TI Designs: Reference Designs
Water Meter Implementation with MSP430FR4xx User's Guide

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Design Resources

TIDM-FRAM-WATERMETER	Design Folder
MSP430FR4133	Product Folder
DRV8837	Product Folder
TPS78233	Product Folder
SN65HVD75	Product Folder
TSS721A	Product Folder

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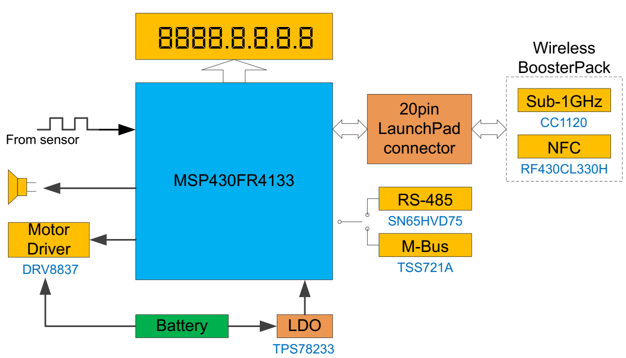
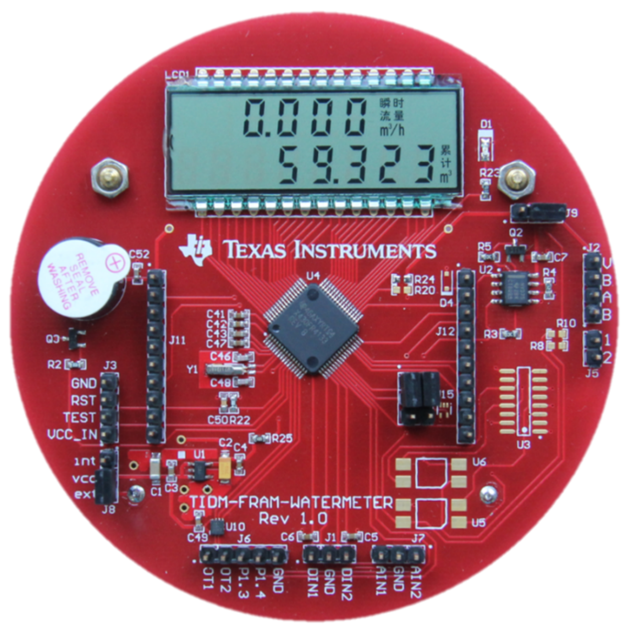
Design Features

- Magnetic Pulse Measurement
- 2.9 µA Standby Current
- Nonvolatile On-Chip FRAM Real-Time Storage
- RS-485 AMR
- Support NFC and Sub-1 GHz BoosterPack™
- Battery Voltage Monitor

Featured Applications

- Water Meter





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1 Overview

1.1 Smart water meter

Water meters measure the water flow in residential and commercial buildings in which a system for a public water supply is implemented. Most traditional water meters are mechanical meters. This kind of meter converts the water flow to the movement of a rotating disc. Each rotation is directly equated to a given volume of water. The functions of mechanical water meters include showing water flow measurement with mechanical pointers. Users can read the water flow by reading the meter dial as shown in Figure 1.

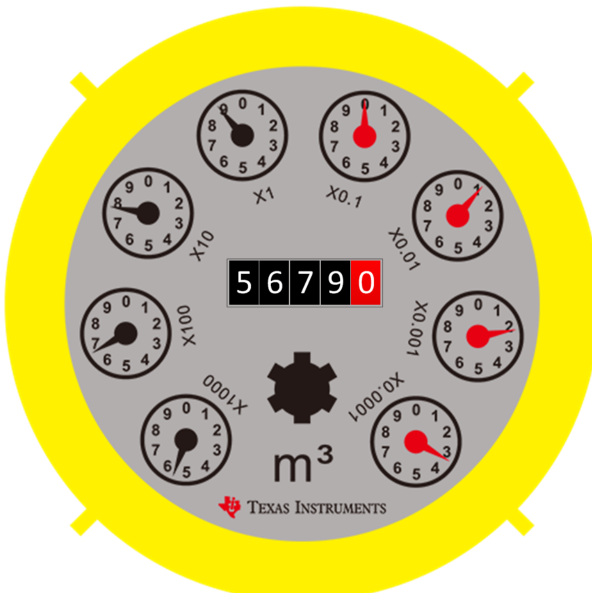


Figure 1. Mechanical Water Meter Dial

With the development of technology, mechanical water meters are gradually being replaced by electronic meters or smart meters. Usually, smart water meters integrate an electronic sensor in mechanical water meters. The normally used sensor is a reed switch, hall-effect sensor, or photoelectric coding register. After processing by the microcontroller unit (MCU) in the electronic module, the water flow data are transmitted to the LCD or output to an information management system.

The smart water meter comprises two main categories:

1. Prepaid Water Meter

   The typical prepaid water meter is an IC card water meter. This new type of water meter combines modern microelectronics, electronic sensors, and smart-IC-card technology to measure water consumption, transmit data about water flow, and settle accounts. In addition to water flow recording and an LCD, the meter can also calculate water bills using the time-sharing charging standard. Because the data transmission and settlement are conducted through IC cards, users can pay their bills in the office. See Figure 2.

Figure 2. Prepaid Water Meter

2. Automatic Meter Reading Water Meter

   Automatic meter reading (AMR) is the technology that automatically collects consumption, diagnostics, and status of the water meter and transmits the data to a central database for billing, troubleshooting, and analyzing. This technology saves vendors the expense of periodic trips to each physical location to read a meter. Another advantage is that billing can be based on real-time consumption rather than on estimates. This timely information coupled with analysis can help both vendors and customers to better control water production and water consumption.

   As shown in Figure 3, AMR is based on wired or wireless transmission technology, such as Meter-Bus and GPRS.

Figure 3. Automatic Meter Reading Water Meter

1.2 Mechanical Water Meter to Electronic Water Meter

In smart water meters, a sensor converts the water flow to an electrical signal, which can be accepted and processed by the MCU. Several kinds of sensors can be used for this purpose, such as a reed switch, hall-effect sensor, infrared photoelectric coding register, thick film resistor, and LC sensor. For more information about LC-sensor-type water meters, please refer to http://www.ti.com/tool/TIDM-3LC-METER-CONV.

Most smart water meters use reed switches or hall-effect sensors to count and measure water usage. In this kind of meter, a magnet is mounted on one rotating disc of the mechanical meter. The reed sensor is conveniently mounted on a PCB to sense the magnet each time it completes a revolution and send out a pulse signal to the MCU.

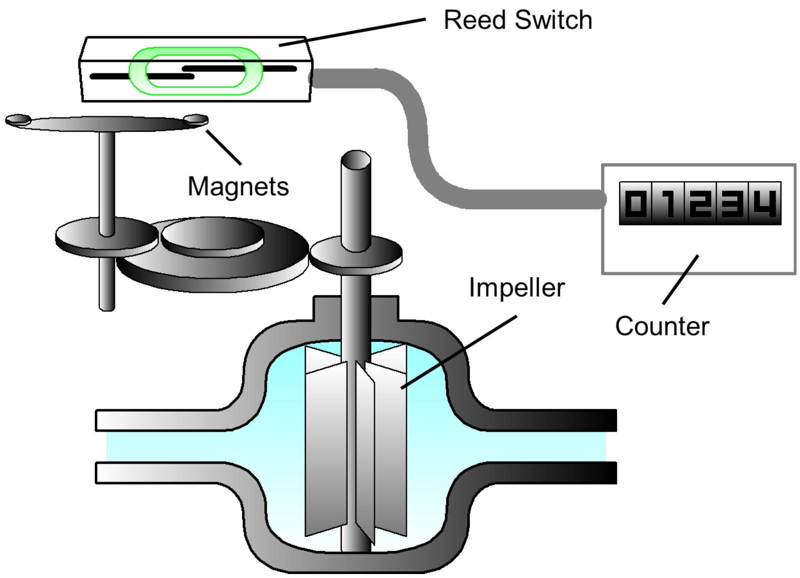


Figure 4. Electromagnetic Pulse Measure Principle

1.3 MSP430FR4133 in a Water Meter

MSP430FR4xx is a new ultra-low-power MSP430 FRAM-based microcontroller series. The abundant peripherals such as the FRAM, LCD_E, and eUSCI modules and the ultra-low-power features are very suitable in water meter applications.

- Ultra-Low-Power: The MSP430FR4133 MCU has 5 low-power modes. The power consumption is under 1 µA when MSP430FR4133 is in LPM3.5 with RTC Counter and LCD_E modules on, which is ideal for battery-powered water meter applications.
- LCD_E: This new LCD module supports up to 4 × 36 or 8 × 32 LCD segments. The module allows the user to configure all LCD pins to be either SEG or COM via software settings, which makes PCB layout convenient and single-layer PCB possible. The LCD_E module also provides an internal charge pump with an adjustable contrast control, which can keep consistent contrast during battery life.
- FRAM: FRAM is a nonvolatile memory that combines the speed, ultra low power, high endurance, and flexibility of SRAM, and high reliability and stability of Flash. MSP430FR4133 contains 15.5 KB FRAM and 2 KB SRAM. With FRAM, no external nonvolatile memory is required to store data in water meter applications.
- ADC: The sample rate of the ADC10 module in MSP430FR4133 is up to 200 ksps. The on-chip bandgap offers 1.2 V external reference and 1.5 V internal reference. With the ADC10 module, users can monitor VCC voltage without additional external components. The ADC10 module can also be used as an input for sensor signals in water meters with thick film.
- For electromagnetic-pulse water meters, both the GPIO and timer can be used to count the pulse. The Timer_A in MSP430FR4133 can work in LPM3 low-power mode, which benefits power saving in water meter applications.

2 Getting Started

2.1 Introduction

The TIDM-FRAM-WATERMETER reference design, featuring the MSP430FR4133 FRAM-based ultra-low-power microcontroller, is a fully-functioning battery-powered platform for the water meter that allows users to evaluate the MSP430FR4xx device in a water meter application.

The reference board design provides everything necessary for a water meter design, including an interface for a reed-switch sensor, an LCD, and interfaces for wired and wireless AMR. The out-of-box experience provides basic functions for water meter applications such as pulse count, valve control, and AMR demo. All the hardware and software are available for developers to easily develop their own water meter application.

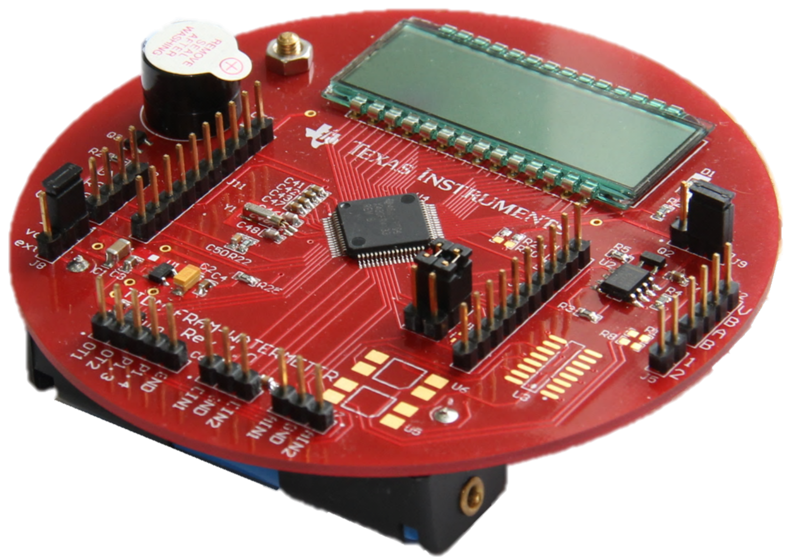


Figure 5. TIDM-FRAM-WATERMETER

2.2 Features

- Magnetic pulse measurement
- High measurement accuracy
- 4 × 24 LCD display
  - Instantaneous flow
  - Total flow
- Ultra-low power
  - MCU in LPM3 during standby
  - 2.9 µA standby current with RTC, LCD, and RF
  - 12 µA average power consumption, 10 years battery life with 1200 mAh battery
- Nonvolatile FRAM technology for application and real-time data storage
- Wired and wireless interface
  - RS-485
  - Meter-Bus
  - RF430CL330HTB NFC BoosterPack
  - CC1120 Evaluation Board Sub-1 GHz BoosterPack
- Battery voltage monitor
- Remote valve control

2.3 Kit Contents

- 1 × TIDM-FRAM-WATERMETER EVM board
- 1 × USB to RS-485 adapter
- 1 × 1200mAh Lithium battery

2.4 Out-of-Box Experience

To become familiar with this reference design, use its pre-programmed User Experience Code. This code demonstrates key features from a user level.

Figure 6 in the next section shows the main parts of the board and the standard configuration for the out-of-box experience. A detailed hardware description is given in Section 3.

To start, install the battery to power on the system and connect a pulse signal to the sensor interface. A more detailed explanation of the operation can be found in Section 4.

The User Experience Source code and more code examples are provided for download at http://www.ti.com/tool/TIDM-FRAM-WATERMETER. The code is licensed under BSD, and TI encourages reuse and modifications to fit specific needs.

In the User Experience Software section all functions are described in detail, and a project structure is provided to help users become familiar with the code.

Details on the Integrated Development Environment (IDE) installation process are provided in the IDE user's guides for IAR (SLAU138) and CCS (SLAU157).

These user's guides also contain detailed step-by-step instructions on how to import projects into the workspace. Links to the latest versions of these documents are always part of the IDE installations in the Windows start menu.

Refer to www.ti.com/ccs for more details on Code Composer Studio (CCS) including getting started videos. CCS covers all basic aspects in great detail (project creation, browsing, debugging, breakpoints, and resource explorer).

3 Hardware

This section describes the hardware design of TIDM-FRAM-WATERMETER EVM board. Figure 6 shows an overview of the hardware.

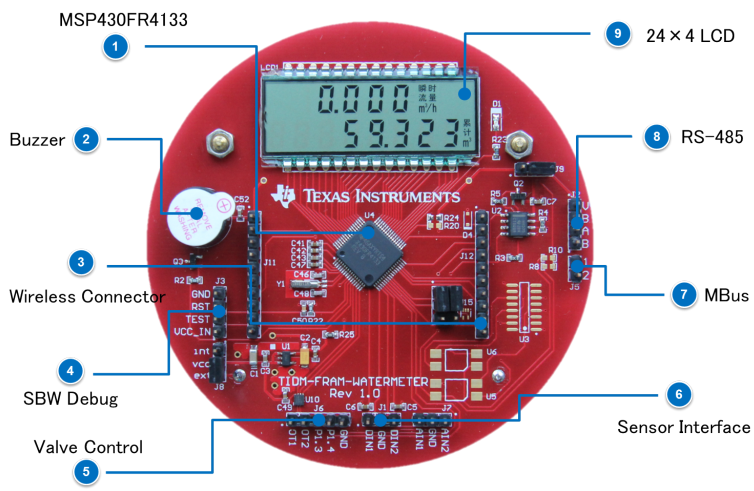


Figure 6. EVM Overview

3.1 Block Diagram

The block diagram is shown in Figure 7.

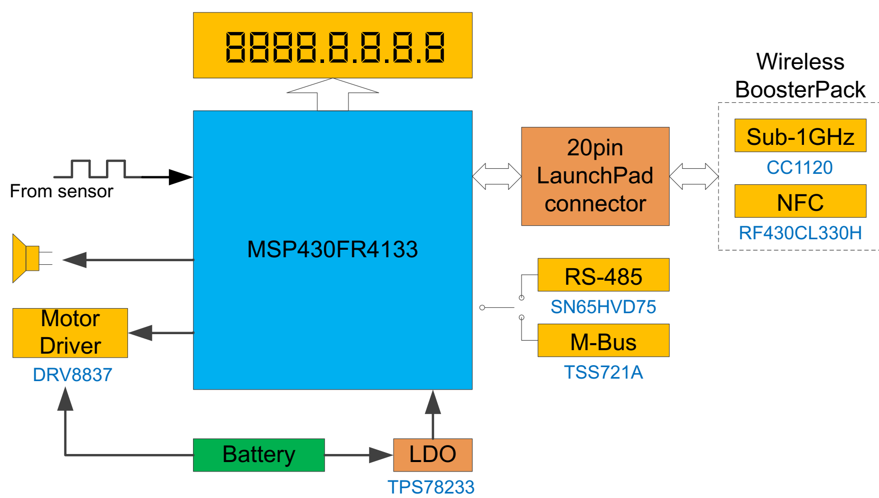


Figure 7. Block Diagram

Note: MSP430FR4133, CC1120, TPS78233, DRV8837, SN65HVD75, RF430CL330H, and TSS721A are devices of Texas Instruments.

3.2 Hardware features

3.2.1 MSP430FR4133

MSP430FR4133 is a FRAM-based MCU device with 15.5 KB of nonvolatile memory and high-GPIO pin count including a segment LCD controller. To learn more about this device, visit www.ti.com/product/MSP430FR4133. The pinout of the PM64 package is shown in Figure 8.

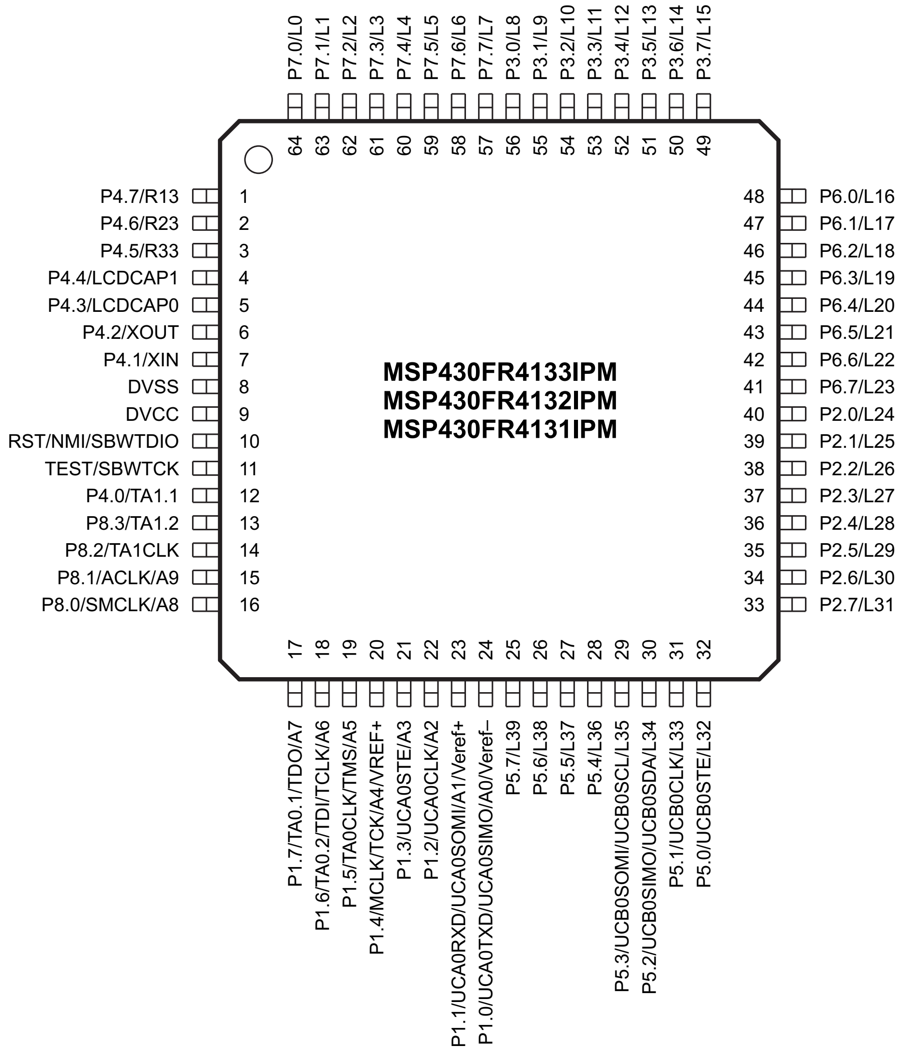


Figure 8. MSP430FR4133 Pinout

3.2.2 Sensor Interface

The sensor interface can measure pulse signal from reed switch and hall effect sensor directly. The frequency to be measured can be up to 9999 Hz so it is very easy to realize high accuracy measurement.

The measurement principle uses MSP430 Timer0_A3 as the pulse counter. Timer0_A3 operates without any CPU intervention, allowing the CPU to remain in low-power mode. The CPU then wakes up and read the TA0R register once per second. The TA0R value will be the instantaneous flow. See Figure 9 for the measurement principle.

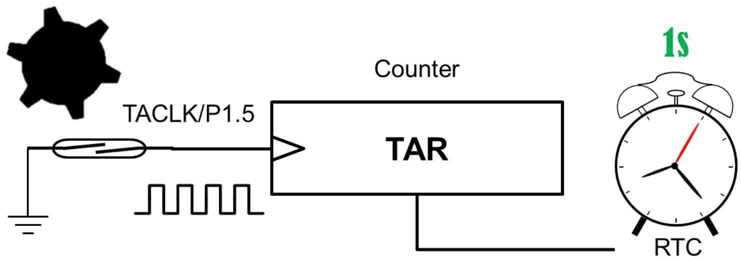


Figure 9. Measurement Principle

When the water meter is working, the system switches between 2 statuses.

TA0CLK and P1.5 share the same pin in MSP430FR4133. In standby status, for low-power design, Timer0_A3 is disabled and P1.5 is configured as a GPIO function with interrupt. When the water meter spins, the system enters into the measuring state. Timer0_A3 is then enabled and works as a counter, and P1.5 is then configured as TA0CLK functionality as counter input. When the water meter stops spinning for 5 seconds, the system will enter into standby status automatically to save power. The total flow is stored in FRAM, so it will not be lost if the power unexpectedly shuts down.

3.2.3 Battery Voltage Monitor

Battery voltage measurement is executed once per minute, and the value is displayed on the segment LCD.

The battery voltage monitor solution in this design does not require additional external components. The ADC module in MSP430FR4133 allows the user to choose VCC as Vref+ reference, and measure 1.5 V on-chip voltage reference. Then, the VCC can be calculated with the following formula:

$$VCC = 1.5\ V \times 1024 \div AD\_result \quad (1)$$

If the VCC voltage >2.8 V, the first line on the LCD will display ‘nor’. If the VCC voltage <2.8 V, the LCD will display ‘Low’ and the buzzer will beep to remind users to replace the battery.

3.2.4 Wireless Connector

A 20-pin wireless connector on board supports most of TI's wireless BoosterPack—such as Sub-1 GHz and NFC—to feature the wireless AMR function of the water meter. See Figure 10 below. The BoosterPack is not included in the kit content. For more information, please refer to Section 5 and the TI website.

Figure 10. Wireless Booster Pack

3.2.5 Debug

The on-board connector J3 is a Spy-Bi-Wire debug interface. Spy-Bi-Wire is a serialized JTAG protocol developed by Texas Instruments for MSP430. In this protocol only two wires are used instead of the usual four pins for the general JTAG interface.

3.2.6 Valve Control

The motor driver device used for valve control is the DRV8837 from Texas Instruments.

The DRV8837 provides an integrated motor driver solution for low-voltage and battery-powered applications for motion control. This motor driver can supply up to 1.8 A of output current. The DRV8837 operates on a motor-power supply voltage from 0 V to 11 V, and a device-power supply voltage of 1.8 V to 7.0 V.

The DRV8837 has a PWM input interface and a PH/EN input interface. Both interfaces are compatible with industry-standard devices. Internal shutdown functions are provided for over-current protection, short-circuit protection, under-voltage lockout, and over-temperature protection.

J6 is a valve control connector. Table 1 shows the pin definition:

Table 1. Valve Control Connector Pin Definition

NAME	DESCRIPTION
OUT1	Drive valve forward to open the valve
OUT2	Drive valve reversal to close the valve
IN1	Valve position detection (Open)
IN2	Valve position detection (Close)
GND	Ground

3.2.7 Wired AMR interface

The EVM supports an RS-485 interface. The transceiver part number is SN65HVD75. SN65HVD75 is 3.3 V-supply RS-485 with IEC ESD protection. For more information, please refer to http://www.ti.com/product/SN65HVD75.

In this interface circuit, only transmit and receive pins are used. The direction of data transmission is automatically controlled by the circuit. See Figure 11.

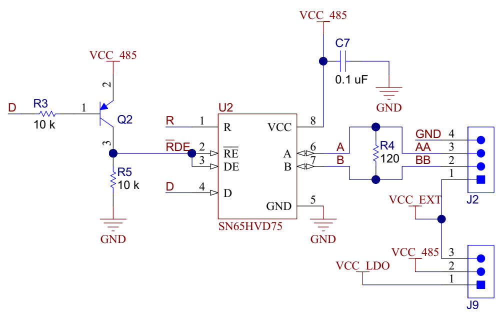


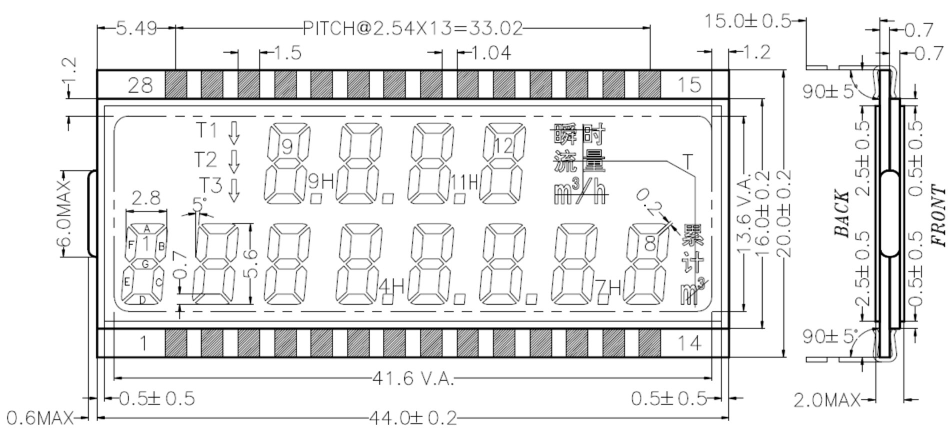
Figure 11. RS-485 Circuit

A PC-based GUI demonstrates communication between the water meter and the PC. For hardware support, a USB-to-RS-485 adapter is needed for protocol conversion.

For information on the Meter-Bus interface, please refer to http://www.ti.com/product/TSS721A.

3.2.8 LCD

A 4 × 24 segment LCD on board uses the first line to display instantaneous flow and the second line to display total flow. Figure 12 shows the specs of the LCD.



PIN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
COM1	1A	1F	2A	2F	3A	3F	4A	4F	5A	5F	6A	6F	7A	7F	8A	8F	9A	9F	10A	10F	11A	11F	12A	12F	COM1	--	--	--
COM2	1B	1G	2B	2G	3B	3G	4B	4G	5B	5G	6B	6G	7B	7G	8B	8G	9B	9G	10B	10G	11B	11G	12B	12G	--	COM2	--	--
COM3	1C	1E	2C	2E	3C	3E	4C	4E	5C	5E	6C	6E	7C	7E	8C	8E	9C	9E	10C	10E	11C	11E	12C	12E	--	--	COM3	--
COM4	T1	1D	T2	2D	T3	3D	4H	4D	5H	5D	6H	6D	7H	7D	T	8D	9H	9D	10H	10D	11H	11D	--	12D	--	--	--	COM4

Figure 12. LCD Specification

The LCD_E module in MSP430FR4133 supports up to 4 × 36 or 8 × 32 LCD segments. The module also allows users to configure each LCD drive pin to be either SEG or COM via software settings, which is very convenient for the PCB layout. The LCD_E module provides an internal charge pump with an adjustable contrast control.

3.2.9 Power

The EVM board can be powered by either the on-board battery or external power supply. Users can switch the power method by switching the jumper on connector J8. By default, the board is powered by the on-board lithium battery. Figure 13 shows the power system.

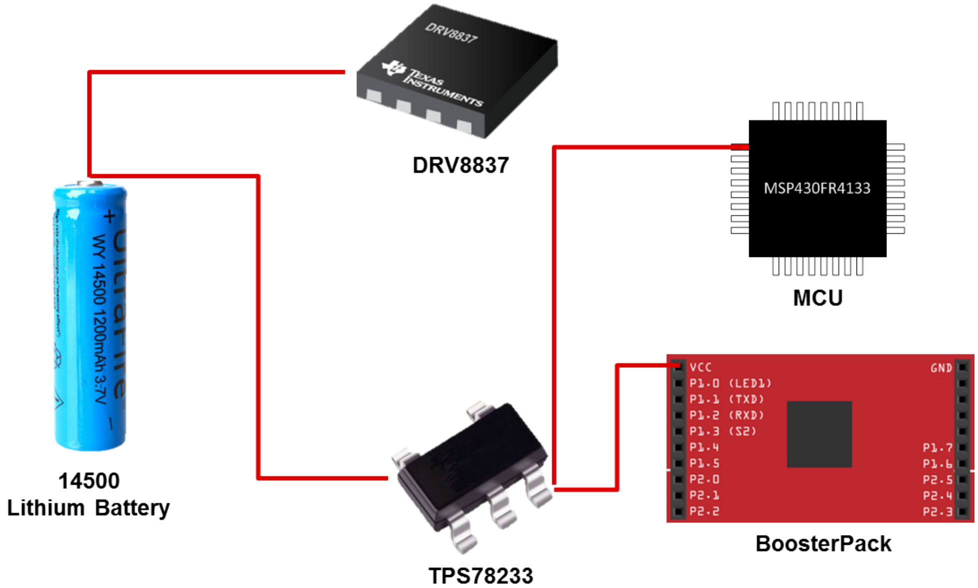


Figure 13. Power Supply

Motor driver DRV8837 is directly powered by a 3.7-V lithium battery. The other parts on board are powered by TPS78233.

TPS78233 is a 3.3 V single-fixed output LDO. The quiescent current of TPS78233 is only 500 nA, and it is very compatible with low-power applications with MSP430.

3.3 Design Files

Schematics and layout prints can be found in Section 8. All design files including schematics and layouts in PDF and native format as well as the Bill of Materials, Gerber files, and TI-TXT firmware images are made available in TIDM-FRAM-WATERMETER.

3.4 Hardware Change Log

Table 2. Hardware Change Log

PCB REVISION	DATE	AUTHOR	DESCRIPTION
Rev 1.0	8/31/2014	A0222632	Initial release for first prototype run.

4 Software

This section describes the functionality and structure of the User Experience Software that is preloaded on the EVM.

4.1 Source Code File Structure

The project is split into multiple files. This split enables users to navigate and reuse parts of the project.

Table 3. List of source files, folders

NAME	DESCRIPTION
main.c	The user experience demo main function, shared ISRs, etc
msp_wm430fr4_golbal.c	Initialization functions
msp_wm430fr4_lcd.c	LCD driver
msp_wm430fr4_rs485.c	RS-485 driver
msp_wm430fr4_nfc.c	NFC driver (4.3.1)
msp_wm430fr4_cc1120.c	Sub-1 GHz driver (4.3.2)

The firmware supports basic measurements and wired/wireless AMR. Users can choose what kind of AMR method they prefer in the User_Config.h file, rebuild the project, and reprogram the MSP430FR4133 on the EVM. NFC and Sub-1 GHz BoosterPack share the same connector interface, so they cannot be used or enabled in the firmware at the same time.

4.2 GUI

The TIDM-FRAM water meter GUI is a PC-based tool used to communicate with water meters via an RS-485 interface. This tool provides users the ability to communicate with the water meter, set commands, control valves, and so on. See Figure 14.

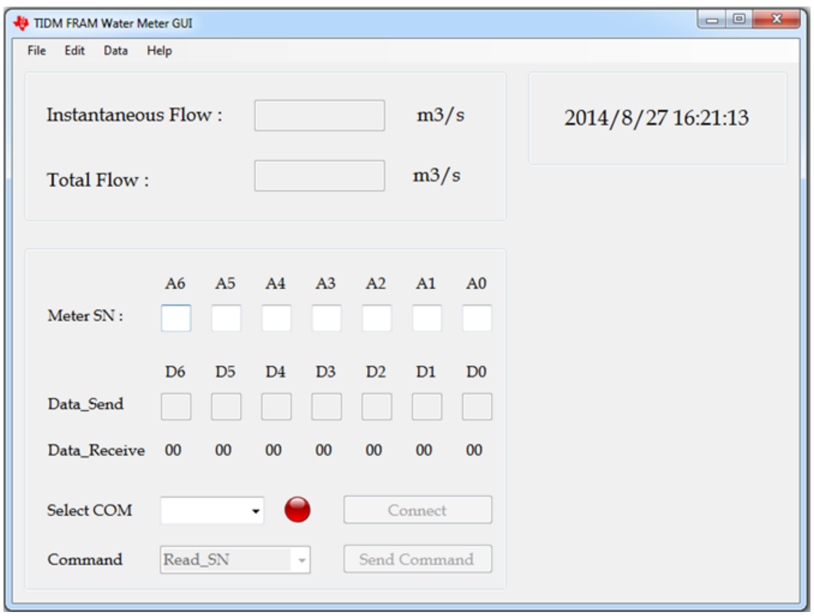


Figure 14. TIDM-FRAM Water Meter GUI

5 Demo Examples

5.1 Magnetic pulse measurement

Step by step:

1. Install the battery and connect J8 to the ext side to power on the system.
2. Connect a pulse signal to the J1 IN2 channel connector. Channel IN1 is not enabled in current firmware. In this demo, a motor board drives a rotor disc that has 8 magnets on it to emulate water flow. Two reed switch sensors are on each side of the motor board. When the rotor disc spins, the reed switch sensor generates the pulse signal. Figure 15 shows the demo setup.

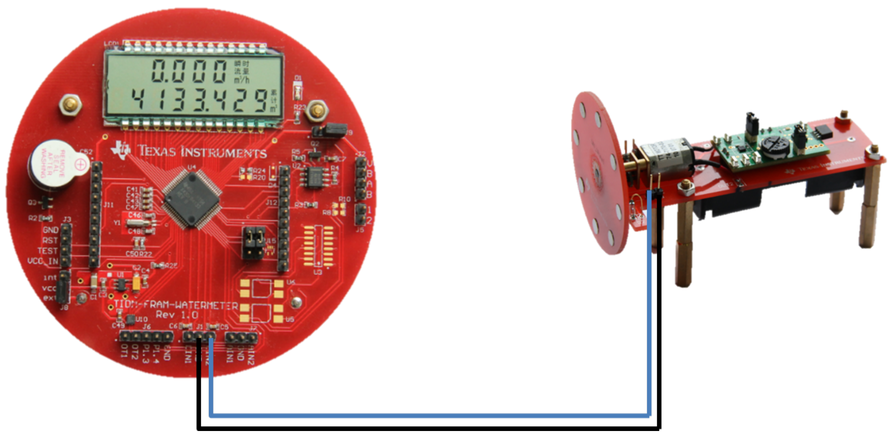


Figure 15. Basic Demo Setup

3. When the rotor disc spins, the EVM board calculates the pulse per second as instantaneous flow and adds it to the total flow. The first line of the LCD shows the instantaneous flow, and the second line shows the total flow.
4. Measurement of the battery voltage will occur once per minute, and the LCD will show the value. See Figure 16.

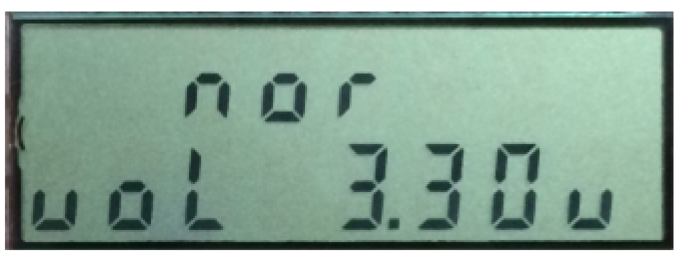


Figure 16. Battery monitor

If voltage >2.8 V, the first line on the LCD will show "nor", which means "normal". If voltage <2.8 V, the first line on the LCD will show "Low".

5.2 Wired AMR

5.2.1 RS-485

Before running the demo, users must install the USB to RS-485 adapter driver for data communication, and Microsoft .Net Framework 4.0 for GUI. The install file can be found in the Software\GUI folder of tidc664.zip.

1. Connect J2 to a PC or laptop with the USB to RS-485 adapter. Put the jumper to the right side of the J9 connector.
2. Launch TI FRAM Water Meter GUI in the Software\GUI folder of tidc664.zip. When the GUI runs, the screen shown in Figure 17 is displayed.

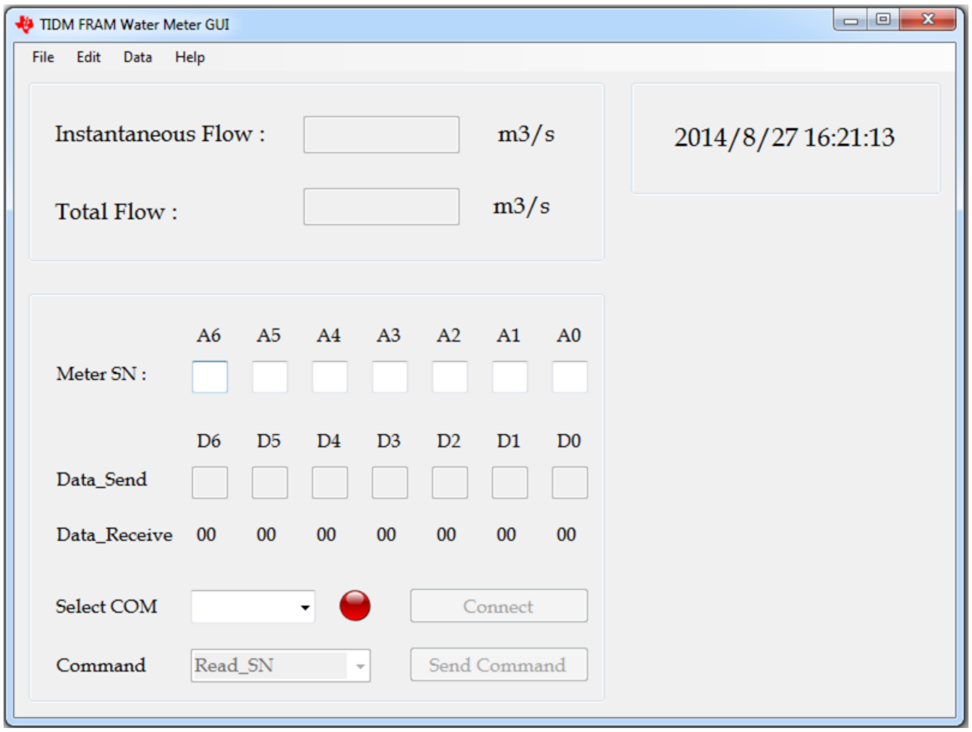


Figure 17. Startup Screen

3. To select the COM port to which the adapter is attached, click the Select COM button. In the drop-down menu, select the appropriate COM port for the adapter. More than one COM port may be listed in the COM window. To identify the appropriate COM port for the adapter, open Windows Device Manager and select the COM port with the name "Prolific USB-to-Serial Comm Port", then click connect. If the connection is successful, the light will turn green.

Figure 18. COM Port

4. When the COM port is open, the Select COM port button is disabled, and the Command button is enabled. Users can choose commands in the Command combo box and send it to the meter by clicking the Send Command button.

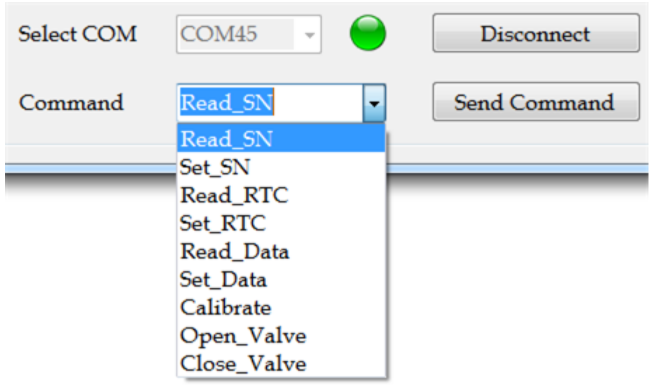


Figure 19. Command box

The GUI supports 9 commands:

- Read_SN: Read the meter serial number. The default SN of the EVM is 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07.
- Set_SN: Set the meter serial number.
- Read_RTC: Read meter local time
- Set_RTC: Calibrate meter time
- Read_data: Read meter data
- Set_data/Calibrate: Set or calibrate meter flow data
- Open_Valve: Open valve*
- Close_Valve: Close valve*

*Need valve support. A valve is needed for this demo.

Figure 20. RS-485 Demo Setup

5.3 Wireless AMR

The TIDM-FRAM-WATERMETER EVM board has a 20-pin connector. This connector supports wireless BoosterPacks such as NFC and Sub-1 GHz that feature wireless AMR in the water meter.

5.3.1 NFC

1. Apply the NFC BoosterPack to the EVM board.
2. Download the NFC firmware into MSP430FR4133. For more firmware information, please refer to Section 4.
3. Put an NFC reader such as a smart phone with an NFC antenna close to the NFC BoosterPack. The tag information will be sent to the phone and shown on the screen. The content of the tag includes the meter number, total flow data, and the last recorded time. See Figure 21:

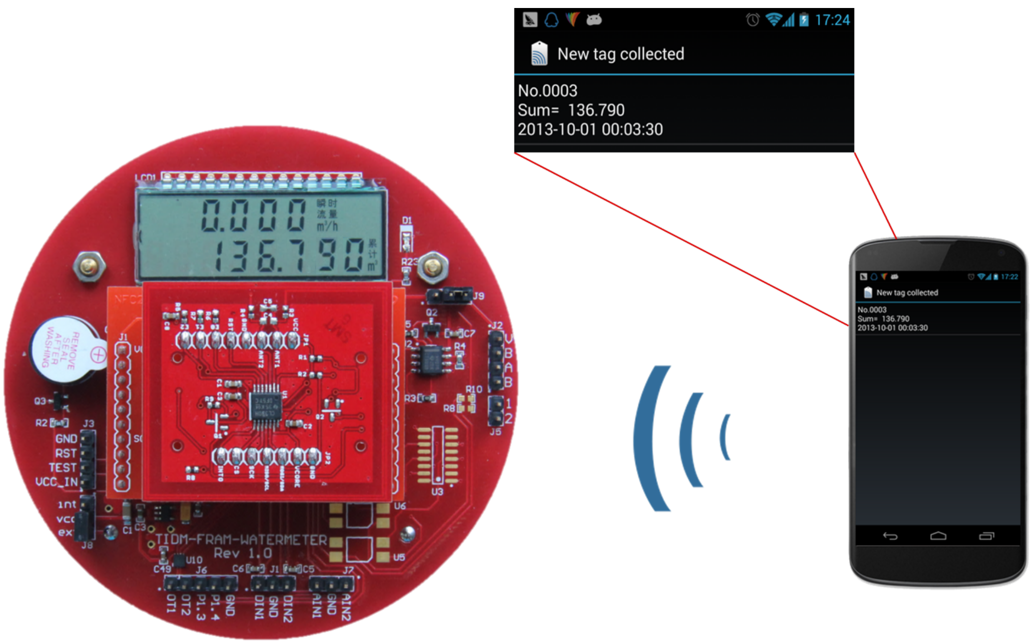


Figure 21. NFC AMR Demo

For more information about NFC, please refer to www.ti.com/NFC.

5.3.2 Sub-1 GHz

1. Apply the CC1120 BoosterPack to EVM board.
2. Download the CC1120 firmware into MSP430FR4133. For more firmware information, please refer to Section 4.
3. A receiver board is needed in this demo. When the demo runs, the CC1120 BoosterPack sends a data package out once per minute. The package includes the meter number and total flow data.
4. When receiver board receives the data package, the content of the package such as the board number and total flow data will be displayed on the receiver board.

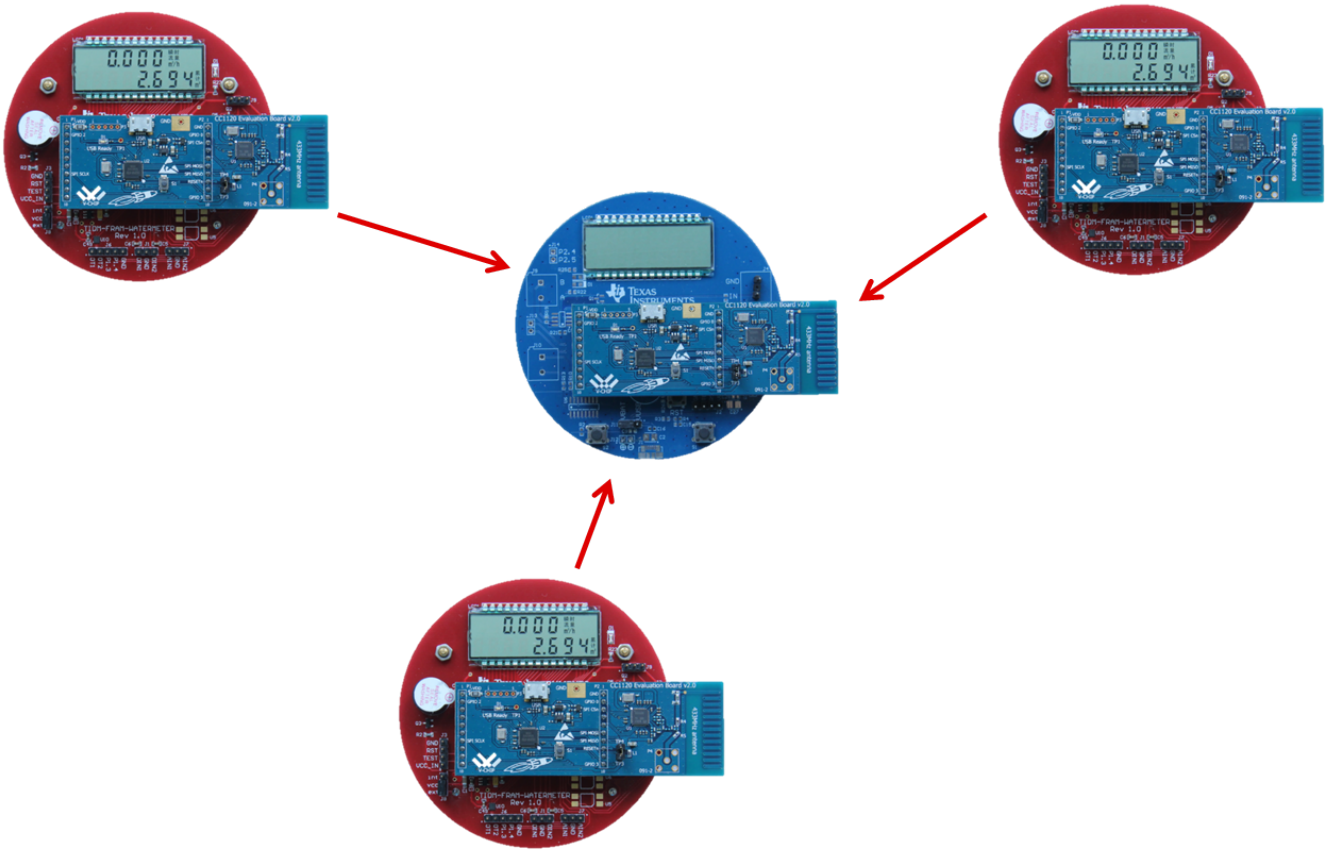


Figure 22. Sub-1 GHz AMR Demo

The CC1120 BoosterPack is made by a third-party V-Chip and can be found at http://www.digirf.com/EN/ProView/80.html.

For more information about CC1120, please refer to www.ti.com/wireless.

6 Test

6.1 Pulse measurement

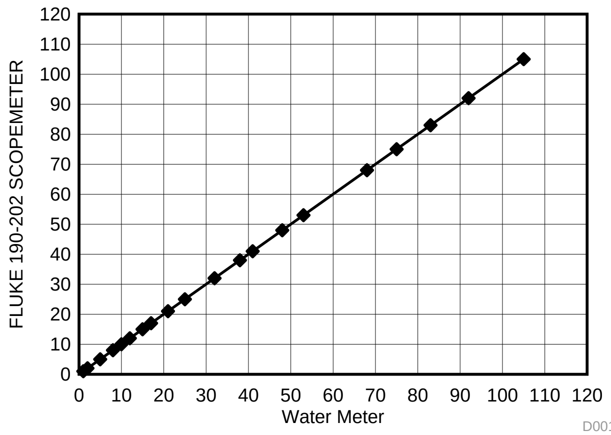


Figure 23. Pulse measurement

Figure 23 shows the pulse count measured by TIDM-FRAM-WATERMETER and FLUKE 190-202 SCOPEMETER. The results are the same.

6.2 Power consumption

Table 4. Power Consumption

WORKING MODE	CURRENT
Standby Mode	2.9 µA @ 25°C
Measuring Mode	Average 12 µA @ 25°C

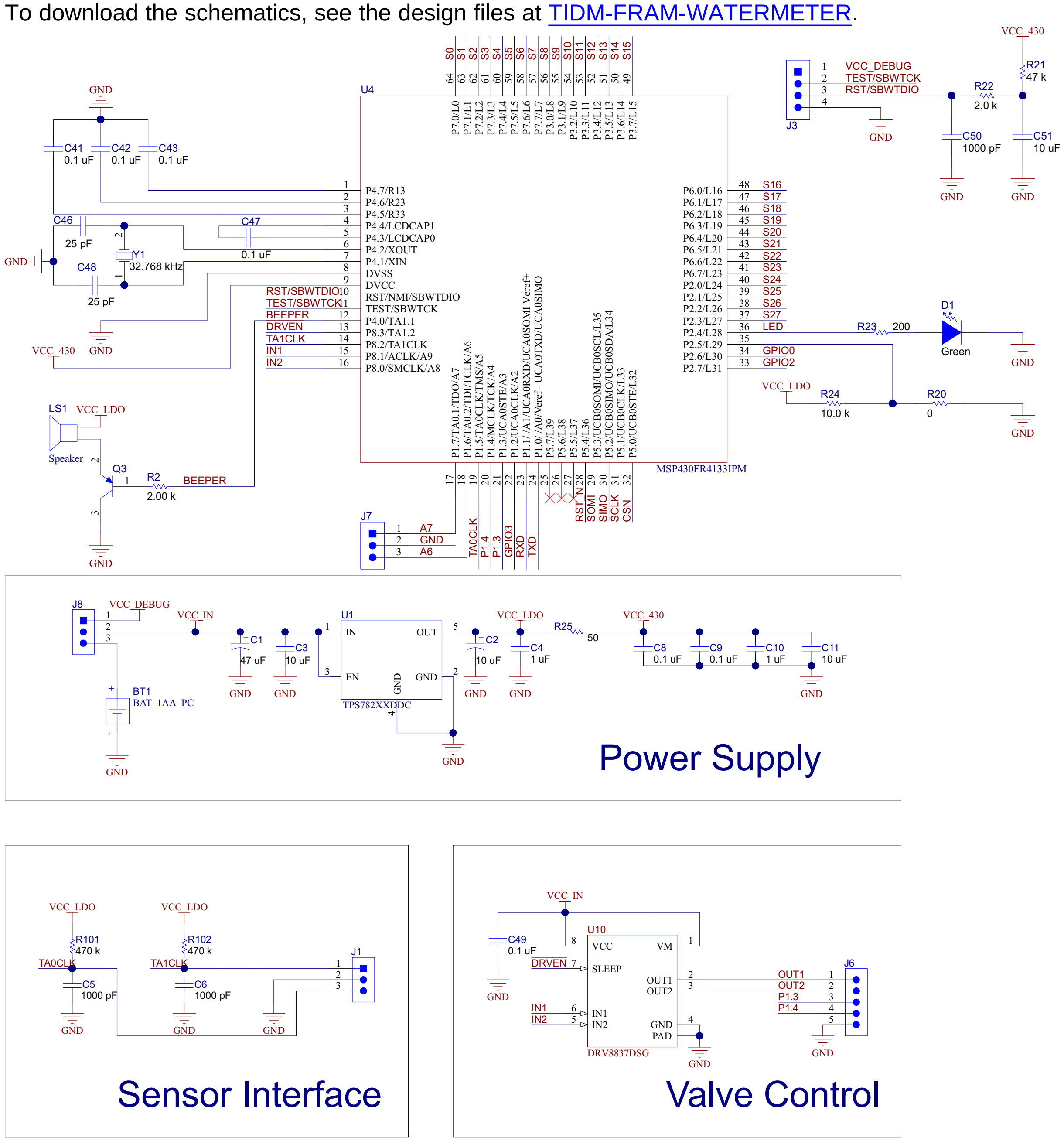
7 Reference

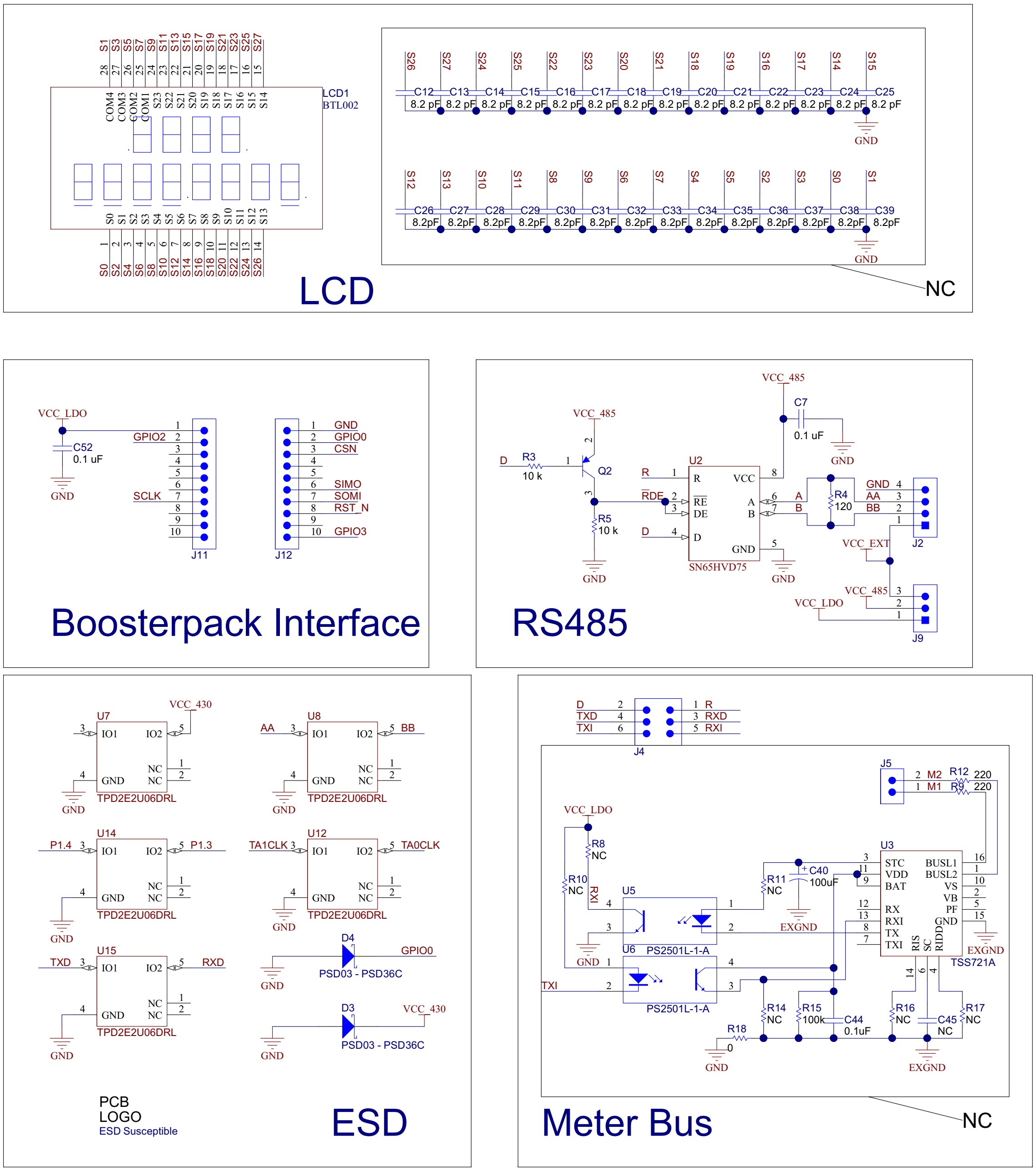
1. MSP430FR4133 Datasheet
2. MSP430FR4xx User's Guide
3. http://en.wikipedia.org/wiki/Water_metering

8 Design Files

8.1 Schematics

To download the schematics, see the design files at TIDM-FRAM-WATERMETER.




LCD
NC
Boosterpack Interface
RS485
PCB
LOGO
ESD Susceptible
ESD
Meter Bus
NC

8.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDM-FRAM-WATERMETER.

Table 5. BOM

DESIGNATOR	QTY	VALUE	PART DESCRIPTION	MANUFACTURER	MANUFACTURER PART NUMBER	DIGIKEY PART NUMBER	PCB FOOTPRINT
BT1	1	2460	Battery Holder, 1AA Cells, PC-mount	Keystone	2460	2460K-ND	BH1AA-PC
C1	1	47uF	CAP, TA, 47uF, 6.3V, +/-10%, 0.8 ohm, SMD	AVX	TPSA476K006R0800	478-3079-1-ND	3216-18
C2	1	10uF	CAP, TA, 10uF, 16V, +/-10%, 3 ohm, SMD	Vishay-Sprague	293D106X9016A2TE3	718-1123-1-ND	3216-18
C3, C11, C51	3	10uF	CAP, CERM, 10uF, 6.3V, +/-20%, X5R, 0603	Kemet	C0603C106M9PACTU	399-5504-1-ND	0603
C4, C10	2	1uF	CAP, CERM, 1uF, 16V, +/-10%, X5R, 0603	Kemet	C0603C105K4PACTU	399-5090-1-ND	0603
C7, C8, C9, C41, C42, C43, C47, C49, C52	9	0.1uF	CAP, CERM, 0.1uF, 16V, +/-5%, X7R, 0603	Kemet	C0603C104J4RACTU	399-1097-1-ND	0603
C46, C48	2	25pF	CAP, CERM, 25pF, 50V, +/-11%, C0G/NP0, 0603	AVX	06035A2R2CAT2A	478-1155-1-ND	0603
C5, C6, C50	3	1000pF	CAP, CERM, 1000pF, 100V, +/-5%, X7R, 0603	AVX	06031C102JAT2A	478-3698-1-ND	0603
D1	1	Green	LED, Green, SMD	Lite-On	LTST-C170KRKT	160-1415-1-ND	LED_LTST-C170
J1, J7, J8, J9	4	3x1	Header, TH, 100mil, 3x1, Gold plated, 230 mil above insulator	Samtec	TSW-103-07-G-S	SAM1029-03-ND	TSW-103-07-G-S
J2, J3	2	4x1	Header, TH, 100mil, 4x1, Gold plated, 230 mil above insulator	Samtec	TSW-104-07-G-S	SAM1029-04-ND	TSW-104-07-G-S
J4	1	3x2	Header, TH, 100mil, 3x2, Gold plated, 230 mil above insulator	Samtec	TSW-103-07-G-D	SAM1028-03-ND	TSW-103-07-G-D
J6	1	5x1	Header, TH, 100mil, 5x1, Gold plated, 230 mil above insulator	Samtec	TSW-105-07-G-S	SAM1029-05-ND	TSW-105-07-G-S

Table 5. BOM (continued)

DESIGNATOR	QTY	VALUE	PART DESCRIPTION	MANUFACTURER	MANUFACTURER PART NUMBER	DIGIKEY PART NUMBER	PCB FOOTPRINT
J11, J12	2	10x1	Header, TH, 100mil, 10x1, Gold plated, 230 mil above insulator	Samtec	TSW-110-07-G-S	SAM1029-10-ND	TSW-110-07-G-S
LCD1	1	LCD	BTL002 4COM LCD	N/A	BTL002	N/A	LCD
LS1	1	BEEPER	Loudspeaker	Soberton Inc	WST-1203UX	433-1047-ND	BEEPER
Q2, Q3	2	PNP	Transistor, PNP, 40V, 0.2A, SOT-23	Diodes Inc.	MMBT3906-7-F	MMBT3906-FDICT-ND	SOT-23
R3, R5	2	10k ohm	RES, 10k ohm, 5%, 0.1W, 0603	Vishay-Dale	CRCW060310K0JNEA	541-10KGCT-ND	0603
R4	1	120 ohm	RES, 120 ohm, 5%, 0.1W, 0603	Vishay-Dale	CRCW0603120RJNEA	541-120GCT-ND	0603
R21	1	47k ohm	RES, 47k ohm, 5%, 0.1W, 0603	Vishay-Dale	CRCW060347K0JNEA	541-47KGCT-ND	0603
R2, R22	2	2.0k ohm	RES, 2.0k ohm, 5%, 0.1W, 0603	Vishay-Dale	CRCW06032K00JNEA	541-2.0KGCT-ND	0603
R23	1	200 ohm	RES, 200 ohm, 5%, 0.1W, 0603	Vishay-Dale	CRCW0603200RJNEA	541-200GCT-ND	0603
R25	1	50 ohm	RES, 50 ohm, 0.5%, 0.1W, 0603	Yageo America	RT0603DRE07150RL	RT0603DRE07150RL-ND	0603
R101, R102	2	470k ohm	RES 470K OHM 1/10W 5% 0603 SMD	Yageo America	RC0603JR-07470KL	311-470KGRTR-ND	0603
U1	1	TPS78233	IC, 150mA, Ultra-Low Quiescent Current, IQ 500nA LDO Linear Regulator	Texas Instruments	TPS78233DDCR	296-24059-1-ND	TSOT-23-5[DDC]
U2	1	SN65HVD75	High Temperature 3.3 V RS-485 Transceiver	Texas Instruments	SN65HVD11SHKJ	296-28287-5-ND	D0008A_N
U4	1	MSP430FR4133	16-bit Ultra-Low-Power MCU	Texas Instruments	MSP430FR4133IPM	N/A	PM0064A_M
U10	1	DRV8837	LOW-VOLTAGE H-BRIDGE IC, DSG0008A	Texas Instruments	DRV8837DSG	296-34806-1-ND	DRV8837DSG
Y1	1	32.768kHz	Crystal, 32.768kHz, 12.5pF, SMD	Abracon Corporation	AB26TRQ-32.768KHZ-T	535-12051-1-ND	XTAL_MS3V-T1R

Table 5. BOM (continued)

DESIGNATOR	QTY	VALUE	PART DESCRIPTION	MANUFACTURER	MANUFACTURER PART NUMBER	DIGIKEY PART NUMBER	PCB FOOTPRINT
C12, C13, C14, C15, C16, C17, C18, C19, C20, C21, C22, C23, C24, C25, C26, C27, C28, C29, C30, C31, C32, C33, C34, C35, C36, C37, C38, C39	28	8.2pF	CAP, CERM, 8.2pF, 50V, +/-3%, C0G/NP0, 0603	AVX	06035A8R2CAT2A	478-1162-1-ND	0603
C45, R8, R10, R11, R14, R16, R17	7	NC	NC	NC	NC	NC	NC
C40	1	100uF	CAP, TA, 100uF, 6.3V, +/-10%, 1.7 ohm, SMD	Vishay-Sprague	293D107X96R3B2TE3	718-1128-1-ND	3528-21
C44	1	0.1uF	CAP, CERM, 0.1uF, 16V, +/-5%, X7R, 0603	Kemet	C0603C104J4RACTU	399-1097-1-ND	0603
D3, D4	2	Diode	Diode, Schottky, 40V, 0.03A, SOD-323	Diodes Inc.	SDMK0340L-7-F	SDMK0340LDICT-ND	sod-323
J5	1	2x1	Header, TH, 100mil, 2x1, Gold plated, 230 mil above insulator	Samtec	TSW-102-07-G-S	SAM1029-02-ND	TSW-102-07-G-S
R9, R12	2	220 ohm	RES, 220 ohm, 5%, 0.1W, 0603	Vishay-Dale	CRCW0603220RJNEA	541-220GCT-ND	0603
R15	1	100k ohm	RES, 100k ohm, 5%, 0.1W, 0603	Vishay-Dale	CRCW0603100KJNEA	541-100KGCT-ND	0603
R18, R20	2	0 ohm	RES, 0 ohm, 5%, 0.1W, 0603	Vishay-Dale	CRCW06030000Z0EA	541-0.0GCT-ND	0603
R24	1	10.0k ohm	RES, 10.0k ohm, 0.1%, 0.1W, 0603	Susumu Co Ltd	RG1608P-103-B-T5	RG16P10.0KBCT-ND	0603
U3	1	TSS721	Meter-Bus Transceiver	Texas Instruments	TSS721A	296-27128-1-ND	D0016A_N
U5, U6	2	PS2501	High Isolation Voltage Single Transistor Type OptoCoupler	California Eastern Laboratories	PS2501L-1-A	PS2501L-1A-ND	PS2501L
U7, U8, U12, U14, U15	5	TPD2E2U06	DUAL CHANNEL HIGH SPEED ESD PROTECTION DEVICE, DRL0005A	Texas Instruments	TPD2E2U06DRL	296-38361-1-ND	DRL0005A

8.3 PCB Layouts

To download the PCB Layouts, see the design files at TIDM-FRAM-WATERMETER

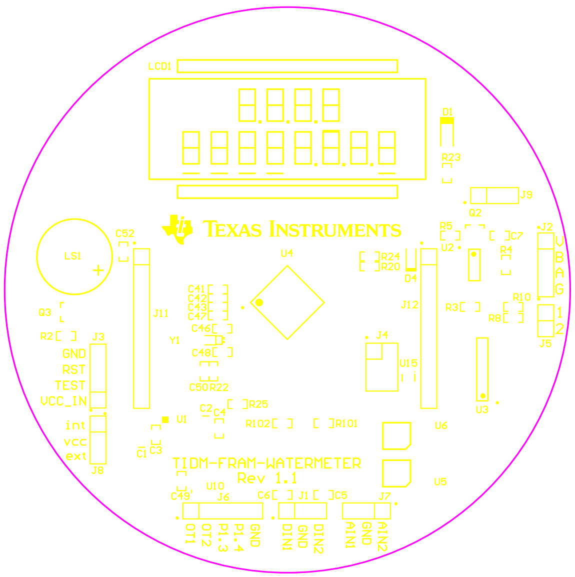


Figure 24. Top Silkscreen Overlay

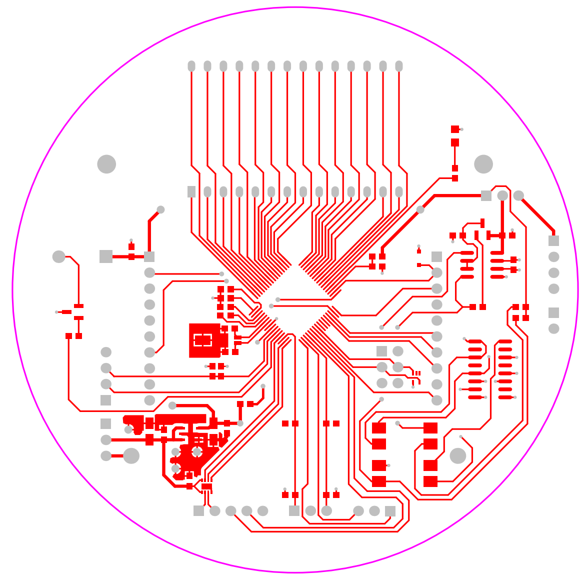


Figure 25. Top Layer

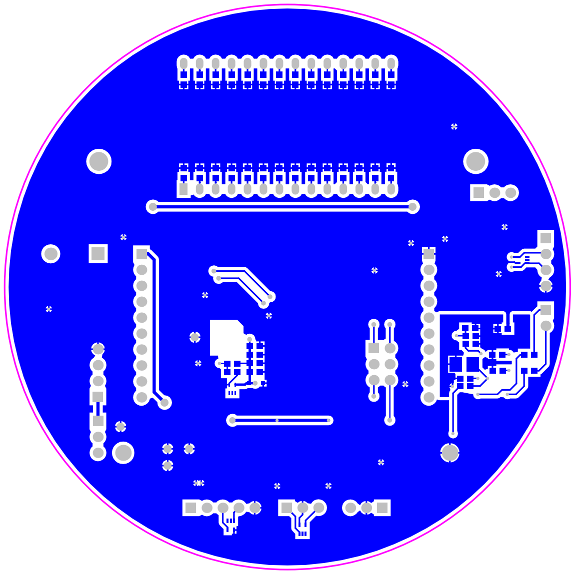


Figure 26. Bottom Layer

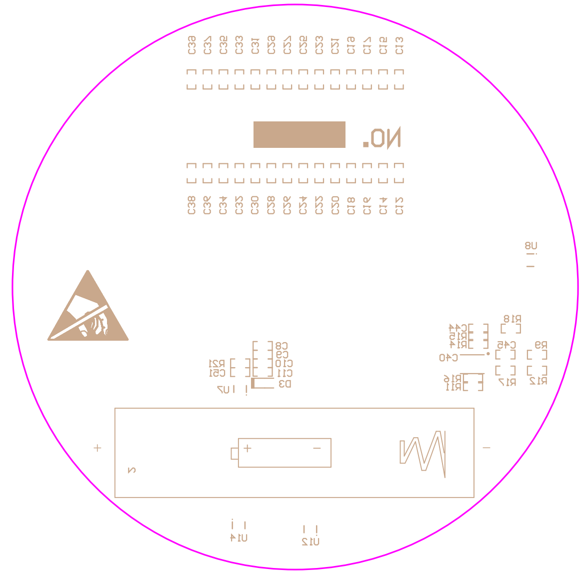


Figure 27. Bottom Silkscreen Overlay

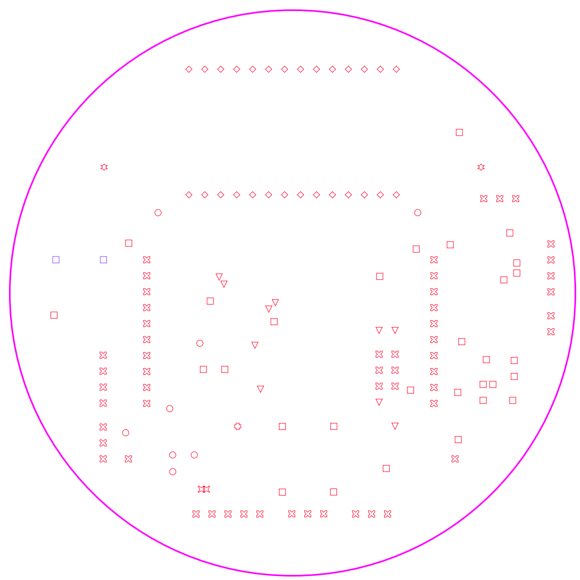


Figure 28. Drill Drawing for Top and Bottom Layers

8.4 Altium Project

To download the Altium project files, see the design files at TIDM-FRAM-WATERMETER.

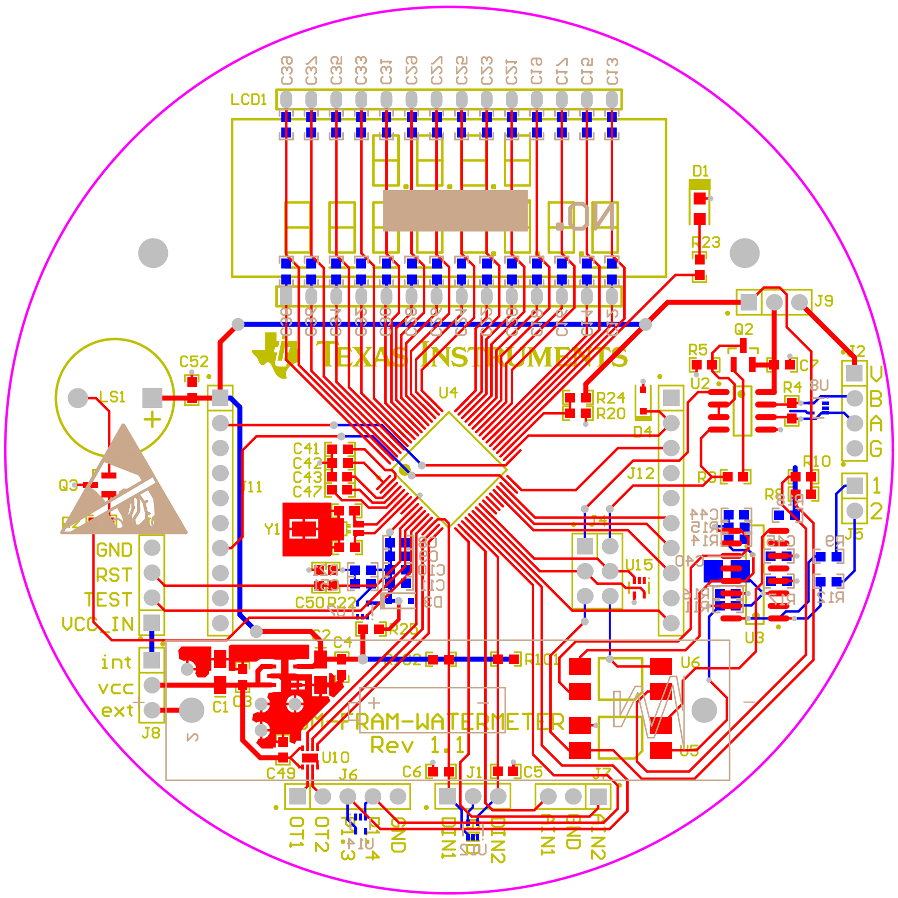


Figure 29. Altium Image 1

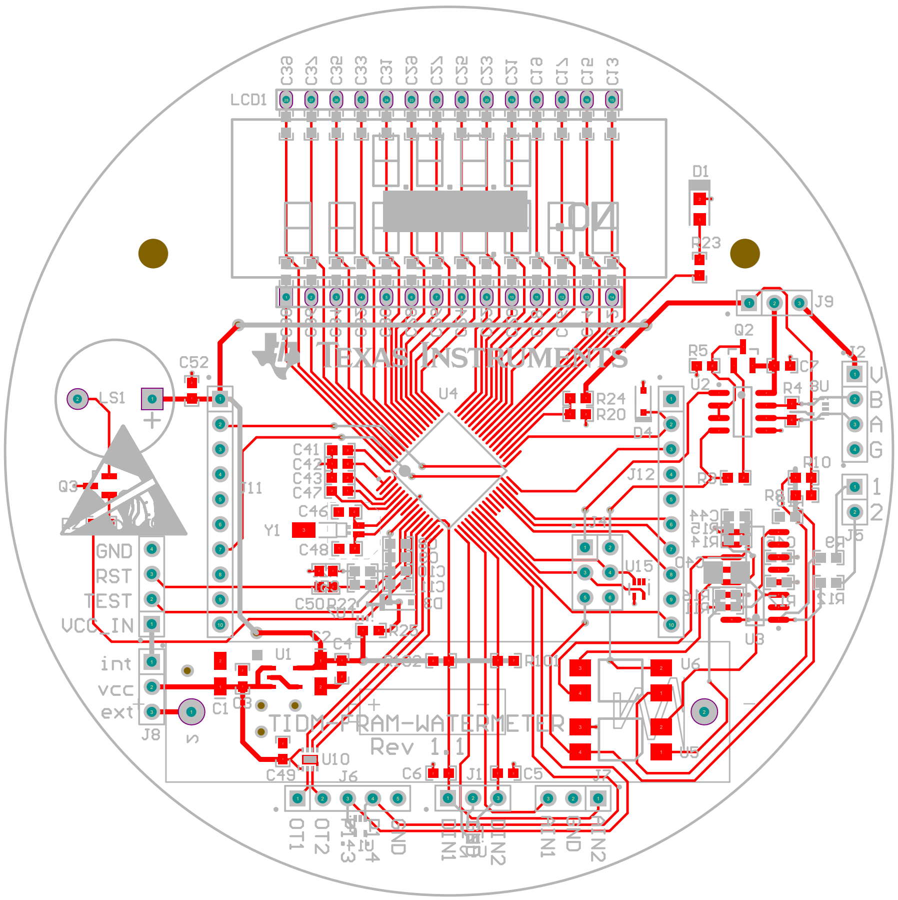


Figure 30. Altium Image 2

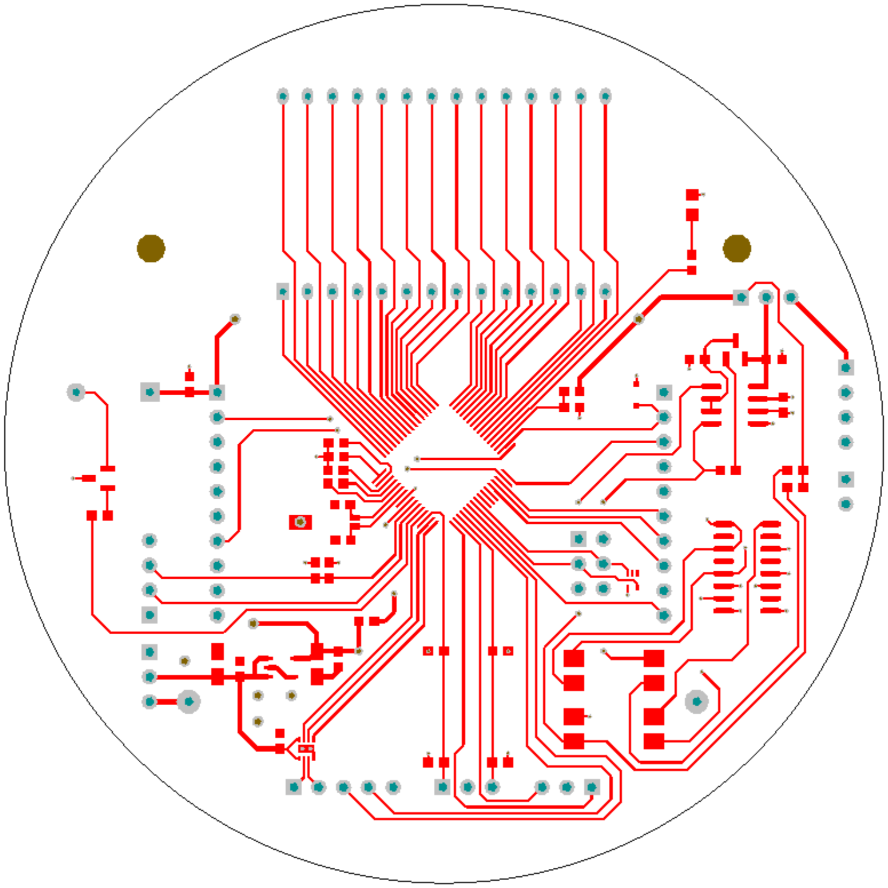


Figure 31. Altium Image 3

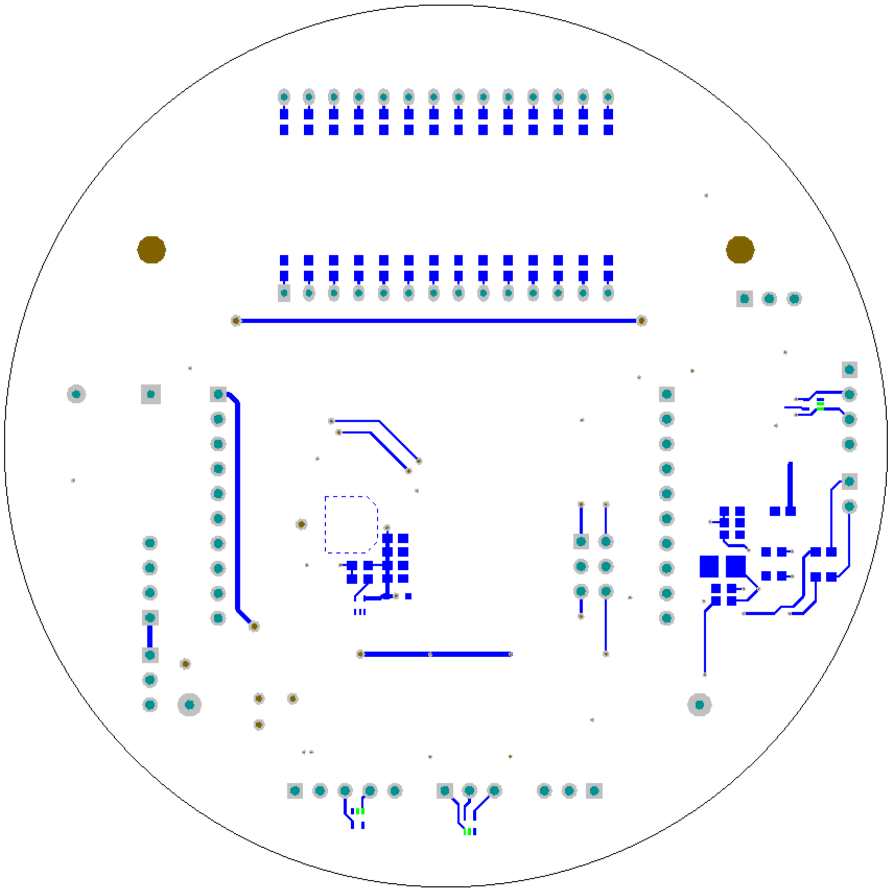


Figure 32. Altium Image 4

8.5 Assembly Drawings

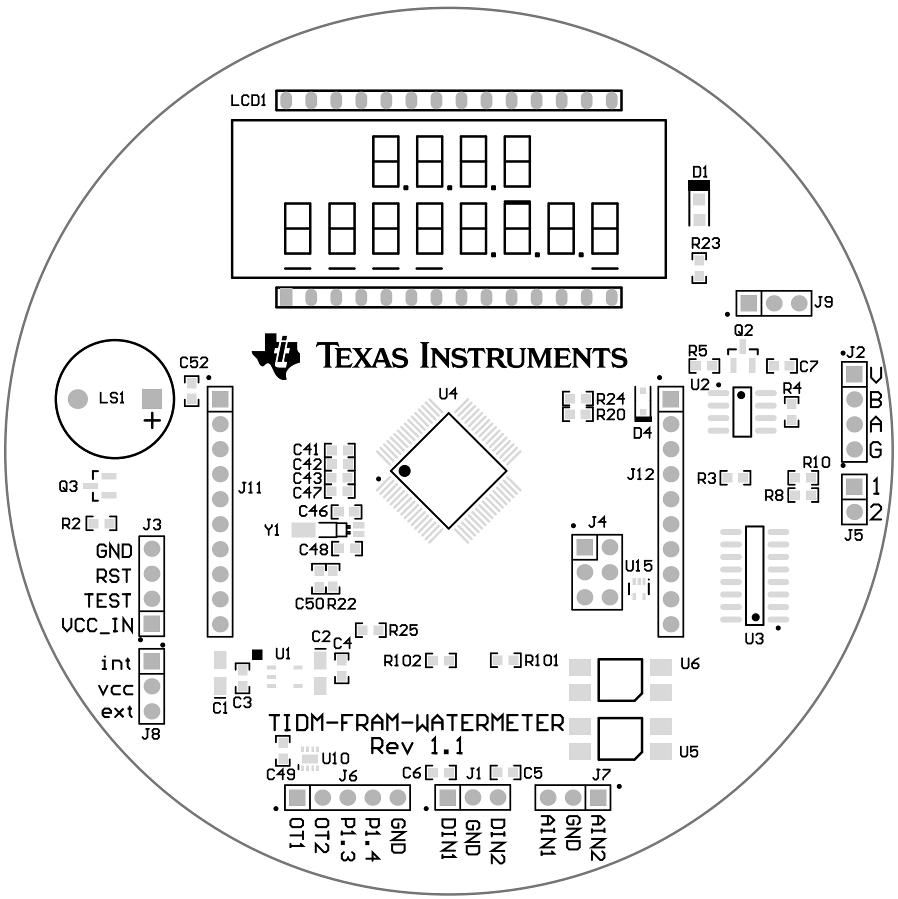


Figure 33. Top Assembly Drawing

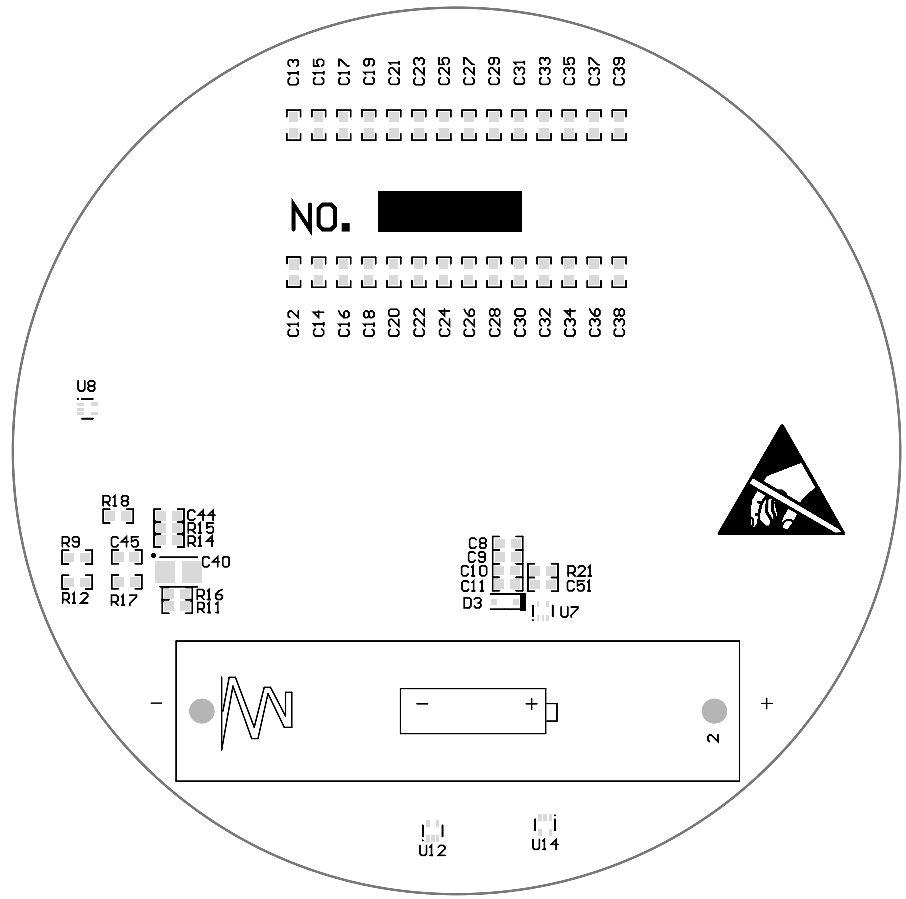


Figure 34. Bottom Assembly Drawing

9 About the Author

LING ZHU is an MSP430 applications engineer at Texas Instruments where he is responsible for developing reference design solutions and customer support for MSP430 value line devices. Ling earned his master of Measure & Control Technology from XIDIAN University in China.

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