62730*, Design Note 040 ([SWRA411](#)).
7. Beuth Verlag, *The wM-Bus Standard*, EN13757-4:2014-2 (www.beuth.de).
8. European Telecommunications Standards Institute, ETSI 300220 v2.4.1 (<http://www.etsi.org>).
9. Texas Instruments, *MSP-EXP430FR4133 Software Examples* ([SLAC682](#)).
10. Texas Instruments, *Water Meter Implementation with FRAM Microcontroller Software* ([TIDC664](#)).
11. Texas Instruments, *SmartRF Studio 7* (<http://www.ti.com/smartrfstudio>).
12. Texas Instruments, *SmartRF Transceiver Evaluation Board "TrxEB" User's Guide*, SmartRF TrxEB User's Guide ([SWRU294](#)).

11 Terminology

wM-Bus— The European RF Metering standard, providing solutions for 169, 433 and 868MHz bands

ETSI Cat. 1 Receiver— Definition for most stringent set of RF parameters in EN300 220 v2.4.1

N-mode— wM-Bus mode at 169 MHz, used in Italy and France for Smart Gas meter rollout. Multiple sub-modes exist, such as Nabef, Ncd and Ng (see [\[4\]](#) and [\[7\]](#))

F-mode— wM-Bus mode at 433 MHz

S-mode— wM-Bus mode at 868.3 MHz, used in OMS Specification and thus in many EU countries

T-mode— wM-Bus mode at 868.95 MHz, used in OMS Specification and thus in many EU countries

C-mode— "Compact" wM-Bus mode at 868.95 MHz, can be used in conjunction with T-mode (same receiver will be able to receive both T- and C-frames)

12 About the Author

MILEN STEFANOV is a system applications engineer at Texas Instruments, where he is responsible for Sub-1GHz RF communications solutions in Smart Grid applications. Milen is working on further improving TI's full wM-Bus system solution, consisting of single chip or MCU+RF devices, a complete wM-Bus protocol stack and a dedicated power management solution. Milen has a system-level expertise on Smart Metering and RF communications and over 16 years of experience working with customers. He has published several technical articles on wM-Bus related topics in the past four years. He earned his master of science in electrical engineering (MSEE) from Technical University in Chemnitz, Germany.

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