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Implementing Wi-Fi Connectivity in a Smart Electric Meter

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Design Resources

TIDC-3PHMTR-WIFIXR	Tool Folder
EVM430-F6779	Tool Folder
CC3100BOOST-RD	Tool Folder
CC31XXEMUBOOST-RD	Tool Folder
CC3100	Product Folder
MSP430F67791	Product Folder

TI E2E™ Community

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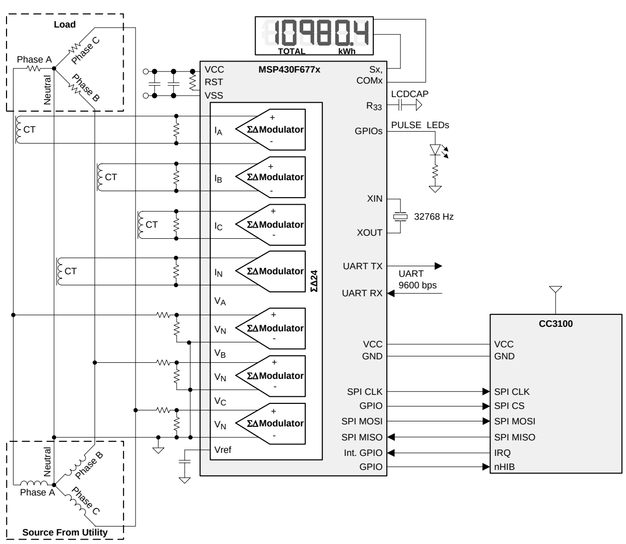
WEBENCH® Calculator Tools

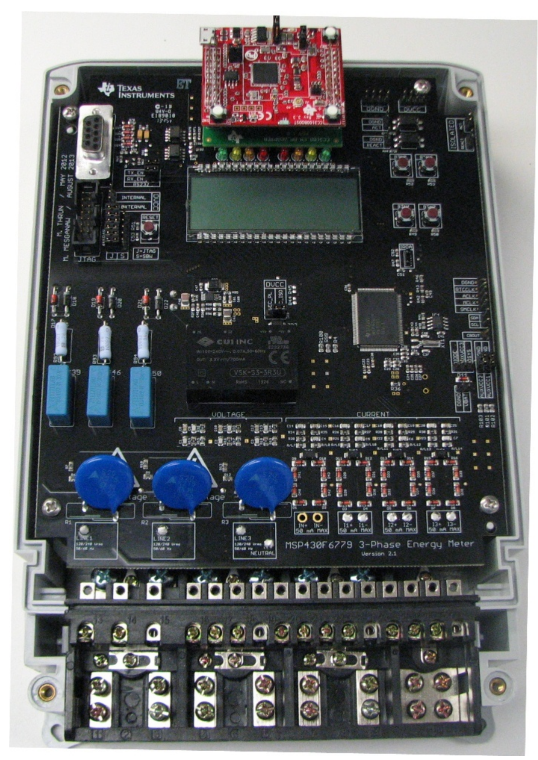
Design Features

- Three-Phase E-Meter Implementation That Calculates Metrology Parameters Such as RMS Current, RMS Voltage, Active and Reactive Power and Energies, Power Factor, and Frequency
- Wi-Fi Connectivity over IEEE-802.11 b/g/n Networks from Any Smart Phone, Tablet, or Computer Through a Standard Web Browser
- 160-Segment LCD Display for Wi-Fi Status and Metrology Parameter Display
- Expandable to Support Other Internet Applications
- PC-Based GUI for Calibration

Featured Applications

- Metering





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1 System Description

This design implements a three-phase energy meter with Wi-Fi connectivity. The e-meter system on chip (SoC) performs all metrology functions and control the SimpleLink™ Wi-Fi transceiver. The smart meter data can then be displayed on any Wi-Fi connected device via a standard web browser.

The e-meter SoC uses the MSP430F67791 device. The MSP430F677x devices are the latest metering SoC that belongs to the MSP430F67xx family of devices. This family of devices belongs to the powerful 16-bit MSP430F6xx platform, which brings in many new features and provides flexibility to support robust poly-phase metrology solutions. These devices find their application in energy measurement and have the necessary architecture to support them. The F677x has a powerful 25-MHz CPU with MSP430CPUx architecture. The analog front-end consists of up to seven independent 24-bit sigma-delta (ΣΔ) analog-to-digital converters (ADC) based on a second-order ΣΔ architecture that supports differential inputs. The ΣΔ ADCs (ΣΔ24_B) operate independently and are capable of 24-bit results. The ADCs can be grouped together for simultaneous sampling of voltages and currents on the same trigger. In addition, the ADCs also has an integrated gain stage to support gains up to 128 for amplification of low-output current sensors. A 32×32-bit hardware multiplier on this chip can be used to further accelerate math intensive operations during energy computation. The software energy library supports calculation of various parameters for up to 3-phase energy measurement. The key parameters calculated during energy measurements are: RMS current and voltage, active and reactive power and energies, power factor, and frequency. These parameters can be viewed either from the calibration GUI, LCD, or through Wi-Fi using a standard web browser.

For the SimpleLink Wi-Fi transceiver, the CC3100 is used. The CC3100 wireless networking solution is part of the new SimpleLink Wi-Fi family that dramatically simplifies the implementation of Internet connectivity. The CC3100 device integrates all protocols for Wi-Fi and Internet, which greatly minimizes host MCU software requirements. With built-in security protocols, the CC3100 solution provides a robust and simple security experience. This subsystem includes an 802.11 b/g/n radio, baseband, and MAC with a powerful crypto engine for fast, secure Internet connections with 256-bit encryption. This design guide has a complete source code provided as a downloadable zip file.

2 Design Features

This section describes various pieces that constitute the hardware for design of a working 3-phase energy meter that uses the F677x.

2.1 EVM430-F6779 Hardware Implementation

2.1.1 Power Supply

The MSP430 family of devices is ultra low-power microcontrollers from Texas Instruments. These devices support a number of low-power modes and also have low-power consumption during active mode when the CPU and other peripherals are active. The low-power feature of this device family allows design of the power supply to be simple and inexpensive. The power supply allows the operation of the energy meter powered directly from the mains. The following sub-sections discuss the various power supply options that are available to users to support their design.

2.1.1.1 Resistor Capacitor (RC) Power Supply

Figure 1 shows a capacitor power supply that provides a single output voltage of 3.3 V directly from the mains of 120-V/230-V_{RMS} AC at 50or 60 Hz.

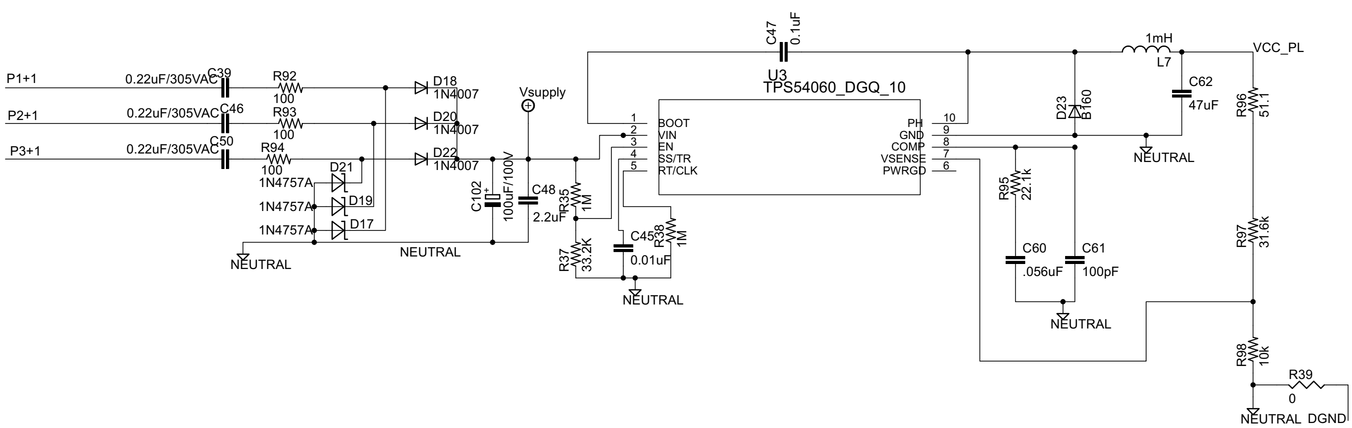


Figure 1. Simple Capacitive Power Supply for the MSP430 Energy Meter

Appropriate values of resistors (R92, R93, and R94) and capacitors (C39, C46, and C50) are chosen based on the required output current drive of the power supply. Voltage from mains is directly fed to an RC-based circuit followed by a rectification circuitry to provide a DC voltage for the operation of the MSP430. This DC voltage is regulated to 3.3 V for full speed operation of the MSP430. The design equations for the power supply are given in SLVA491. The above configuration allows all three phases to contribute to the current drive, which is approximately three times the drive available from only one phase. If even higher output drive is required, the same circuitry can be used followed by an NPN output buffer. Another option would be to replace the above circuitry with a transformer- or switching-based power supply.

2.1.1.2 Switching-Based Power Supply

Figure 2 shows a switching-based power supply that provides a single output voltage of 3.3 V directly from the AC mains 100 to 230 V_{RMS}. In the configuration shown, the meter is powered as long as AC voltage is on Phase C, corresponding to pad “LINE 3" on the hardware and P3+1 on the schematic. The internal circuitry of a switching power supply is omitted from this application note. For the drive of the power supply, refer to the documentation of the power supply module.

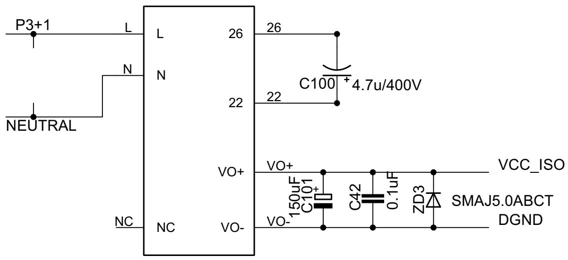


Figure 2. Switching-Based Power Supply for the MSP430 Energy Meter

2.1.2 Analog Inputs

The MSP430 analog front end, which consists of the ΣΔ ADC, is differential and requires that the input voltages at the pins do not exceed ±930 mV (gain = 1). In order to meet this specification, the current and voltage inputs need to be divided down. In addition, the ΣΔ24 allows a maximum negative voltage of –1 V. Therefore, AC signals from mains can be directly interfaced without the need for level shifters. This sub-section describes the analog front end used for voltage and current channels.

2.1.2.1 Voltage Inputs

The voltage from the mains is usually 230 V or 120 V and needs to be brought down to a range of 930 mV. The analog front end for voltage consists of spike protection varistors followed by a simple voltage divider and a RC low-pass filter that acts like an anti-alias filter.

Figure 3 shows the analog front end for the voltage inputs for a mains voltage of 230 V. The voltage is brought down to approximately 549 mV_{RMS}, which is a 779-mV peak, and fed to the positive input. This voltage is within the MSP430ΣΔ analog limits by a safety margin greater than 15%. This margin allows accurate measurements even during voltage spike conditions.

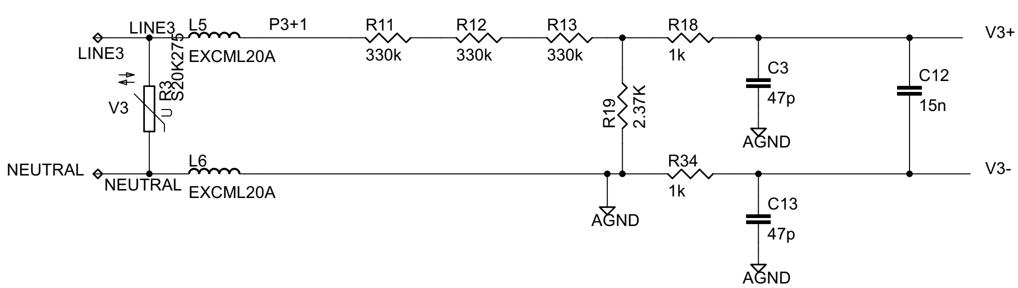


Figure 3. Analog Front End for Voltage Inputs

2.1.2.2 Current Inputs

The analog front end for current inputs is slightly different from the analog front end for the voltage inputs. Figure 4 shows the analog front end used for a current channel.

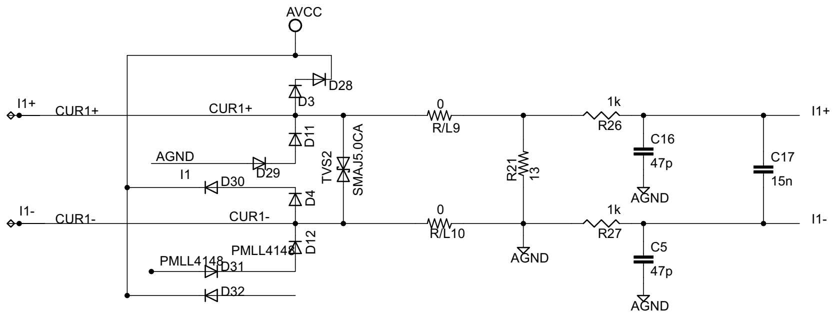


Figure 4. Analog Front End for Current Inputs

In the figure, Resistor R21 is the burden resistor that would be selected based on the current range used and the turns ratio specification of the current transformer (CT; CTs with a turns ratio of 2000:1 are used for this design). The value of the burden resistor for this design is around 13 Ω. The anti-aliasing circuitry, consisting of resistors and capacitors, follow the burden resistor. Based on this EVM's maximum current of 100 A, CT turns ratio of 2000:1, and burden resistor of 13 Ω, the input signal to the converter is a fully differential input with a voltage swing of ±919 mV maximum when the maximum current rating of the meter (100 A) is applied. In addition, footprints for suppressant inductors are also available. These inductor footprints are shown below as R/L9 and R/L10 and by default are populated with 0-Ω resistors.

2.1.3 Interfacing to the CC3100BOOST

To add Wi-Fi capabilities to the EVM430-F6779 EVM, the CC3100BOOST BoosterPack is connected to the EVM. Since the CC3100BOOST uses the BoosterPack connectors instead of the EM connectors, the CC3100_EM_BP_ADAPTER adapter must be used to connect the pins on the RF connector of the EVM430-F6779 to the pins on the CC3100BOOST. Figure 5 and Figure 6 show the EM and BoosterPack sides of the CC3100_EM_BP_ADAPTER adapter board.

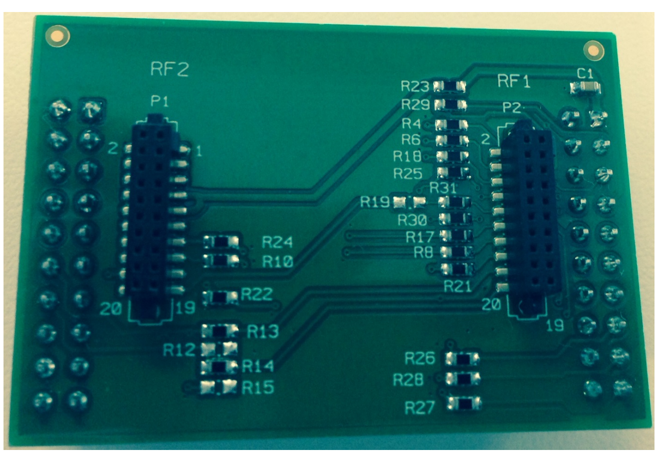


Figure 5. CC3100_EM_BP_ADAPTER EM Female Connection

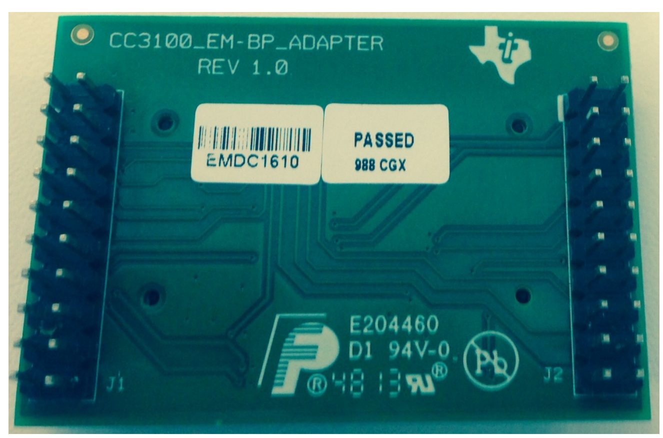


Figure 6. CC3100_EM_BP_ADAPTER BoosterPack Male Connection

To connect the CC3100BOOST to the EVM, the EM female connector is placed in the EVM430-F6779's RF connector and the BoosterPack male connector is inserted into the CC3100BOOST's BoosterPack female connector. To properly orient the CC3100BOOST to the adapter, J1 on the adapter should be connected to P1/P3 of the CC3100BOOST and J2 of the adapter should be connected to P4/P2 of the CC3100BOOST. Since the BoosterPack connections are not keyed, take care to make sure that each pin of the CC3100BOOST is connected to the proper pin of the adapter and that the CC3100BOOST does not have its orientation reversed with respect to the adapter. To connect the EVM430-F6779 to the adapter, RF1 of the adapter is connected to RF2 of the EVM430-F6779 and RF2 of the adapter is connected to RF1 of the EVM430-F6779.

Figure 7 show the connections made from the EVM430-F6779 to the male EM connectors, and Figure 8 shows the connections made from the adapter onto the female EM connectors. Similarly, Figure 9 shows the connections made from the adapter to the male BoosterPack headers and Figure 10 shows the connections made from the CC3100BOOST to the female BoosterPack headers. The resulting mapping between the EVM430-F6779 and the CC3100BOOST is shown in Table 1. Each row in Table 1 represents a mapping between a pin of the EM header to the corresponding pin on the CC3100BOOST, where the highlighted rows represent the connections that are actually used for communication between the MSP430F6779 and the CC3100. Pins that do not have a mapping in Table 1 are denoted by "—".

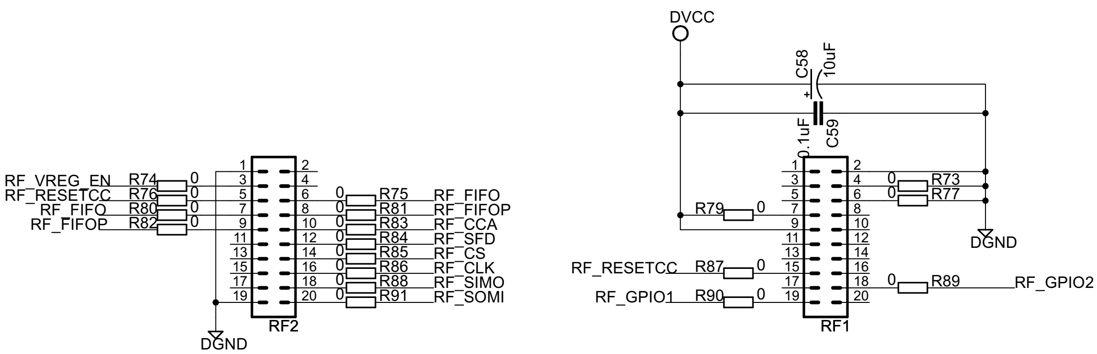


Figure 7. Connections on EVM430-F6779 EM Male Connectors

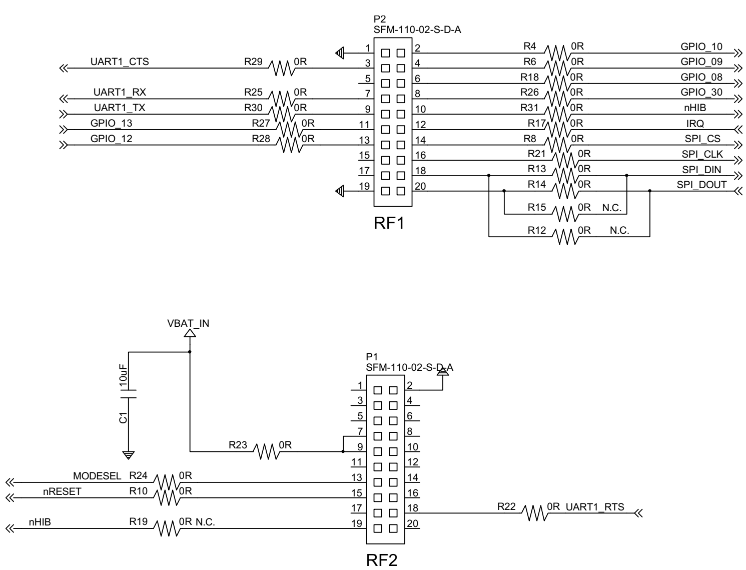


Figure 8. Connections on the CC3100_EM_BP_ADAPTER EM Female Connectors

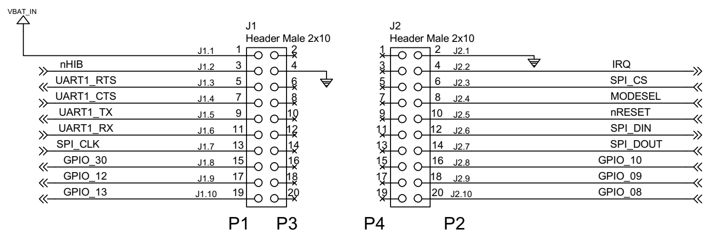


Figure 9. Connections on the CC3100_EM_BP_ADAPTER BoosterPack Male Connectors

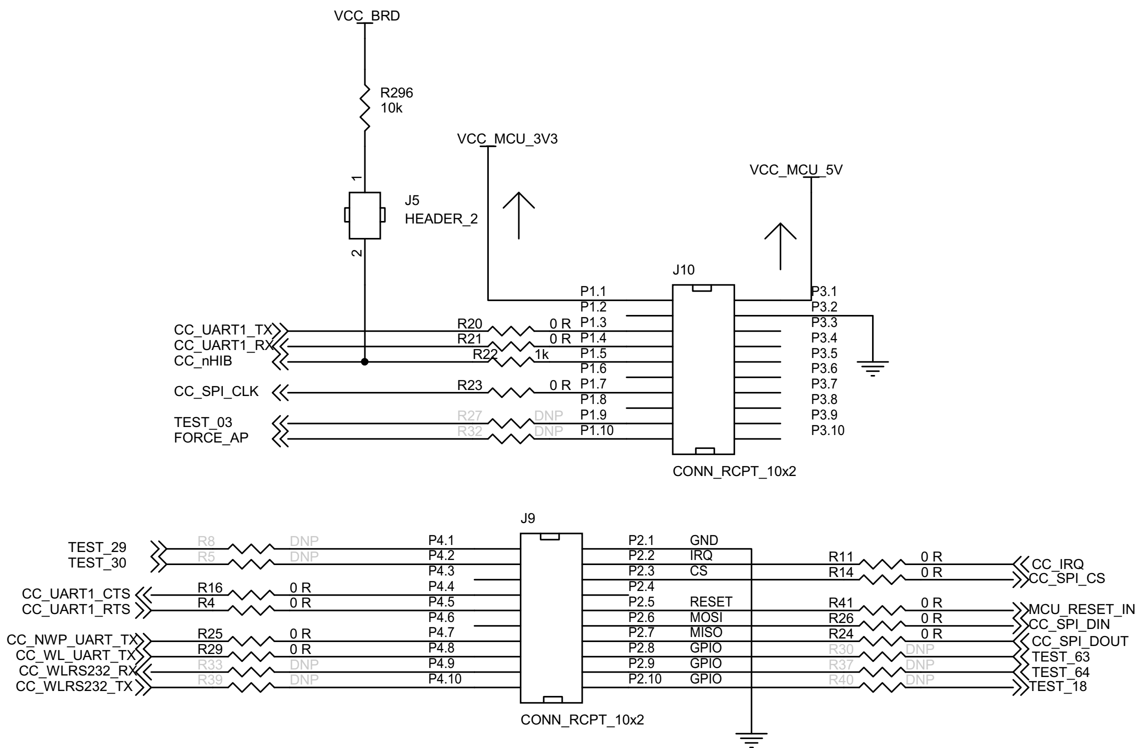


Figure 10. Connections on the CC3100BOOST BoosterPack Female Connectors

Table 1. Mapping Between the EVM430-F6779 and CC3100BOOST

EVM430-F6779 CONNECTION	EVM430-F6779 CONNECTION NAME	CC3100BOOST CONNECTION	ADAPTER CONNECTION NAME
RF2, pin 1	DGND	P3, pin 2 and P2, pin 1	GND
RF2, pin 3	RF_VREG_EN	P1, pin 4	CC_UART1_TX
RF2, pin 5	RF_RESETCC	—	—
RF2, pin 7	RF_FIFO	P1, pin 6	Not Connected To CC3100
RF2, pin 9	RF_FIFOP	P1, pin 5	CC_nHIB
RF2, pin 11	Not Connected To F6779	P1, pin 10	Not Connected To CC3100
RF2, pin 13	Not Connected To F6779	P1, pin 9	Not Connected To CC3100
RF2, pin 15	Not Connected To F6779	—	—
RF2, pin 17	Not Connected To F6779	—	—
RF2, pin 19	DGND	P3, pin 2 and P2, pin 1	GND
RF2, pin 2	Not Connected To F6779	P2, pin 8	Not Connected To CC3100
RF2, pin 4	Not Connected To F6779	P2, pin 9	Not Connected To CC3100
RF2, pin 6	RF_FIFO	P2, pin 10	Not Connected To CC3100
RF2, pin 8	RF_FIFOP	P1, pin 8	Not Connected To CC3100

Table 1. Mapping Between the EVM430-F6779 and CC3100BOOST (continued)

EVM430-F6779 CONNECTION	EVM430-F6779 CONNECTION NAME	CC3100BOOST CONNECTION	ADAPTER CONNECTION NAME
RF2, pin 10	RF_CCA	P3, pin 2	Not Connected To CC3100
RF2, pin 12	RF_SFD	P2, pin 2	CC_IRQ
RF2, pin 14	RF_CS	P2, pin 3	CC_SPI_CS
RF2, pin 16	RF_CLK	P1, pin 7	CC_SPI_CLK
RF2, pin 18	RF_SIMO	P2, pin 6	CC_SPI_DIN
RF2, pin 20	RF_SOMI	P2, pin 7	CC_SPI_DOUT
RF1, pin 1	Not Connected To F6779	—	—
RF1, pin 3	Not Connected To F6779	—	—
RF1, pin 5	Not Connected To F6779	—	—
RF1, pin 7	DVCC	P1, pin 1	CC_MCU_3V3
RF1, pin 9	DVCC	P1, pin 1	CC_MCU_3V3
RF1, pin 11	Not Connected To F6779	—	—
RF1, pin 13	Not Connected To F6779	P2, pin 4	Not Connected To CC3100
RF1, pin 15	RF_RESETCC	P2, pin 5	MCU_RESET_IN
RF1, pin 17	Not Connected	—	—
RF1, pin 19	RF_GPIO1	P1, pin 2	Not Connected To CC3100
RF1, pin 2	DGND	P3, pin 2 and P2, pin 1	GND
RF1, pin 4	DGND	—	—
RF1, pin 6	DGND	—	—
RF1, pin 8	Not Connected To F6779	—	—
RF1, pin 10	Not Connected To F6779	—	—
RF1, pin 12	Not Connected To F6779	—	—
RF1, pin 14	Not Connected To F6779	—	—
RF1, pin 16	Not Connected To F6779	—	—
RF1, pin 18	RF_GPIO2	P1, pin 3	CC_UART1_TX
RF1, pin 20	Not Connected To F6779	—	—
—	—	P3, pin 1	VCC_MCU_5V
—	—	P3, pin 3	Not Connected To CC3100
—	—	P3, pin 4	Not Connected To CC3100
—	—	P3, pin 5	Not Connected To CC3100
—	—	P3, pin 6	Not Connected To CC3100
—	—	P3, pin 7	Not Connected To CC3100
—	—	P3, pin 8	Not Connected To CC3100
—	—	P3, pin 9	Not Connected To CC3100
—	—	P3, pin 10	Not Connected To CC3100
—	—	P4, pin 1	Not Connected To CC3100
—	—	P4, pin 2	Not Connected To CC3100
—	—	P4, pin 3	Not Connected To CC3100
—	—	P4, pin 4	CC_UART1_CTS
—	—	P4, pin 5	CC_UART1_RTS
—	—	P4, pin 6	Not Connected To CC3100
—	—	P4, pin 7	CC_NWP_UART_TX
—	—	P4, pin 8	CC_WL_UART_TX
—	—	P4, pin 9	Not Connected To CC3100
—	—	P4, pin 10	Not Connected To CC3100

2.2 Software Implementation

The software for the implementation of 3-phase metrology is discussed in this section. The first subsection discusses the setup of various peripherals of the MSP430. In the next sections, the entire metrology software is described as two major processes: the foreground process and the background process. Subsequently, the Wi-Fi communication software is described.

2.2.1 Peripherals Setup

The major peripherals are the 24-bit sigma delta (ΣΔ24_B) ADC, clock system, timer, LCD, watchdog timer (WDT), and so on.

2.2.1.1 ΣΔ24 Setup

The F677x family has up to seven independent sigma delta data converters. For a 3-phase system, at least six ΣΔs are necessary to independently measure three voltages and currents. The code accompanying this application note addresses the metrology for a 3-phase system with limited discussion to anti-tampering; however, the code supports the measurement of the neutral current. The clock to the ΣΔ24 (the modulation frequency, or f_M) is derived from system clock configured to run at 16 MHz. The sampling frequency is defined as $f_s = \frac{f_M}{OSR}$, the OSR is chosen to be 256 and the modulation frequency f_M, is chosen as 1.048576 MHz, resulting in a sampling frequency of 4.096 ksps. The ΣΔ24s are configured to generate regular interrupts every sampling instant.

The following are the ΣΔ channels associations:

- A0.0+ and A0.0– Voltage V1
- A1.0+ and A1.0– Voltage V2
- A2.0+ and A2.0– Voltage V3
- A4.0+ and A4.0– Current I1
- A5.0+ and A5.0– Current I2
- A6.0+ and A6.0– Current I3

Optional neutral channel can be processed via channel A3.0+ and A3.0–.

2.2.1.2 Real-Time Clock (RTC_C)

The RTC_C is a real-time clock module that is configured to give precise one-second interrupts. Based off these one-second interrupts, the time and date are updated in the software as necessary.

2.2.1.3 LCD Controller (LCD_C)

The LCD controller on the MSP430F677X can support up to 8-mux displays and 320 segments, and is also equipped with an internal charge pump that can be used for good contrast. In the current design, the LCD controller is configured to work in 4-mux mode using 160 segments with a refresh rate set to ACLK/64, which is 512 Hz. When segments are set to blink, the blinking frequency is set to 1 Hz. For information, about the parameters displayed on the LCD please refer to Section 5.1.

2.2.2 Foreground Process

The foreground process includes the initial setup of the MSP430 hardware and software immediately after a device RESET. Figure 11 shows the flowchart for this process.

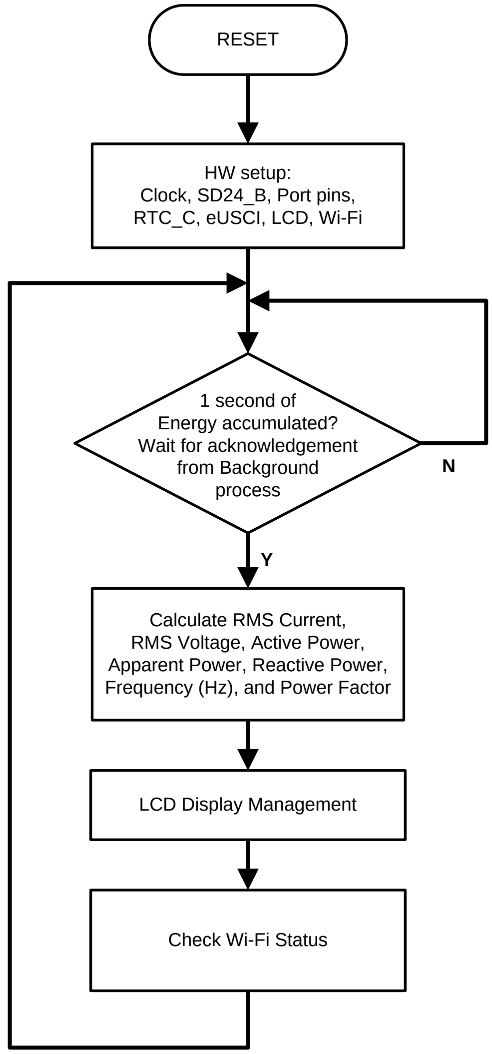


Figure 11. Foreground Process

The initialization routines involve the setup of the ADC, clock system, general purpose I/O (port) pins, RTC module for clock functionality, LCD, and the USCI_A0 for UART functionality. In addition, the EVM is configured for communication to the CC3100 to enable Wi-Fi.

After the hardware is setup, the foreground process waits for the background process to notify it to calculate new metering parameters. This notification is done through a status flag every time a frame of data is available for processing. The data frame consists of processed current, voltage, active, and reactive quantities accumulated for one second. This data frame is equivalent to the accumulation of 50 or 60 cycles of data synchronized to the incoming voltage signal. In addition, a sample counter keeps tracks of how many samples have been accumulated over this frame period. This count can vary as the software synchronizes with the incoming mains frequency.

The data samples set consist of processed current, voltage, active, and reactive energy. Processed voltages are accumulated in 48-bit registers. In contrast, processed currents, active energies, and reactive energies are accumulated in separate 64-bit registers to further process and obtain the RMS and mean values. Using the foreground's calculated values of active and reactive power, the apparent power is calculated. The frequency (in Hertz) and power factor are also calculated using parameters calculated by the background process using the formulas in Section 2.2.2.1.

2.2.2.1 Formulae

This section briefly describes the formulas used for the voltage, current, and energy calculations.

As described in the previous sections, voltage and current samples are obtained from the ΣΔ converters at a sampling rate of 4096 Hz. All of the samples that are taken in one second are kept and used to obtain the RMS values for voltage and current for each phase. The RMS values are obtained by the following formulas:

$$V_{RMS,ph} = K_{v,ph} \times \sqrt{\frac{\sum_{n=1}^{Sample\ count} v_{ph}(n) \times v_{ph}(n)}{Sample\ count}} \qquad I_{RMS,ph} = K_{i,ph} \times \sqrt{\frac{\sum_{n=1}^{Sample\ count} i_{ph}(n) \times i_{ph}(n)}{Sample\ count}}$$

where

- ph = Phase whose parameters are being calculated (for example, Phase A(=1), B(=2), or C(=3)),
- $v_{ph}(n)$ = Voltage sample at a sample instant ‘n’
- $i_{ph}(n)$ = Each current sample at a sample instant ‘n’
- Sample count = Number of samples in one second
- $K_{v,ph}$ = Scaling factor for voltage
- $K_{i,ph}$ = Scaling factor for each current (1)

Power and energy are calculated for a frame’s worth of active and reactive energy samples. These samples are phase corrected and passed on to the foreground process, which uses the number of samples (or sample count) to calculate phase active and reactive powers through the following formulas:

$$P_{ACT,ph} = K_{ACT,ph} \frac{\sum_{n=1}^{Sample\ count} v(n) \times i_{ph}(n)}{Sample\ count} \qquad P_{REACT,ph} = K_{REACT,ph} \frac{\sum_{n=1}^{Sample\ count} v_{90}(n) \times i_{ph}(n)}{Sample\ count} \qquad P_{APP,ph} = \sqrt{P_{ACT,ph}^{2} + P_{REACT,ph}^{2}}$$

where

- $v_{90}(n)$ = Voltage sample at a sample instant ‘n’ shifted by 90 degrees
- $K_{ACT,ph}$= Scaling factor for active power
- $K_{REACT,ph}$= Scaling factor for reactive power (2)

In addition to calculating the per-phase active and reactive powers, the cumulative sum of these parameters are also calculated by the below equations:

$$P_{ACT,Cumulative} = \sum_{ph=1}^{3} P_{ACT,ph} \qquad P_{REACT,Cumulative} = \sum_{ph=1}^{3} P_{REACT,ph} \tag{3}$$

NOTE: For reactive energy, the 90° phase shift approach is used for two reasons:

1. It allows accurate measurement of the reactive power for very small currents.
2. It conforms to the measurement method specified by IEC and ANSI standards.

The calculated mains frequency is used to calculate the 90 degree-shifted voltage sample. Because the frequency of the mains varies, the mains frequency is first measured accurately to phase shift the voltage samples accordingly (see Section 2.2.3.3). The application's phase shift implementation consists of an integer part and a fractional part. The integer part is realized by providing an N sample delay. The fractional part is realized by a fractional delay filter (see Section 2.2.3.2).

Using the calculated powers, energies are calculated by the following equations:

$$E_{ACT,ph} = P_{ACT,ph} \times \text{Sample count}$$

$$E_{REACT,ph} = P_{REACT,ph} \times \text{Sample count} \tag{4}$$

From there, the energies are also accumulated to calculate the cumulative energies, by the following equations:

$$E_{ACT,Cumulative} = \sum_{ph=1}^{3} E_{ACT,ph} \quad E_{REACT,Cumulative} = \sum_{ph-1}^{3} E_{REACT,ph} \tag{5}$$

The background process calculates the frequency in terms of samples per mains cycle. The foreground process then converts this frequency to Hertz with the following formula:

$$\text{Frequency (Hz)} = \frac{\text{Sampling Rate (samples per second)}}{\text{Frequency (samples per cycle)}} \tag{6}$$

After the active power and apparent power have been calculated, the absolute value of the power factor is calculated. In the meter's internal representation of power factor, a positive power factor corresponds to a capacitive load and a negative power factor corresponds to an inductive load. The sign of the internal representation of power factor is determined by whether the current leads or lags voltage, which is determined in the background process. Therefore, the internal representation of power factor is calculated by the following formula:

$$\text{Internal Representation of Power Factor} = \begin{cases} \dfrac{P_{Act}}{P_{Apparent}}, \text{if capacitive load} \\ -\dfrac{P_{Act}}{P_{Apparent}}, \text{if inducitive load} \end{cases} \tag{7}$$

2.2.3 Background Process

The background process uses the ΣΔ interrupt as a trigger to collect voltage and current samples (seven values in total). These samples are used to calculate intermediate results. Since 16-bit voltage samples are used, the voltage samples are further processed and accumulated in dedicated 48-bit registers. In contrast, since 24-bit current samples are used, the current samples are processed and accumulated in dedicated 64-bit registers. Per-phase active power and reactive power are also accumulated in 64-bit registers.

The background function deals mainly with timing critical events in software. Once sufficient samples (approximately one second's worth) have been accumulated, then the foreground function is triggered to calculate the final values of V_{RMS}, I_{RMS}, active, reactive and apparent powers, active, reactive and apparent energy, frequency, and power factor. The background process is also wholly responsible for the calculation of energy proportional pulses, frequency (in samples per cycle), and determining current lead and lag conditions. Figure 12 shows the flow diagram of the background process.

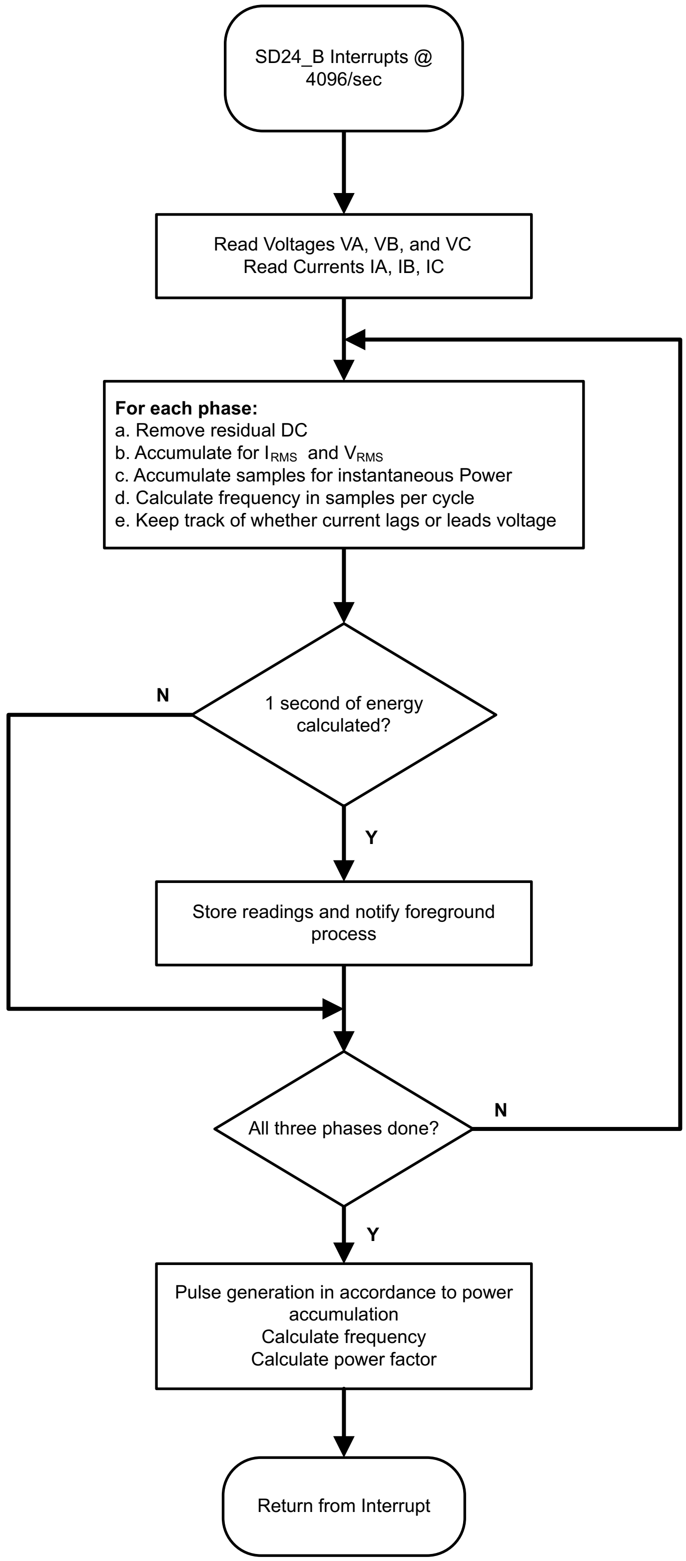


Figure 12. Background Process

2.2.3.1 Voltage and Current Signals

The ΣΔ converter has fully differential input architecture and each ΣΔ pin can accept negative inputs; therefore, no level-shifting is necessary for the incoming AC voltage (unlike single-ended or pseudo-differential converters).

The output of each ΣΔ is a signed integer and any stray DC or offset value on these ΣΔs are removed using a DC tracking filter. A separate DC estimate for all voltages and currents are obtained using the filter and voltage and current samples respectively. This estimate is then subtracted from each voltage and current sample.

The resulting instantaneous voltage and current samples are used to generate the following intermediate results:

- Accumulated squared values of voltages and currents, which is used for V_{RMS} and I_{RMS} calculations, respectively.
- Accumulated energy samples to calculate active energies.
- Accumulated energy samples using current and 90° phase shifted voltage to calculate reactive energies.

These accumulated values are processed by the foreground process.

2.2.3.2 Phase Compensation

When a CT is used as a sensor, it introduces additional phase shift on the current signals. Also, the voltage and current input circuit’s passive components may introduce another phase shift. The relative phase shift between voltage and current samples need to be compensated to ensure accurate measurements. The ΣΔ converters have programmable delay registers (ΣΔ24PREx) that can be applied to a particular channel. This built-in feature (PRELOAD) is used to provide the phase compensation required. Figure 13 shows the usage of PRELOAD to delay sampling on a particular channel.

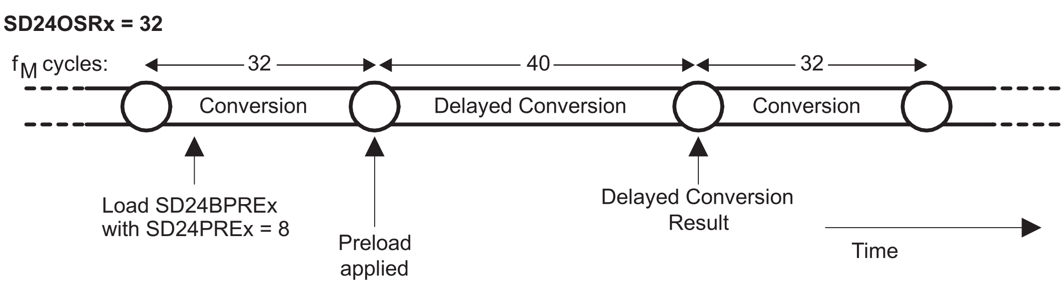


Figure 13. Phase Compensation using PRELOAD Register

The fractional delay resolution is a function of input frequency (f_{IN}), OSR and the sampling frequency (f_S).

$$\text{Delay resolution}_{Deg} = \frac{360^o \times f_{IN}}{OSR \times f_S} = \frac{360^o \times f_{IN}}{f_M} \quad (8)$$

In the current application, for input frequency of 60 Hz, OSR of 256, and sampling frequency of 4096, the resolution for every bit in the preload register is about 0.02° with a maximum of 5.25° (maximum of 255 steps). Because the sampling of the seven channels are group triggered, an method often used is to apply 128 steps of delay to all channels and then increase or decrease from this base value. This adjustment increases or decreases the delay timing to compensate for phase lead or lag and puts the practical limit in the current design to ± 2.62 degrees. When using CTs that provide a larger phase shift than this maximum, sample delays along with fractional delay must be provided. This phase compensation can also be modified on the fly to accommodate temperature drifts in CTs, but ensure that conversions on the ΣΔ have been stopped.

2.2.3.3 Frequency Measurement and Cycle Tracking

The instantaneous voltage of each phase is accumulated in 48-bit registers. In contrast, the instantaneous current, active power, and reactive power are accumulated in 64-bit registers. A cycle tracking counter and sample counter keep track of the number of samples accumulated. When approximately one second's worth of samples have been accumulated, the background process stores these accumulation registers and notifies the foreground process to produce the average results such as RMS and power values. Cycle boundaries are used to trigger the foreground averaging process since it produces very stable results.

For frequency measurements, a straight line interpolation is used between the zero crossing voltage samples. Figure 14 depicts the samples near a zero cross and the process of linear interpolation.

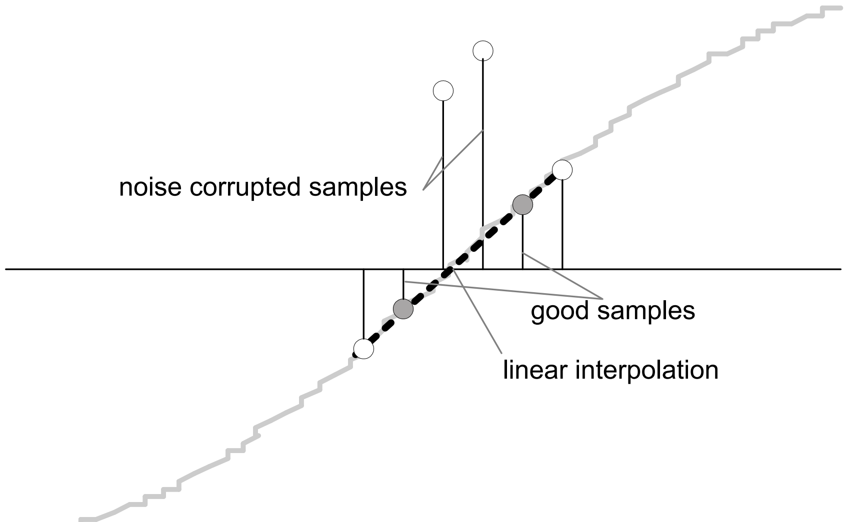


Figure 14. Frequency Measurement

Since noise spikes can also cause errors, the application uses a rate of change check to filter out the possible erroneous signals and make sure that the two points are interpolated from are genuine zero crossing points. For example, with two negative samples, a noise spike can make one of them positive and thus make the negative and positive pair looks as if there is a zero crossing.

The resultant cycle-to-cycle timing goes through a weak low pass filter to further smooth out cycle-to-cycle variations. This filtering results in a stable and accurate frequency measurement tolerant of noise.

2.2.3.4 LED Pulse Generation (per_sample_energy_pulse_processing)

In electricity meters, the energy consumed is normally measured in fraction of kilowatt-hour (KWh) pulses. This information can be used to accurately calibrate any meter for accuracy measurement. Typically, the measuring element (MSP430) is responsible to generate pulses proportional to the energy consumed. To serve both these tasks efficiently, pulse generation has to be accurate with relatively little jitter. Although, time jitters are not an indication of bad accuracy, it would give a negative indication on the overall accuracy of the meter. Therefore, the jitter has to be averaged out.

This application uses average power to generate these energy pulses. The average power (calculated by the foreground process) is accumulated every ΣΔ interrupt, thereby spreading the accumulated energy from the previous one-second time frame evenly for each interrupt in the current one-second time frame. This time frame is equivalent to converting power to energy. Once the accumulated energy crosses a threshold, a pulse is generated. The amount of energy above this threshold is kept and new energy value is added on top of it in the next interrupt cycle. Because the average power tends to be a stable value, this way of generating energy pulses is very steady and free of jitter.

The threshold determines the energy “tick” specified by meter manufacturers and is a constant. The threshold is usually defined in pulses per kWh or just in KWh. One pulse needs to be generated for every energy tick. For example, in this application, the number of pulses generated per KWh is set to 6400 for active and reactive energies. The energy tick in this case is 1 KWh per 6400. Energy pulses are generated and available on a header and also through LEDs on the board. General purpose I/O (port) pins are used to produce the pulses.

In the EVM, the LEDs that are labeled LED1, LED2, LED3, and LED_ACT correspond to the active energy consumption for phase A, phase B, phase C, and the cumulative 3-phase sum, respectively. LED_REACT corresponds to the cumulative 3-phase reactive energy sum. The number of pulses per kWh and each pulse-width can be configured in software. Figure 15 shows the flow diagram for pulse generation.

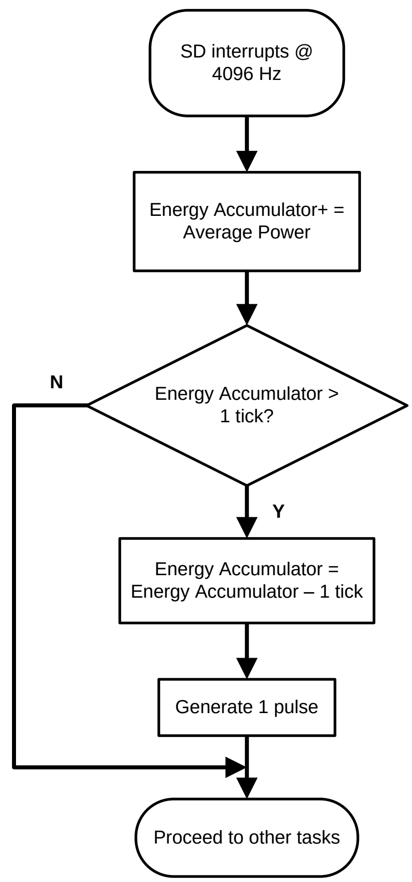


Figure 15. Pulse Generation for Energy Indication

The average power is in units of 0.01 W and 1 KWh threshold is defined as

1 KWh threshold = 1/0.01 × 1 KW × (number of interrupts per second) × (number of seconds in one hour)

= 100000 × 4096 × 3600 = 0x15752A00000

2.2.4 Wi-Fi Software

2.2.4.1 Software Overview

To add Wi-Fi capabilities to the EVM430-F6779, a CC3100 host driver is integrated into the EVM430-F6779 software. This extra software is located in the *CC3100* folder of the downloadable software zip file associated with this design. These files can also be viewed from the *CC3100 Wi-Fi* folder in the e-meter IAR project. This host driver has a portion that is platform-independent and platform-dependent. The platform-independent part is primarily located in the *SimpleLink* folder within the CC3100 folder. Since this portion is platform-independent, it can be directly copied to other devices and other applications without having to make any file changes. The platform-dependent portion is located in the *EVM430-F6779 Driver* folder. The files in this folder are specifically tailored for the EVM430-F6779; however, the chip-specific details have been abstracted to make it easy to port to other MSP430 devices. Table 2 mentions the different files in this folder and an associated description for each file.

Table 2. EVM430-F6779 Driver Files

FILENAME	DESCRIPTION
board.c	This file defines the functions needed to enable/disable the CC3100 and receiving interrupts from it. In addition, this file maps the host driver's interrupt handler to the events associated to the MSP430 port pin that the CC3100 interrupt request pin (IRQ) is connected to.
board.h	To make the EVM430-F6779 Driver files more portable to other devices, an additional level of abstraction was added so that any necessary operations on the MSP430 pins associated with communication to the CC3100 (nHIB, IRQ, MOSI, MISO, Chip Select, and SPI CLK) uses a generic name for this operation. As an example for disabling the CC3100, instead of performing an operation such as “P4OUT &=~BIT1”, this is done by “NHIB_OUT&= ~NHIB_BIT_NAME”, where the mapping of NHIB_OUT to P4OUT, NHIB_BIT_NAME to BIT1, and other mappings are declared in board.h. From this file, the following mappings can be easily configured: SPI channel name (for example, UCA0, UCB1, etc.), chip select port pin, SPI clock port pin, SPI MOSI pin, SPI MISO pin, nHIB port pin, IRQ port pin, and the different LCD symbols for Wi-Fi status indication (as referred to in Section 5.1). This file also declares the function prototypes for the functions in board.c.
CC3100config.c	This file contains the code necessary for running the desired Wi-Fi application. For this particular case, the code is configured for creating an http web server; however, other applications can be selected instead by replacing the contents of this file to correspond to the desired application. The CC3100 SDK that is available online has many other application examples that may be ported to the EVM430-F6779, similar to the http web server example used for this design.
CC3100config.h	Declares the function prototypes for the functions in spi.h.
spi.c	This file defines the SPI driver functions needed by the platform-independent portion of the software in order to properly communicate with the CC3100. In this code, the SPI is configured for 3-pin, 8-bit SPI with a 4-MHz SPI clock and the F6779 configured as the SPI master.
spi.h	Declares the function prototypes for the functions in spi.h.
user.h	This file can be modified to change what features of the CC3100 host driver should be enabled.

To properly enable adding Wi-Fi capabilities to this EVM, the *WIFI_SUPPORT* option must be enabled in the *emeter-3ph-neutral-6779(A).h* file. Because the Wi-Fi module uses the the same RF connector that is used for ZigBee communication, the ZigBee code must be disabled when using Wi-Fi. This is done by disabling *IHD430_SUPPORT* in this same file.

2.2.4.2 Start-Up Sequence

After the EVM430-F6779 is powered and its peripherals are configured, the CC3100 is configured for operation by the EVM. When configuring the CC3100, first the CC3100 is configured to its default state. As a result of this, all of the CC3100's persistent settings previously stored in non-volatile memory will be replaced with default settings. By putting the device in its default state, it is put in a known state to be used as a base state for later configuration actions. Afterwards, the device is configured for WLAN AP mode without security. When configuring the network, the resulting network's SSID name is set to a user-defined value. After resetting the device for the new configurations to take place and waiting for the occurrence of the necessary *SL_NETAPP_IPV4_ACQUIRED*, a network with the user-defined SSID name is generated. At this stage, the CC3100 waits for a client to connect to it. After a client connects to the network, the client can view the metrology parameters through a web browser.

2.2.4.3 Communication Between CC3100 and EVM430-F6779

Once a client has been connected, the real-time metrology parameter values can be viewed from a web browser by visiting certain metrology webpages. These metrology webpages are located in the CC3100's serial flash system. When the client enters the website for one of these webpages, the CC3100 would know to send the webpage that is stored in its memory to the client. To support webpages that have their content dynamically updated, the CC3100 allows user-defined tokens to be present in the html file. Once the CC3100 has a request to send a webpage that has a user-defined token in it that is not in its predefined list of tokens, the CC3100 would invoke a callback function in the EVM software. When this callback function is invoked, the EVM would send the token value corresponding to the requested token to the CC3100. After providing the proper token value to the CC3100, the CC3100 would replace the token name in the html page with the value send to it by the F6779. This feature of the CC3100 is used for updating the metrology webpages with the metrology parameter values.

The length of a token value must be less than 64 bytes. As a result, five tokens are used in this application: one for each of the data for the three phases' metrology parameters, one with the data for the neutral channel's metrology parameters, and one for the date/time/energy readings. Additionally, six metrology webpages can be visited to view the metrology parameters and five more internal webpages for each of the five tokens. Table 3 shows a description of each webpage. The internal webpages have no content besides the raw token value of its corresponding token. These internal webpages are used solely not for displaying the metrology parameters but for querying the values of these parameters for updating the six metrology webpages with these values.

Table 3. Webpage Descriptions

WEBPAGE NAME	DESCRIPTION
main.html	Defines the navigation bar that has link to each metrology webpage and other default settings used in the display of each page.
metrology.html	Metrology webpage that has the metrology parameter values for Phase A, Phase B, Phase C, Neutral, and time/date/energy. This page gets these parameters by querying PhaseA.html, PhaseB.html, PhaseC.html, PhaseN.html, and Time.html. Since an internal webpage is queried once a second, only one webpage is queried at a time, and all five internal webpages are queried, each parameter is updated only once every five seconds. This page can be accessed by clicking the *All EVM Readings:* tab in the navigation bar.
metrologyA.html	Metrology webpage that has the metrology values parameters for Phase A. This page gets these parameters by querying PhaseA.html. Since this internal webpage is queried every second, each parameter on this page is updated once a second. This page can be accessed by clicking the *Phase A* tab in the navigation bar.
metrologyB.html	Metrology webpage that has the metrology values parameters for Phase B. This page gets these parameters by querying PhaseB.html. Since this internal webpage is queried every second, each parameter on this page is updated once a second. This page can be accessed by clicking the *Phase B* tab in the navigation bar.
metrologyC.html	Metrology webpage that has the metrology values parameters for Phase C. This page gets these parameters by querying PhaseC.html. Since this internal webpage is queried every second, each parameter on this page is updated once a second. This page can be accessed by clicking the *Phase C* tab in the navigation bar.
metrologyEDT.html	Metrology webpage that has the date, time, and the active energy for each phase. This page gets these parameters by querying Time.html. Since this internal webpage is queried every second, each parameter on this page is updated once a second. This page can be accessed by clicking the *Date/Time/Energy* tab in the navigation bar.
metrologyN.html	Metrology webpage that has the metrology values parameters for neutral. This page gets these parameters by querying PhaseN.html. Since this internal webpage is queried every second, each parameter on this page is updated once a second. This page can be accessed by clicking the *Neutral* tab in the navigation bar.
PhaseA.html	Internal webpage that is queried for the metrology parameters associated with Phase A. This webpage contains no other content besides the token needed for receiving parameters for Phase A. This page can be visited by typing the proper address in the browser. By doing this, the unparsed token value for Phase A is displayed. Note that this value does not get updated unless the webpage is manually refreshed.
PhaseB.html	Internal webpage that is queried for the metrology parameters associated with Phase B. This webpage contains no other content besides the token needed for receiving parameters for Phase B. This page can be visited by typing the proper address in the browser. By doing this, the unparsed token value for Phase B is displayed. Note that this value does not get updated unless the webpage is manually refreshed.
PhaseC.html	Internal webpage that is queried for the metrology parameters associated with Phase C. This webpage contains no other content besides the token needed for receiving parameters for Phase C. This page can be visited by typing the proper address in the browser. By doing this, the unparsed token value for Phase C is displayed. Note that this value does not get updated unless the webpage is manually refreshed.
PhaseN.html	Internal webpage that is queried for the metrology parameters associated with the neutral channel. This webpage contains no other content besides the token needed for receiving parameters for neutral. This page can be visited by typing the proper address in the browser. By doing this, the unparsed token value for the neutral channel is displayed. Note that this value does not get updated unless the webpage is manually refreshed.
Time.html	Internal webpage that is queried for the metrology parameters associated with each phase’s active energy and time/date. This webpage contains no other content besides the token needed for receiving these parameters. This page can be visited by typing the proper address in the browser. By doing this, the unparsed token value for these parameters is displayed. Note that this value does not get updated unless the webpage is manually refreshed.

Each of the five tokens has a metrology webpage that can be visited to view the real-time metrology data that corresponds to a token. In addition to these five metrology webpages, a sixth metrology webpage has the metrology data for all five tokens present. When a metrology page is requested, the entire page is loaded with the displayed metrology parameters not being filled in yet. Then, using JavaScript, the metrology webpage does a new http request for an internal webpage every second. For the metrology webpages that only correspond to one token, the requested internal webpage always corresponds to one token associated with that metrology webpage. For the one metrology webpage that has all five tokens, the requested internal webpage alternates between the five internal webpages that correspond to each token (that is, the first request would request Phase A's internal webpage, the next request would request Phase B's internal webpage, and so on).

If the request for the internal webpage is successful, the result should only be the token values since the internal webpages have no other content. The received data is then checked to see if the data is valid. If the data is valid, it is parsed to find the values of each metrology parameter so that it could be displayed on the webpage. If invalid data is received consecutively for a particular token value, then an alert is send to the browser stating that invalid data was received and that the connection should be checked.

Figure 16 and Figure 17 show the formatting of valid token values for all the tokens. In this messaging format, every parameter is represented by the string representation of its numerical value. Note that this representation must have the decimal point included for each parameter (an example voltage value should be sent as "120.00" instead of "12000") because the webpage does not add a decimal point after parsing data. In addition, each metrology value's string representation must have a ";" after it to parse one metrology parameter form another. For the neutral case, although the same token format is used as the other phases, only the current portion of the token value has a value. The other parameters for the neutral channel instead have a space character (" ") to represent it. Table 4 shows the expected units of the parameters sent from the F6779 to the CC3100.

Voltage	;	Current	;	Active Power	;	Reactive Power	;	Apparent Power	;	Power Factor	;	Frequency	;

Figure 16. Token Format for Phase A, Phase B, Phase C, and Phase N Tokens

Date	;	Time	;	Active Energy A	;	Active Energy B	;	Active Energy C	;

Figure 17. Token Format for Date/Time/Active Energy Token

Table 4. Expected Units For Metrology Parameters Sent for Webpage Display

METROLOGY PARAMETER	EXPECTED UNITS
Voltage	Volts
Current	Amps
Active Power	Watts
Reactive Power	Var
Apparent Power	VA
Power Factor	Unitless; This value should be a value between 0 and 1.
Frequency	Hz
Date	Year/Month/Day (YY/MM/DD)
Time	Hour:Minute:Second (HH:MM:SS)
Active Energy A	Active Energy Ticks, where one tick corresponds to [1/(pulses_per_kwh)]kWh; since the pulses_per_kwh setting is configured in software to a default value to 6400, the active energy parameter displayed on the website is therefore in units of (1/6400) kWh.
Active Energy B	Active Energy Ticks, where onetick corresponds to [1/(pulses_per_kwh)]kWh; since the pulses_per_kwh setting is configured in software to a default value to 6400, the active energy parameter displayed on the website is therefore in units of (1/6400) kWh.
Active Energy C	Active Energy Ticks, where 1 tick corresponds to [1/(pulses_per_kwh)]kWh; since the pulses_per_kwh setting is configured in software to a default value to 6400, the active energy parameter displayed on the website is therefore in units of (1/6400) kWh.

3 Block Diagram

Figure 18 depicts a block diagram that shows the high level interface used for a 3-phase energy meter application using the F677x. A 3-phase, 4-wire star connection to the AC mains is shown in this case. Current sensors are connected to each of the current channels and a simple voltage divider is used for corresponding voltages. The CT has an associated burden resistor that has to be connected at all times to protect the measuring device. The choice of the CT and the burden resistor is done based on the manufacturer and current range required for energy measurements. The CTs can be easily replaced by Rogowski coils with minimal changes to the front end. The choice of voltage divider resistors for the voltage channel is selected to ensure the mains voltage is divided down to adhere to the normal input ranges that are valid for the MSP430ΣΔ24. Refer to the MSP4305xx/6xx user's guide and device-specific datasheet for these numbers.

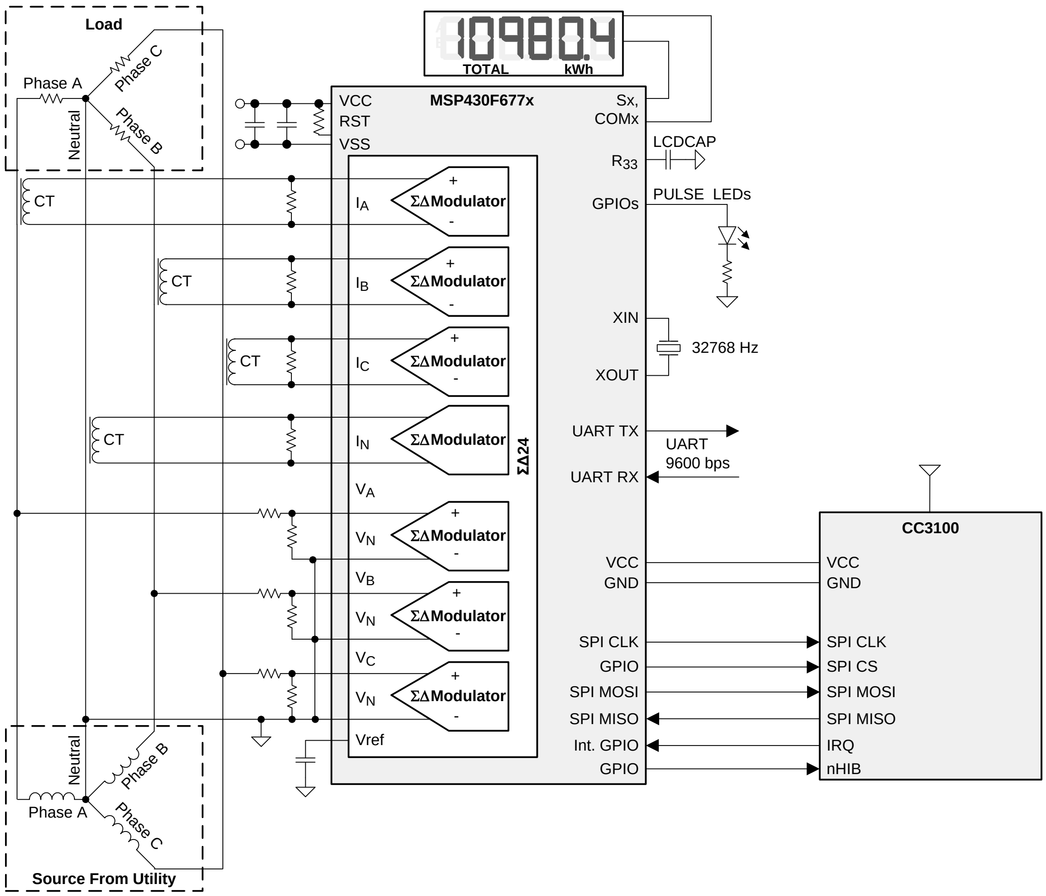


Figure 18. TIDC-3PHMTR-WIFIXR System Block Diagram

Other signals of interest in Figure 18 are the PULSE LEDs, which are used to transmit active and reactive energy pulses used for accuracy measurement and calibration. In addition, the pulses are also used to transmit the active power consumed for each individual phase.

By connecting the meter to the CC3100BOOST, Wi-Fi functionality is added to the meter. The CC3100BOOST communicates with the F6779 using SPI, where the F6779 acts as the master device. In addition to the SPI lines, a GPIO output pin must be connected to the CC3100BOOST's nHIB line. This pin is used to enable or disable the CC3100. Also, a GPIO input pin that has interrupt capability must be connected to the CC3100's IRQ pin to provide an event interrupt from the CC3100 to the F6779. In particular, for the F6779, all port 1 and port 2 pins are valid options for being connected to the CC3100's IRQ pin.

4 Wi-Fi Energy Meter Demo

The energy meter evaluation module (EVM) associated with this application note has the MSP430F677x and demonstrates energy measurements. The complete demonstration platform consists of the EVM that can be easily hooked to any test system, metrology software and a PC GUI, which will be used to view results and perform calibration. By adding the CC3100BOOST and the necessary BoosterPack to EM adapter, Wi-Fi capabilities can be added to this meter.

4.1 Overview

The following figures of the EVM best describe the EVM430-F6779 and CC3100BOOST BoosterPack. Figure 19 is the top view of the energy meter and discusses the location of various pieces of the EVM based on functionality. Similarly, Figure 20 shows the front side of the CC3100BOOST and its different components.

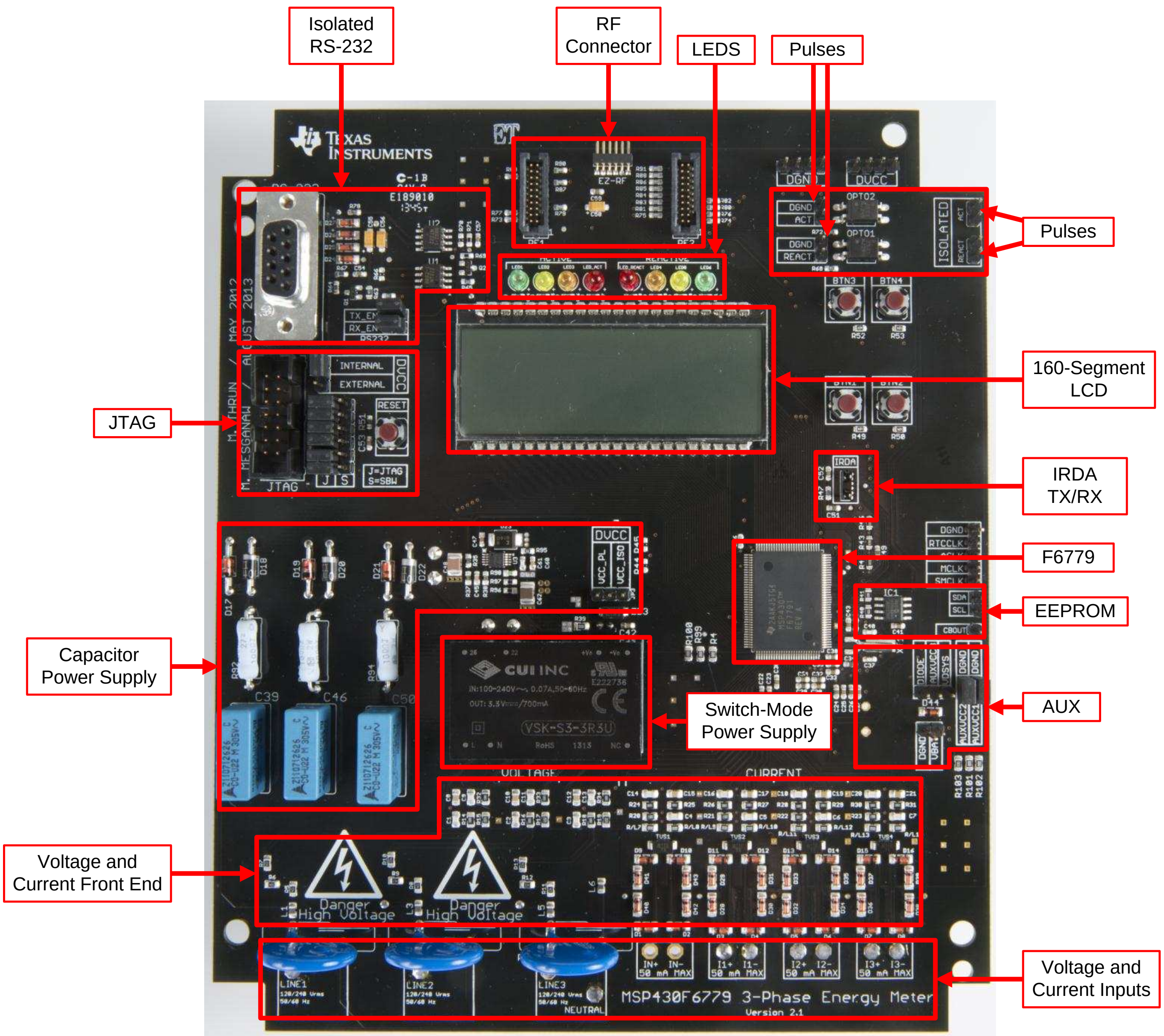


Figure 19. Top View of the EVM With Components Highlighted

WARNING

HIGH VOLTAGE: Electric shock possible when connecting board to live wires. Boards should be handled with care by a professional. For safety, use of isolated test equipment with overvoltage and overcurrent protection is highly recommended.

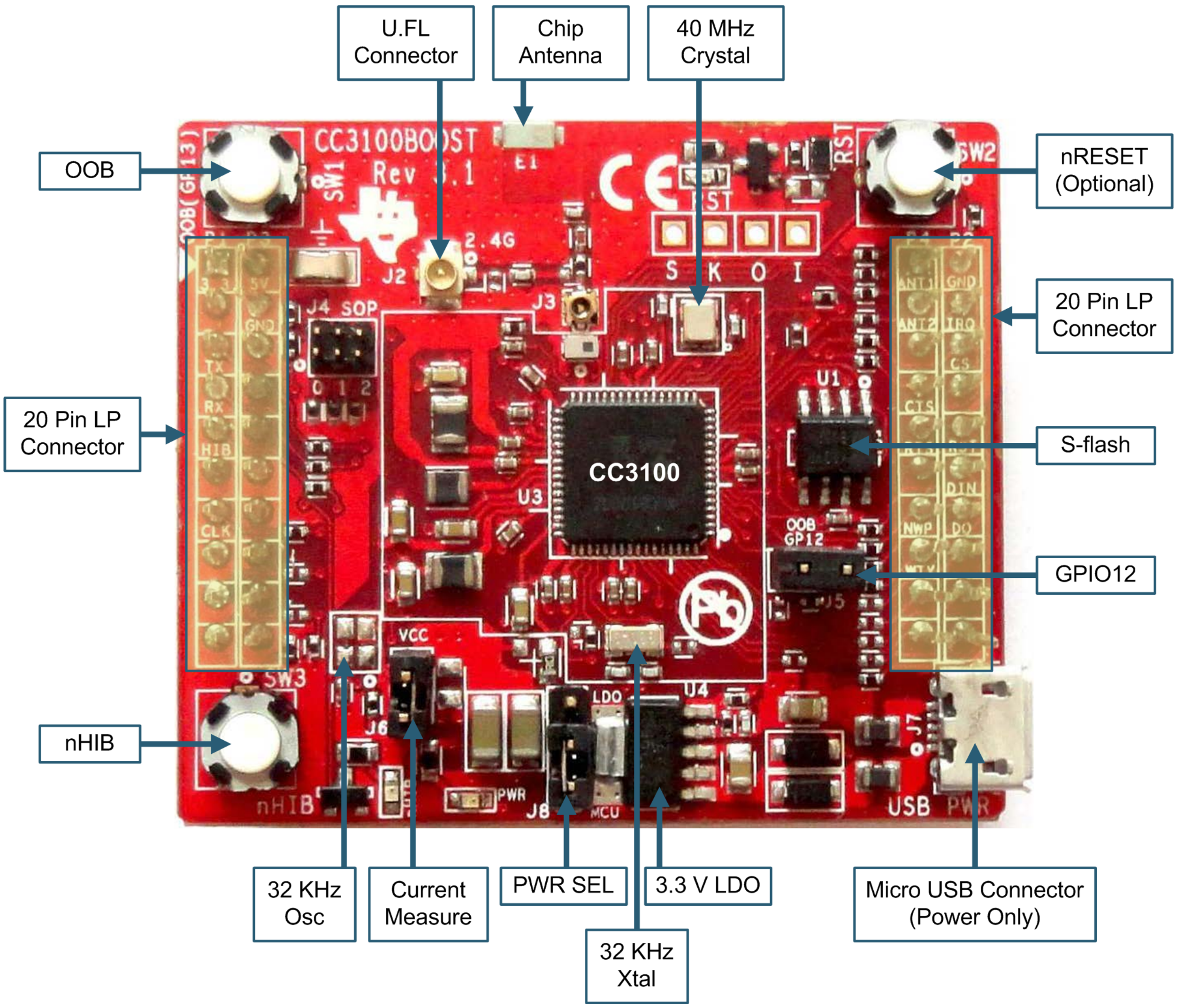


Figure 20. Front View of the CC3100BOOST With Components Highlighted

4.1.1 Connections to the Test Setup or AC Voltages

CAUTION

Do note leave EVM powered when unattended.

All three pads of the JMP4/P2 and JMP1/P3 jumper pads should never be shorted together.

AC voltage or currents can be applied to the board for testing purposes at these points:

- Pad “LINE1” corresponds to the line connection for phase A.
- Pad “LINE2” corresponds to the line connection for phase B.
- Pad “LINE3” corresponds to the line connection for phase C.
- Pad “Neutral” corresponds to the Neutral voltage. The voltage between any of the three line connections to the neutral connection should not exceed 230-V AC at 50/60 Hz.
- I1+ and I1– are the current inputs after the sensors for phase A. When a current sensor is used, make sure the voltages across I1+ and I1– does not exceed 930 mV. This pad is currently connected to a CT on the EVM.
- I2+ and I2– are the current inputs after the sensors for phase B. When a current sensor is used, make sure the voltages across I2+ and I2– does not exceed 930 mV. This pad is currently connected to a CT on the EVM.
- I3+ and I3– are the current inputs after the sensors for phase C. When a current sensor is used, make sure the voltages across I3+ and I3– does not exceed 930 mV. This pad is currently connected to a CT on the EVM.
- IN+ and IN– are the current inputs after the sensors for the neutral current. When a current sensor is used, make sure the voltages across IN+ and IN– does not exceed 930 mV. This is currently not connected to the EVM.

Figure 21 and Figure 22 show the various connections that need to be made to the test setup for proper functionality of the EVM. When a test AC source needs to be connected, the connections have to be made according to the EVM design.

Figure 21 shows the connections from the top view. VA+ , VB+, and VC+ corresponds to the line voltage for phases A, B, and C, respectively. VN corresponds to the neutral voltage from the test AC source.

Figure 22 shows the connections from the front view. IA+ and IA– correspond to the current inputs for phase A, IB+ and IB– correspond to the current inputs for phase B, and IC+ and IC– correspond to the current inputs for phase C. VN corresponds to the neutral voltage from the test setup. Although the EVM hardware and software supports measurement for the neutral current, the EVM obtained from Texas Instruments do not have a sensor connected to the neutral ADC channel.

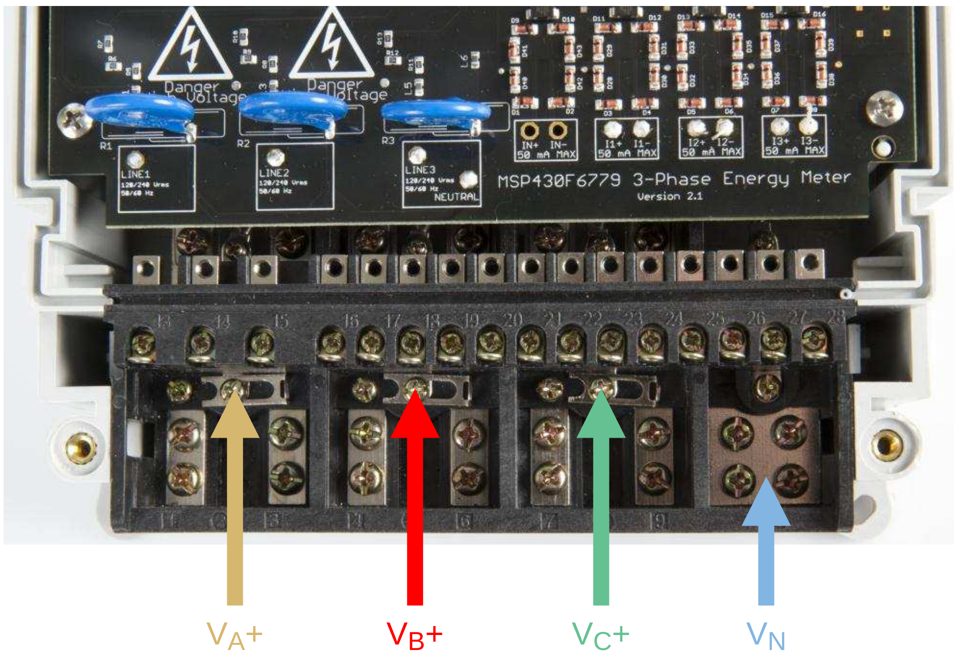


Figure 21. Top View of EVM with Test Setup Connections

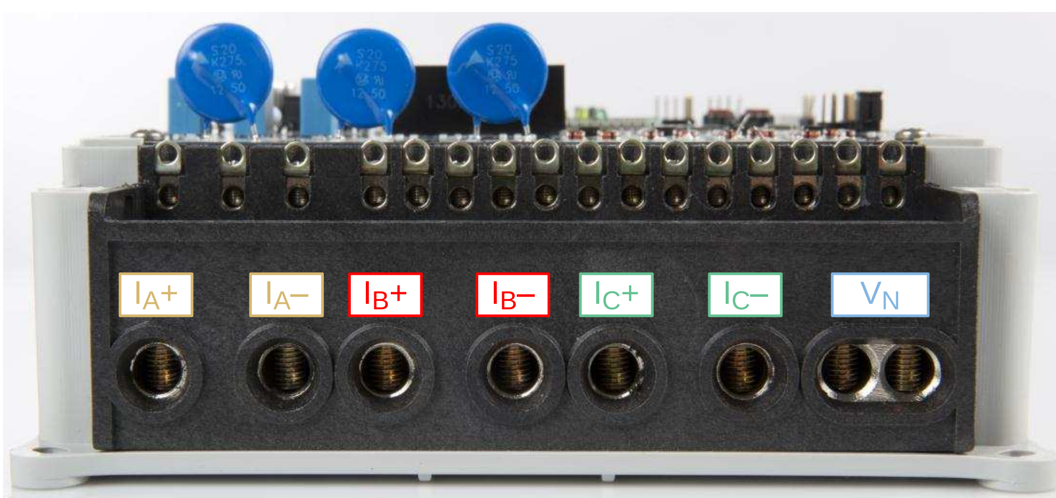


Figure 22. Front View of the EVM With Test Setup Connections

4.1.2 Power Supply Options and Jumper Settings

The CC3100BOOST and the EVM can be configured to operate with different sources of power. The CC3100BOOST can either be powered from the EVM or the 3.3-V LDO output that is powered from USB via the CC3100BOOST's J7 USB connector. When powering the CC3100BOOST from the EVM, the EVM must be powered either from mains using the switching power supply option or from an external power source that can provide up to 350 mA at 3.3 V. If the CC3100BOOST is selected to be powered from the EVM, the CC3100BOOST's jumper resistor connecting "VDD_ANA2" to "VCC_LDO_3V3"(R35) will need to be changed to connect it to "VBAT_CC" (R50) instead. If the CC3100BOOST is powered via USB, then the EVM430-F6779 can be powered from either JTAG, external power, or AC mains through either the capacitive or switching power supplies. For this case, when the CC3100BOOST is connected to the EVM and the EVM is connected to AC mains, do not connect the CC3100BOOST's USB to non-isolated equipment.

Various jumper headers and jumper settings are present to add to the flexibility to the board. Some of these headers require that jumpers be placed appropriately for the board to correctly function. Table 5 indicates the functionality of each jumper on the board and the associated functionality.

This EVM and the CC3100BOOST provide various jumper settings and headers that can be used for debugging. Table 5 shows all the different header names and jumper setting on this EVM. Table 6 shows the utilized headers and jumper settings on the CC3100BOOST.

Table 5. Header Names and Jumper Settings on the EVM430-F6779

HEADER AND OPTION NAME	TYPE	MAIN FUNCTIONALITY	VALID USE-CASE	COMMENTS
ACLK (Not isolated, do not probe)	1-pin Header	ACLK Output (WARNING)	Probe here to measure the frequency of ACLK.	The software does not output ACLK by default and will have to be modified to output ACLK. This header is not isolated from AC voltage, so do not connect any measuring equipment.
ACT (Not isolated, do not probe)	1-pin Header	Active Energy Pulses (WARNING)	Probe between here and ground for cumulative three-phase active energy pulses.	This header is not isolated from AC voltage, so do not connect measuring equipments unless isolators external to the EVM are available. See Isolated ACT instead.
AUXVCC1 (Not isolated, do not probe)	2-pin Header	AUXVCC1 selection/ External power (WARNING)	Place a jumper here to connect AUXVCC1 to GND. This jumper must be present if AUXVCC1 is not used as a backup power supply. Alternatively, this jumper can be used to provide a back-up power supply to the MSP430. To do so, simply connect the alternative power supply to this header and configure the software to use the backup power supply as needed. In addition, on the bottom of the board, a footprint is present that allows the addition of a super capacitor.	
AUXVCC2 (Not isolated, do not probe)	2-pin Jumper/ Header	AUXVCC2 selection/ AUXVCC2 external power (WARNING)	Place a jumper here to connect AUXVCC2 to GND. This jumper must be present if AUXVCC2 is not used as a backup power supply. Alternatively, it can be used to provide a back-up power supply to the MSP430. To do so, simply connect the alternative power supply to this header and configure the software to use this backup power supply as needed.	
AUXVCC3 (Not isolated, do not probe)	2-pin Jumper/ Header	AUXVCC3 selection/ External power (WARNING)	To power the RTC externally regardless of whether DVCC is available, provide external voltage at AUXVCC3, disable the internal AUXVCC3 charger in software, and do not connect a jumper at this header. Alternatively, place a jumper at the "VDSYS" option to connect AUXVCC3 to VDSYS so that it is powered from whichever supply (DVCC, AUXVCC1, or AUXVCC2) is powering the chip. If this jumper is placed, disable the internal charger in software. To power the RTC externally only when DVCC is not available, enable the internal charger, place a jumper at the "Diode", option and apply external voltage at the VBAT header.	
DGND (Not isolated, do not probe)	Header	Ground voltage header (WARNING)	Not a jumper header, probe here for GND voltage. Connect negative terminal of bench or external power supply when powering the board externally.	Do not probe if the board is powered from AC mains, unless the AC mains are isolated. This voltage can be hot or neutral if AC wall plug is connected to the meter.
DVCC (Not isolated, do not probe)	Header	VCC voltage header (WARNING)	Not a jumper header, probe here for VCC voltage. Connect positive terminal of bench or external power supply when powering the board externally.	Do not probe if the board is powered from AC mains, unless the AC mains are isolated.
DVCC External (Do not connect JTAG if AC mains is the power source Isolated JTAG or supply is fine)	Jumper Header Option	JTAG external power selection option (WARNING)	Place a jumper at this header option to select external voltage for JTAG programming.	This jumper option and the DVCC Internal jumper option comprise one 3-pin header used to select the voltage source for JTAG programming.

Table 5. Header Names and Jumper Settings on the EVM430-F6779 (continued)

HEADER AND OPTION NAME	TYPE	MAIN FUNCTIONALITY	VALID USE-CASE	COMMENTS
DVCC Internal (Do not connect JTAG if AC mains is the power source).	Jumper Header Option	JTAG internal power selection option (WARNING)	Place a jumper at this header option to power the board using JTAG and to select the voltage from the USB FET for JTAG programming.	This jumper option and the DVCC External jumper option comprise one 3-pin header used to select the voltage source for JTAG programming.
DVCC VCC_ISO ISO (Not isolated, do not probe)	Jumper Header Option	Switching-mode supply Select	Place a jumper at this header position to power the board via AC mains using the switching power supply.	Place a jumper only if AC mains voltage is needed to power the DVCC rail. This header option and the DVCC VCC_PL header option comprise one 3-pin header that selects a capacitive power supply, a switching-mode power supply, or neither.
DVCC VCC_PL (Not isolated, do not probe)	Jumper Header Option	Capacitor power supply select (WARNING)	Place a jumper at this header position to power the board through AC mains using the capacitor power supply.	Place a jumper only if AC mains voltage is needed to power the DVCC rail. Do not debug using JTAG unless AC source is isolated or JTAG is isolated. This header option and the DVCC VCC_ISO header option comprise one 3-pin header that selects a capacitive power supply, a switching-mode power supply, or neither
Isolated Act	1-pin Header	Isolated Active Energy Pulses	Not a jumper header, probe between here and ground for cumulative 3-phase active energy pulses.	This header is Isolated from AC voltage, so it is safe to connect to scope or other measuring equipment since isolators are already present.
Isolated React	1-pin Header	Isolate reactive energy pulses	Not a jumper header, probe between here and ground for cumulative 3-phase reactive energy pulses.	This header is Isolated from AC voltage, so it is safe to connect to scope or other measuring equipment since isolators are already present.
J (Do not connect JTAG if AC mains is the power source)	Jumper Header Option	4-wire JTAG programming option (WARNING)	Place jumpers at the J header options of all of the six JTAG communication headers to select 4-wire JTAG.	There are six headers that jumpers must be placed at to select a JTAG communication option. Each of these six headers have a J option and an S option to select either 4-wire JTAG or SBW. To enable 4-wire JTAG, all of these headers must be configured for the J option. To enable SBW, all of the headers must be configured for the S option.
MCLK (Not isolated, do not probe)	1-pin Header	MCLK output (WARNING)	Probe here to measure the frequency of MCLK.	The software does not output MCLK by default and will have to be modified to output MCLK. Probe only when AC mains is isolated.
REACT (Not isolated, do not probe)	1-pin Header	Reactive energy pulses (WARNING)	Not a jumper header, probe between here and ground for cumulative 3-phase reactive energy pulses.	This header is not isolated from AC voltage so do not connect measuring equipments unless isolators external to the EVM are available. See Isolated REACT instead.
RTCCLK	1-pin Header	RTCCLK output	Probe here to measure the frequency of RTCCLK, which is used for calibrating the RTC.	The software does not output RTCCLK by default and will have to be modified to output RTCCLK.
RX_EN	Jumper Header	RS-232 receive enable	Place a jumper here to enable receiving characters using RS-232.	—

Table 5. Header Names and Jumper Settings on the EVM430-F6779 (continued)

HEADER AND OPTION NAME	TYPE	MAIN FUNCTIONALITY	VALID USE-CASE	COMMENTS
S (Do not connect JTAG if AC mains is the power source)	Jumper Header Option	SBW JTAG programming option (WARNING)	Place jumpers at the S header options of all of the six JTAG communication headers to select SBW.	There are six headers that jumpers must be placed at to select a JTAG communication. Each of these six headers that have a J option and an S option to select either 4-wire JTAG or SBW. To enable 4-wire JTAG, all of these headers must be configured for the J option. To enable SBW, all of the headers must be configured for the S option.
SCL (Not isolated, do not probe)	1-pin Jumper Header	I2C/EEPROM SCL probe point (WARNING)	Probe here to probe I2C SCL line.	Probe only when AC mains is isolated.
SDA (Not isolated, do not probe)	1-pin Jumper Header	I2C/EEPROM SDA probe point (WARNING)	Probe here to probe I2C SDA line.	Probe only when AC mains is isolated.
SMCLK (Not isolated, do not probe)	1-pin Header	SMCLK output (WARNING)	Probe here to measure the frequency of SMCLK.	The software does not output MCLK by default and will have to be modified to output SMCLK. Probe only when AC mains is isolated.
TX_EN	Jumper Header	RS-232 transmit enable	Place a jumper here to enable RS-232 transmissions.	—
VBAT	2-pin Jumper Header	AUXVCC3 external power for AUXVCC3 *Diode* option (WARNING)	When the *Diode* option is selected for AUXVCC3, apply voltage at this header so that the RTC could still be powered when the voltage at DVCC is removed.	—

Table 6. Utilized Header Names and Jumper Settings on the CC3100BOOST

HEADER AND OPTION NAME	TYPE	MAIN FUNCTIONALITY	VALID USE-CASE	COMMENTS
J5	2-pin Jumper Header	Reserved (WARNING)	Closed: GPIO_12 is hard pulled to VCC Open: GPIO_12 is pulled to GND using a 33-K resistor.	Do not probe here when the CC3100BOOST is connected to the EVM430-F6779 and the EVM is connected to non-isolated mains AC voltage.
J6	2-pin Jumper Header	Current Measurement (WARNING)	For Hibernate and LPDS currents, connect an ammeter across J26: Range (<500 µA). For active current, mount a 0.1-Ω resistor on R42 and measure the voltage across the 0.1 Ω resistor using a voltmeter (range <50-mV peak-peak)). Otherwise, short this jumper.	Do not probe here when the CC3100BOOST is connected to the EVM430-F6779 and the EVM is connected to non-isolated mains AC voltage.
J8	3-pin Jumper Header	Power Selection (WARNING)	Choose the power supply from the Lauchpad or the on-board USB. Connect a jumper to this header's "LDO" option to power the CC3100BOOST from the on-board USB using a 3.3-V LDO. Connect a jumper to this board's *MCU* option to power it from the EVM430-F6779. Note that if the CC3100BOOST is selected to be powered from the EVM, the CC3100BOOST's jumper resistor connecting "VDD_ANA2" to "VCC_LDO_3V3"(R35) will need to be changed to connect it to "VBAT_CC" (R50) instead.	Do not probe here when the CC3100BOOST is connected to the EVM430-F6779 and the EVM is connected to non-isolated mains AC voltage.
J9	20-pin Header	BoosterPack Header (WARNING)	P2/P4 of BoosterPack Connection	Do not probe here when the CC3100BOOST is connected to the EVM430-F6779 and the EVM is connected to non-isolated mains AC voltage. See Section 2.1.3 for more information on the individual pins on this header.
J10	20-pin Header	BoosterPack Header (WARNING)	P1/P3 of BoosterPack Connection	Do not probe here when the CC3100BOOST is connected to the EVM430-F6779 and the EVM is connected to non-isolated mains AC voltage. See Section 2.1.3 for more information on the individual pins on this header.

5 Results

5.1 Viewing Results by LCD

The LCD display scrolls between metering parameter approximately every two seconds. For each metering parameter that is displayed on the LCD, three items are actually displayed on the screen: the corresponding phase of the parameter, a one- or two-character symbol used to distinguish which parameter is being displayed, and the actual value of the parameter. The phase of the parameter is displayed on the top line of the LCD and can take the values of A, B, C, and t for phase A, phase B, phase C, and the aggregate-sum of these phases, respectively. The parameter symbol is displayed on the left of the second line of the LCD. To the right of the parameter symbol is the actual value of the parameter.

Table 7 shows the different metering parameters that are displayed on the LCD and the associated units in which they are displayed. The *SYMBOL* column shows which characters correspond to which metering parameter. The *COMMENTS* column provides a brief interpretation of the displayed metering parameters.

Table 7. Displayed Parameters

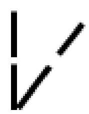
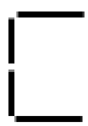
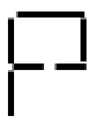
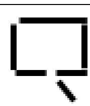
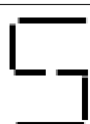
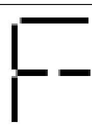
PARAMETER NAME	SYMBOL	UNITS	COMMENTS
Voltage		Volts (V)	—
Current		Amps (A)	—
Active power		Watt (W)	—
Reactive power		Volt-Ampere Reactive (var)	—
Apparent power		Volt-Ampere (VA)	—
Frequency		Hertz (Hz)	—

Table 7. Displayed Parameters (continued)

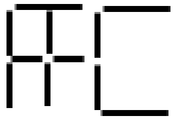
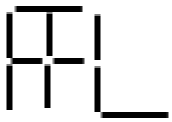
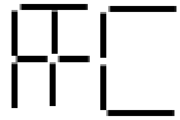
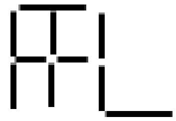
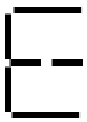
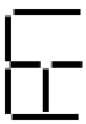
PARAMETER NAME	SYMBOL	UNITS	COMMENTS
Power factor	 Or 	Constant between 0 and 1	The characters  are used if the load is determined to be a capacitive load. The characters  are used if the load is determined to be an inductive load.
Total consumed active energy		100 ticks	Every 10 ticks increments the tenths place by 1.
Total consumed reactive energy		100 ticks	Every 10 ticks increments the tenths place by 1.

Figure 23 shows an example of phase A's measured frequency of 49.99 Hz being displayed on the LCD.

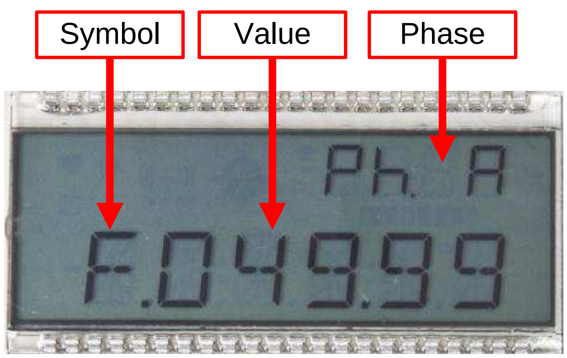
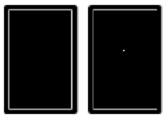
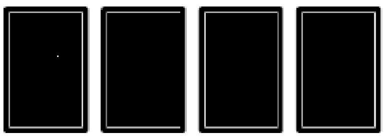
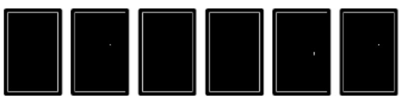
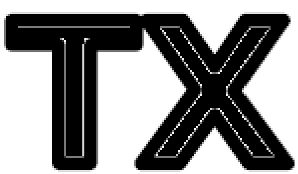


Figure 23. LCD Display

In addition to displaying the metrology results on the LCD, the LCD is also used to display the Wi-Fi status.

[Table 8](#) shows the different LCD symbols, what each symbol represents, and the sequence order in which each set of actions take place where items at lower sequence numbers should occur first.

Table 8. Displayed Parameters

SYMBOL	SEQUENCE NUMBER	STATUS
	1	The EVM has started up and has begun setting up the CC3100. The CC3100 must be connected to the EVM before start-up to properly execute subsequent instructions after this step.
	2	The CC3100 has been sent the command to be set to be in Default mode.
	3	The CC3100 has been sent the command to be put in Access Point mode.
 blinking	4	The CC3100 is waiting for a client to connect to it.
 no blinking	5	A client has been connected to the CC3100.
 blinking	6	The CC3100 has recently received an http request for one of the metrology result webpages or for dynamically updating these metrology result webpages with new values.
	—	An unexpected or general event has occurred.

5.2 Viewing Results by GUI

1. Connect the EVM to a PC with an RS-232 cable.
2. Open the *GUI* folder and open *calibration-config.xml* in a text editor.
3. Change the *Port Name* field within the *Meter* tag to the COM port connected to the meter. In Figure 24, this field is changed to COM2.

```
                <step current="25.000" phase="0.0" gain="1.0"/>
                <step current="30.000" phase="0.0" gain="1.0"/>
                <step current="35.000" phase="0.0" gain="1.0"/>
                <step current="40.000" phase="0.0" gain="1.0"/>
                <step current="45.000" phase="0.0" gain="1.0"/>
                <step current="50.000" phase="0.0" gain="1.0"/>
                <step current="55.000" phase="0.0" gain="1.0"/>
            </correction>
        </phase>
        <temperature/>
        <rtc/>
    </cal-defaults>
    <meter position="1">
        <port name="\\.\com2" speed="9600"/>
    </meter>
```

Figure 24. GUI Config File Changed to Communicate with Meter

4. Run calibrator.exe, which is located in the GUI folder. If the COM port in calibration-config.xml was changed in the previous step to the com port connected to the EVM, the GUI opens (see Figure 25).

   If the GUI connects properly to the EVM, the top left button is green. If there are problems with connections or if the code is not configured correctly, the button is red. Click the green button to view the results.

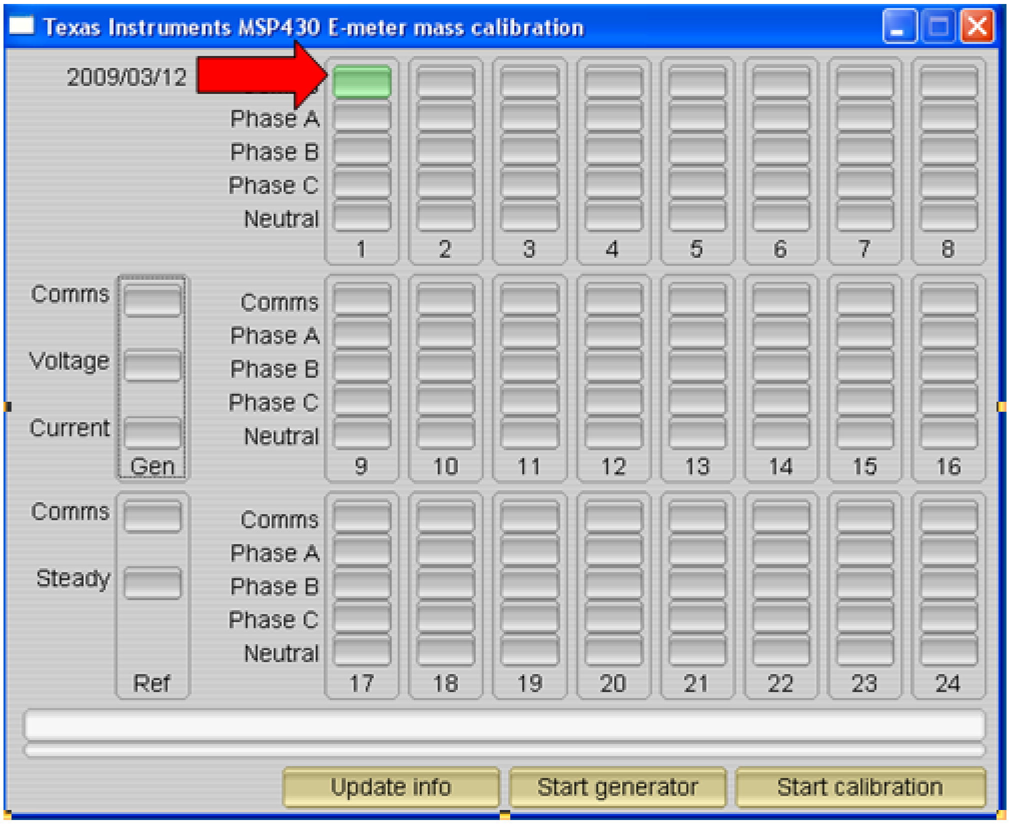


Figure 25. GUI Startup Window

When you click on the green button, the results window opens (see Figure 26). In the figure, there is a trailing 'L' or 'C' on the power factor values to indicate an inductive or capacitive load, respectively.

Figure 26. Results Window

5.3 Viewing Results by Wi-Fi

5.3.1 EVM and CC3100BOOST Preparation

To view the metrology parameters using Wi-Fi, the EVM and CC3100BOOST must be configured. This configuration only needs to be done once if the configuration settings are not changed afterwards. For configuring the CC3100BOOST and EVM, follow these steps:

1. Load the metrology webpage onto the CC3100BOOST by following these instructions:
   (a) Connect the CC3100BOOST to the CC31XXEMUBOOST so that the arrows pointing to P1,1 on both CC3100BOOST and CC31XXEMUBOOST are aligned with each other.
   (b) If it is not already done so, connect the jumper on J8 of the CC3100BOOST to select the *MCU* option so that the CC3100BOOST can be powered from the CC31XXEMUBOOST.
   (c) If it is not already done so, install CCS UniFlash for the CC3100/CC3200. Install the necessary drivers for the CC31XXEMUBOOST.
   (d) Open CCS UniFlash.
   (e) From the UniFlash program, click *File → Open Configuration*. In the window that results, select the *http_server.ucf* file that is located in the *Webpages/uniflash_template* directory that is within the design's software folder. Press *Open* then press *OK*. The screen shown in Figure 27 should then appear.

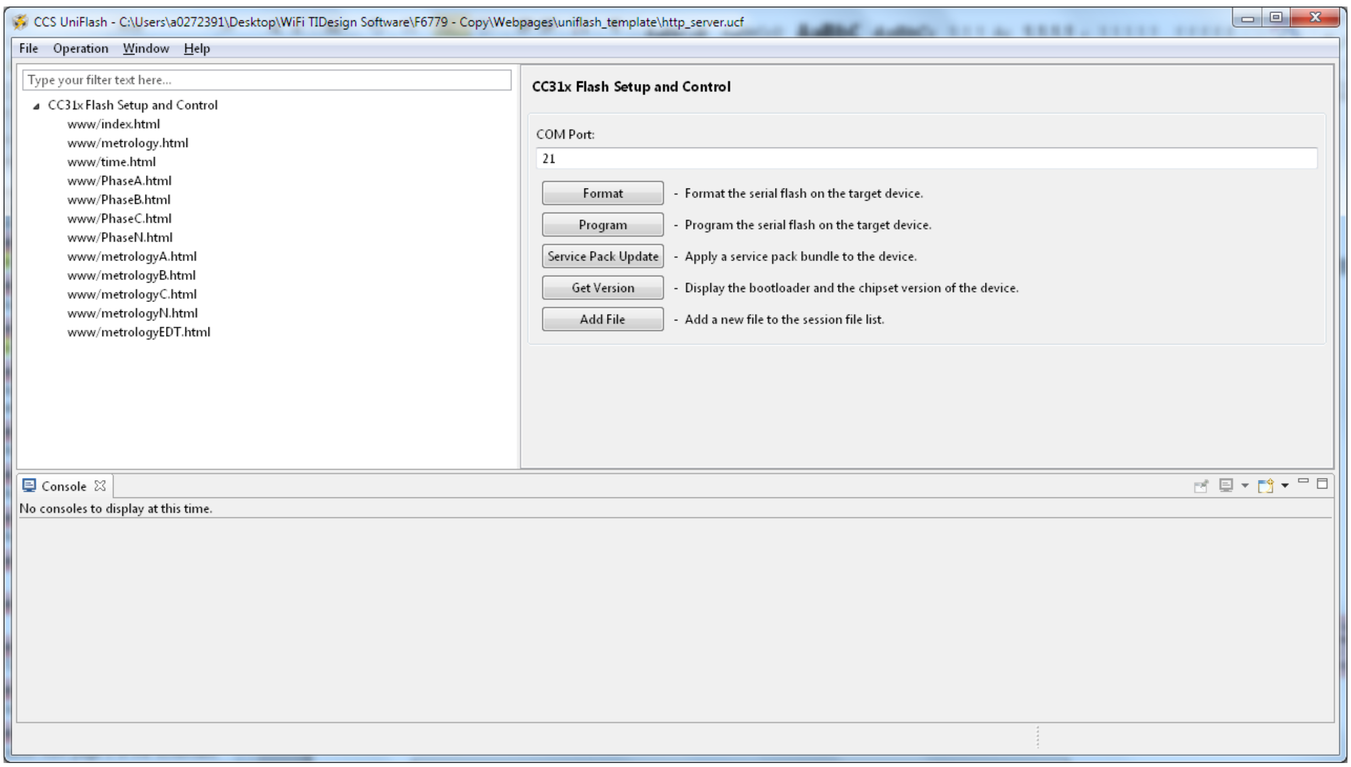


Figure 27. UniFlash CC31x Flash Setup and Control Window

Verify that all of the webpages mentioned in Table 3 are shown in the left pane. Note that main.html is renamed to index.html in this screen.

(f) If not already done so, click on each webpage listed and modify the *URL* field (highlighted in Figure 28) to point to the absolute location of the corresponding webpage. Each webpage should be located in the *Webpages\html* directory within the design software's folder. Ensure that the webpage names are properly mapped to its corresponding webpage location.

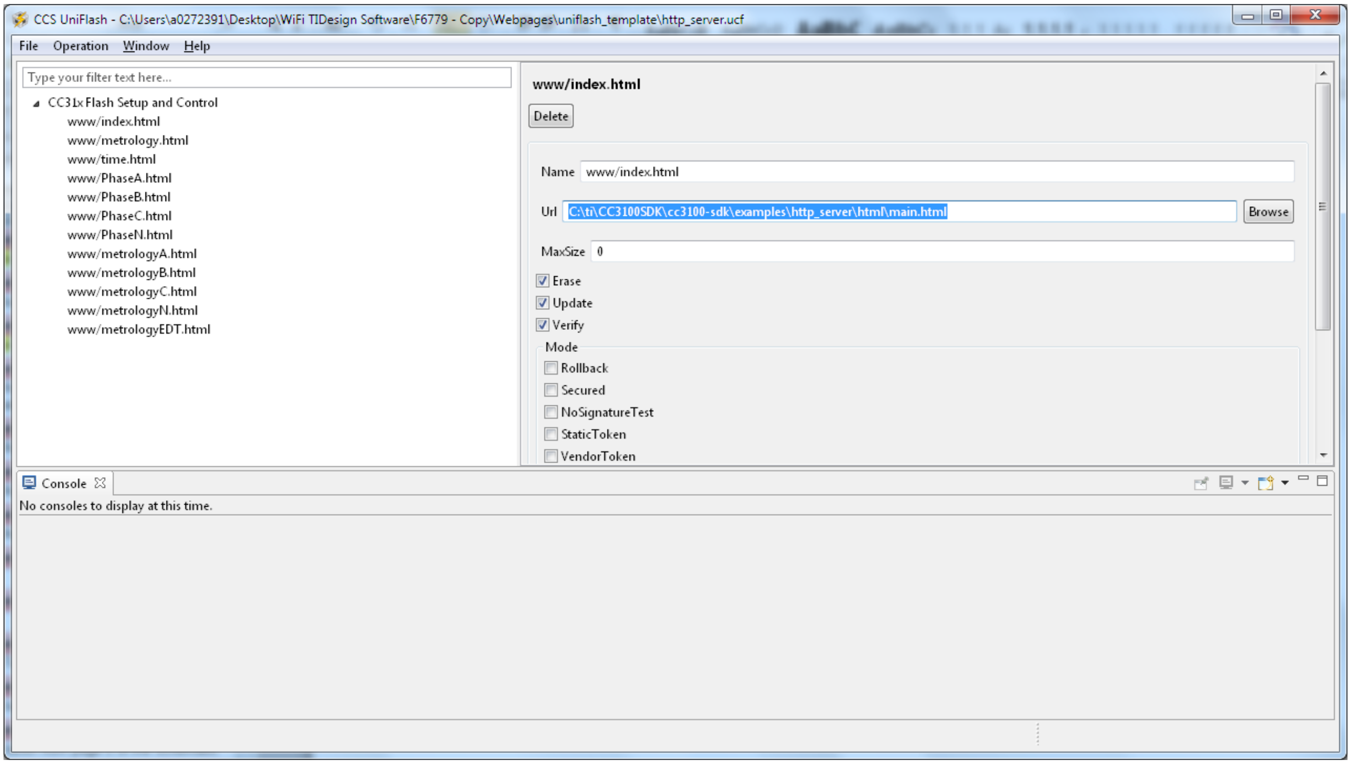


Figure 28. UniFlash CC31x Flash Setup and Control Window

(g) Connect the CC31XXEMUBOOST to a computer by connecting a USB cable to connector J6 of the CC31XXEMUBOOST. As a result of connecting this cable, four new COM ports should appear in device manager, as shown in Figure 29. The third new COM port will be used for programming (COM47 in this case).

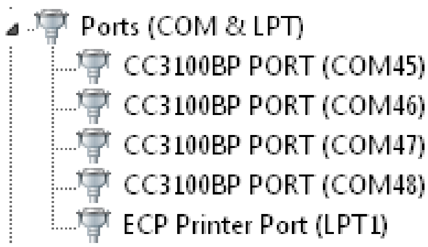


Figure 29. Device Manager

(h) Click on the *CC31xx Flash Setup and Control* label on the left window pane. The screen in Figure 28 should reappear. At this screen, change the *COM PORT* value to the COM port associated with programming, as was determined in the previous step.

(i) Click *Format* to format the device. After clicking *Format*, a message appears in the console stating to please restart the device. After receiving this message, press the RST (SW2) switch on the CC3100BOOST.

(j) After formatting is complete, click *Program*. A message appears in the console mentioning to please restart the device. After receiving this message, press the RST (SW2) switch on the CC3100BOOST. After the program action has completed, the metrology webpages should now be loaded onto the CC3100 device.

2. Configure the CC3100BOOST power selection jumper for its intended power source (see Section 4.1.2). If the CC3100BOOST is to be powered from the EVM and not already done so, ensure that the CC3100BOOST's jumper resistor connecting *VDD_ANA2* to *VCC_LDO_3V3 (R35)* is changed to connect to *VBAT_CC (R50)* instead.
3. Open the IAR workspace file *emeter.eww* in IAR. This file is located in the *emeter-ng* folder of the design's software folder.
4. Modify the *SSID_NAME* macro in CC3100config.c (located in the CC3100 WiFi/EVM430-F6779 folder in the emeter-F6779A project) to the desired network name for the EVM.
5. Load this software onto the EVM430-F6779. After loading the software, turn the EVM off.
6. Connect the CC3100_EM_BP_ADAPTER to the EVM430-F6779.
7. Connect the CC3100BOOST to the CC3100_EM_BP_ADAPTER.
8. Configure the jumper settings on the EVM430-F6779 for its intended power source (see Section 4.1.2)

5.3.2 Viewing Metrology Webpages

1. Power the CC3100BOOST and EVM. If the CC3100BOOST is not powered from the EVM, make sure that the CC3100BOOST is powered first before the EVM. The LCD goes through displaying the symbols corresponding to sequences 1 to 4 shown in Table 8. The LCD shows the antennae symbol blinking and the network created by the CC3100BOOST should now appear when searching for Wi-Fi networks to join. The name of this network would be set to the SSID macro value in the EVM software.
2. Connect to the network created by the CC3100 by using either a computer or smart phone. If this network is not viewable in the available wireless networks, refresh this list of networks. When connected to the CC3100BOOST's network, the blinking antennae should stop blinking and the metrology webpages can be viewed.
3. Open a web browser from the station that is connected to the CC3100BOOST's network and type in "mysimplelink.net" or "192.168.1.1" into the browser's URL bar. Click *Enter*.

4. If a window such as the one shown in Figure 30 pops up, enter “admin” as both the user name and password then press *OK.*

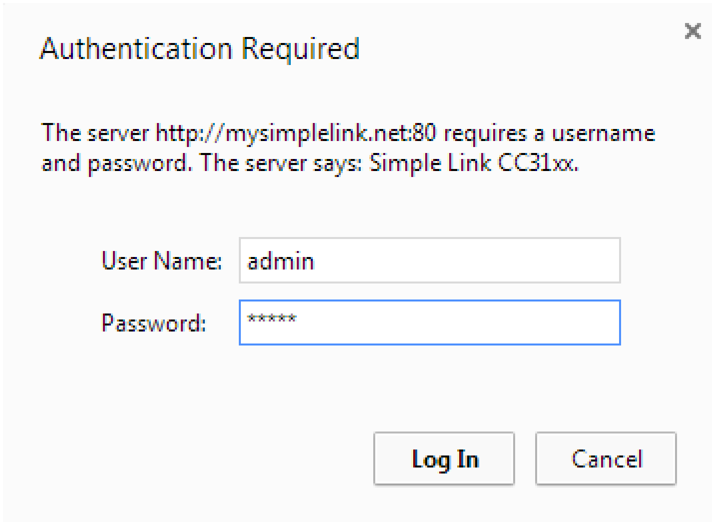


Figure 30. Authentication Page for Accessing Metrology Data

The resulting webpage should then appear, as shown in Figure 31.

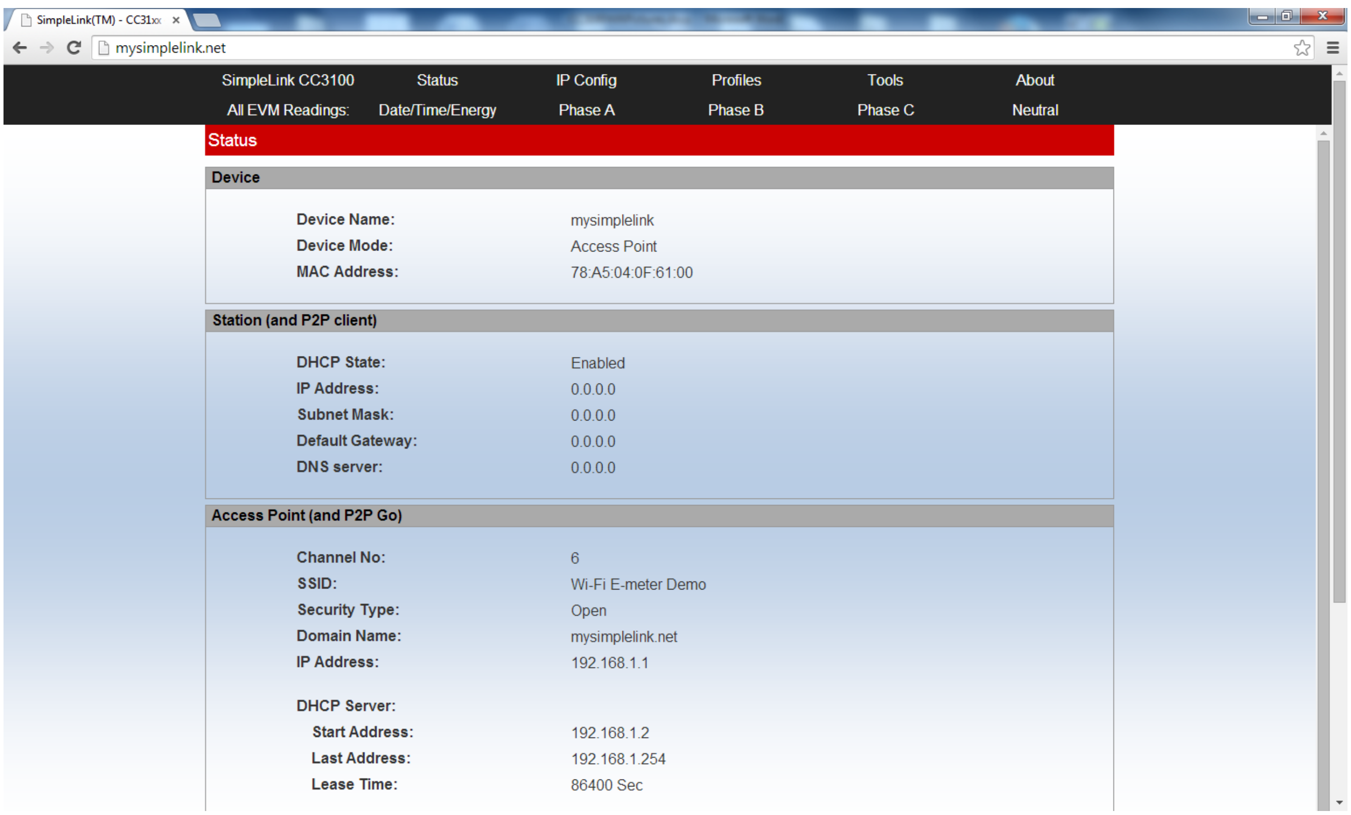


Figure 31. Index.html Webpage

By clicking on the links on the second row of the navigation bar, the different metrology parameters can be viewed. Figure 33 to Figure 38 show the different metrology webpages. The values of the metrology parameters shown in the webpages were obtained by applying the conditions shown in the metering GUI in Figure 32.

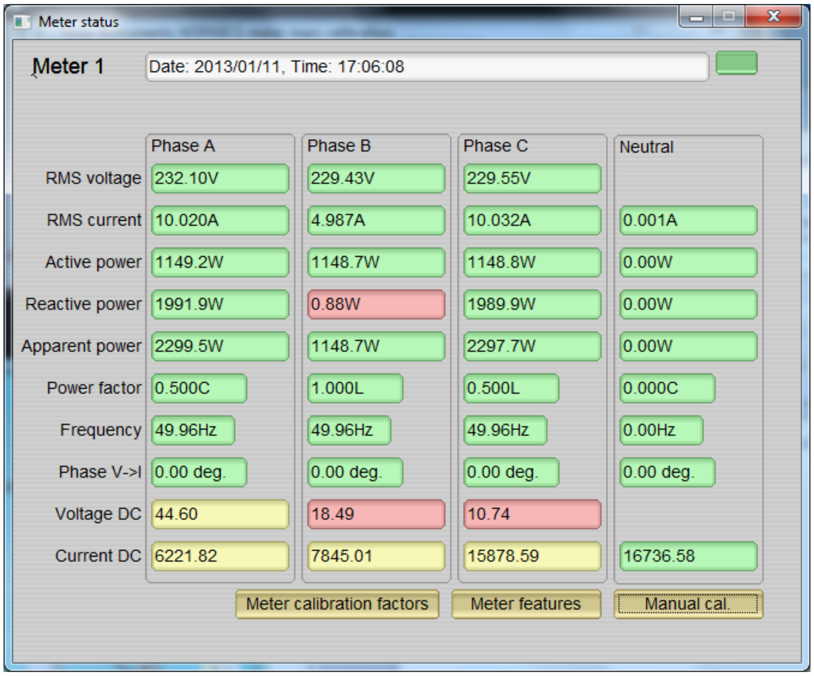


Figure 32. Metrology GUI Showing Metrology Parameter Values

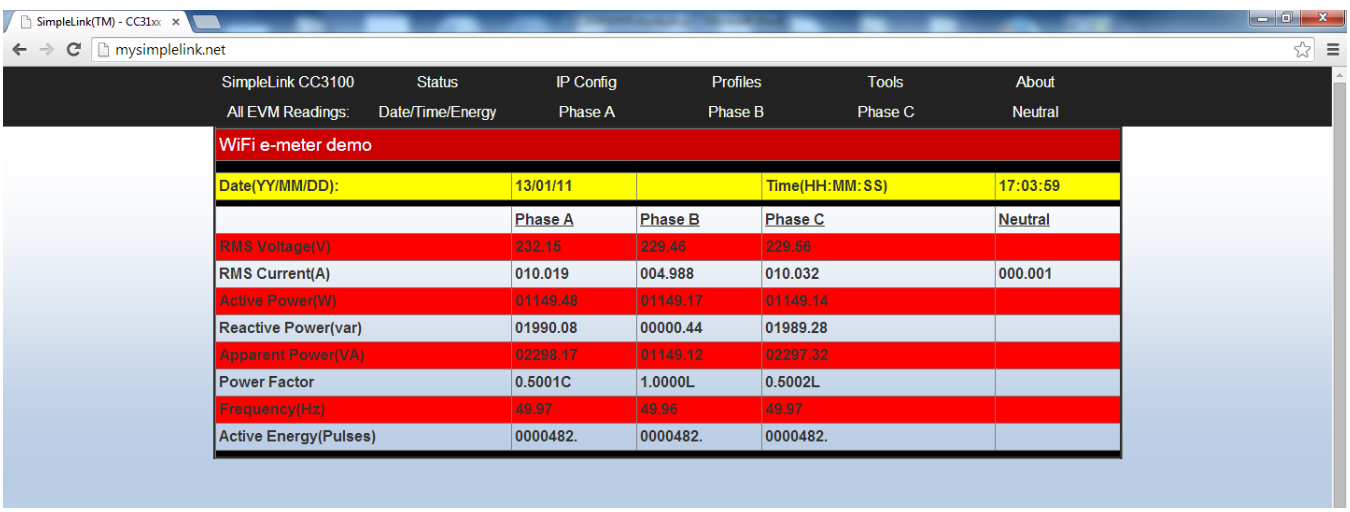


Figure 33. “All EVM Readings” Metrology Webpage

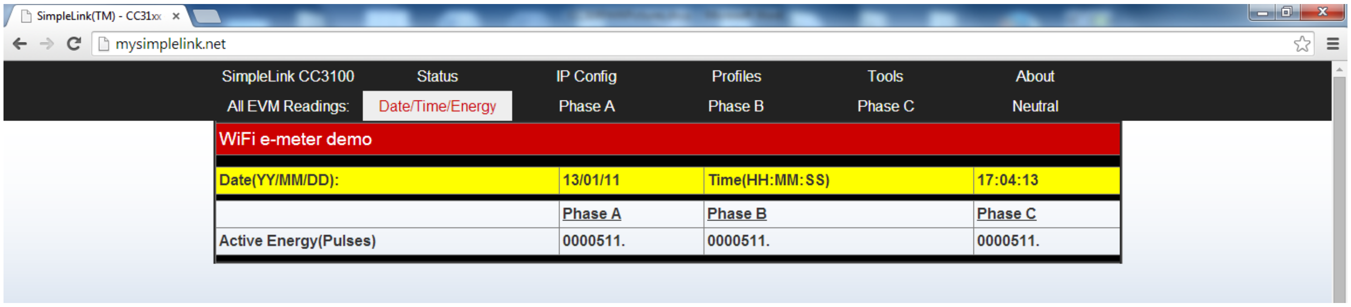


Figure 34. "Date/Time/Energy" Metrology Webpage

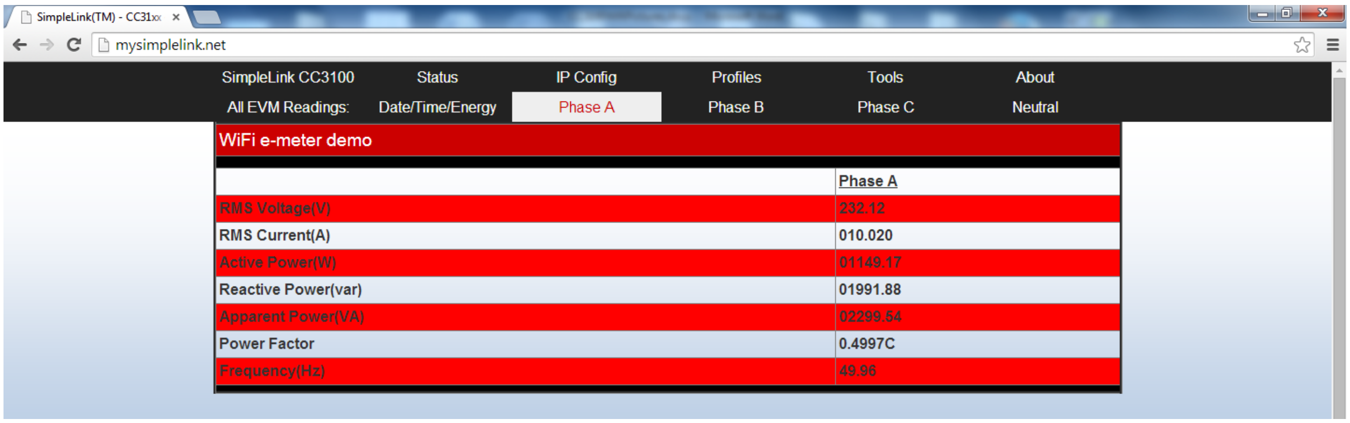


Figure 35. "Phase A" Metrology Webpage

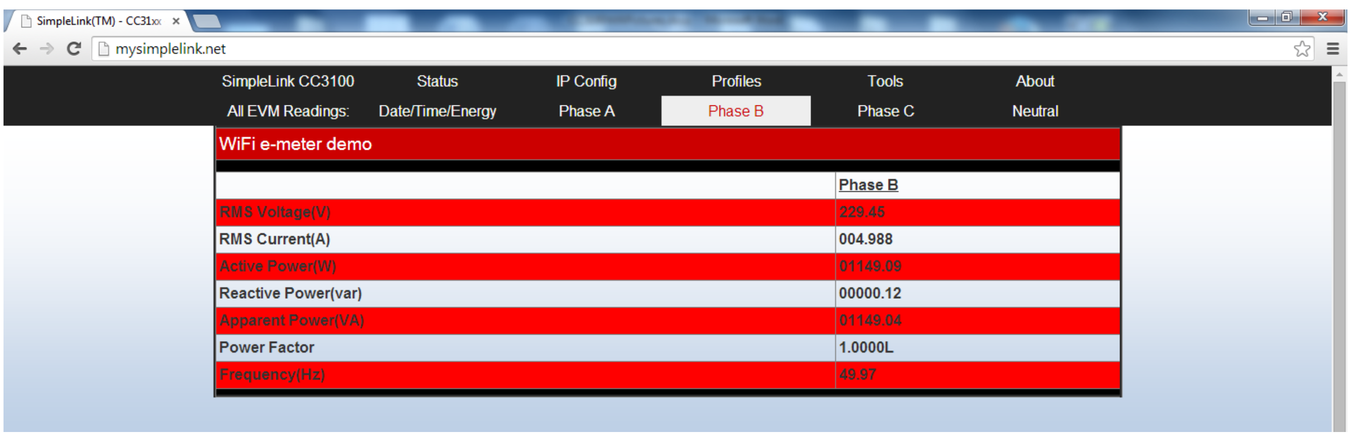


Figure 36. "Phase B" Metrology Webpage

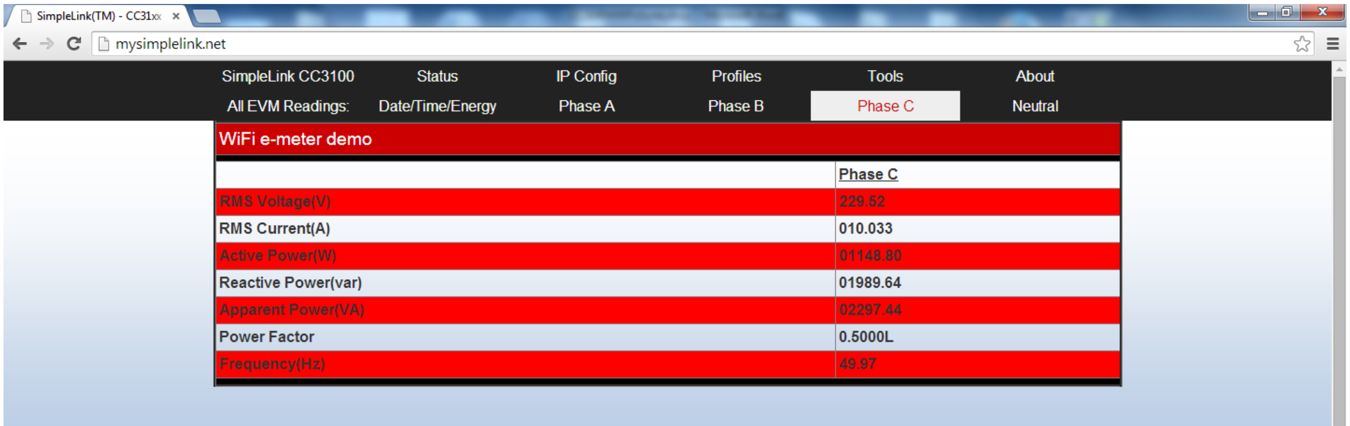


Figure 37. “Phase C” Metrology Webpage

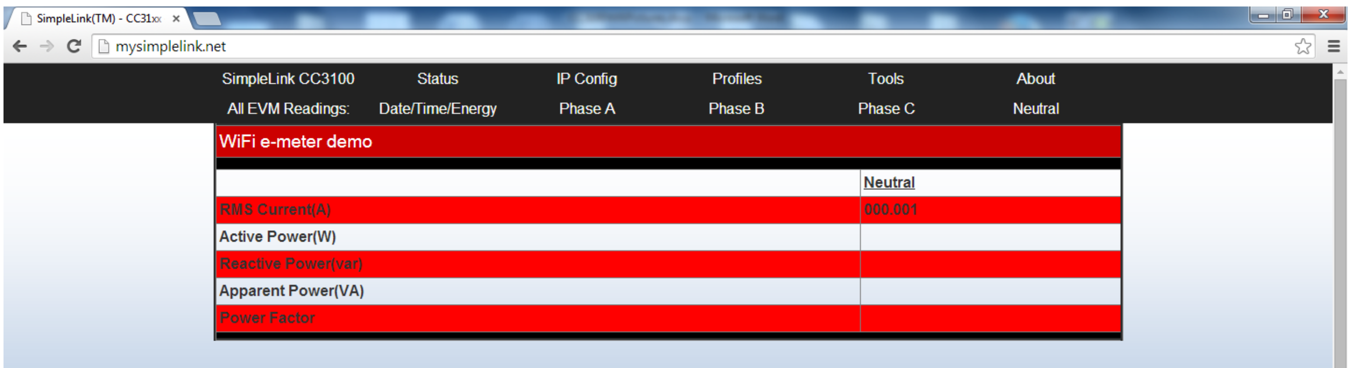


Figure 38. “Neutral” Metrology Webpage

5.3.3 Supported Browsers

The metrology webpages have been verified with Google Chrome 37.0.2062.103 m, Mozilla Firefox 31.0, Internet Explorer 8.0.7601.17514, and Safari (via IOS 7.1.2). Figure 39 to Figure 42 show the “All EVM Readings” metrology webpage for each of these browsers.

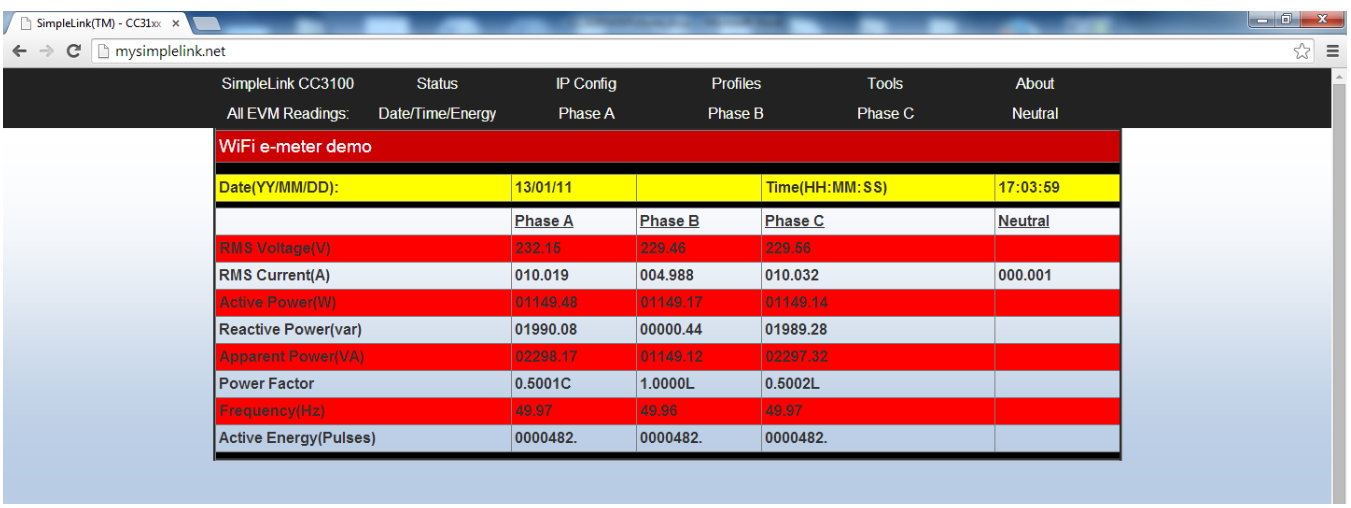


Figure 39. “All EVM Readings” Metrology Webpage (Google Chrome)

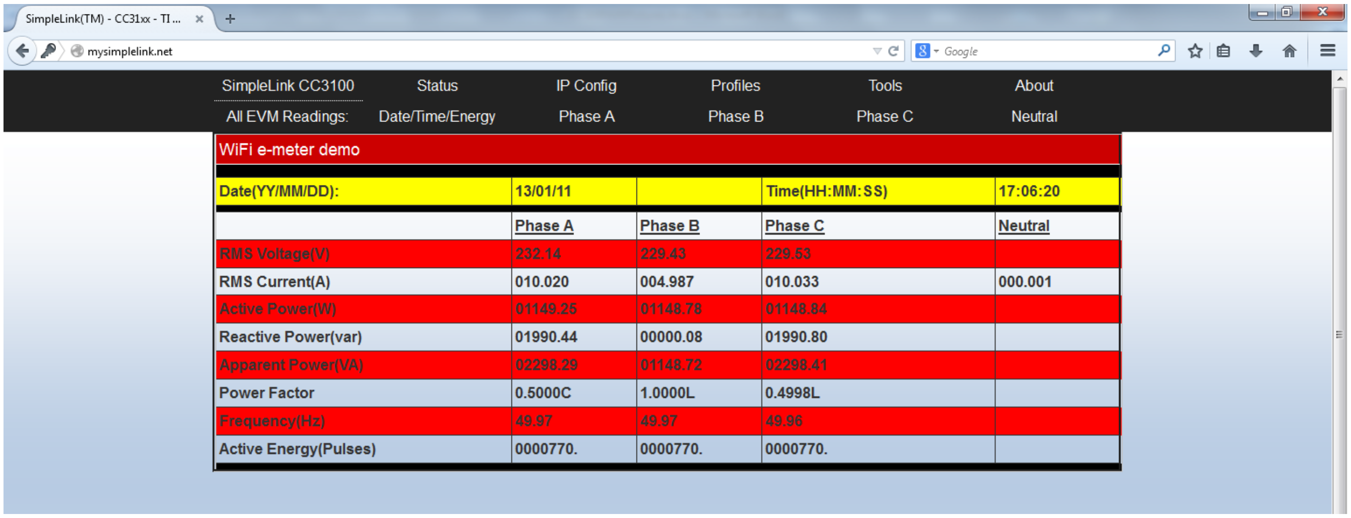


Figure 40. "All EVM Readings" Metrology Webpage (Mozilla Firefox)

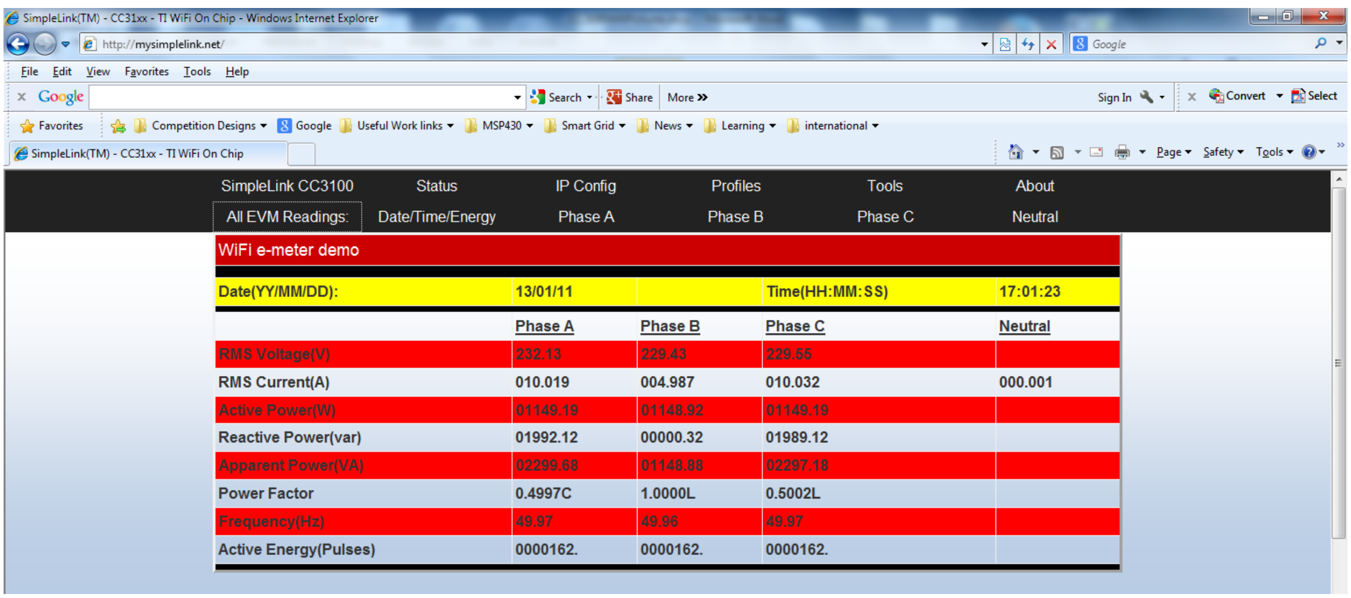


Figure 41. "All EVM Readings" Metrology Webpage (Internet Explorer)

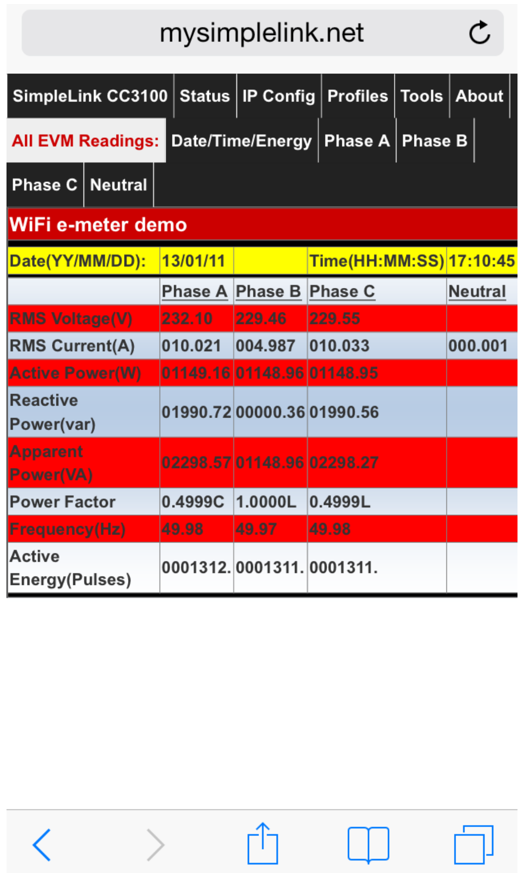


Figure 42. “All EVM Readings” Metrology Webpage (Safari through iOS 7.1.2)

To get the metrology webpages to properly display in a web browser, some of the web browser's default settings may have to be changed. For Mozilla Firefox, one of these default changes that may have to be changed is the proxy configuration. Particularly, no proxies should be used to access the internet. Make this change by selecting the *Advanced* section in the Firefox *Options* page and selecting the network tab within the advanced section, as is shown in Figure 43. From this screen, the *Settings* button should be pressed and the window in Figure 44 should pop up. From this window, the no proxy option should be changed to be selected as shown in the figure.

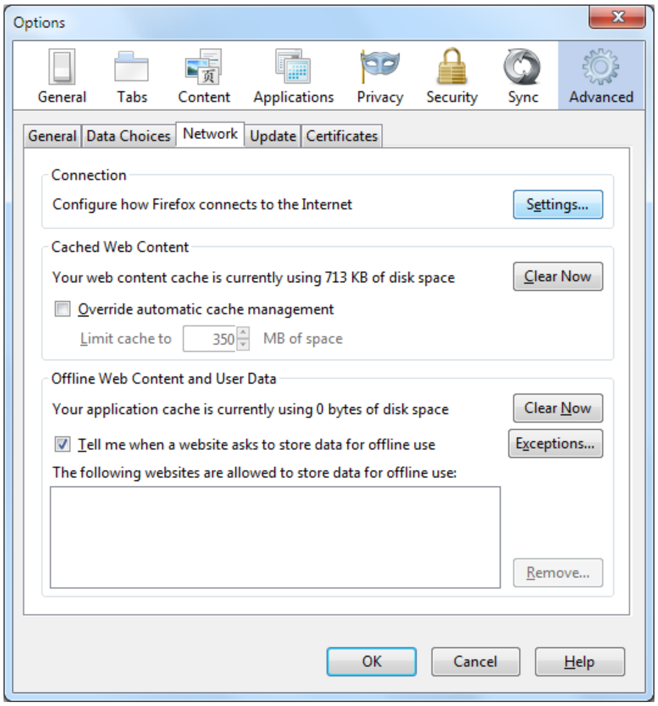


Figure 43. Firefox Options

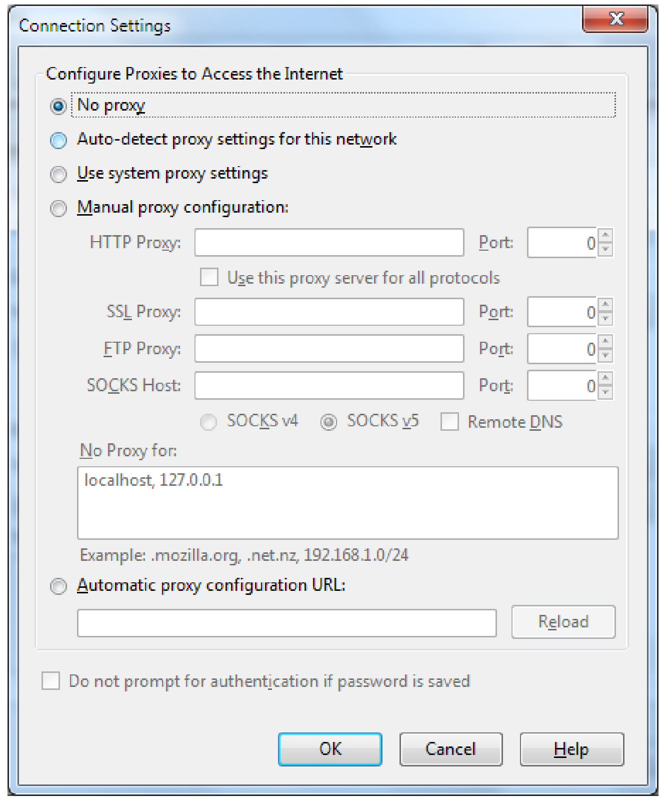


Figure 44. Proxy Settings

If using Internet Explorer, webpage caching may need to be disabled so that the values of the metrology parameters could be updated dynamically. This action can be done by opening the *Internet Options* window shown in Figure 45 and clicking *Settings* in the *Browsing History* section. From the resulting screen that pops up, the *Check for newer versions of stored pages* field should be changed to *Every time I visit the webpage*, as shown in Figure 46.

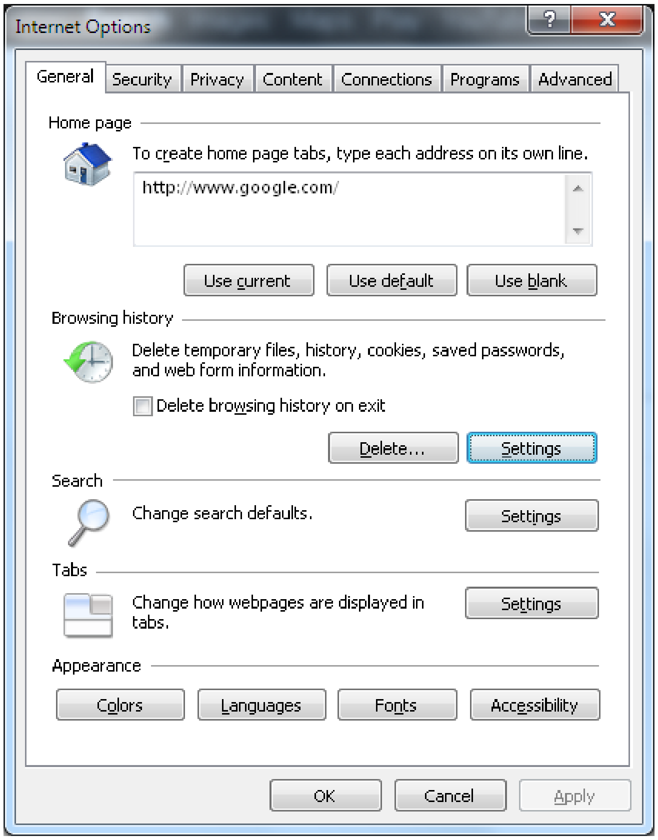


Figure 45. Internet Options Window

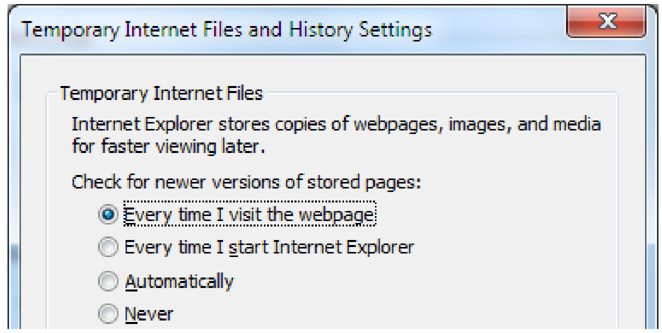


Figure 46. Webpage Caching Settings

5.4 Metrology Accuracy Results

In this section, metrology results are shown for cumulative 3-phase active energy. Figure 47 shows the results over a dynamic range of 2000:1 using the customized CTs that are provided with the EVM430-F6779. Table 9 shows the values for the error. Changing the EVM's CTs may result in better performance. Figure 48 shows the results over the same dynamic range using high-end CTs over the same current range. Table 10 shows the values for the error. All results were calibrated at 230 V, 10 A, 50 Hz.

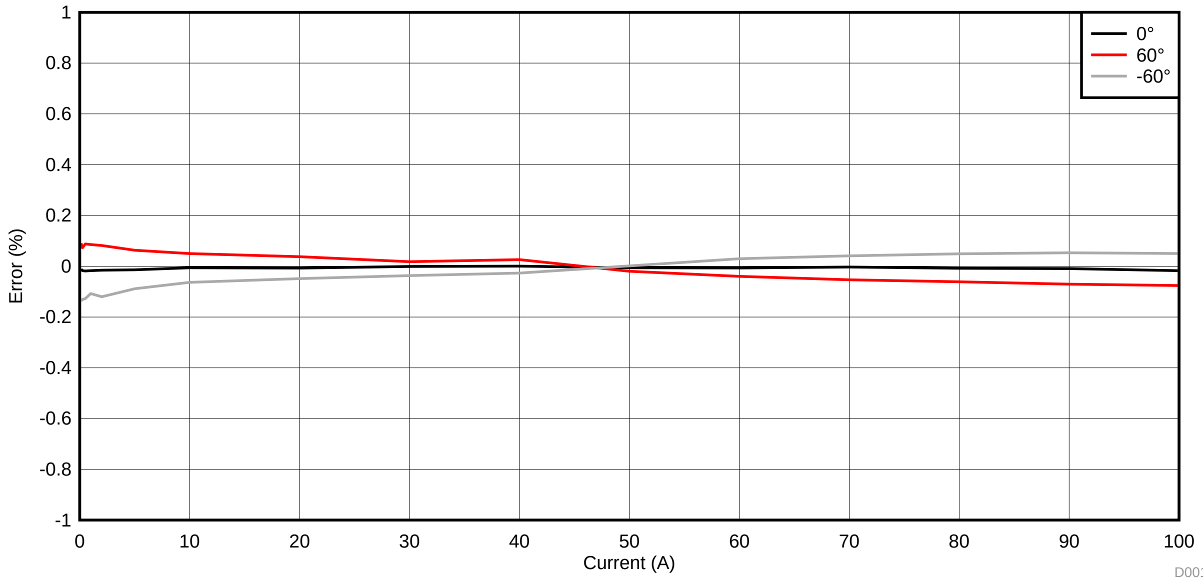


Figure 47. Energy Measurement Error Across Current with Customized CTs on EVM430-F6779

Table 9. Energy Measurement Error with Customized CTs on EVM430-F6779 (%)

CURRENT (A)	0°	60°	–60°
0.05	–0.02	0.0445	–0.147
0.1	–0.011	0.093	–0.1373
0.25	–0.0173	0.073	–0.131
0.5	–0.0187	0.0877	–0.1277
1	–0.0173	0.0853	–0.1077
2	–0.0157	0.0815	–0.1203
5	–0.014	0.0627	–0.0887
10	–0.006	0.0497	–0.0633
20	–0.0073	0.0377	–0.049
30	–0.001	0.018	–0.037
40	0.0003	0.026	–0.027
50	–0.006	–0.0197	0.0013
60	–0.007	–0.04	0.0297
70	–0.003	–0.0533	0.041
80	–0.0083	–0.0613	0.049
90	–0.0093	–0.0707	0.053
100	–0.0177	–0.0763	0.0497

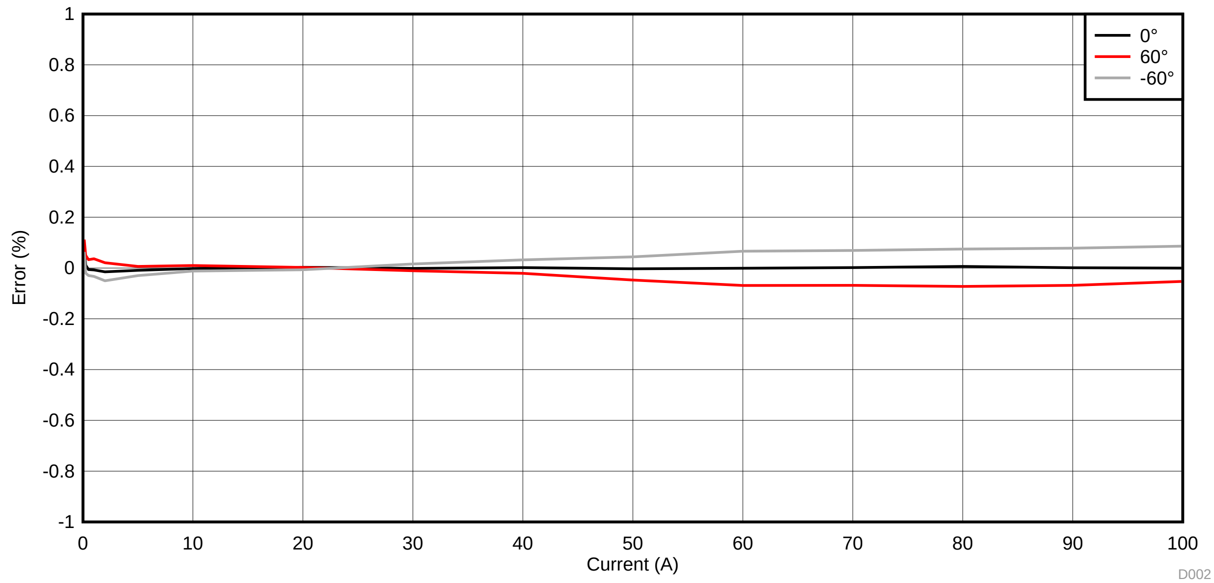


Figure 48. Energy Measurement Error Across Current with High-End CTs

Table 10. Energy measurement error with high-end CTs (%)

CURRENT (A)	0°	60°	–60°
0.05	0.048	0.1445	0.144
0.1	0.0857	0.1185	0.0725
0.25	0.011	0.05	-0.02
0.5	–0.006	0.0327	–0.0295
1	–0.0075	0.0365	–0.033
2	–0.015	0.0207	–0.0505
5	–0.009	0.006	–0.03
10	–0.002	0.0097	–0.012
20	0.0027	0.0023	–0.007
30	–0.0017	–0.0107	0.016
40	0.0015	–0.021	0.032
50	–0.003	–0.0473	0.0437
60	–0.001	–0.0687	0.066
70	0.0017	–0.0683	0.069
80	0.006	–0.0727	0.0747
90	0.001	–0.0683	0.078
100	–0.0007	–0.0527	0.0863

6 Design Files

6.1 Schematics

To download the schematics, see the design files at TIDC-3PHMTR-WIFIXR.

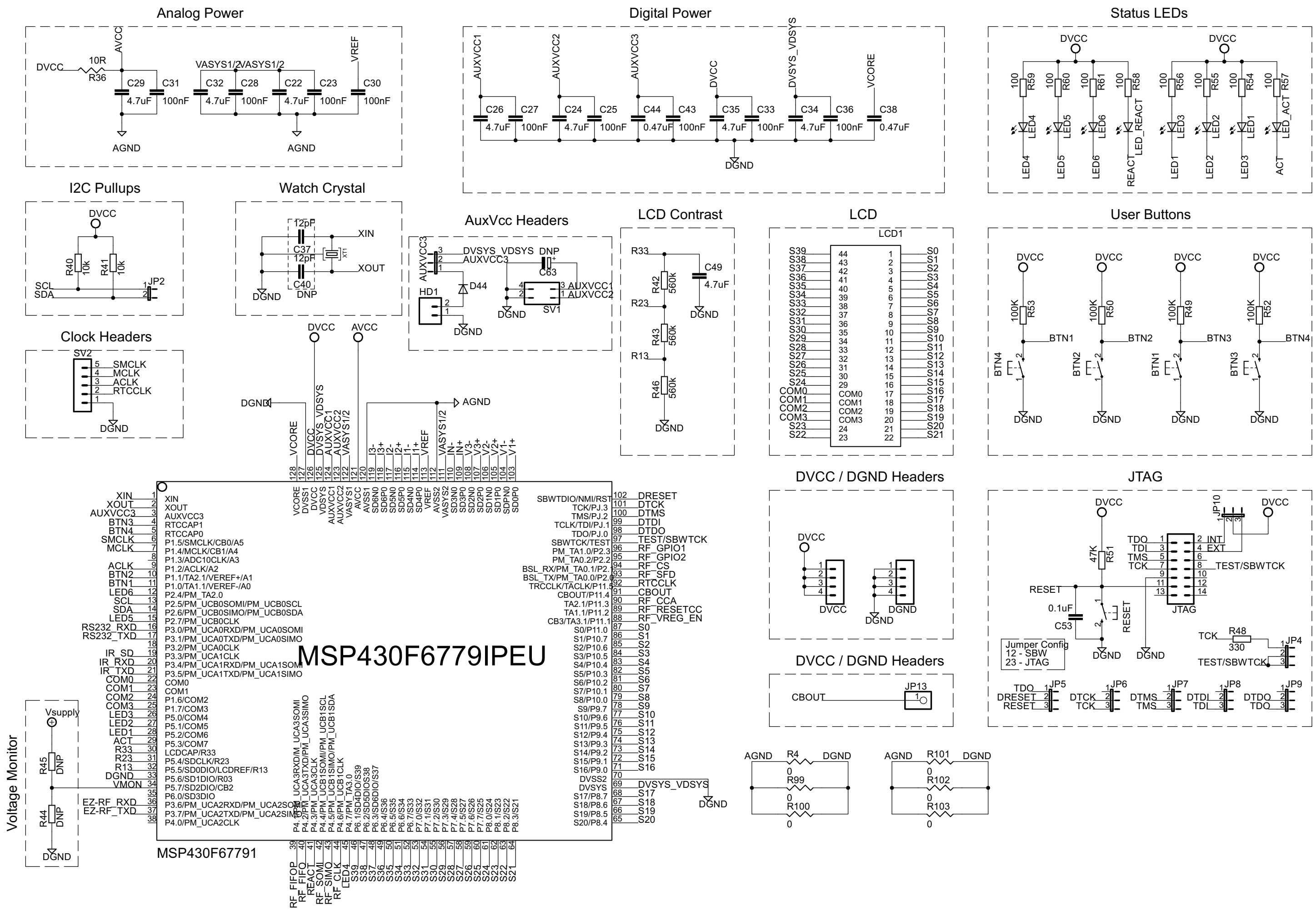


Figure 49. EVM430-F6779 Schematic Page 1

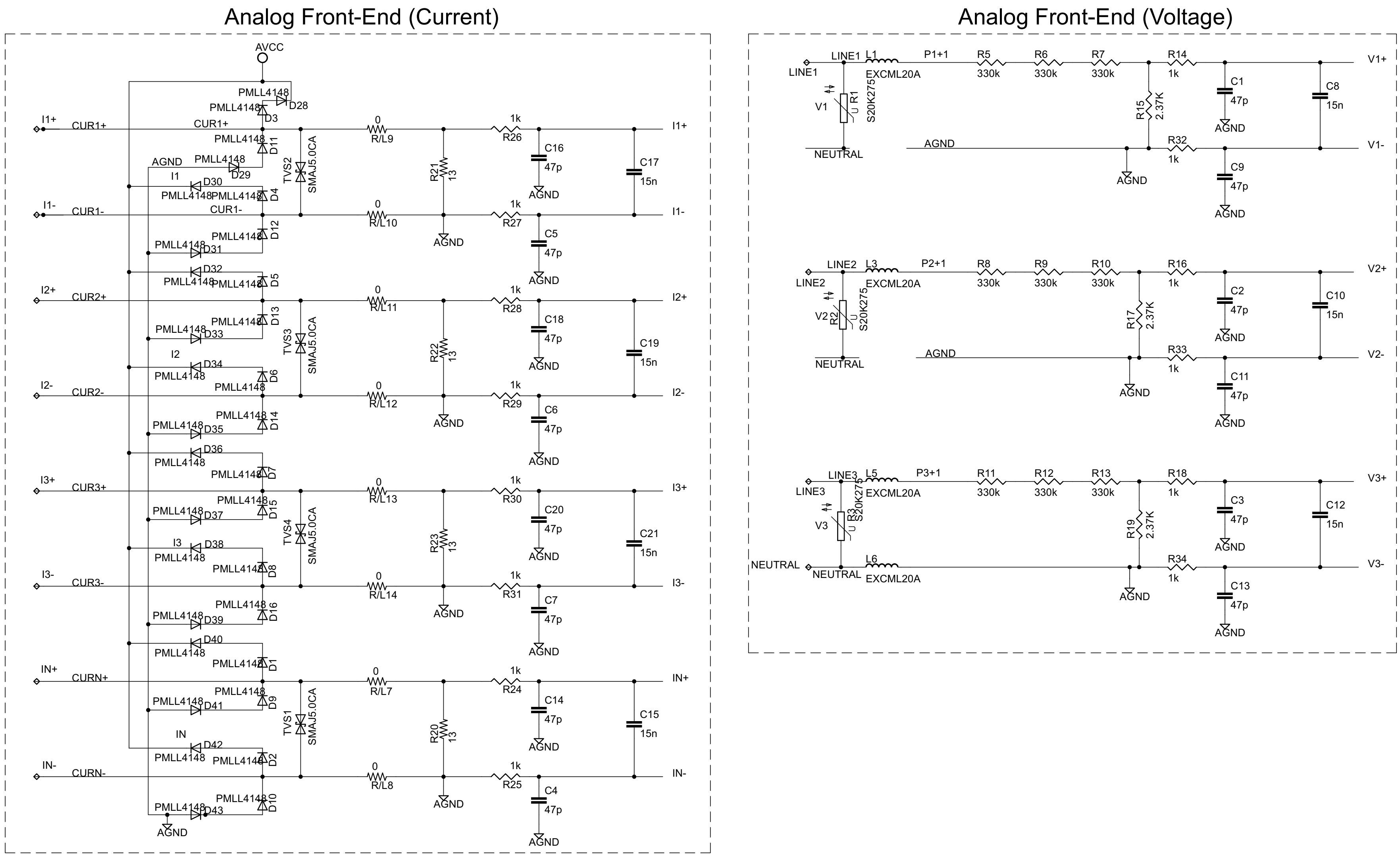


Figure 50. EVM430-F6779 Schematic Page 2

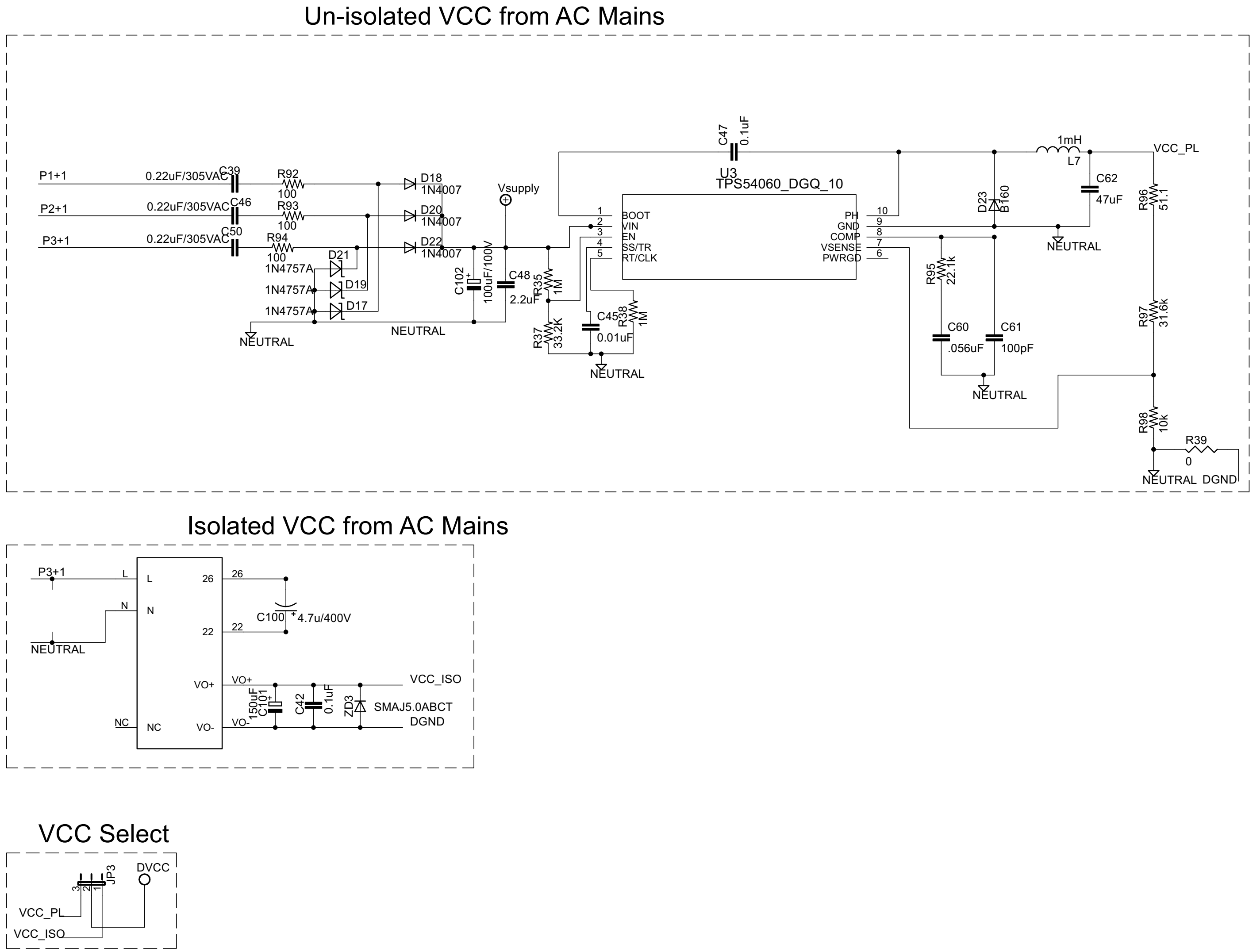


Figure 51. EVM430-F6779 Schematic Page 3

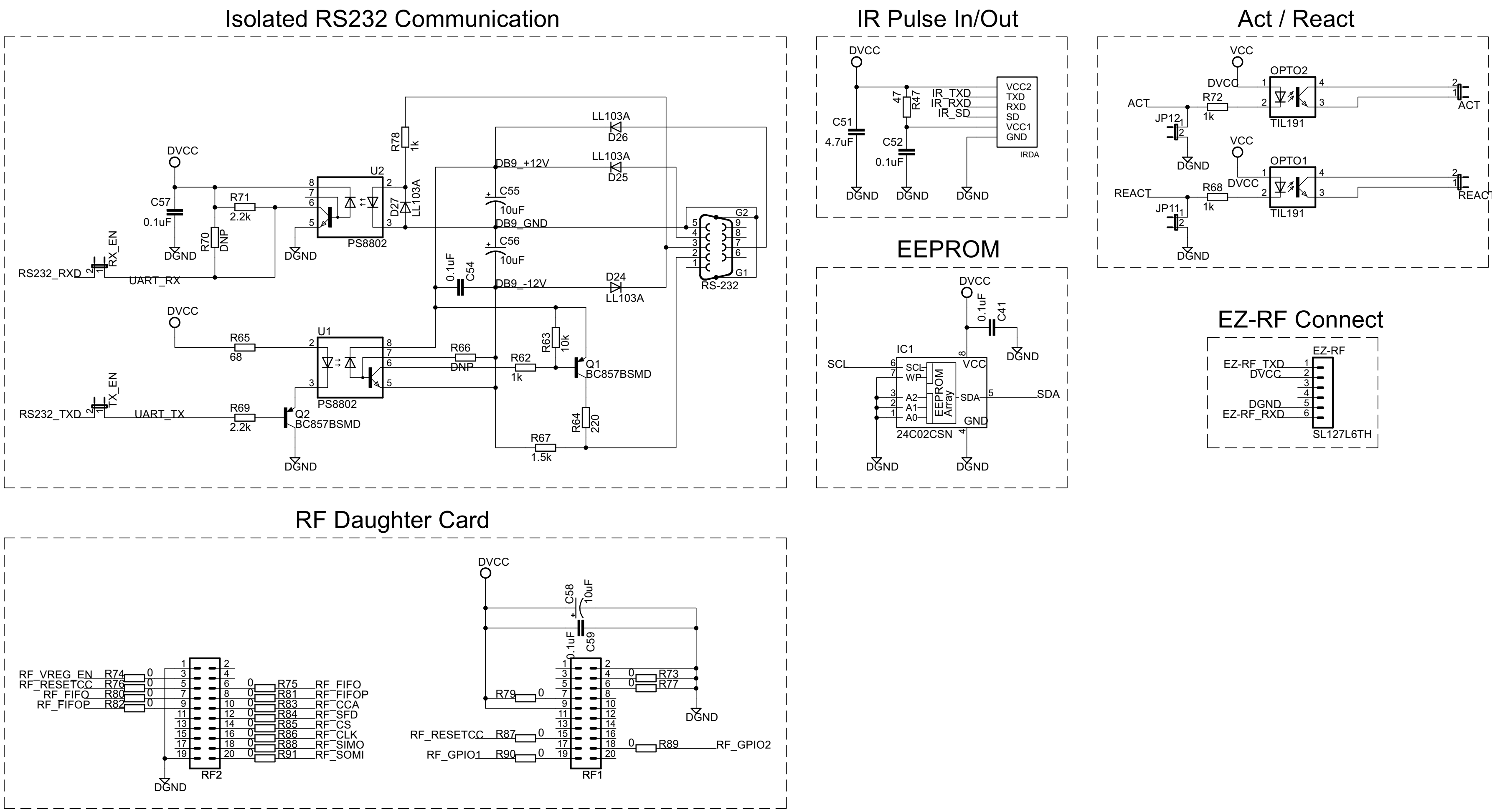


Figure 52. EVM430-F6779 Schematic Page 4

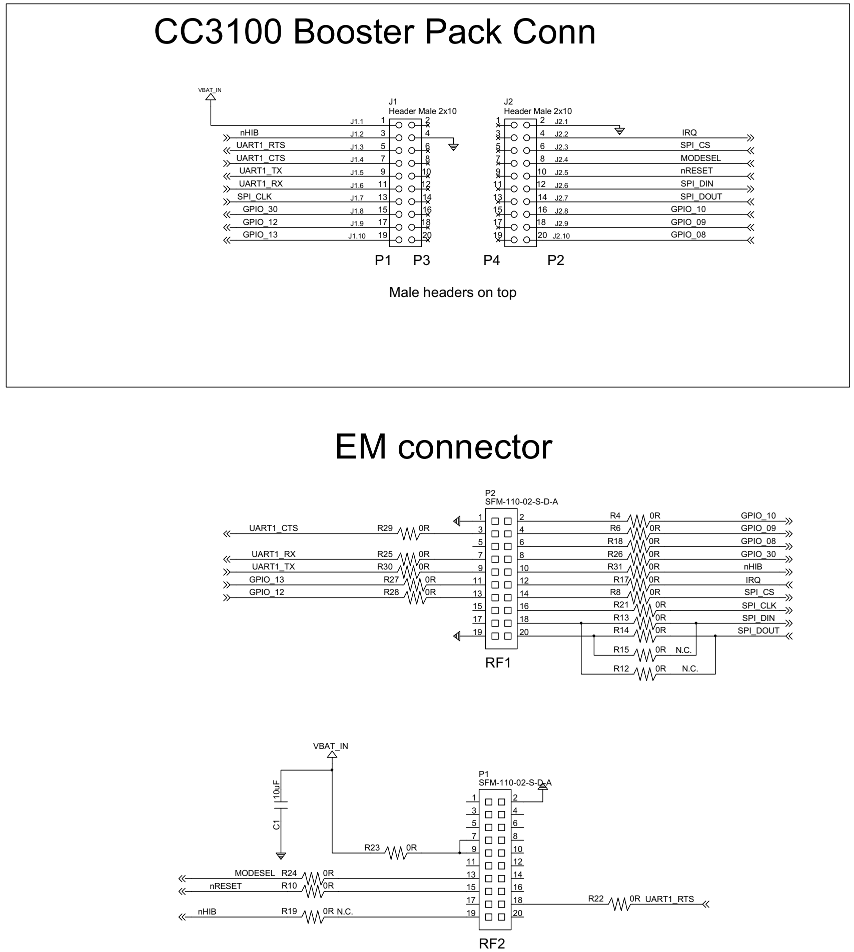


Figure 53. EM-BP_ADAPTER Schematic

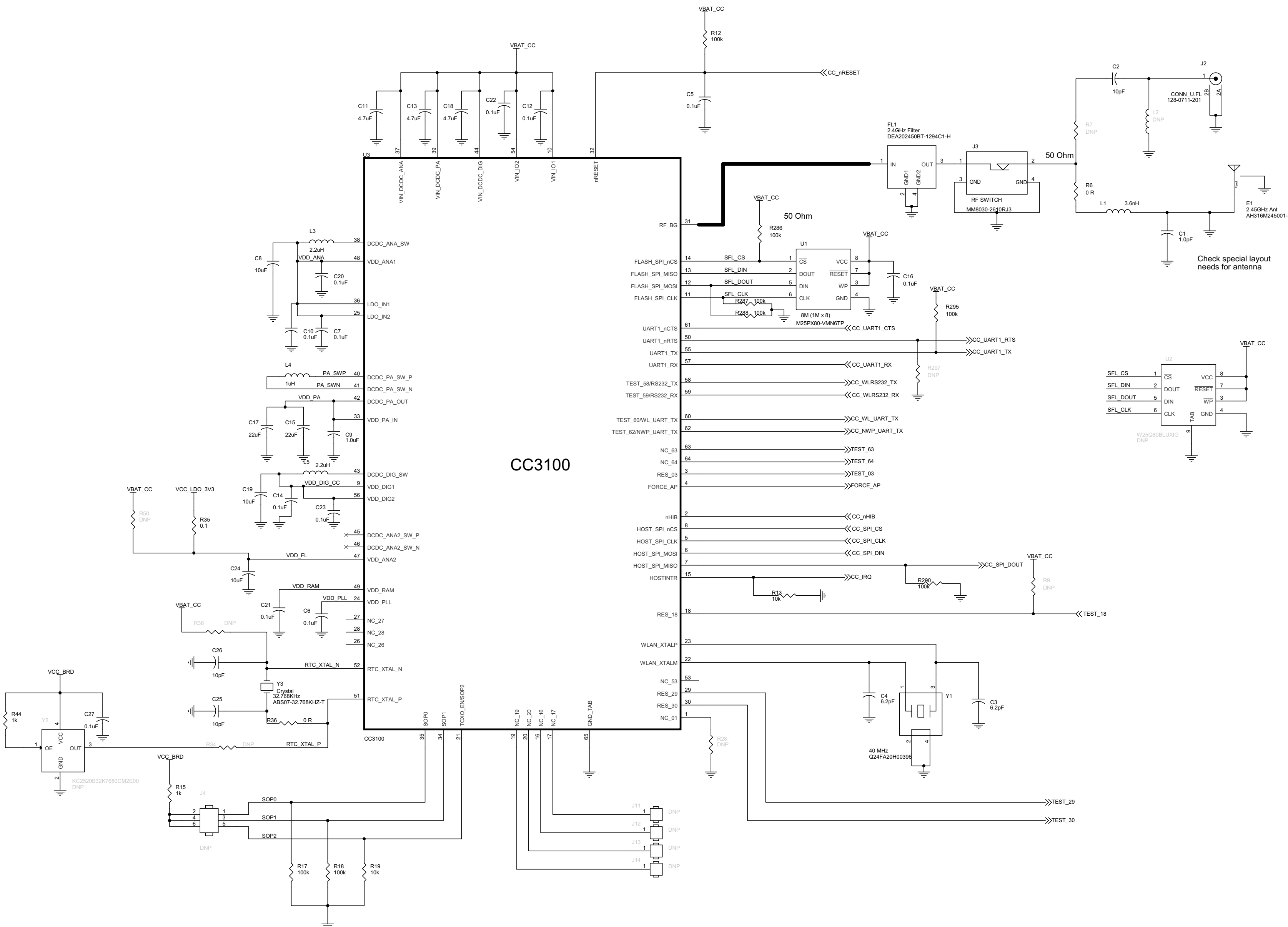


Figure 54. CC3100BOOST Schematic Page 1

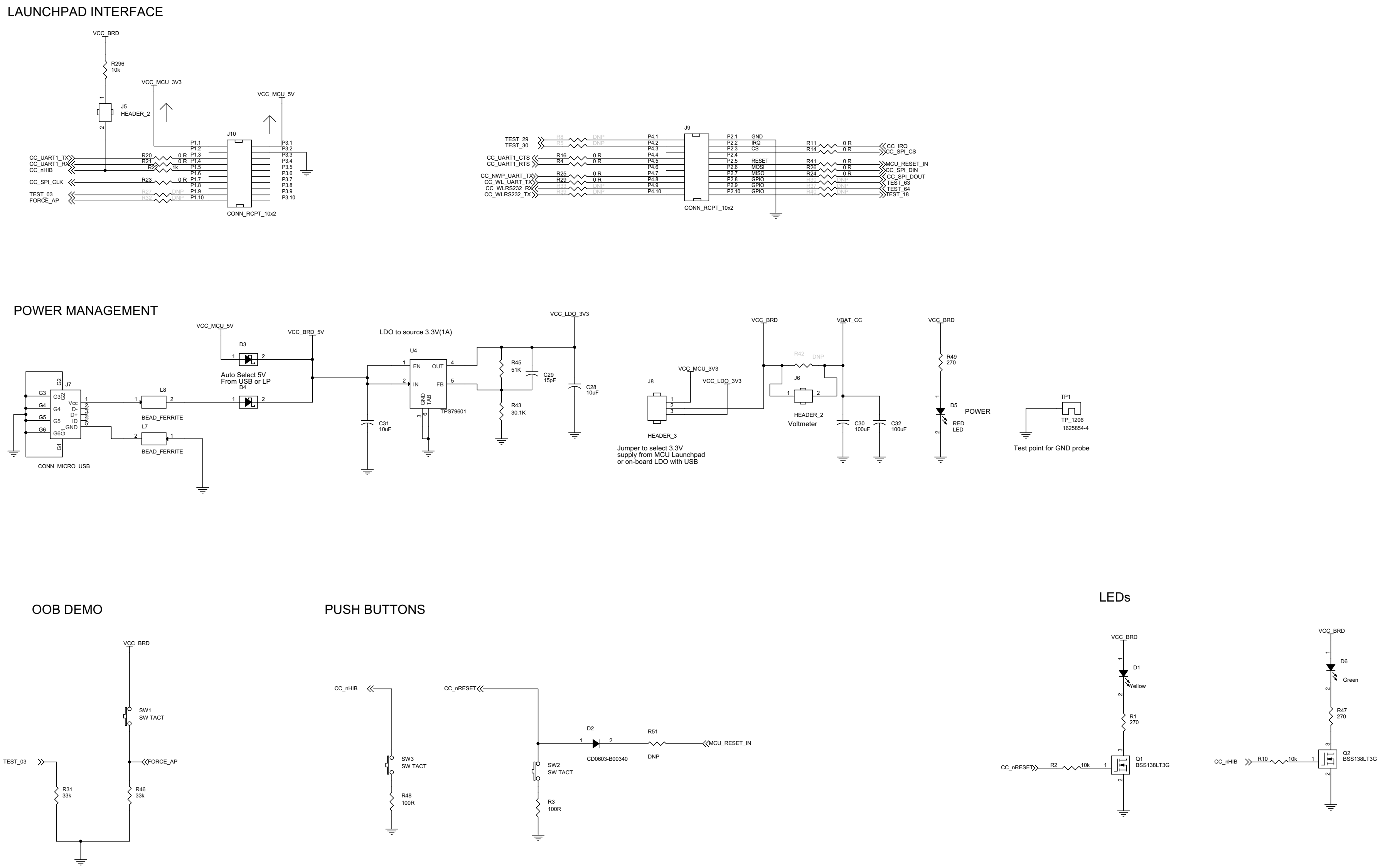


Figure 55. CC3100BOOST Schematic Page 2

6.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDC-3PHMTR-WIFIXR.

Table 11. BOM: EVM430-F6779

LINE	QTY	VALUE	DIGIKEY NUMBER	DESCRIPTION	BOARD DESIGNATOR
1	1	24C02CSN	24LC02B-I/SN-ND	IC EEPROM 2-KB, 400-KHZ 8SOIC	IC1
2	1	32.768 KHZ	300-8341-1-ND	Crystal 32.768 KHZ, 6 pF SMD	XT1
3	2	12 pF	311-1059-1-ND	CAP CER 12 pF, 50 V 5% NPO 0603	C37 C40
4	7	15 n	311-1143-1-ND	CAP CER 0.015 µF, 50 V 10% X7R 0805	C8 C10 C12 C15 C17 C19 C21
5	12	100 nF	311-1343-1-ND	CAP CER 0.1 µF, 50 V Y5V 0603	C23 C25 C27 C28 C30 C31 C33 C36 C43
6	7	0.1 µF	311-1343-1-ND	CAP CER 0.1 µF, 50 V Y5V 0603	C41 C42 C52 C53 C54 C57 C59
7	2	0.47 µF	311-1428-1-ND	CAP CER 0.47 µF, 16 V 10% X7R 0603	C38 C44
8	8	4.7 µF	311-1455-1-ND	CAP CER 4.7 µF, 10 V 10% X5R 0603	C22 C24 C26 C29 C32 C34 C35 C51 C49
9	14	47 p	311-1484-1-ND	CAP CER 47 pF, 500 V 5% NPO 0805	C1 C2 C3 C4 C5 C6 C7 C9 C11 C13 C14 C16 C18 C20
10	1	10 µF	399-3685-1-ND	CAP TANT 10 µF, 6.3 V 20% 1206	C55 C56 C58
11	1	4.7 u/400 V	399-6097-ND	CAP ALUM 4.7 µF, 400 V 20% Radial	C100
12	8	—	3M9447-ND	Conn Header Vert SGL 2POS Gold	ACT JP2 JP11 JP12 REACT RX_EN TX_EN HD1
13	8	—	3M9448-ND	Conn Header Vert SGL 3POS Gold	JP3 JP4 JP5 JP6 JP7 JP8 JP9 JP10 AUXVCC3
14	8	—	961105-6404-AR	Conn Header Vert SGL 5POS Gold	SV2
15	3	—	3M9449-ND	CONN HEADER VERT SGL 4POS Gold	DGND DVCCs
16	1	—	A106735-ND	CONN HEADER VERT DUAL 4POS Gold	SV1
17	8	0	RMCF0805ZT0R00CT-ND	RES 0.0 Ω, 1/8 W 0805 SMD	R/L7 R/L8 R/L9 R/L10 R/L11 R/L12 R/L13 R/L14
18	4	S20K275	495-1417-ND	Varistor 275 V_{RMS} 20-MM Radial	R1 R2 R3
19	2	Orange	511-1245-ND	LED 3.1 MM, 610 NM Orange Transparent	LED_3 LED_4
20	2	Green	511-1247-ND	LED 3.1 MM, 563 NM Green Transparent	LED_1 LED_6
21	2	Red	511-1249-ND	LED 3.1 MM, 650 NM Red Transparent	LED_ACT LED_REACT
22	2	Yellow	511-1251-ND	LED 3.1 MM, 585 NM Yellow Transparent	LED_2 LED_5
23	32	PMLL4148	568-1749-1-ND	Diode SW GPP 75 V, 200 MA SOD80C	D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12 D13 D14 D15 D16 D28 D29 D30 D31 D32 D33 D34 D35 D36 D37 D38 D39 D40 D41 D42 D43 D44
24	2	BC857BSMD	568-6094-1-ND	Transistor PNP 45 V, 100 MA SOT23	Q1 Q2
25	1	TFBS4711-TT1	751-1068-1-ND	TXRX IRDA 115.2 KB, 1.9 MM 6-SMD	IRDA
26	1	—	A32036-ND	CONN D-SUB RCPT STR 9POS 30GOLD	RS1
27	4	LL103A	LLSD103ADICT-ND	Diode Schottky 40 V, 350 MW MINIMELF	D24 D25 D26 D27
28	1	—	MHC14K-ND	Conn Header 14 POS Straight Gold	JTAG
29	6	EXCML20A	P10191CT-ND	Bead Core 4 A, 100 MHZ 0805 SMD	L1 L3 L5 L6

Table 11. BOM: EVM430-F6779 (continued)

LINE	QTY	VALUE	DIGIKEY NUMBER	DESCRIPTION	BOARD DESIGNATOR
30	1	150uF	P14374-ND	CAP ALUM 150 µF, 10 V 20% RADIAL	C101
31	4	—	P8079SCT-ND	Switch Tactile SPST-NO 0.02 A, 15 V	BTN1 BTN2 BTN3 BTN4 RESET
32	2	TIL191	PS2501-1A-ND	Optocoupler 1CH TRANS 4-DIP	OPTO1 OPTO2
33	2	PS8802	PS8802-1-F3-AXCT-ND	Optoisolator Analog HS OUT 8SSOP	U1 U2
34	1	68	RMCF0603FT68R0CT-ND	RES TF 68 Ω, 1% 0.1 W 0603	R65
35	8	100	RMCF0603JT100RCT-ND	RES 100 Ω, 1/10 W 5% 0603 SMD	R54 R55 R56 R57 R58 R59 R60 R61
36	2	1 k	RMCF0603JT1K00CT-ND	RES 1 KΩ, 1/10 W 5% 0603 SMD	R62 R68 R72 R78
37	1	1.5 k	RMCF0603JT1K50CT-ND	RES 1.5 KΩ, 1/10 W 5% 0603 SMD	R67
38	1	220	RMCF0603JT220RCT-ND	RES 220 Ω, 1/10 W 5% 0603 SMD	R64
39	2	2.2 k	RMCF0603JT2K20CT-ND	RES 2.2K Ω, 1/10 W 5% 0603 SMD	R69 R71
40	1	330	RMCF0603JT330RCT-ND	RES 330 Ω, 1/10 W 5% 0603 SMD	R48
41	1	47 K	RMCF0603JT47K0CT-ND	RES 47 KΩ, 1/10 W 5% 0603 SMD	R51
42	1	47	RMCF0603JT47R0CT-ND	RES 47 Ω, 1/10 W 5% 0603 SMD	R47
43	18	0	RMCF0603ZT0R00CT-ND	RES 0.0 Ω, 1/10 W 0603 SMD	R73 R74 R75 R76 R77 R79 R80 R81 R82 R83 R84 R85 R86 R87 R88 R89 R90 R91
44	5	560 k	RMCF0805FT560KCT-ND	RES TF 560 KΩ, 1% 0.125 W 0805	R42 R43 R46
45	4	100 K	RMCF0805JT100KCT-ND	RES 100 KΩ, 1/8 W 5% 0805 SMD	R49 R50 R52 R53
46	3	10 k	RMCF0805JT10K0CT-ND	RES 10 KΩ, 1/8 W 5% 0805 SMD	R40 R41 R63
47	1	10 R	RMCF0805JT10R0CT-ND	RES 10 Ω, 1/8 W 5% 0805 SMD	R36
48	14	1 k	RMCF0805JT1K00CT-ND	RES 1.0 KΩ, 1/8 W 5% 0805 SMD	R14 R16 R18 R24 R25 R26 R27 R28 R29 R30 R31 R32 R33 R34
49	3	2K37	RMCF0805FT2K37CT-ND	RES 2.37 KΩ, 1/8 W 1% 0805 SMD	R15 R17 R19
50	9	330 k	RMCF0805JT330KCT-ND	RES 330 KΩ, 1/8 W 5% 0805 SMD	R5 R6 R7 R8 R9 R10 R11 R12 R13
51	4	13	RMCF0805FT13R0CT-ND	RES 13 Ω, 1/8 W 1% 0805 SMD	R20 R21 R22 R23
52	1	0	RMCF0805ZT0R00CT-ND	RES 0.0 Ω, 1/8 W 0805 SMD	R4 R39 R99 R100 R101 R102 R103
53	2	—	Must Order From Samtec	Conn Header 20POS 1.27 MM GLD SMD	RF1 RF2
54	1	SMAJ5.0ABCT	SMAJ5.0ABCT-ND	Diode TVS 5.0 V, 400 W UNI 5% SMD	ZD3
55	4	SMAJ5.0CA	SMAJ5.0CABCT-ND	Diode TVS 5.0 V, 400 W BI 5% SMD	TVS1 TVS2 TVS3 TVS4
56	1	SL127L6TH		Mill-Max 850-10-006-20-001000	EZ-RF
57	1	TI_160SEG_LCD	Custom		LCD1
58		DNP			R44 R45
59		DNP			C63
60	1	DNP			R66
61	1	DNP			R70

Table 11. BOM: EVM430-F6779 (continued)

LINE	QTY	VALUE	DIGIKEY NUMBER	DESCRIPTION	BOARD DESIGNATOR
62	1	CUI_XR	102-1801-ND	Isolated Power Supply, 3.3 V, 700 mA	U$1
63	1	MSP430F67791IPEU	From Texas Instruments		
64	1	100 µF	1189-1020-ND	CAP Electrolytic 100 µF 100 V 20%, 10 mm(diameter) × 25 mm (height), ZL Rubycon, 5-mm spacing	C102
65	3	0.22 µF	495-2320-ND	CAP Poly 0.22 µF 305-V AC/630-V DC X2 10% (B32922C3224M)	C39 C46 C50
66	1	2.2 µF	445-4497-2-ND	CAP Ceramic 2.2 µF, 100 V X7R 1210	C48
67	1	0.01 µF	445-5100-1-ND	CAP CER 10000 pF, 25 V 10% X7R 0603	C45
68	1	47 µF	587-1383-1-ND	CAP Ceramic 47 µF, 10 V X5R 1210	C62
69	1	0.1 µF	399-1095-1-ND	CAP Ceramic 0.1 µF, 10 V X5R 0603	C47
70	1	.056 µF	490-6433-1-ND	CAP Ceramic .056 µF, 25 V X7R 10% 0603	C60
71	1	100 pF	399-6841-1-ND	CAP Ceramic 100 pF, 25 V NPO, 5% 0603	C61
72	1	B160	641-1107-1-ND	Diode Schottky 1 A ,60 V B160 SMB	D23
73	3	48 V	1N4757ADICT-ND	Diode Zener 51 V, 1 W 1N4757A D0-41	D17 D19 D21
74	3	1N4007	1N4007FSCT-ND	Diode Gen Purpose 1000 V, 1 A DO41	D18 D20 D22
75	1	1 mH	Must order from CoilCraft (MSS1038-105)	Inductor, SMT, MSS1038-105 (.402 x .394 inch)	L7
76	1	1 M	A102234CT-ND	RES 1 MΩ, 1/16 W 1% 0603	R35 R38
77	1	33.2 k	RNCS0603BKE33K2CT-ND	RES 33.2 KΩ, 1/16 W .1% 0603	R37
78	1	22.1 k	A102241CT-ND	RES 22.1 KΩ, 1/16 W 1% 0603	R95
79	1	51.1	A102292TR-ND	RES 51.1 Ω, 1/16 W 1% 0603	R96
80	1	31.6 k	A102261DKR-ND	RES 31.6 KΩ, 1/16 W 1% 0603	R97
81	1	10.0 k	A102331CT-ND	RES 10.0 KΩ, 1/16 W 0.1% 0603	R98
82	3	100	P100W-2BK-ND	RES 100 Ω, 2 W 5% AXIAL	R92 R93 R94
83	1	TPS54060ADGQ	296-30339-5-ND	IC Reg Buck ADJ 0.5 A 10MSOP	U3

Table 12. BOM: CC3100-EM-BP_ADAPTER-Rev1.0

LINE	QTY	VALUE	DIGIKEY NUMBER	DESCRIPTION	BOARD DESIGNATOR
1	2	M50-4301045	952-1404-5-ND	Conn RCPT 1.27 MM SMD AU 20POS	P1 P2
2	1	10 µF	490-3896-1-ND	CAP CER 10 µF, 6.3 V 20% X5R 0603	C1
3	2	Header Male 2×10	609-3375-ND	Conn Header 20POS .100 STR 15AU	J1 J2
4	19	0 R	311-0.0HRCT-ND	RES 0.0 Ω, 1/10 W JUMP 0603 SMD	R4 R6 R8 R10 R13 R14 R17 R18 R21 R22 R23 R24 R25 R26 R27 R28 R29 R30 R31
5	3	DNP			R12 R15 R19

Table 13. BOM: CC3100BOOST_Rev4p0-A

LINE	QTY	VALUE	DIGIKEY NUMBER	DESCRIPTION	BOARD DESIGNATOR
1	1	10 pF	478-5991-1-ND	CAP CER 10 pF 50 V NP0 0402	C2
2	1	CONN_MICRO_USB	609-4618-1-ND	Conn USB Micro B RECPT SMT R/A	J7
3	1	1 k	A106129CT-ND	RES 1.00 KΩ 1/16 W 5% 0402	R22
4	1	CONN_U.FL	J983CT-ND	Conn UMC RCPT STR 50 Ω SMD	J2
5	1	TP_1206	A106146CT-ND	1206 Probe Pad	TP1
6	1	HEADER_3	A106719-ND	Conn HDR BRKWAY .100 3POS VERT	J8
7	2	HEADER_2	5-146285-2-ND	Conn HEADR BRKWAY .100 2POS STR	J5 J6
8	1	Crystal	535-9542-1-ND	Crystal 32.768 KHZ 12.5 pF SMD	Y3
9	1	2.45-GHz Ant	587-2200-1-ND	ANT Bluetooth W-LAN ZIGBEE WIMAX	E1
10	2	22 µF	587-3262-1-ND	CAP CER 22 µF 4 V 20% X5R 0603	C15 C17
11	2	BSS138LT3G	BSS138LT3GOSCT-ND	MOSFET N-CH 50 V 200 MA SOT-23	Q1 Q2
12	2	100 µF	445-6008-1-ND	CAP CER 100 µF 6.3V 20% X5R 1206	C30 C32
13	1	CC3100	Texas Instruments Part Number: CC3100R	802.11bg Wi-Fi Processor	U3
14	1	CD0603-B00340	CD0603-B00340CT-ND	Diode Schottky 40 V 0.03 A 0603	D2
15	3	4.7 µF	1276-1056-1-ND	CAP CER 4.7 µF 6.3 V 20% X5R 0402	C11 C13 C18
16	1	2.4-GHz Filter	445-172335-1-ND	Filter Bandpass 2.45 GHZ WLAN SMD	FL1
17	1	DNP	DNP	Do Not Mount	R51
18	14	0 R	P0.0JCT-ND	RES 0.0 Ω 1/10 W JUMP 0402 SMD	R4 R6 R11 R14 R16 R20 R21 R23 R24 R25 R26 R29 R36 R41
19	2	100 R	P100JCT-ND	RES 100 Ω 1/10 W 5% 0402 SMD	R3 R48
20	3	270	P270GCT-ND	RES 270 Ω 1/10 W 5% 0603 SMD	R1 R47 R49
21	1	0.1	P.10AHCT-ND	RES 0.1 Ω 1/10 W 5% 0603 SMD	R35
22	3	SW TACT	P8070SCT-ND	Switch Tactile SPST-NO 0.02 A 15 V	SW1 SW2 SW3
23	1	1.0 pF	490-6073-1-ND	CAP CER 1 pF 50 V NP0 0402	C1
24	2	10 pF	490-6186-1-ND	CAP CER 10 pF 50 V 1% NP0 0402	C25 C26
25	1	15 pF	490-5888-1-ND	CAP CER 15 pF 50 V 5% NP0 0402	C29
26	2	6.2 pF	490-8224-1-ND	CAP CER 6.2 pF 50 V NP0 0402	C3 C4
27	1	1.0 µF	490-5409-2-ND	CAP CER 1 µF 10 V 20% X5R 0402	C9
28	3	10 µF	490-3896-1-ND	CAP CER 10 µF 6.3 V 20% X5R 0603	C8 C19 C24
29	2	10 µF	490-1709-1-ND	CAP CER 10 µF 10 V 10% X5R 0805	C28 C31
30	1	LED	475-1409-1-ND	LED CHIPLED 570 NM Green 0603 SMD	D6
31	12	0.1 µF	587-1227-1-ND	CAP CER 0.1 µF 10 V 10% X5R 0402	C5 C6 C7 C10 C12 C14 C16 C20 C21 C22 C23 C27

Table 13. BOM: CC3100BOOST_Rev4p0-A (continued)

LINE	QTY	VALUE	DIGIKEY NUMBER	DESCRIPTION	BOARD DESIGNATOR
32	1	1 µH	490-6699-1-ND	Inductor Power 1.0UH 1007	L4
33	2	2.2 µH	490-5114-1-ND	Inductor 2.2 µH 20% 1300 MA 1008	L3 L5
34	1	3.6 nH	490-6756-1-ND	Inductor 3.6 NH 0.1 NH 0402	L1
35	1	LED	475-2558-1-ND	LED CHIPLED 587 NM YLW 0603 SMD	D1
36	1	8 M (1 M × 8)	M25PX80-VMN6TPCT-ND	IC FLASH 8MB 75MHZ 8SO	U1
37	2		MBR130T1GOSCT-ND	Diode Schottky 30 V 1 A SOD123	D3 D4
38	2	BEAD_FERRITE	240-2389-1-ND	Ferrite 1.5 A 40 Ω 0805 SMD	L7 L8
39	1	RF Switch	490-5907-2-ND	Conn SWG JACK STR 50 Ω SMD	J3
40	1	Crystal	Epson Part Number: Q24FA20H00396	Crystal 40 MHZ 8 pF SMD	Y1
41	1	30.1 K	311-30.1KLRCT-ND	RES 30.1 KΩ 1/16 W 1% 0402 SMD	R43
42	2	33 k	311-33.0KLRCT-ND	RES 33.0 KΩ 1/16 W 1% 0402 SMD	R31 R46
43	8	100 k	311-100KJRCT-ND	RES 100 KΩ 1/16 W 5% 0402 SMD	R12 R17 R18 R286 R287 R288 R290 R295
44	5	10 k	311-10KJRCT-ND	RES 10 KΩ 1/16 W 5% 0402 SMD	R2 R10 R13 R19 R296
45	2	1 k	311-1.0KJRCT-ND	RES 1.0 KΩ 1/16 W 5% 0402 SMD	R15 R44
46	1	51 K	1276-4178-1-ND	RES 51 KΩ 1/16 W 1% 0402	R45
47	1	LED	67-1551-1-ND	LED SUPR RED DIFF 660 NM SMD 0603	D5
48	2	CONN_RCPT_10x2	SAM1196-10-ND	Conn RCPT .100" 20POS Dual Gold	J9 J10
49	1	TPS79601	296-13761-1-ND	IC, VREG, LDO, 1.2 to 5.5 V, 2.7 to 5.5 V, —, 6PIN, SOT-223	U4

6.3 Layer Plots

To download the layer plots, see the design files at TIDC-3PHMTR-WIFIXR.

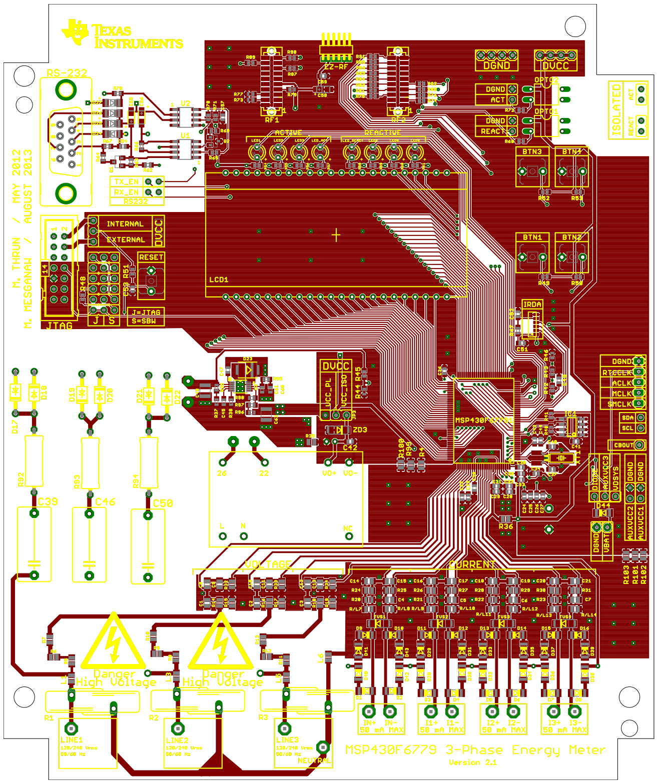


Figure 56. EVM430-F6779 Top Layer

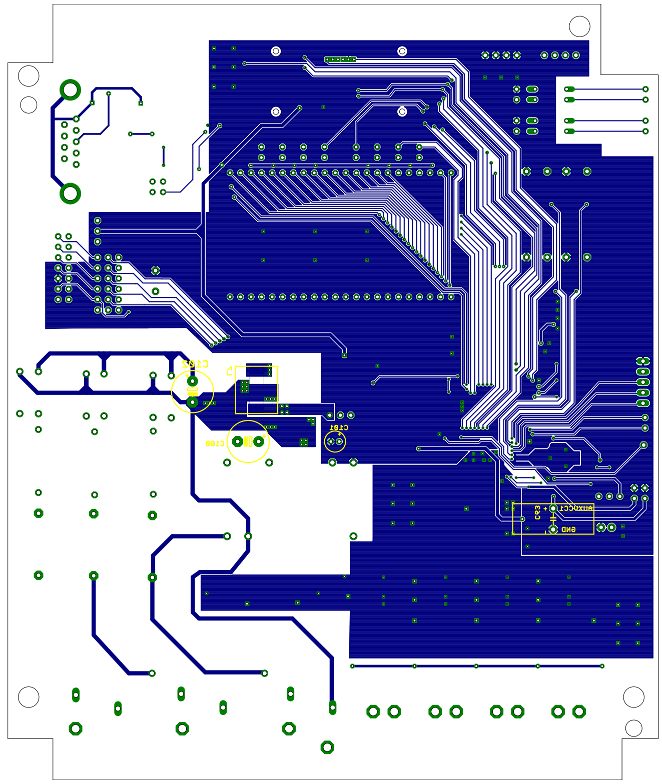


Figure 57. EVM430-F6779 Bottom Layer

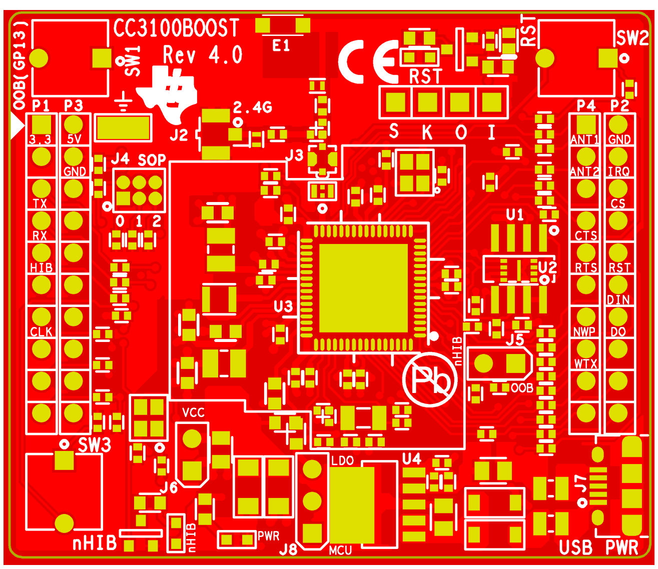


Figure 58. CC3100BOOST Top Silk

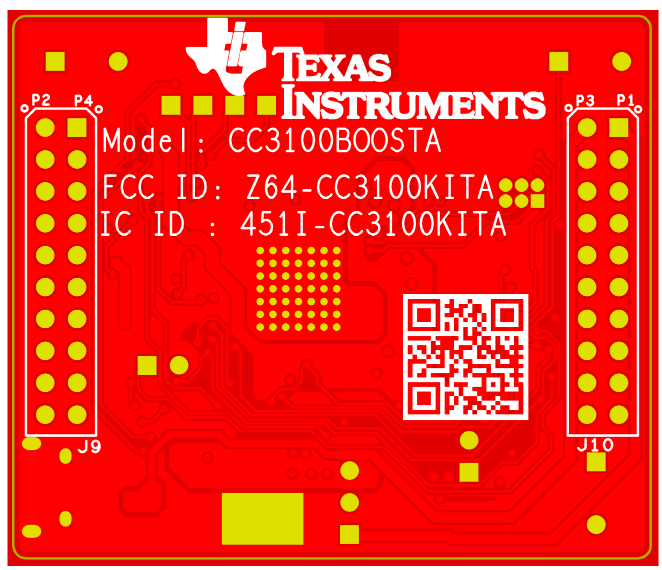


Figure 59. CC3100BOOST Bottom Silk

6.4 CAD Project Files

To download the CAD project files, see the design files at TIDC-3PHMTR-WIFIXR.

6.5 Gerber Files

To download the Gerber files, see the design files at [TIDC-3PHMTR-WIFIXR](http://www.ti.com/tool/TIDC-3PHMTR-WIFIXR).

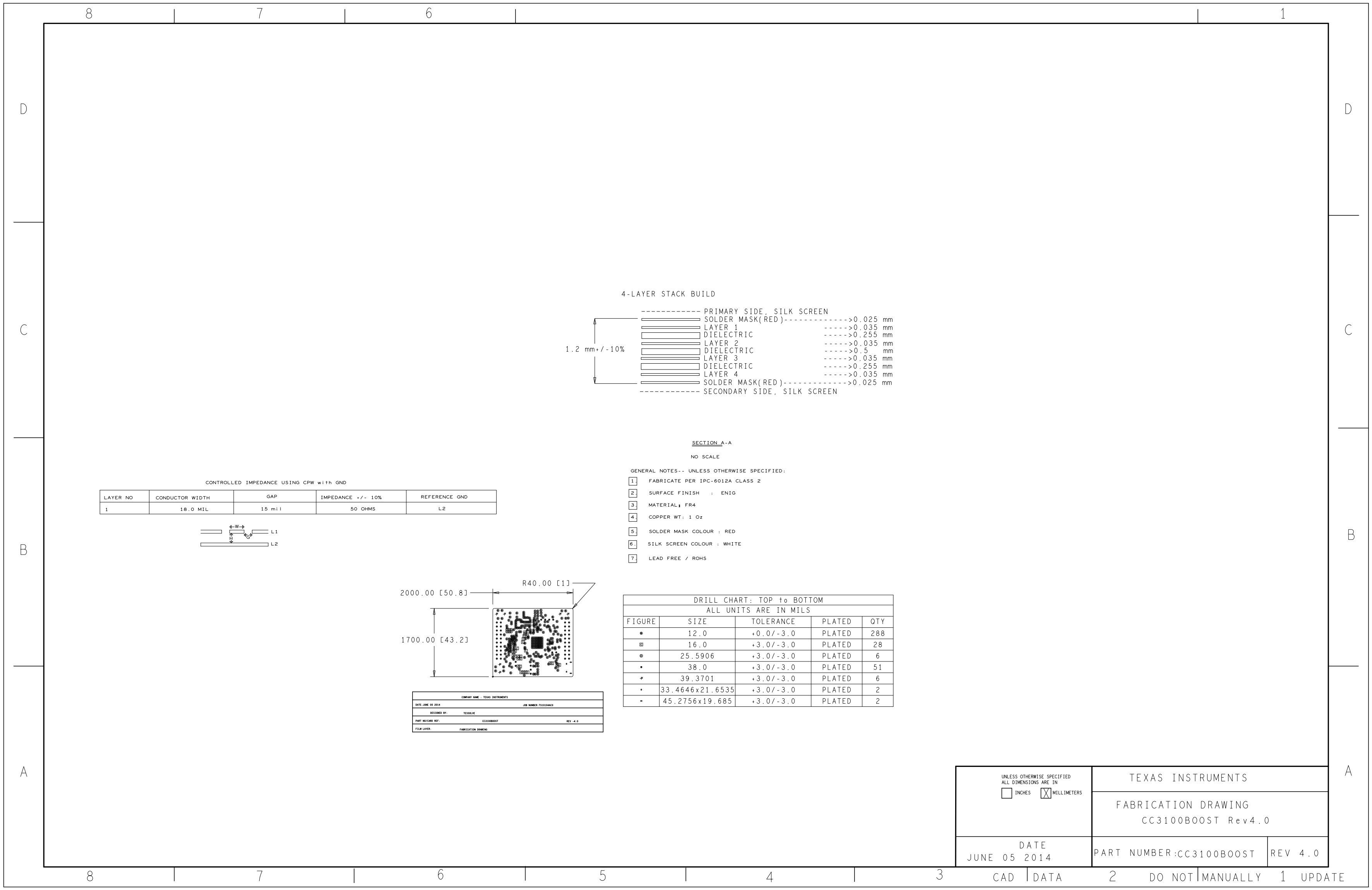


Figure 60. Fabrication Drawing

6.6 Assembly Drawings

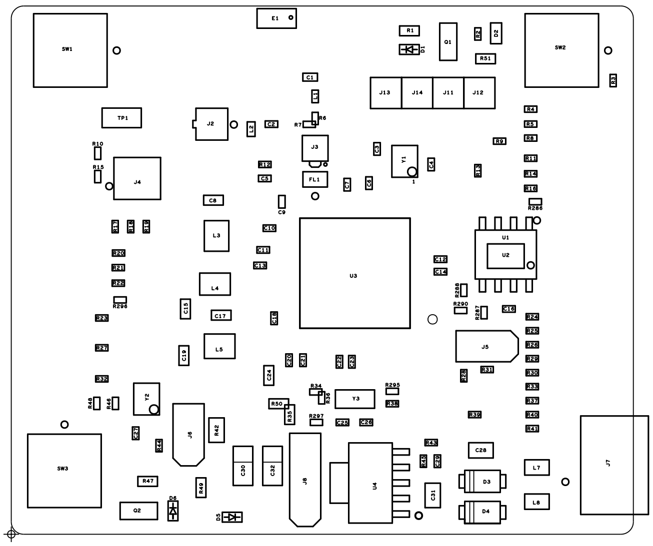


Figure 61. Primary Side

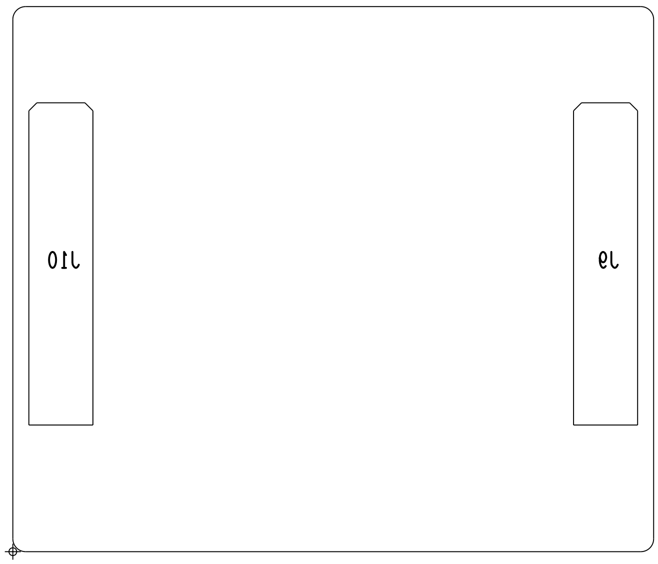


Figure 62. Secondary Side

6.7 Software Files

To download the software files, see the design files at TIDC-3PHMTR-WIFIXR.

7 References

1. CC3100 SimpleLink™ Wi-Fi® and IoT Solution BoosterPack Hardware (SWRU371)
2. CC3100\CC3200 SimpleLink™ Wi-Fi® NetworkProcessor Subsystem (SWRU368)

8 About the Author

MEKRE MESGANAW is a system applications engineer in the Smart Grid and Energy group at Texas Instruments, where he primarily works on electricity metering customer support and reference design development. Mekre received his bachelor of science and master of science in computer engineering from the Georgia Institute of Technology.

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