Quick Start Guide to the Smart Meter Reference Design

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ABSTRACT

The smart meter reference design from Texas Instruments is a comprehensive tool that demonstrates the capabilities of a smart meter. The smart meter board (SMB) performs energy or electricity metering and has the capability of transferring key meter data via wired and wireless sensors to form a simple automatic meter reading (AMR) system. This is a quick start guide to reference design SMB 2.5. The SMB is capable of measuring energy and transmitting this information via wired (PLC) or wireless (RF) communication modules. This document details step-by-step procedures to set up this demonstration.

Project collateral and source code discussed in this application report can be downloaded from the following URL: http://www-s.ti.com/sc/techlit/slaa467.zip.

Contents

List of Figures

1 Board Introduction

This section describes the demo kit contents and discusses the board specifics.

1.1 Demo Requirements

The SMB demo requires the following in addition to the kit contents:

- A power strip for connection of energy meter and PLC modem to AC mains voltage
- A second power strip for connection of loads (lamp, cell phone charger, etc.).
- A PC with the PLC Terminal software installed. The PLC terminal software is provided in the zip file accompanying this document.

1.2 Demo Requirements

The SMB kit consists of the following:

- Smart meter board SMB 2.5 + power cord for AC (included)
- PLC modem daughter board (included)
- Two CC2530 RF transceiver daughter boards [5] (included)
- PLC modem DK board + USB cable + power cable (included)
- IHD430 low-cost segment-based in-home display (included)
- Power strip for load connections (not included)
- Regional plug converters for connection to the mains voltage (not included)

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1.3 Board Images

Figure 1 and Figure 2 show the board images of the SMB 2.5.

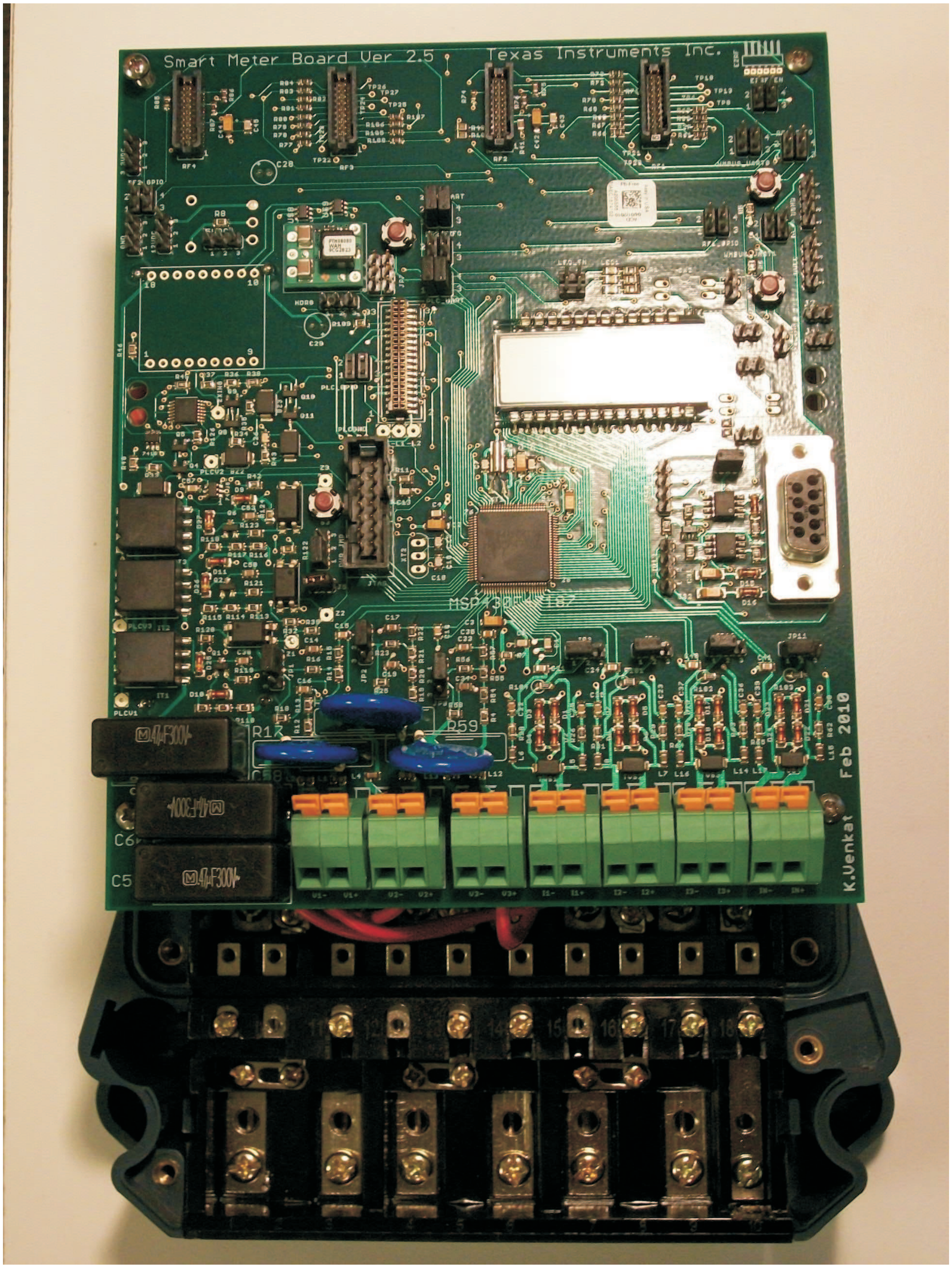

Figure 1. SMB 2.5 Board Top View

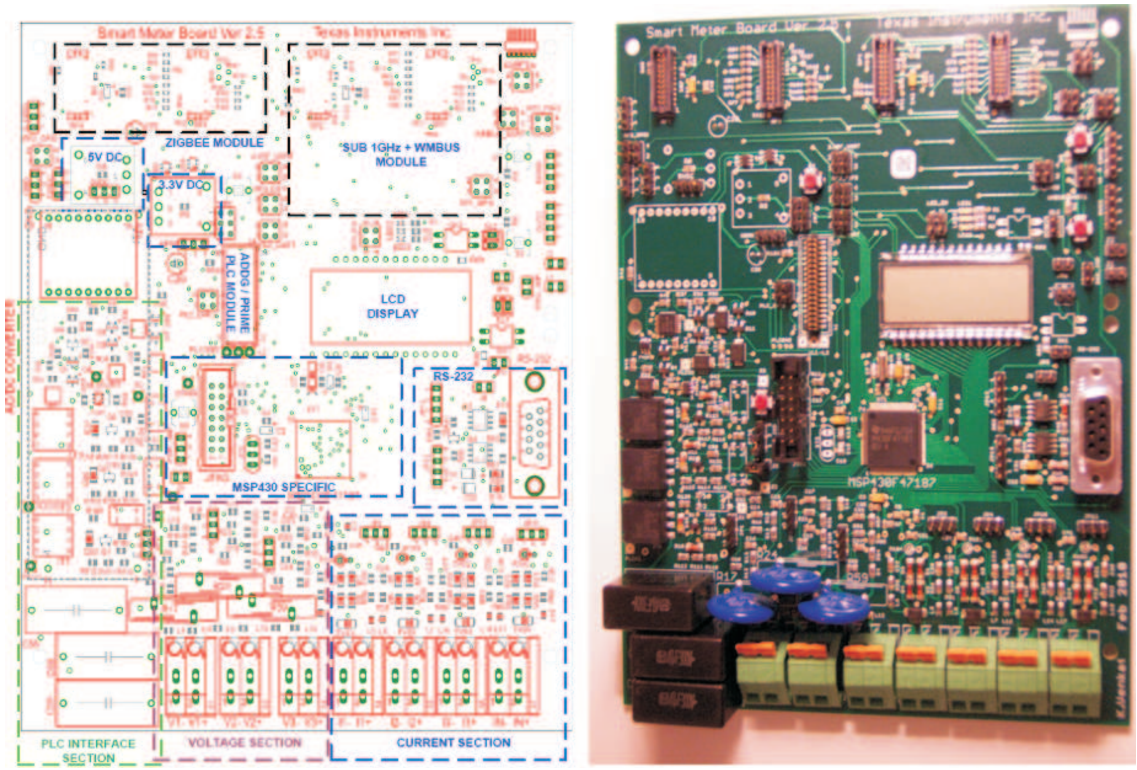

Figure 2. SMB 2.5 Board and Corresponding Functional Block Diagram

Figure 2 shows the functional blocks of the SMB. The following is a brief description of each of these blocks:

- Current section: The current section consists of all the necessary signal conditioning required for the current channels. The SMB 2.5 supports up to three phases plus one more channel for tamper detection. Therefore, the total number of current channels can go up to four, as shown.
- Voltage section: The voltage section consists of all the necessary signal conditioning required for the voltage channels. The SMB 2.5 supports up to three phases; therefore, the total number of voltage channels can go up to three, as shown.
- PLC interface section: The PLC interface section contains all the necessary circuitry that forms the zero-crossing and low-voltage coupling circuitry necessary for the PLC modem to communicate on the AC mains.
- AC/DC converter: The power supply module is able to generate a DC voltage from 110/220 V AC voltage. The power supply module is populated underneath the board and is visible from the side view of the SMB. The DC voltage from the power supply module is regulated at 12 V DC. The power supply is able to drive a current of about 450 mA at 12 V DC.
- MSP430 section: The MSP430™ MCU device is used to perform the metrology portion of the SMB. The device chosen could be any from the MSP430F471x6 or MSP430F471x7 family. Because the devices are pin-for-pin compatible, the SMB can work with any of these devices.
- ZigBee module: The CC2530 is the ZigBee module that is used on the SMB for the demo. The CC2530 has the smart energy profile (SEP) 1.0 + ZigBee Pro running and is interfaced to the MSP430 via the universal asynchronous receiver/transmitter (UART) at a baud rate of 115.2 kbps. The MSP430 periodically sends instantaneous power consumption to the ZigBee module for wireless transmission.
- Sub 1-GHz / WMBUS module: The SMB 2.5 has a separate interface for the sub-1-GHz module to support RF transmission. The hardware is configured to support all wireless transceivers from Texas Instruments. Currently, the SMB 2.5 demo does not have software ready to support this type of interface, but it is in process.

- LCD display: The LCD display that is present on the SMB 2.5 displays instantaneous power consumption in Watts. The refresh rate of this LCD is every second, and the display corresponds to the same information sent to the PLC modem and the RF transceivers. The resolution of this instantaneous power reading is 10 mW.
- RS-232 interface: The RS-232 interface section connects the SMB 2.5 to the PC. This interface facilitates the ability of the PC to connect individually to the MSP430, C2000™, WMBUS module, etc. The objective is to perform debug, calibration, etc., when the SMB 2.5 is used as an evaluation module. For a successful SMB 2.5 demo, the RS-232 interface should not be activated.
- DC power: The power supply module provides regulated 12 V DC. On-board modules are capable of providing a DC-to-DC conversion for 3.3 V and 5 V DC.

2 Demo Setup Instructions

This section discusses the step-by-step instructions to run the demo on the SMB 2.5. The SMB 2.5 arrives with all devices pre-programmed to perform the desired actions; therefore, no programming is necessary. The MSP430 device has a IEEE Standard 1149.1-1990, IEEE Standard Test Access Port and Boundary-Scan Architecture (JTAG) interface that allows for programming; however, this interface should not be used unless you would like to modify the existing code.

2.1 SMB Board Setup

The following is the step-wise instructions to run the demo.

WARNING

Failure to adhere to these steps and/or not heed the safety requirements at each step may lead to shock, injury, and damage to the hardware. Texas Instruments is not responsible or liable in any way for shock, injury, or damage caused due to negligence or failure to heed advice.

1. Examine the SMB 2.5 prior to powering up the board; the board must be examined for the following.
   (a) Check that all connections of the daughter cards fit well in their respective sockets. If the daughter cards are removed, ensure correct orientation when re-inserting. Failure to have the right orientation will damage the daughter cards. Figure 3 and Figure 4 show the orientation of the PLC and RF modules, respectively.

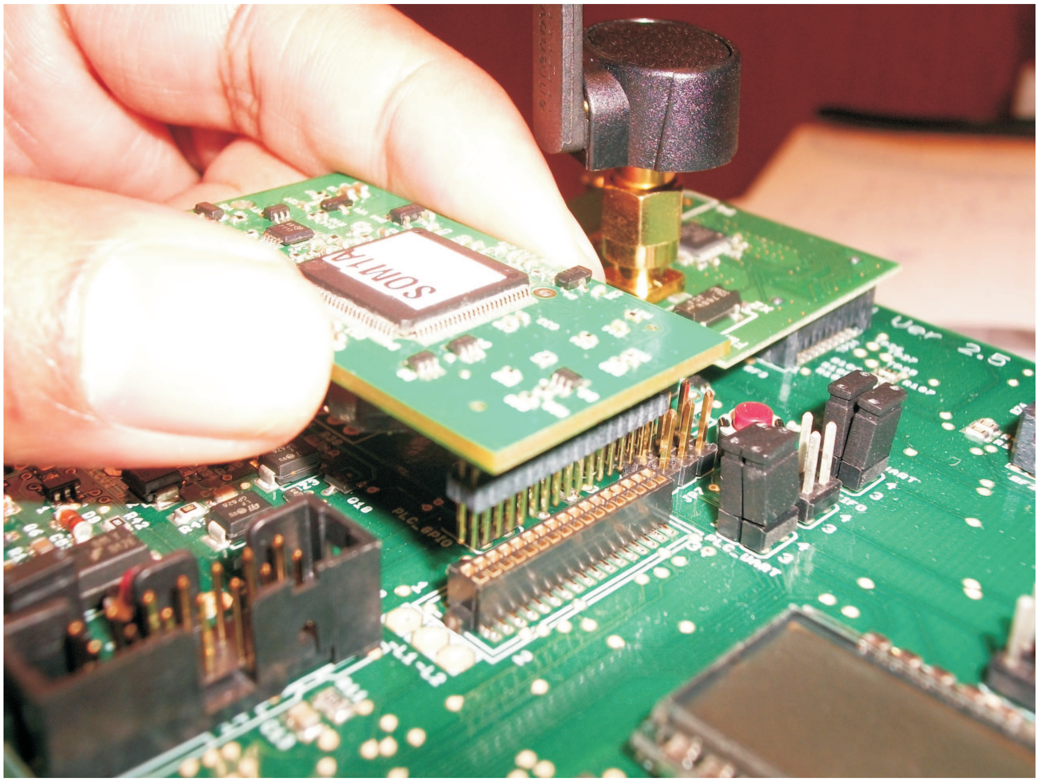

Figure 3. PLC Module Orientation and insertion

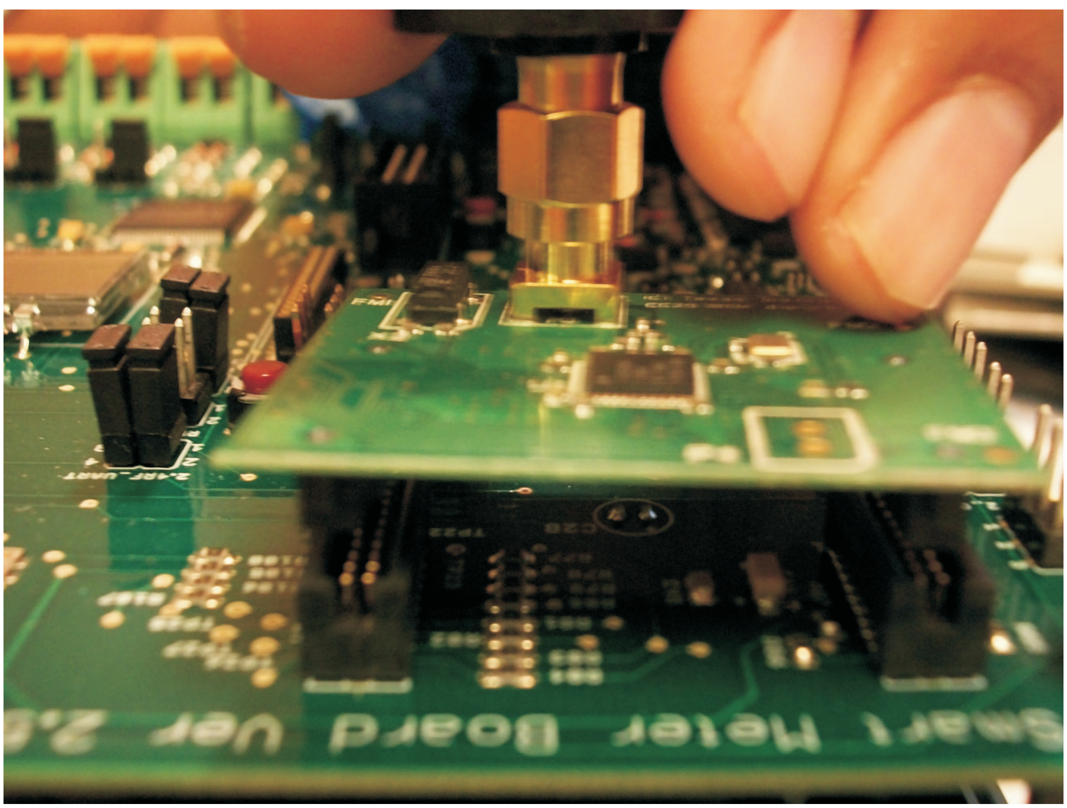

Figure 4. CC2530 RF Module Orientation and Insertion

(b) Ensure that the power cord is fixed firmly on the SMB 2.5 between connectors V1+ and V1-, as shown in Figure 5. If not, make sure you follow the steps shown in Figure 5 and Figure 7.

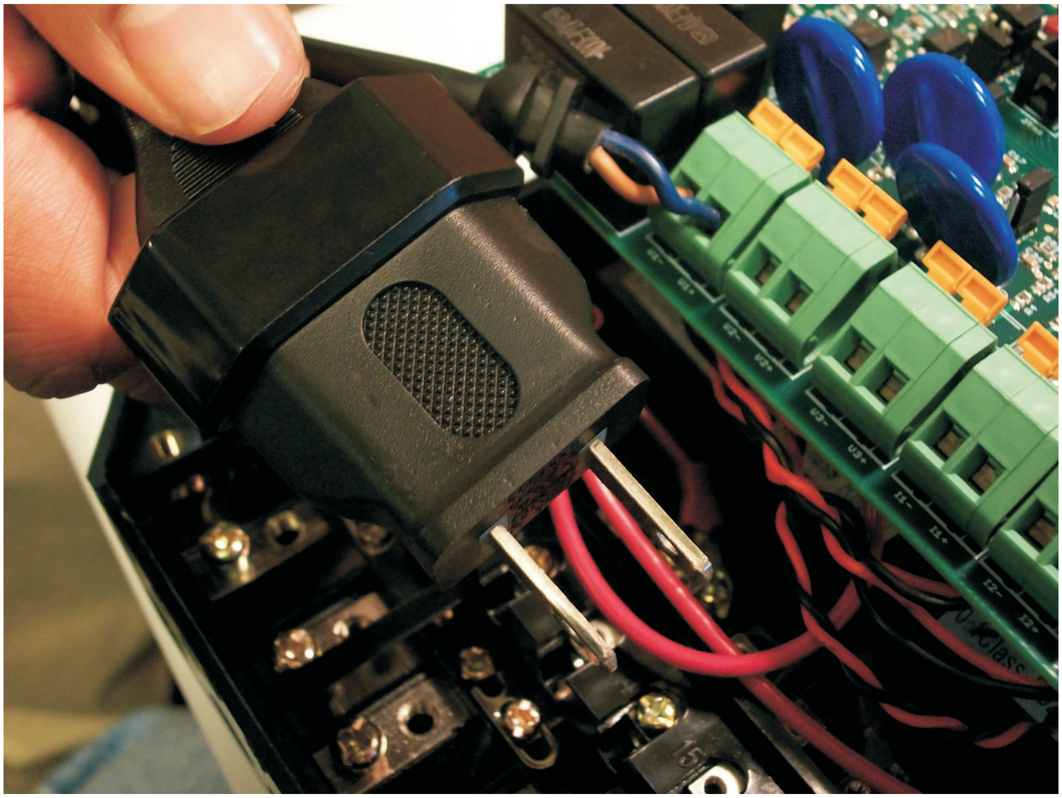

Figure 5. AC Power Cord Between V1+ and V1-

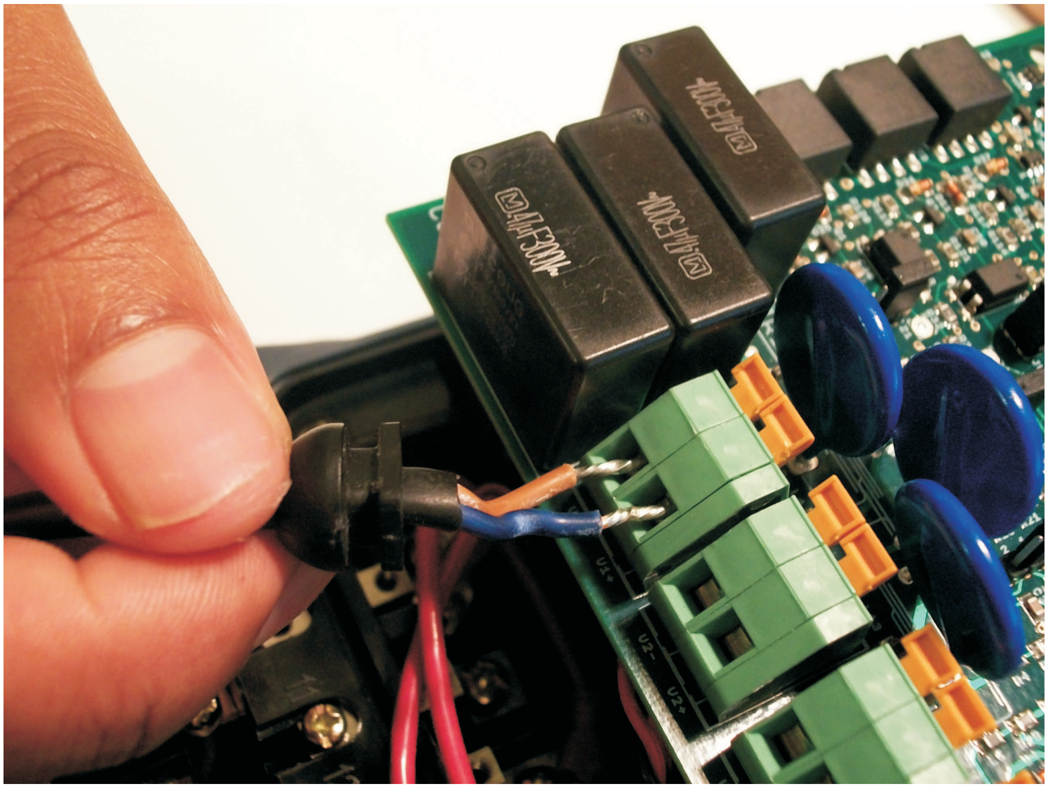

Figure 6. AC Power Cord Connector

(c) Make sure to press down with a flat-head screwdriver to release the contacts, if the power cord needs to be inserted. Do not attempt to use your fingers to push down on the connector head. Figure 7 indicates the type of flat-head screwdriver and the proper procedure to use.

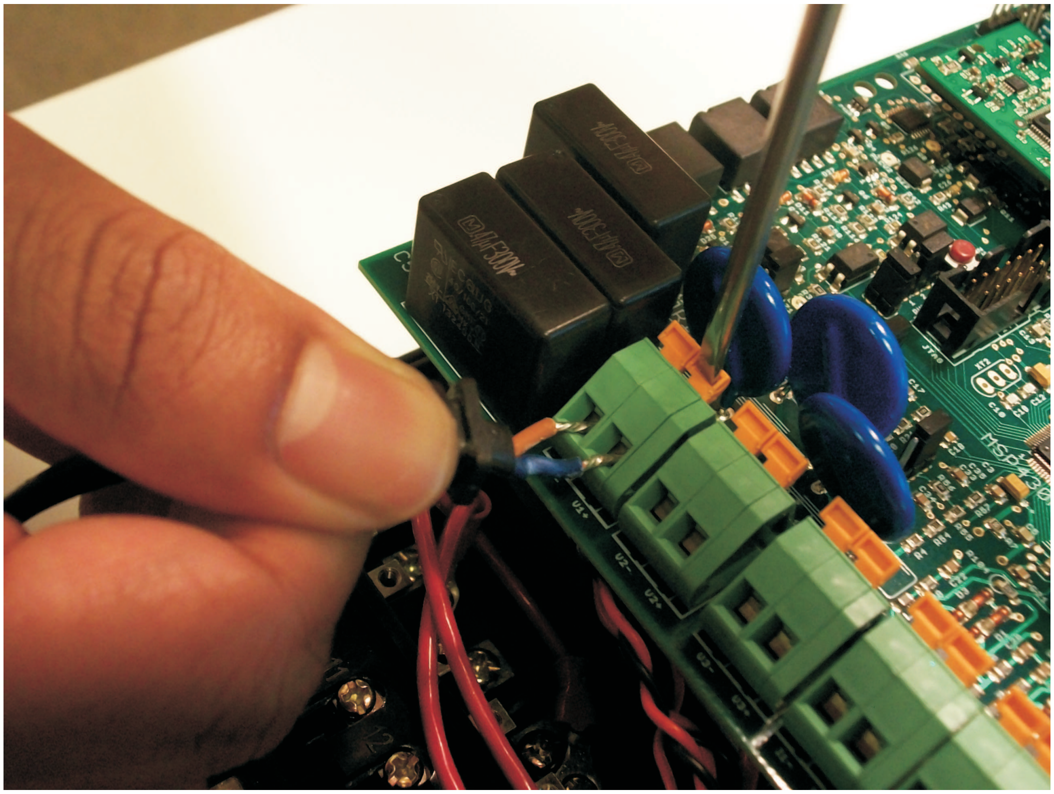

Figure 7. AC Power Cord Insertion Between V1+ and V1-

(d) Ensure the load strip is connected between GND (neutral) and one end of the current transformer (CT); i.e., I1- for phase 1 as shown in Figure 8. The load strip is an adaptation of a regular power strip with the exception that the AC plug is cut and the wires have been modified to be screwed in to the terminals.

Figure 8. Power Strip Connector to Energy Meter

2. Validate the connectivity of the sensors and the respective voltage and currents before powering the board.
   (a) Check the resistances between the positive and negative points for each phase; for example, between V1+ and V1-, V2+ and V2-, and V3+ and V3-. A multimeter can be used across the green connector pairs as shown in Figure 9.

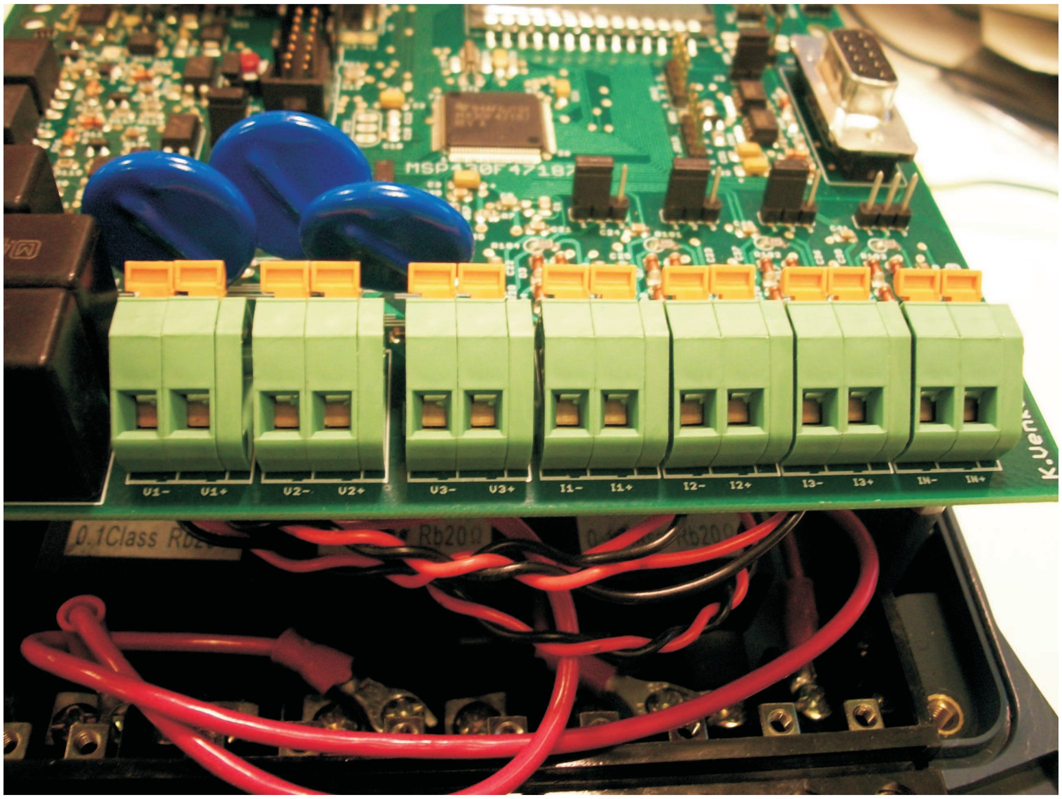

Figure 9. Connectors for Voltage and Current

   All resistances across voltage pairs V1+ and V1- should read close to 1 MΩ and across current pairs I1+ and I1- should read close to 6.5 Ω.

   If any of these values do not match, the board is unusable and should not be powered by the AC mains.

   (b) Check if there is a short across any of the voltage pairs using a multimeter. If there is a short on one of the voltage pairs, the connections should be verified again and the previous step must be rechecked.

3. Check for jumper settings: There are various jumpers on the board that need to be in place for a successful demonstration. The following jumpers need to be configured:
   (a) 2.4RF_UART: Jumper between [1 2] and jumper between [3 4]
   (b) PLC_UART: Jumper between [1 2] and jumper between [3 4]
   (c) PWR_JMP: Jumper between [2 3]
   (d) J5: Place jumper across the two pins
   (e) JP1, JP2, JP3, JP4, JP9, JP10, and JP11: Place jumper between [1-2]. If the jumper is placed on even one of these headers between [2-3], the MSP430 will not perform metrology correctly, and damage to MSP430 can occur.

Figure 10 shows the board with all the jumper locations of interest.

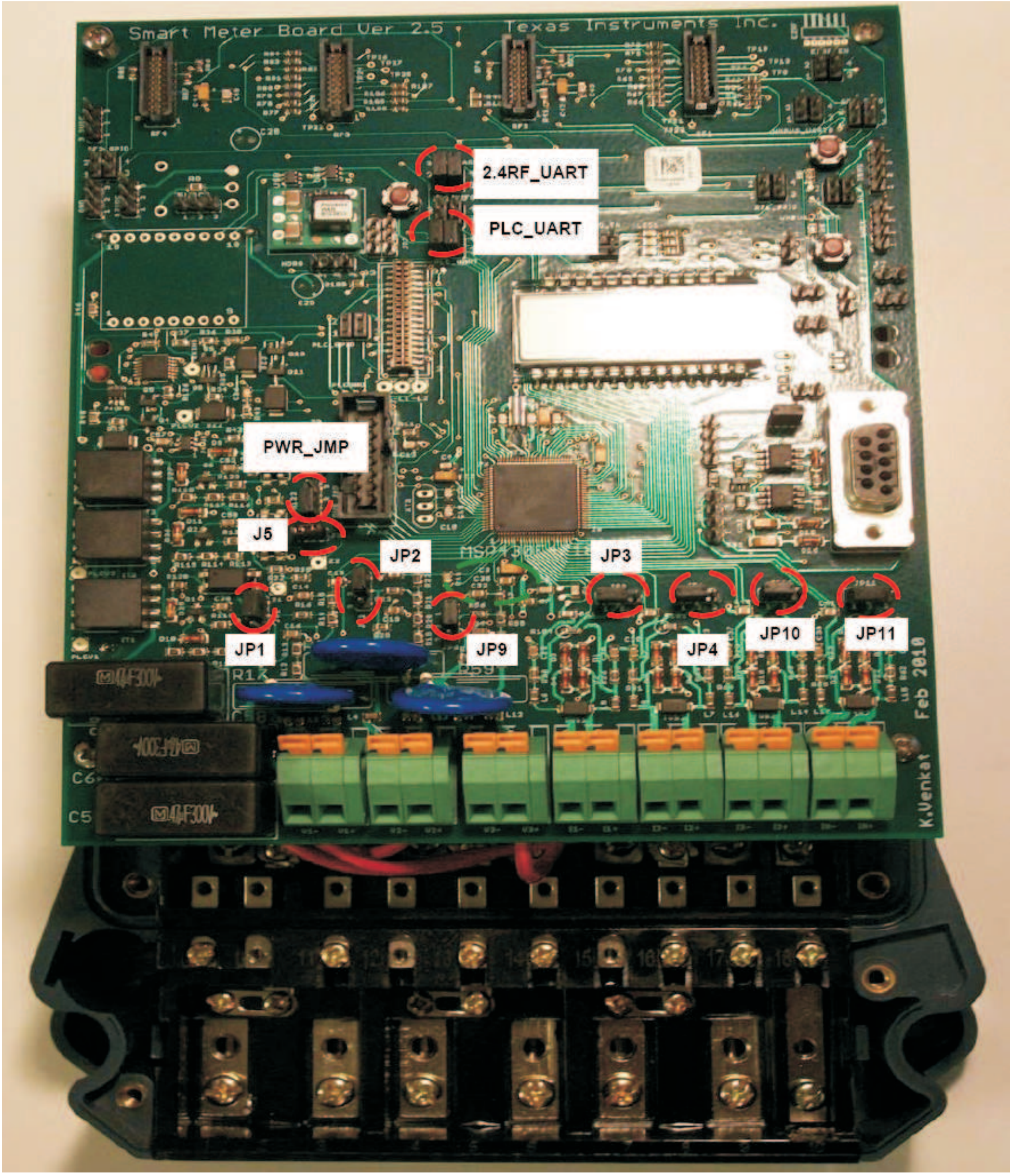

Figure 10. Jumper Locations of Interest on SMB 2.5

2.2 PLC Board Setup

Once the SMB is setup, the PLC board on the receive side must be set up correctly. See the PLC manuals from Texas Instruments for setup of the PC GUI. This manual is included in the PLC software directory in the downloadable zip file accompanying this document.

Follow the start-up sequence for PLC GUI described in Section 2.3. However, communication to the PLC modem can be established, if needed, by separately powering it using AC mains voltage to check health status.

2.3 ZigBee In-Home Display (IHD)

Most IHDs have their own setup mechanism and most join the ZigBee network once turned on. In this section, the low-cost IHD430 is discussed. Follow the start-up sequence for IHDs that is described in the following sections.

2.3.1 Introduction

The IHD430 is a low-cost display unit that is primarily used to display readings from the smart meter board 2.5. It also has the capability to communicate with a similar IHD430. The IHD430 comes with one IHD with connected CC2530 module, an antenna for the CC2530, and two AAA 1.5-V batteries.

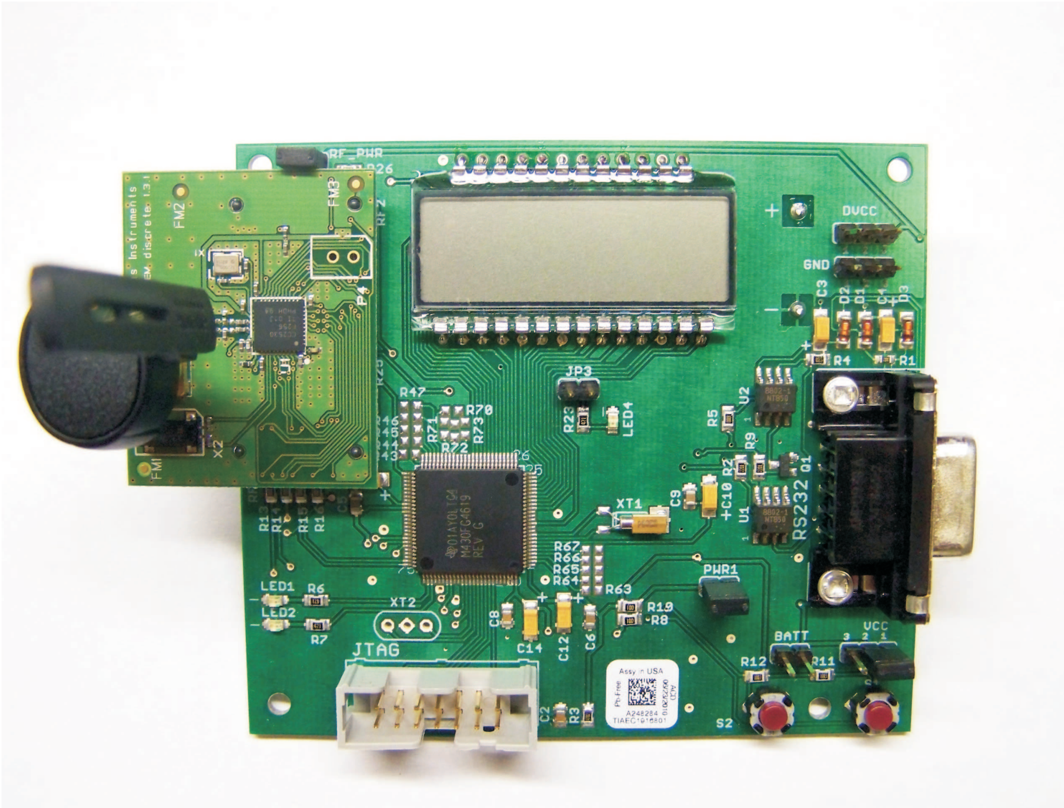

Figure 11. MSP430F461x IHD Board

2.3.1.1 Devices Supported

The IHD430 is based on the Texas Instruments ultra-low power MSP430 family of microcontrollers [1] and Texas Instruments Chipcon wireless evaluation modules (EVM). The board contains a MSP430F461x microcontroller. It has support to connect any low-power wireless transceivers for ZigBee or sub-1-GHz communication from Texas Instruments.

2.3.1.2 Tools Requirement

The IHD430 shipped is pre-installed with code that configures the IHD430 to act as a receiver and display received values on the LCD. If it is desired to modify the pre-installed code, a MSP430 Flash emulation tool (MSP-FET430UIF) is required to download and debug code on the MSP430 and a SmartRF05 EB board is required to reprogram the on-board CC2530. The on-board MSP430 uses the standard 4-wire JTAG connection for JTAG communication.

2.3.1.3 Functional Overview

The IHD430 contains components that enable a wide range of applications. Figure 12 shows the components of the IHD430.

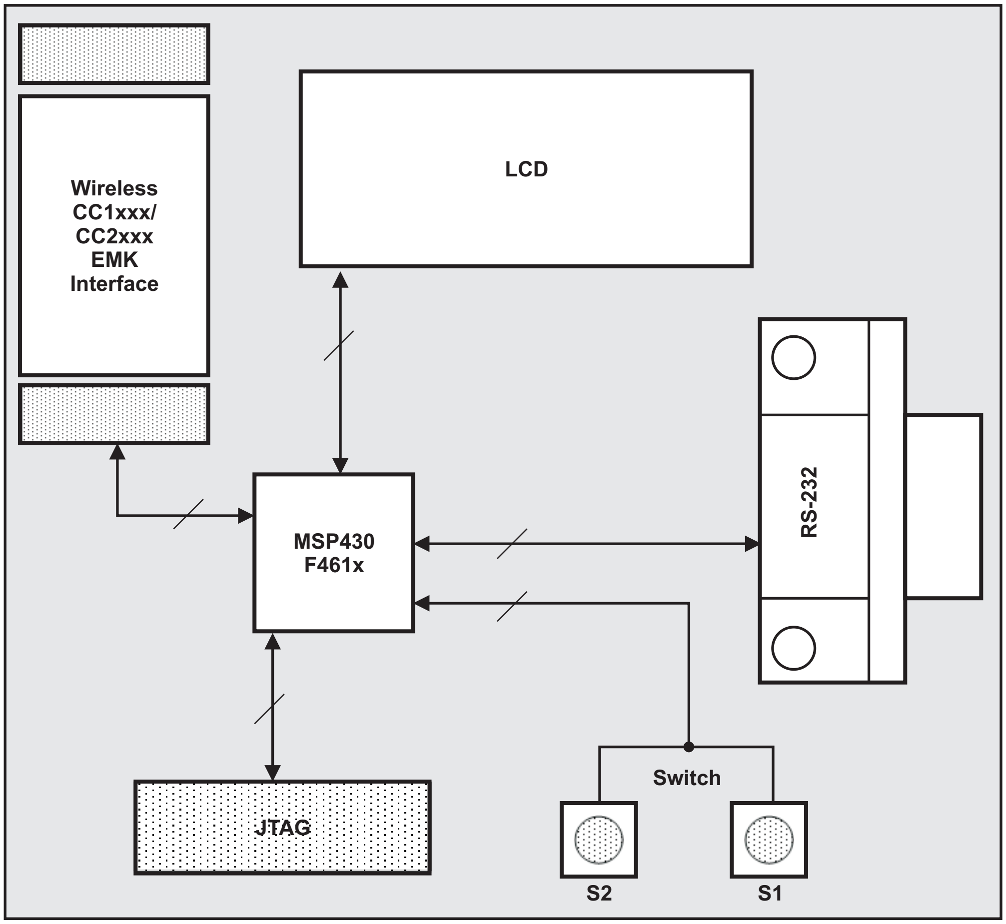

Figure 12. IHD430 Board Block Diagram

The IHD430 has a CC2530 that enables wireless ZigBee communication. The CC2530 is connected via an RF connector and, therefore, can be easily replaced with another pin-to-pin compatible EM module. In addition, it contains a JTAG connector that can used to program the MSP430 and power the entire board via FET debugger. Other components include two push-button switches and an RS-232 DB-9 header for PC communication via UART. Data is available on the on-board 4-mux LCD or via the RS-232 link.

2.3.1.4 Hardware Installation

Power may be provided locally from two on-board AAA batteries, externally from a Flash emulation tool (FET), or from an external supply. The power source is selected by configuring jumpers on **V_{CC}** and **BATT** headers. By placing a jumper on the **PWR1** header, power is supplied to the on-board MSP430. Figure 13 shows the jumper hierarchy and configuration options.

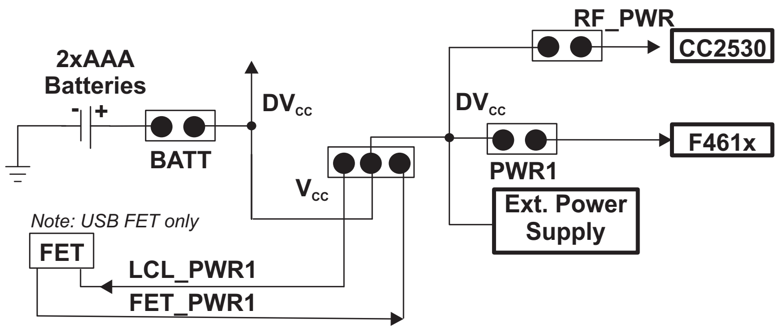

Figure 13. Power Selection Jumpers

The battery header **BATT** is used to select the on-board batteries to power the system independently from the FET. By placing a jumper on the **BATT** header, the entire board is powered (**DV_{CC}**).

The power selection header **V_{CC}** is a 3-pin header that is used to select the power connection between the board and the USB-FET interface only. A jumper on this header is needed only when JTAG communication is required. A jumper placed on the pins [1-2] selects the JTAG FET as the power source. A jumper placed on the pins [2-3] selects external or local power, either from the batteries or an external supply, to be applied to the FET for proper logic threshold level matching during program/debug.

Header **PWR1** has been provided to enable/disable power to the on-board MSP430. A jumper placed on **PWR1** provides power to the MSP430 device. MSP430 device current consumption can be measured via this header.

Header **RF_PWR** has been provided to enable/disable power to the CC2530. It should be noted that the power to the CC2530 is independent from the **PWR1** jumper. Removing power from the on-board MSP430 via the **PWR1** jumper does not remove power from the CC2530 and vice versa. A jumper on this header should be removed when CC2530 is not in use to save power.

Once the required power selections have been made via jumpers, the IHD430 is ready to be used.

After powering a SMB or powering another IHD430 configured as a transmitter, the IHD430 receiver should briefly display *Ihd430* until data is received from the SMB transmitter or IHD transmitter. Once it receives this data, the IHD430 displays it on its LCD. Press S2 to enable or disable data transmission through the RS-232 UART. Press S1 to make the IHD430 enter a low-power sleep mode. Power consumption can be further reduced by removing the **RF_PWR** jumper.

3 Running the Demonstration

In this section, procedures to run the demo are discussed. It is assumed that the previous section has been read completely and the instructions followed. The following are the summary of the required connections before turning on the demo.

3.1 Preliminary Steps

1. Connect SMB 2.5 to the AC power cord for AC mains supply. Regional plug adaptors are the responsibility of the user. Do not connect to the power strip yet and, if there is a switch on the power strip, make sure it is in off position.
2. Connect PLC modem daughter card firmly on the SMB.
3. Connect ZigBee CC2530 transceiver daughter card firmly on the SMB.
4. Check to see that all Jumpers are in place for the SMB 2.5.
5. Secure and connect the load strip according to Figure 8.

6. Connect the PLC receive modem to the same power strip as the SMB 2.5 (point 1).
7. Connection of the PLC receive modem to PC is complete, and the GUI is installed correctly on the PC.
8. Check again for all values of resistances across voltage and current pairs for all three phases.

Once all the above steps are complete, the setup should look like Figure 14 (except that the figure is missing the daughter cards, which should have been inserted on the board at this point in time).

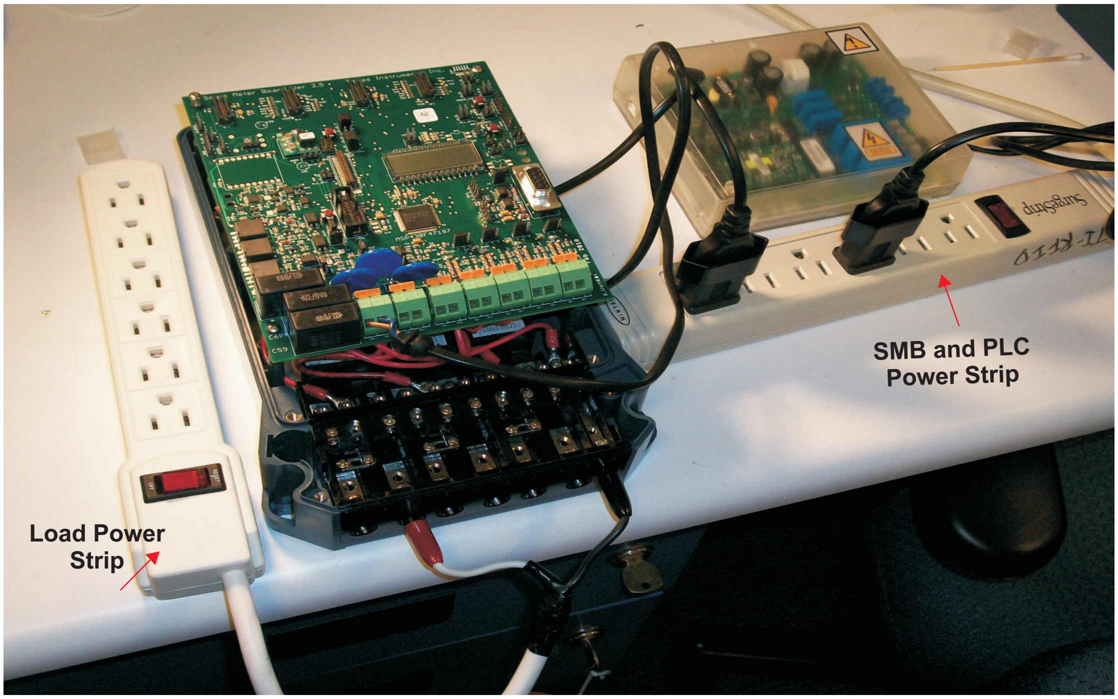

Figure 14. Demo Setup for SMB 2.5

3.2 Running the Demo

This is the final section that allows the Smart meter demonstration using the SMB 2.5.

1. Turn on the power strip that is connected to the AC mains supply (white power strip on the right of the SMB in Figure 14). The LCD should show a value of *000.00*. This value indicates that the active power reading is zero. This also indicates that there is no load connected. The PLC modem on the SMB has an LED toggle synchronous to the load.
2. Connect any load such as a lamp, cell phone charger, etc. to the load power strip (white power strip to the left of the SMB in Figure 14). The LCD display should immediately start to display a non-zero value indicating that energy consumption has started.
3. Turn on the IHD to see the value of the instantaneous power on the screen. It is important to note that the IHD should be turned on only after the CC2530 on the SMB is turned on.
4. Ensure that the receive modem is connected and the GUI opened, for the PLC portion of the demo. It is assumed that the correct COM port has been selected and is ready to accept data. On the SMB, press switch S1 to immediately start to transmit data to the PLC modem for transmission on the mains. Ensure that a non-metallic object is used to press the switch as shown in Figure 16 and that S1 pressed only after the PC is completely set up and communication of the receive modem is confirmed to be working.

This data immediately appears on the PC GUI with an associated time stamp. The location and operation of the switch on the SMB is shown in Figure 15 and Figure 16.

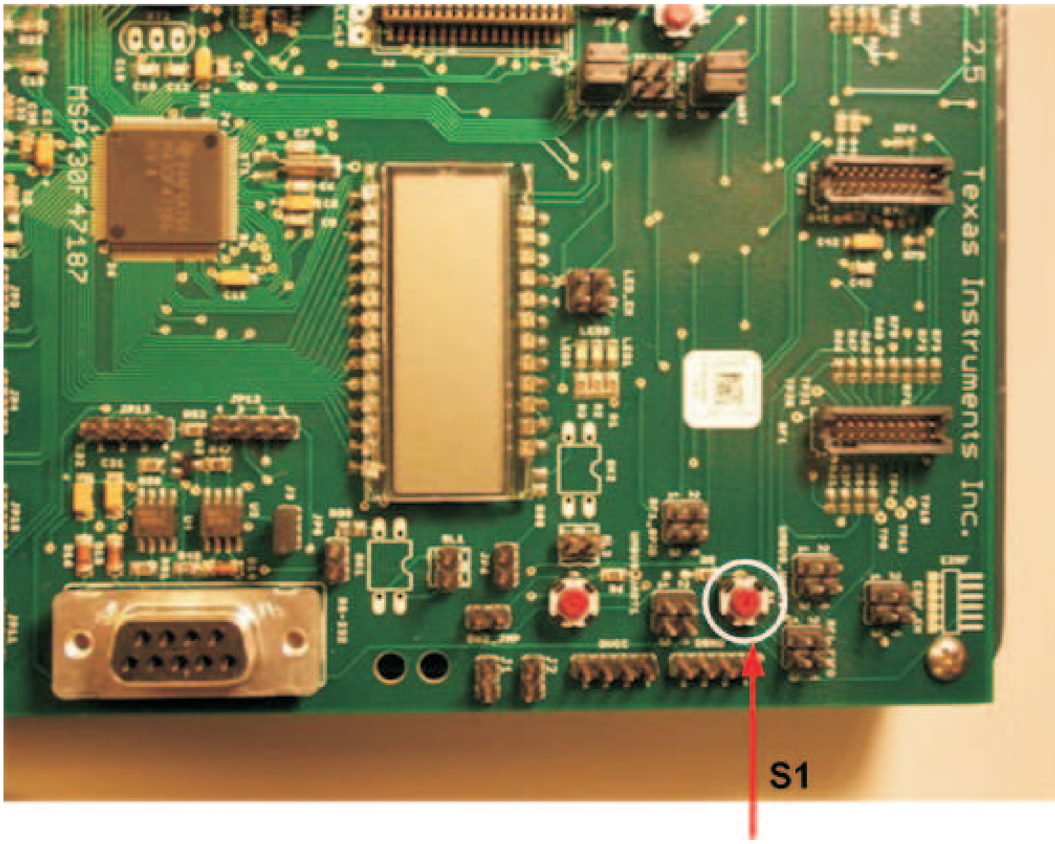

Figure 15. Switch Position S1 on the Top Right Corner of the SMB

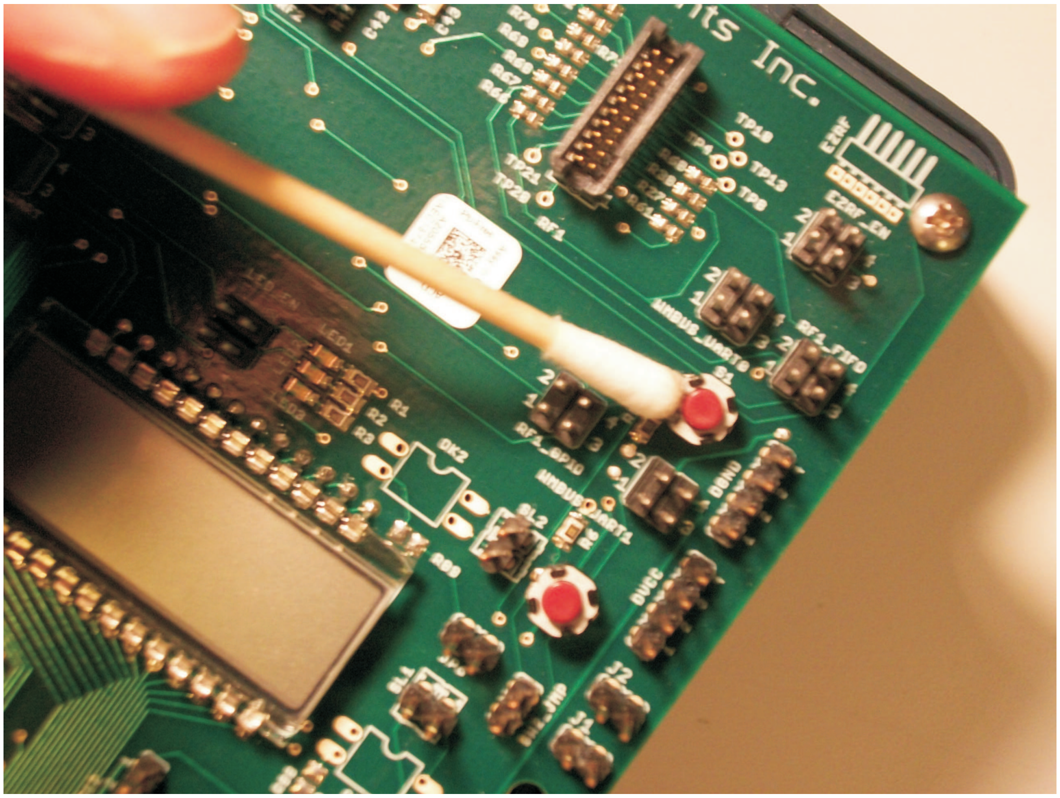

Figure 16. PLC Data Transmission Initiation

Press switch S1 to toggle start/stop of data transmission from the PLC modem of the SMB to the PC GUI.

After the demo is complete:

5. Ensure that the PLC transmission is turned off using Switch S1, the load is turned off, and the mains AC voltage is turned off.

4 References

1. *MSP430x4xx Family Users Guide* (SLAU056)
2. *Implementation of a Three-Phase Electronic Watt-Hour Meter Using MSP430F471xx* (SLAA409)
3. *MSP430x461x1, MSP430x461x Mixed Signal Microcontroller Data Sheet* (SLAS675)
4. *MSP430F471x3, MSP430F471x6, MSP430F471x7 Mixed Signal Microcontroller Data Sheet* (SLAS626)
5. CC2530 Evaluation Module Kit: http://focus.ti.com/docs/toolsw/folders/print/cc2530emk.html

IMPORTANT NOTICE

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