TI Designs
Zero Standby Power NFC for Flow Meter Designs

TI Designs

This design demonstrates the use case of adding NFC function to flow meter designs with minimal impact on power consumption to the host. The additional NFC function consumes zero power while waiting to be energized by the RF field generated by the NFC reader.

Design Resources

TIDM-NFC-WATERMTR	Design Folder
MSP430FR6989	Product Folder
RF430CL330H	Product Folder
TPS782	Product Folder
EVM430-FR6989	Tools Folder
RF430CL330HTB	Tools Folder

TI E2E™ Community

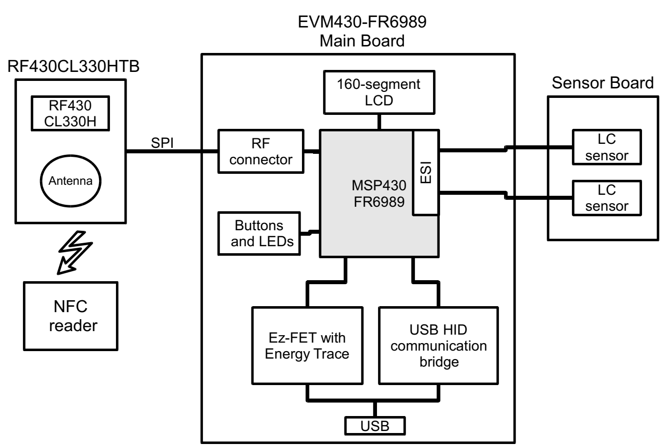
ASK Our E2E Experts
WEBENCH® Calculator Tools

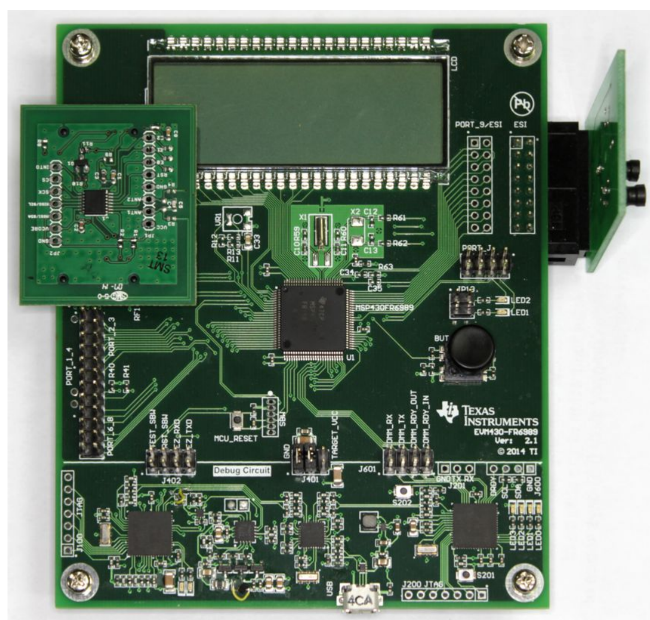
Design Features

- Provide NFC Function for Flow Meter Designs
- Zero Standby Power for NFC Function
- NFC Reader Provides Power to NFC Chip for Communication
- Minimize Impact on Power Consumption to Host

Featured Applications

- Gas Meter
- Heat Meter
- Flow Meter





An IMPORTANT NOTICE at the end of this TI reference design addresses authorized use, intellectual property matters and other important disclaimers and information.

1 System Description

Many smart flow meters are battery-powered. The amount of the energy is limited by the battery capacity. Adding extra functions to the system consumes more energy, which reduces the battery life. Therefore, minimizing the power consumption of the extra functions is one of the key factors to prolong the system lifetime.

This TI Design adds near field communications (NFC) capability to flow meters. The NFC Interface Transponder RF430CL330H provides data exchange capability between flow meters and NFC readers and is compliant to ISO14443B. The RF430CL330H transponder consumes zero power while waiting to be energized by the RF field generated by the NFC reader. In addition, the RF430CL330H transponder can be powered by harvesting the energy from the RF field generated by the NFC readers. These two approaches minimize the impact of power consumption to flow meters.

For testing, this TI Design uses an EVM430-FR6989 evaluation kit and an RF430CL330HTB target board. The EVM430-FR6989 evaluation kit simulates the flow meter operation using LC sensors for rotation detection. The RF430CL330HTB target board is plugged in to the EVM430-FR6989 main board to provide NFC function.

1.1 MSP430FR6989

The MSP430FR6989 is an MSP430™ ultra-low-power (ULP) FRAM platform that combines uniquely embedded FRAM and a holistic ULP system architecture, allowing innovators to increase performance at lowered energy budgets. FRAM technology combines the speed, flexibility, and endurance of SRAM with the stability and reliability of flash at much lower power.

1.2 EVM430-FR6989

The EVM430-FR6989 evaluation kit is used to get the test result for this TI Design. This water meter reference design kit is an easy-to-use evaluation module for the MSP430FR698x family of microcontrollers. The kit consists of three boards: the main board, the sensor board, and the motor board.

The main board of the EVM consists of the MSP430FR6989 with different user interfaces such as LCD, buttons, and LEDs. The built-in eZ-FET enables direct programing to the MCU without extra FET tools. The eZ-FET also supports EnergyTrace™ technology for monitoring power consumption of the system. The MSP430FR6989 also supports EnergyTrace++™ to monitor the usage of different modules inside the MCU.

Designed for flow meter applications, the sensor board is a daughter board consisting of two LC sensors. The sensors are connected to the ESI module of the MSP430FR6989. Users can design their own sensor boards for any specific applications that use ESI. In this TI Design, this LC board is not used and replaced by the TMR sensor board.

The motor board drives the rotor disc to simulate water or gas flow. The buttons control the rotating direction of the disc while the variable resistor controls the rotating speed. Visit http://www.ti.com/tool/EVM430-FR6989 for a detailed description.

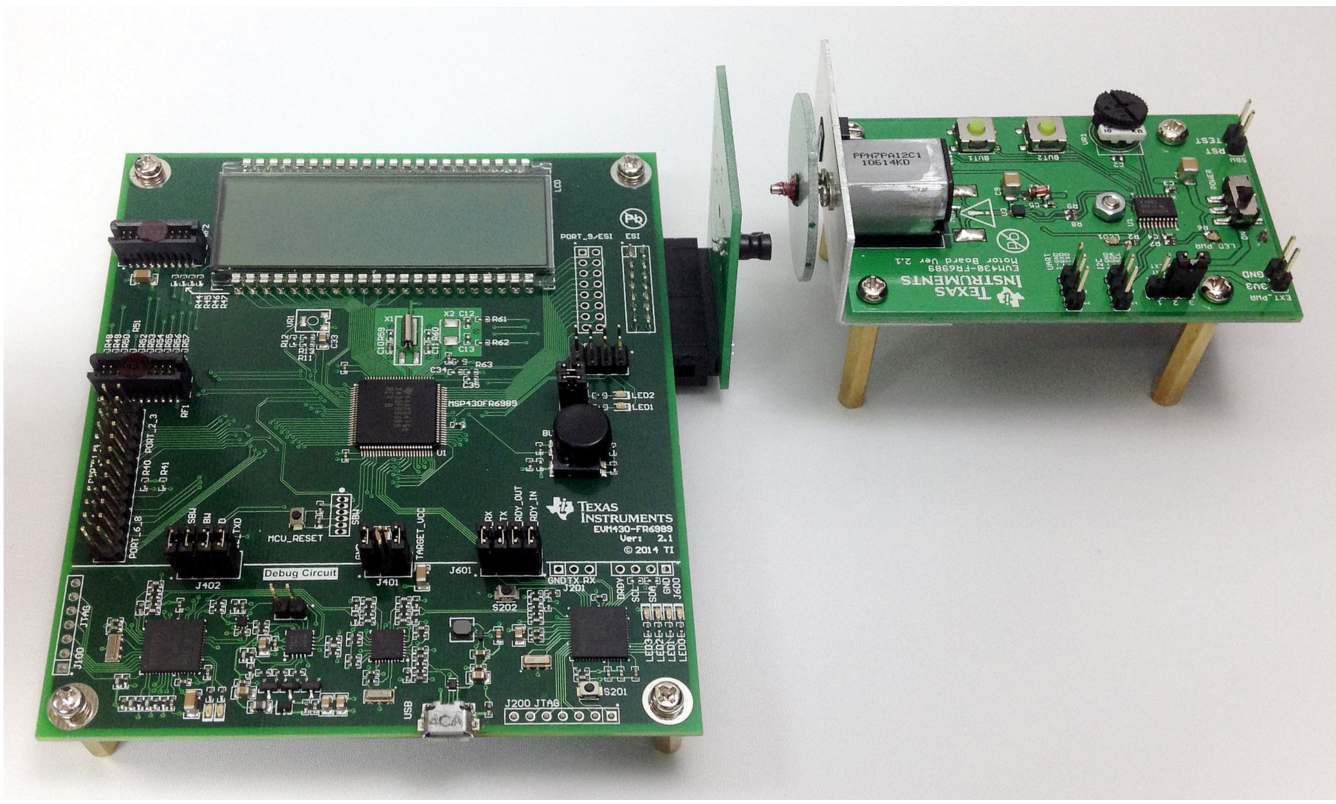


Figure 1. EVM430-FR6989 Evaluation Kit

1.3 RF430CL330H

The Dynamic NFC Interface Transponder RF430CL330H is an NFC Tag Type 4 device that combines a wireless NFC interface and a wired SPI or I^{2}C interface to connect the device to a host. The NDEF message in the SRAM can be written and read from the integrated SPI or I^{2}C serial communication interface and can also be accessed and updated wirelessly through the integrated ISO14443B-compliant RF interface that supports up to 848 kbps. As a general NFC interface, the RF430CL330H enables end equipment to communicate with the fast-growing infrastructure of NFC-enabled smartphones, tablets, and notebooks.

1.4 RF430CL330HTB

The TI RF430CL330H target board demonstrates the capabilities of the RF430CL330H and help aid in the development process by providing a working hardware or firmware reference example for NFC operations. Visit http://www.ti.com/tool/rf430cl330htb for a detailed description.

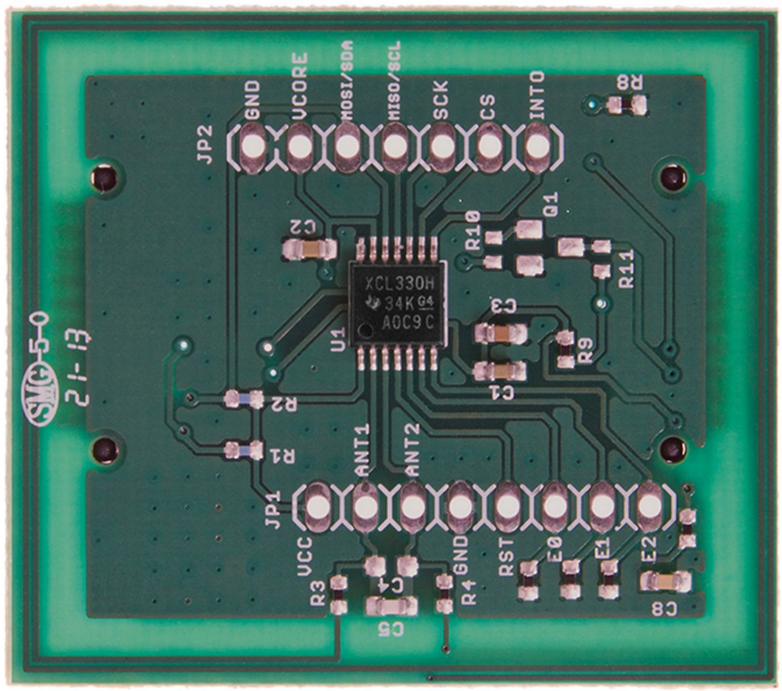


Figure 2. RF430CL330HTB Target Board

2 System Design Theory

This design uses two approaches to provide NFC function with minimal power consumption of the RF430CL330H that draw from the host, which is the MSP430FR6989 mixed signal microcontroller.

2.1 Power Off RF430CL330H While Waiting to be Energized by RF Field

This approach is based on the application note *Using RF430CL330H VCORE Pin to Wake Up Host MCU via a Presented NFC/RFID High Frequency Magnetic Field* (SLOA200).

When a 13.56-MHz field is applied, the RF430CL330H VCORE pin (pin 13 of the RF430CL330H) is raised to 1.5 V. A simple NPN transistor switch circuit is added. The VCORE drives the base of the transistor to provide an active low interrupt to the connected host indicating that a 13.56-MHz RF field was detected. The RF430CL330H should be powered and configured so it can respond to the commands.

When the RF field is not detected, the host switches off the RF430CL330H so that device consumes zero power.

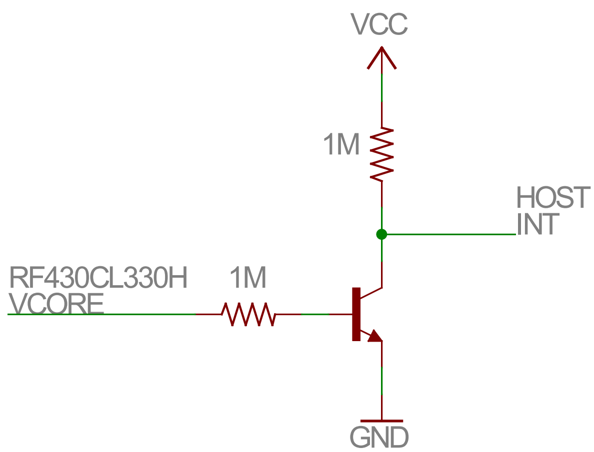


Figure 3. Wake Circuit

2.2 Minimize Power Consumption When RF Field is Detected

When the RF430CL330H detects an RF field, the device triggers the host and the host powers up the RF430CL330H. Data exchange is performed by accessing the SRAM of the RF430CL330H. The RF430CL330H acts as an NFC Tag Type 4. The NFC reader access the SRAM by communicating with the RF430CL330H using ISO14443B-Compliant 13.56-MHz RF interface. The RF430CL330H acknowledge the read or write activities to the host by sending End of Read (EOR) or End of Write (EOW) interrupts. The host accesses the SRAM of the RF430CL330H through SPI or I^2C interface. The data stored in the SRAM is in NDEF message structure. The host powers down the RF430CL330H after finishing the data exchange process.

The RF430CL330H consumes 40 µA from the host when the supply voltage is above 3 V. If the supply voltage is below 3 V, the RF430CL330H obtains power from the RF field and consumes 0 µA from the host.

3 Software Description

The rotation detection function of this software is based on the TI Design TIDM-2LC-WATERMTR. This code is simplified by keeping the most basic functions to operate the system.

When the system starts, the hardware modules, such as the clock system and the ESI, are initialized. After that, the system starts TSM calibration to find the optimum time delay for measuring the oscillation of the LC sensor. The LCD shows the number "8888" when the optimum delay is found. Then the calibration starts to find the suitable reference voltage for rotation detection. The calibration requires the wheel of the motor board to rotate to find the maximum and the minimum oscillating level of the LC sensors. After the calibration is completed, the interrupts are set up. The system goes to low power mode. The ESI interrupts are set to show the updated ESI counter value on the LCD. The navigation button toggles the LCD on or off regardless the direction of the button is pressed.

When an NFC reader such as an NFC-enabled smartphone is near the RF430CL330H target board, the target board triggers the EVM430-FR6989 main board. The main board powers up the target board and writes texts and the value of the ESICNT1 to the RF430CL330H SRAM. The NFC reader reads the data inside the SRAM. When the NFC reader moves away from the target board, the target board generates an EOR interrupt. The main board powers down the target board and returns to low power mode.

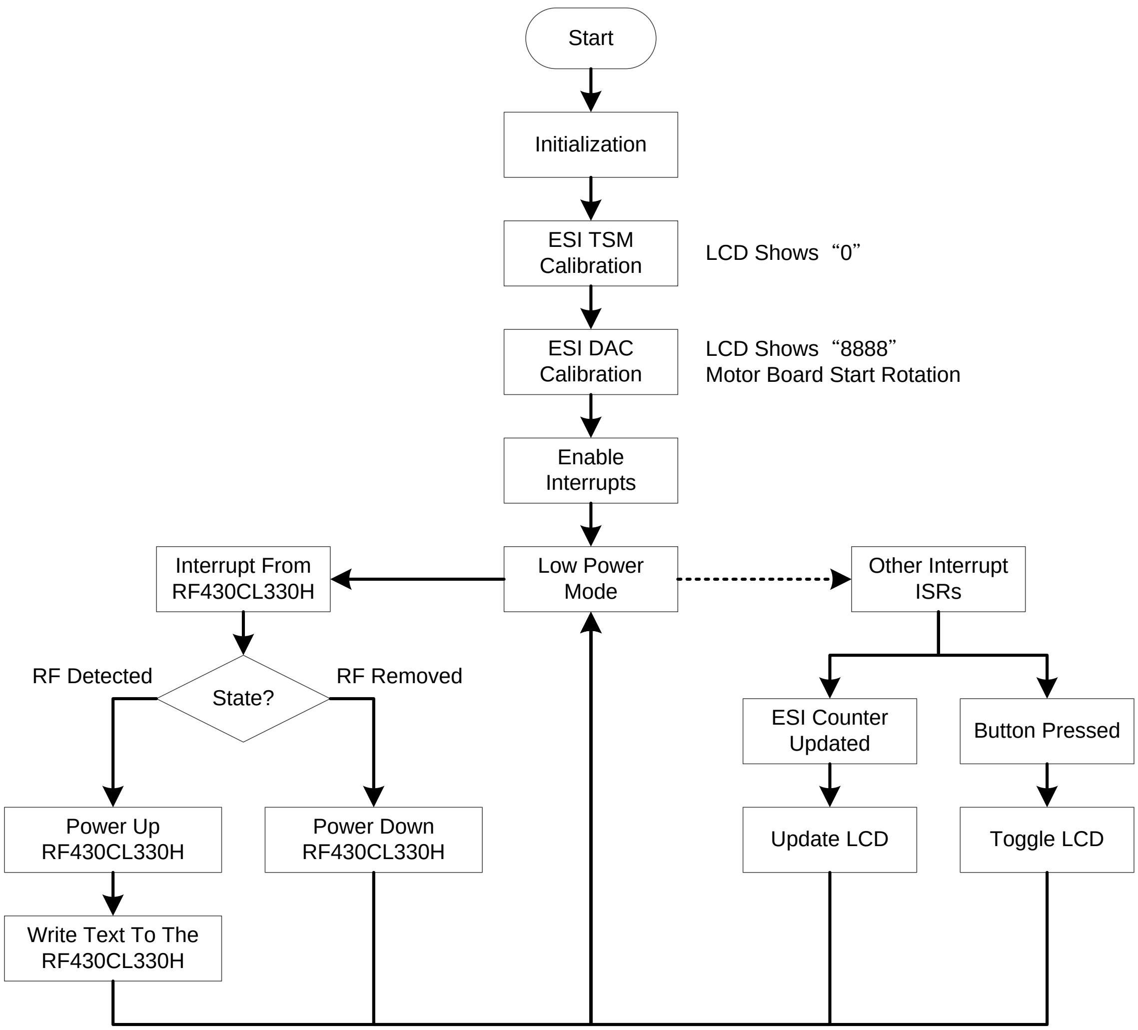


Figure 4. Software Flow

4 Test Setup

4.1 RF430CL330HTB Modification

The target board RF430CL330HTB is not fully pin-compatible with the EVM430-FR6989 main board. Modify the target board RF430CL330HTB as follows:

1. Remove R9 on the RF430CL330HTB to disconnect power being supplied to the RF430CL330H from the system power.
2. Remove R12 to prevent back powering.
3. Add Q1. This can be any general purpose NPN such as 2N2222 or 2N3904 in SOT-23 package.
4. Add R10 and R11 (1 MΩ, 0402 package).
5. Remove R8 (The test uses SPI instead of I^2C, DNP for SPI).
6. Remove R1 and R2 (Remove the I^2C pullup resistors to prevent leakage).
7. Modify the connection of the RF connectors of the RF430CL330HTB target board as shown in Table 1 and Figure 6 to make it compatible with the EVM430-FR6989 main board.

Table 1. Modifications to RF Connector of RF430CL330HTB Target Board

RF430CL330HTB		EVM430-FR6989	
PIN	FUNCTION	BEFORE MODIFICATION	AFTER MODIFICATION
RF1 (pin 6)	CS	(Not connected)	P3.7
RF1 (pin 16)	SCK	P3.6	(No change)
RF1 (pin 18)	MOSI	P3.4	(No change)
RF1 (pin 20)	MISO	P3.5	(No change)
RF2(pin 13)	INT0	(Not connected)	P1.0
RF2(pin 15)	P1.0	P8.7	P1.1
RF2(pin 19)	VIN_3.6V	P8.5	(No change)
RF2(pin 20)	RF2_RST	(Not connected)	P2.2

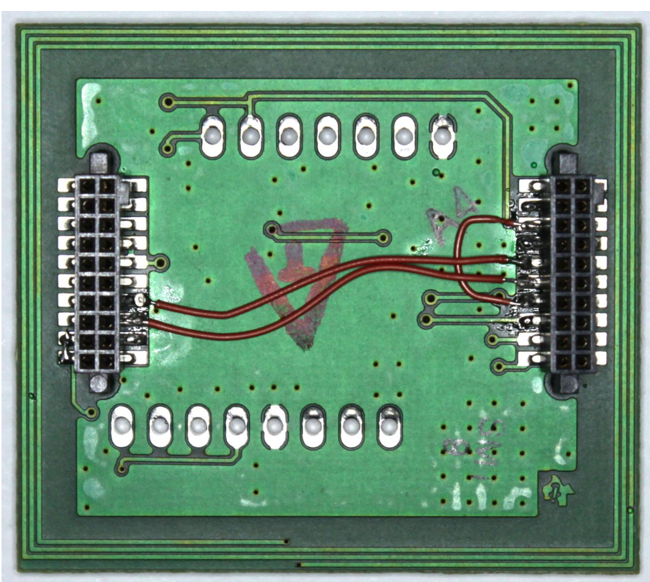


Figure 5. RF430CL330HTB Bottom View

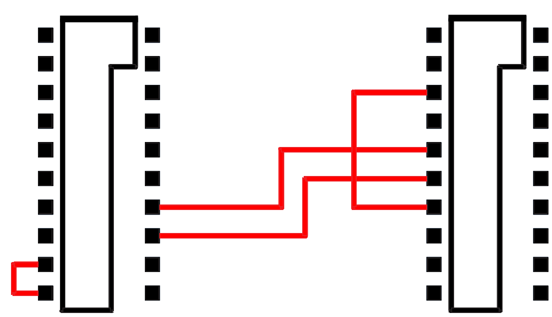


Figure 6. Wire Connection of RF430CL330HTB Target Board (Bottom View)

4.2 Test Procedure

Follow this testing procedure by using the EVM430-FR6989 and Code Composer Studio™ (CCS) version 6.1.

1. Prepare:
   (a) Modify the RF430CL330H target board as described in Section 4.1.
   (b) Attach the RF430CL330H target board to the RF connector of the EVM430-FR6989 main board as shown in Figure 7.
   (c) Attach the LC sensor board to the ESI port of the EVM430-FR6989 main board as shown in Figure 7.

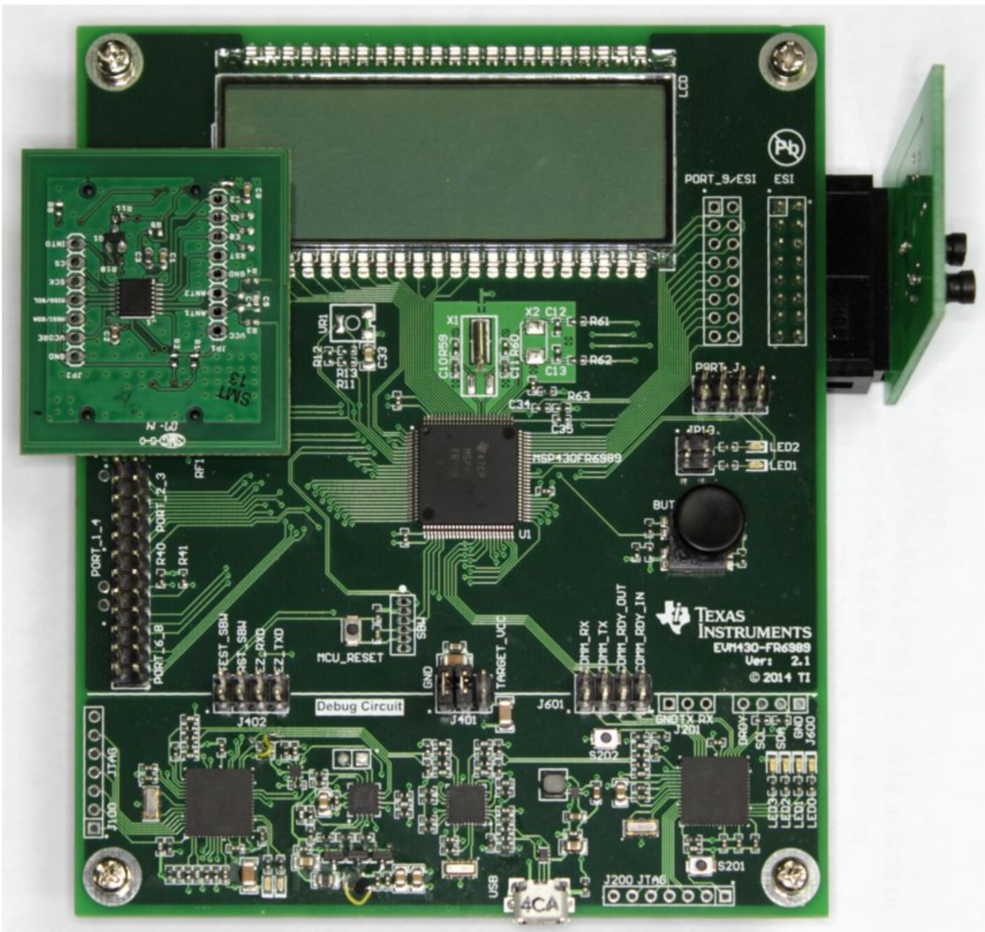


Figure 7. EVM430-FR6989 Main Board With RF430CL330HTB Target Board Attached

(d) Connect the jumpers of the EVM430-FR6989 main board as shown in Figure 8.

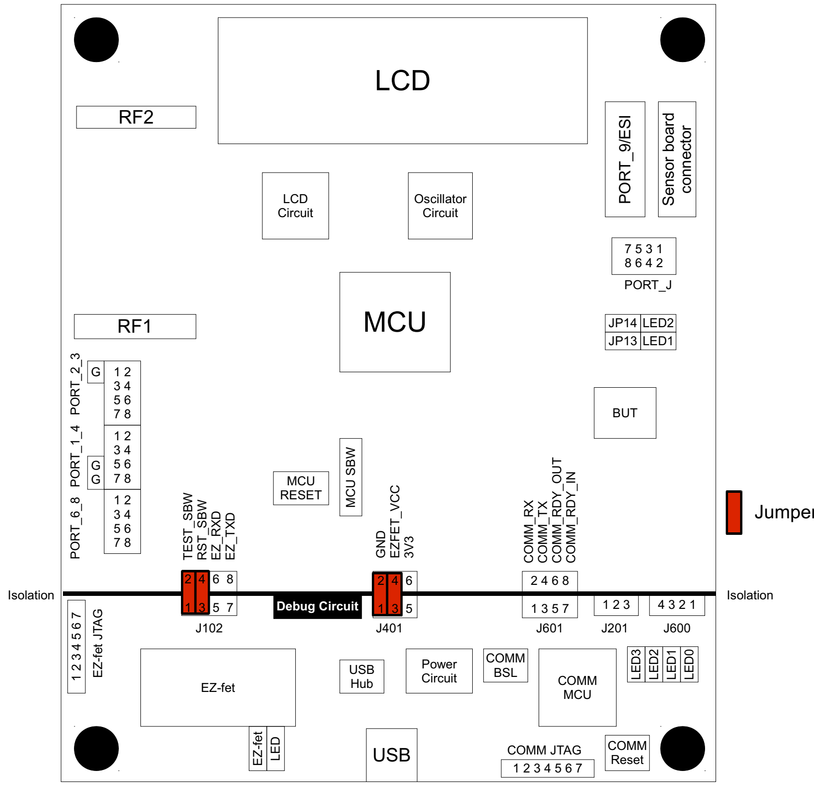


Figure 8. Jumper Setting of Main Board

(e) Connect the EVM430-FR6989 main board to the PC with an USB cable.

(f) Place the motor board to the location that the wheel of the motor board is about 5 mm away to the LC sensors as shown in Figure 1.

(g) Switch on the motor board.

2. Start the test:

(a) Launch CCS and load the test project.

(b) Start and run the debug session of the CCS.

(c) The main board shows "0" on the LCD. Make sure the wheel of the motor board is not rotating.

(d) While calibrating, "8888" is shown on the LCD of the main board.

(e) Start rotating the wheel by pressing the BUT1 or BUT2 of the motor board. Adjust the variable resistor to change the rotation speed.

(f) After the calibration is completed, the counter number of the ESI is shown on the LCD.

(g) Press the navigation button to toggle off the LCD.

3. During the test:
   (a) Pause the debugging session.
   (b) Set the energy trace measurement duration to 30 seconds.
   (c) Start free run mode (Menu → Run → Free run).
   (d) During the measurement period, place the NFC reader near the RF430CL330H target board.
   (e) The NFC reader shows the following text:
   "Device ID: 1234
   ESICNT1 = xxxxx"

   "xxxxx" is the value of the ESICNT1, which is the same value shows on the LCD.

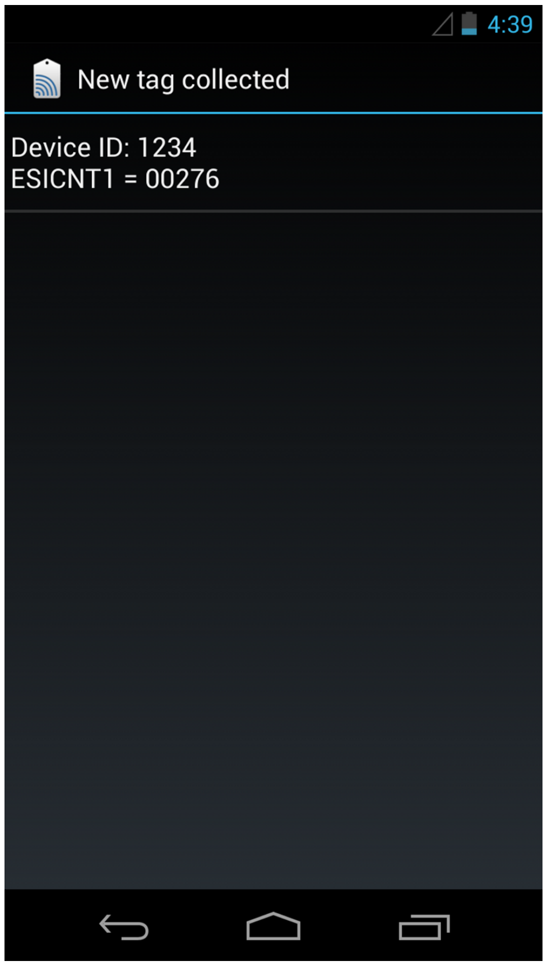


Figure 9. Screenshot of NFC-Enabled Smartphone Reading Data of the RF430CL330HTB Target Board Written by the EVM430FR6989

   (f) Move the NFC reader away from the target board.
   (g) After the measurement period, the power consumption profile of that measurement period is generated on the "Power" tab by the EnergyTrace function.

5 Test Data

The following figures show the power profile measured for 30 seconds after the ESI calibration is finished and the LCD is toggled off. This simulates the normal operation of the flow meters in detecting rotation of the propellers.

The flow of the power measurement is done as follows:

1. At T = 0 seconds: Start measuring.
2. At T = 10 seconds: Place the NFC reader.
3. At T = 20 seconds: Remove the NFC reader.
4. At T = 30 seconds: Finish measuring.

5.1 Test Result at VCC = 3.3 V

Figure 10 shows the power profile measured for 30 seconds when the system is powered at 3.3 V. When the RF field is not present, the system base current is measured at 8.18 µA (0.027 mW / 3.3 V). When the RF is detected, a burst is observed. The MSP430FR6989 writes text data to the RF430CL330H during that period. After that, the power became steady at about 204 mW, which translates to 61.8 µA.

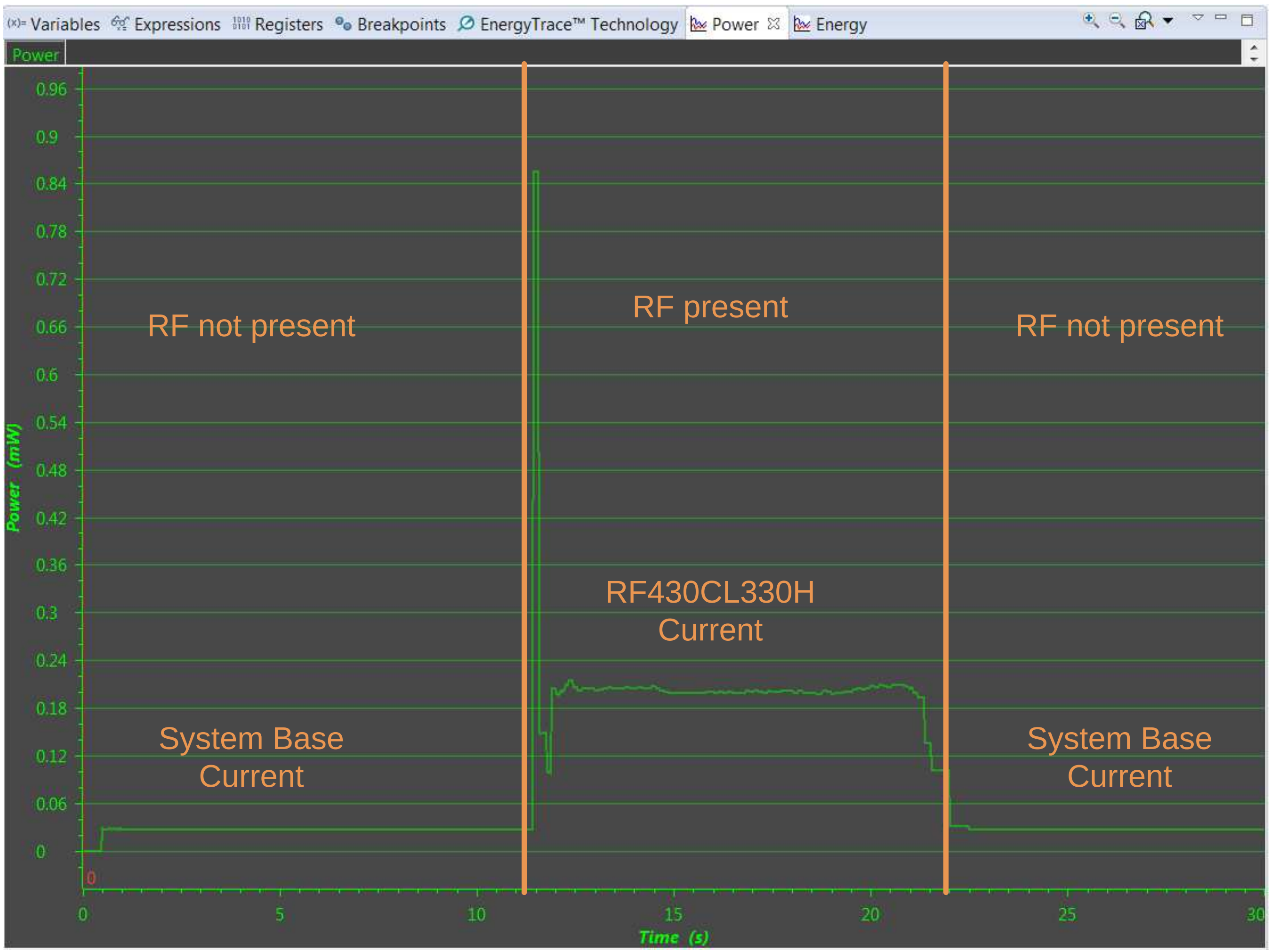


Figure 10. Power Profile of 30-Second Measurement at 3.3-V Power Supply

5.2 Test Result at VCC = 2.5 V

The same test is also conducted with the power supply voltage reduced to 2.5 V. Voltage regulator TPS78225 is added to the EVM430-FR6989 main board to lower the supply voltage to 2.5 V. The connection is shown in Figure 11. Note that the jumpers on the J401 should be removed.

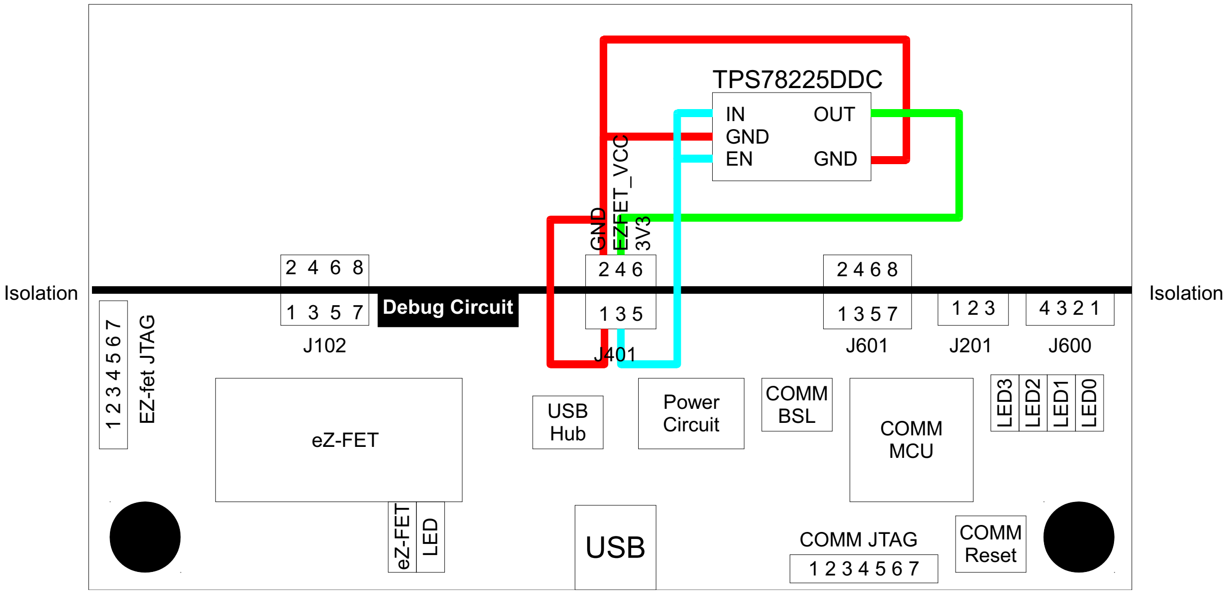


Figure 11. Voltage Regulator Connection on the EVM430-FR6989 Main Board

The test result shown in Figure 12 indicates that at a 2.5-V power supply, when the RF is present, the power consumption is reduced compared with a 3.3-V power supply. The current is 10.6 uA (0.035 mW / 3.3V). The system base current is still 8.18 uA (0.02 mW/3.3 V). Note that the power is measured before the voltage regulator. The voltage used in the calculation is still 3.3 V.

As mentioned in Section 2.2, the RF430CL330H obtains power from the RF field and consumes 0 µA from the host. The additional 2.42 µA is contributed by the wake circuit ((2.5 V – VCE) / 1 MΩ, where VCE is the voltage between the collector and the emitter of the transistor).

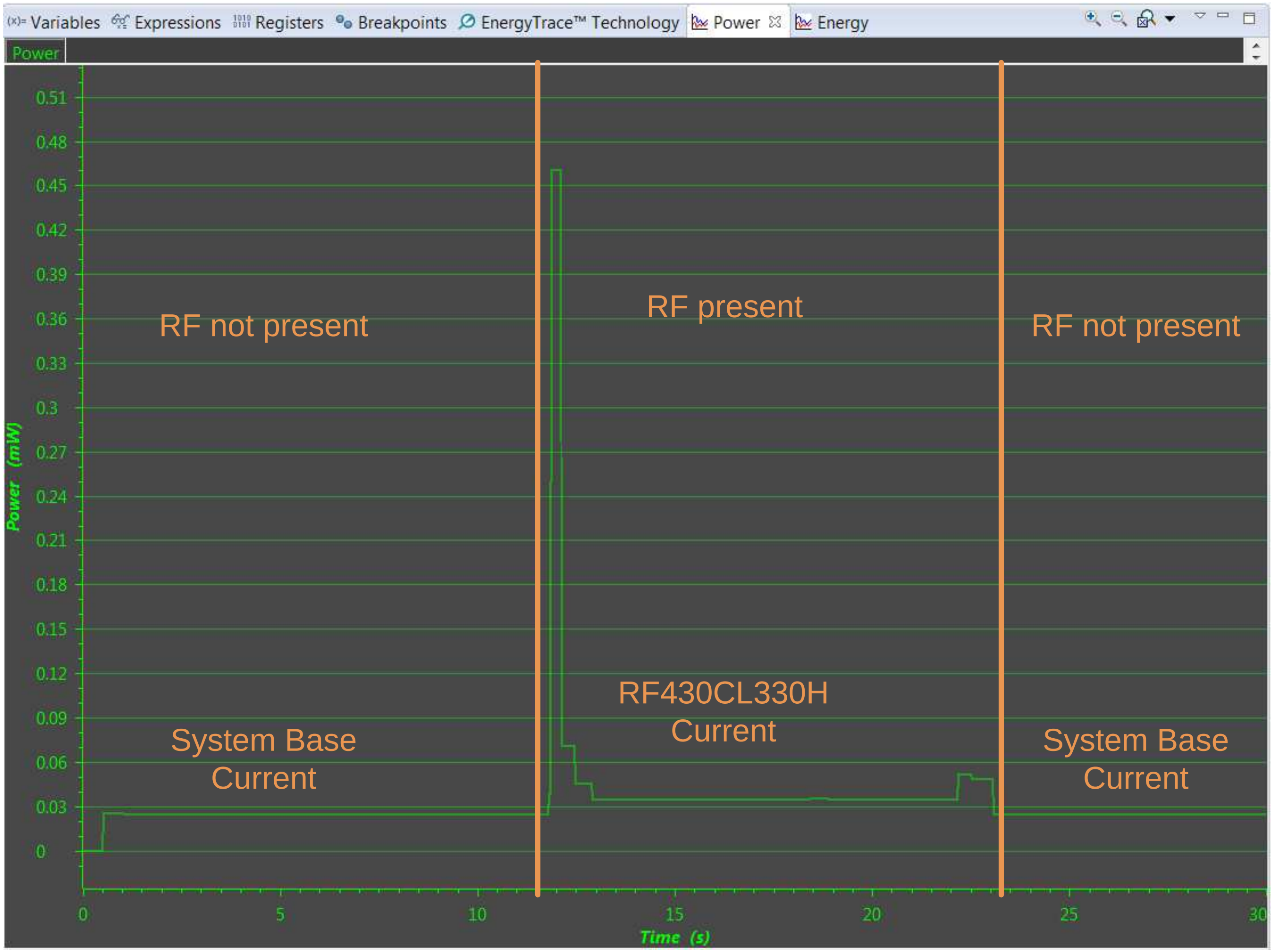


Figure 12. Power Profile of 30-Second Measurement at 2.5-V Power Supply

6 Design Files

6.1 Schematics

To download the schematics, see the design files for the following:

- EVM430-FR6989
- TIDM-LC-WATERMTR
- RF430CL330HTB

6.2 Bill of Materials

To download the bill of materials (BOM), see the design files for the following:

- EVM430-FR6989
- TIDM-LC-WATERMTR
- RF430CL330HTB

6.3 Layer Plots

To download the layer plots, see the design files for the following:

- EVM430-FR6989
- TIDM-LC-WATERMTR
- RF430CL330HTB

6.4 Gerber Files

To download the Gerber files, see the design files for the following:

- EVM430-FR6989
- TIDM-LC-WATERMTR
- RF430CL330HTB

7 Software Files

To download the software files, see the design files at TIDM-NFC-WATERMTR.

8 About the Author

ZACK MAK is a system application engineer at Texas Instruments where he is responsible for developing reference design solutions for the industrial segment. Zack earned his bachelor of electronic and communication engineering from City University of Hong Kong.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265