

TI Designs

Wi-Fi Enabled Level 1 and Level 2 Electric Vehicle Service Equipment Reference Design



TI Designs

This verified TI Design details how to implement J1772-compliant level 1 and level 2 electric vehicle service equipment (EVSE) with added Wi-Fi® functionality. The CC3100 network processor enables highly embedded devices like the EVSE to easily connect to an existing wireless network or directly to a device. By integrating this functionality in an EVSE, the design is capable of remote-power monitoring and control of the charging state of the connected electric vehicle.

Design Resources

TIDA-00637	Design Folder
CC3100	Product Folder
OPA1717	Product Folder
UCC28910	Product Folder
TPS62063	Product Folder
LM7322	Product Folder
TPL7407L	Product Folder
MSP430F6736	Product Folder

Design Features

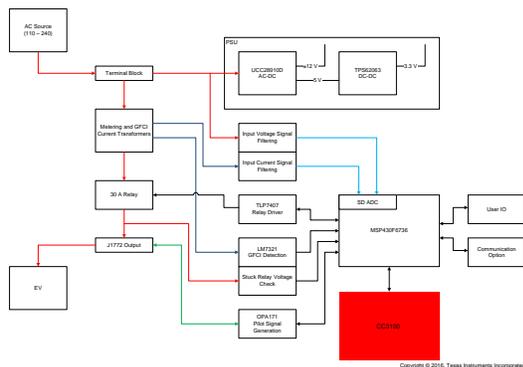
- Full Implementation of J1772-Compliant Service Equipment
- Wi-Fi Support for Remote Monitoring and Control of EVSE
- High Current Relay Drivers for Support of High Current Contactors
- Standardized Pilot Wire Signaling Protocol
- Integrated Utility Meter-Grade Energy Measurement
- Option for Communication Daughter Card Add-in

Featured Applications

- Level 1 and Level 2 Electric Vehicle Service Equipment (EVSE)



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1 System Description

This TI Design has an EVSE with Wi-Fi connectivity for display and control of operational data. The MSP430F6736 performs all energy measurements and EVSE control functions and controls the SimpleLink™ technology Wi-Fi transceiver. The data can be displayed on any Wi-Fi connected device by using a standard Web browser.

Electric vehicles (EVs) have existed for over a century, but they have had limited market success until recent times. Modern advances in battery technology drive efficiency, and market forces have accelerated the demand and deployment rates of EVs that can compete with traditional internal-combustion vehicles. Many vehicle owners now have to plug and unplug high-powered devices into their home-electricity system on a regular basis.

Traditional international-combustion vehicles benefit from a broad network of gas stations for rapid energy delivery to the vehicle and to extend the vehicles range. While technology improves, EVs suffer from slow energy-delivery rates that require vehicles to be stationary for long periods of time to recharge. The slow energy-delivery systems that support EVs also highlight the shortcomings of the gas station model.

The slow rate of charging is the result of using low battery-charge currents to avoid damage and the energy capacity of the local grid connection. Adding a high-power connection may create issues with safety and reliability. Public charge stations help tap into higher current connections that are available in commercial buildings, but these stations must be able to charge all varieties of electric vehicles.

These problems are mitigated through EVSE that controls the power flow that goes into EVs. Many vehicle manufacturers have adopted the J1772 SAE standard for AC electrical connections to a vehicle. This standard translate into international localizations, and only the form factors differ.

The standard design of electric vehicle (EV) charging systems on the market have an AC-DC converter for the battery-charging system that is integrated into the vehicle so only AC power is required. External DC-DC and charge circuitry is enabled on some vehicles, but this configuration is not within the scope of this design. To facilitate the power delivery to the vehicle, the EVSE sits between a stable grid connection and the vehicle, shown in [Figure 1](#).

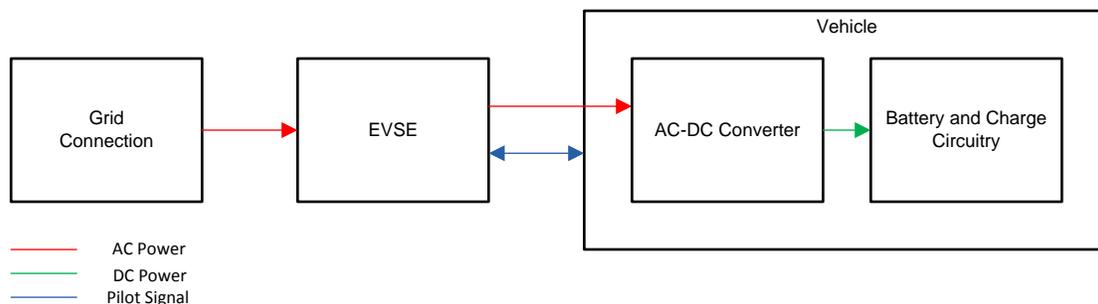


Figure 1. EVSE Position in Power Flow

The core of the EVSE operation for AC power delivery is communication with the vehicle through a single-line pilot wire. This EVSE operation is based on level 1 and level 2 devices (see [Table 1](#)). The single-line pilot wire enables negotiation with the vehicle for power status, available power, and charge state. The EVSE must be able to control AC power delivery to the plug (up to a 240-V AC and 80 A) for robust relay or contactor driving.

Table 1. Level 1 and Level 2 Charging Standards

LEVEL	DEFINITION	ENERGY RATING
Level 1	Alternating current energy to the onboard charger of the vehicle; from the most common U.S. grounded household receptacle, referred to as a 120-V outlet.	120-V AC 16 A (= 1.92 kW)
Level 2	Alternating current energy to the onboard charger of the vehicle; 208 V to 240-V, single phase. The maximum current specific is 32 A (continuous) with a branch-circuit breaker rated at 40 A.	208- to 240-V AC 12 A to 80 A (= 2.5 kW to 19.2 kW)

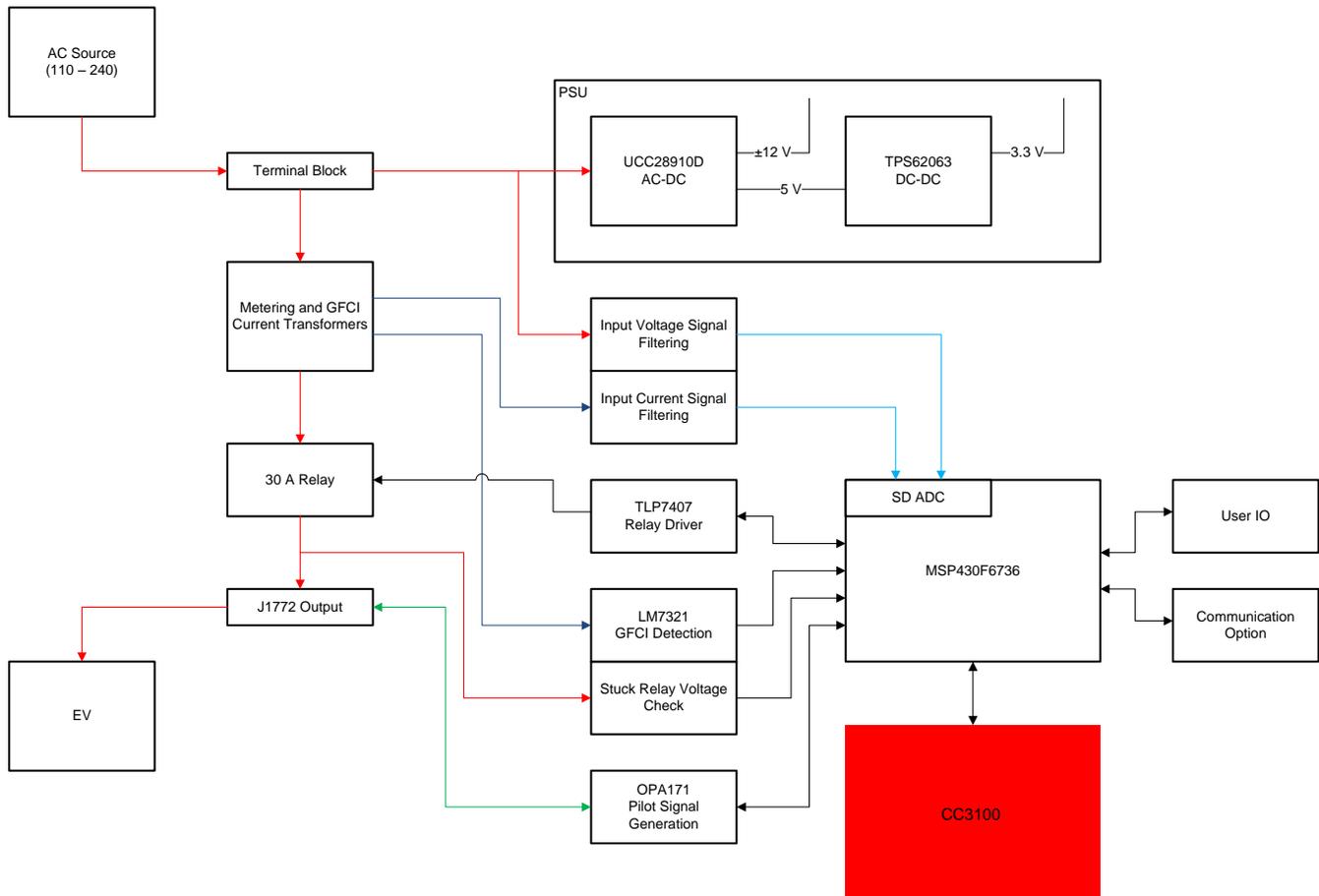
This implementation of an EVSE contains a basic set of features that are expandable to enable additional usage scenarios. The primary functionality includes:

- Level 1 and level 2 operation (120 V to 240 V)
- Power delivery up to 30 A (expandable by using larger relays)
- Pilot signal-wire communication support
- Latched-relay detection
- Energy metering

In a home installation, it is beneficial to know the current state of the EVSE and how it is used without being at the vehicle. Adding the ability to connect the EVSE to a standard home Wi-Fi network enables a user to remotely check if the station is unused, charging a vehicle, finished charging, or if an error is occurring.

2 Block Diagram

Figure 2 shows the block diagram.



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Figure 2. TIDC-EVSE-WiFi® Block Diagram

2.1 Highlighted Products

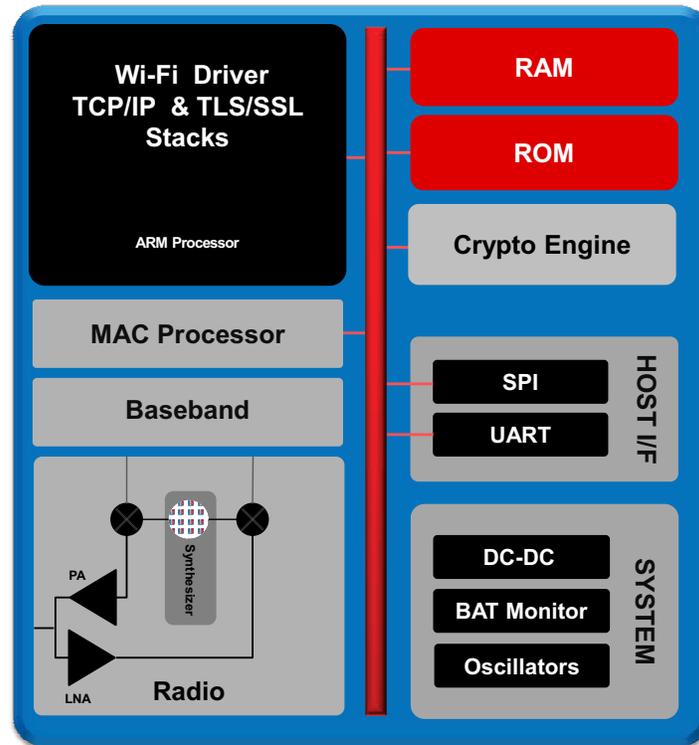
This TI Design features the following devices:

- [CC3100](#) – Wi-Fi network processor
- [MSP430F6736](#) – mixed-signal microcontroller (MCU)
- [UCC289210D](#) – 700-V flyback switcher with a constant voltage, constant current, and primary-side control
- [TPS62063](#) – 3-MHz, 1.6-A step-down converter
- [OPA171](#) – 36-V, power-power, rail-to-rail output (RRO), general-purpose operational amplifier (op amp)
- [LM7322](#) – high output current and unlimited capacitor load, ± 15 -V op amp
- [TLP7407](#) – 40-V, 7-channel NMOS array, low-side driver

For more information on each of these devices, see their respective product folders at www.ti.com.

2.1.1 CC3100 SimpleLink™ Technology Wi-Fi® Network Processor

Figure 3 shows the CC3100 hardware overview.



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Figure 3. CC3100 Hardware Overview

The following list shows the features of the CC3100 Wi-Fi network processor.

- Wi-Fi network processor and power-management subsystems
- Wi-Fi CERTIFIED™ chip
- Wi-Fi network processor subsystem
 - Dedicated ARM® MCU offloads Wi-Fi and Internet protocols from the external MCU
 - Wi-Fi driver and multiple internet protocols in ROM
 - 802.11 b/g/n radio, baseband, and medium access control (MAC), Wi-Fi driver, and supplicant
 - TCP/IP Stack
 - Industry-standard BSD socket application programming interfaces (APIs)
 - Eight simultaneous TCP or UDP sockets
 - Two simultaneous TLS and SSL sockets
 - Powerful crypto engine for fast, secure Wi-Fi and Internet connections with 256-bit AES encryption for TLS and SSL connections
 - Station, AP, and Wi-Fi Direct® modes
 - WPA2 personal and enterprise security
 - SimpleLink solution connection manager for autonomous and fast Wi-Fi connections
 - SmartConfig™ technology, AP mode, and WPS2 for easy and flexible Wi-Fi provisioning
 - TX power
 - 18.0 dBm at 1 DSSS
 - 14.5 dBm at 54 OFDM

- RX sensitivity
 - –95.7 dBm at 1 DSSS
 - –74.0 dBm at 54 OFDM
- Application throughput
 - UDP: 16 Mbps
 - TCP: 13 Mbps
- Host interface
 - Interfaces with 8-, 16-, and 32-bit MCU or ASICs over SPI or UART interface
 - Low external host driver footprint: less than 7 KB of code memory and 700 B of RAM memory required for TCP client application
- Power-management subsystem
 - Integrated DC-DC supports wide range of supply voltage
 - V_{BAT} wide-voltage mode: 2.1 V to 3.6 V
 - Preregulated 1.85-V mode
 - Advanced low-power modes
 - Hibernate with RTC: 4 μ A
 - Low-power deep sleep (LPDS): 115 μ A
 - RX traffic (MCU active): 53 mA at 54 OFDM
 - TX traffic (MCU active): 223 mA at 54 OFDM, maximum power
 - Idle connected: 690 μ A at DTIM = 1
- Clock source
 - 40.0-MHz crystal with internal oscillator
 - 32.768-KHz crystal or external RTC clock
- Package and operating temperature
 - 0.5-mm pitch, 64-pin, 9-mm \times 9-mm QFN
 - Ambient temperature range: –40°C to +85°C

2.1.2 MSP430F6736

Figure 4 shows the block diagram of the MSP430F6737.

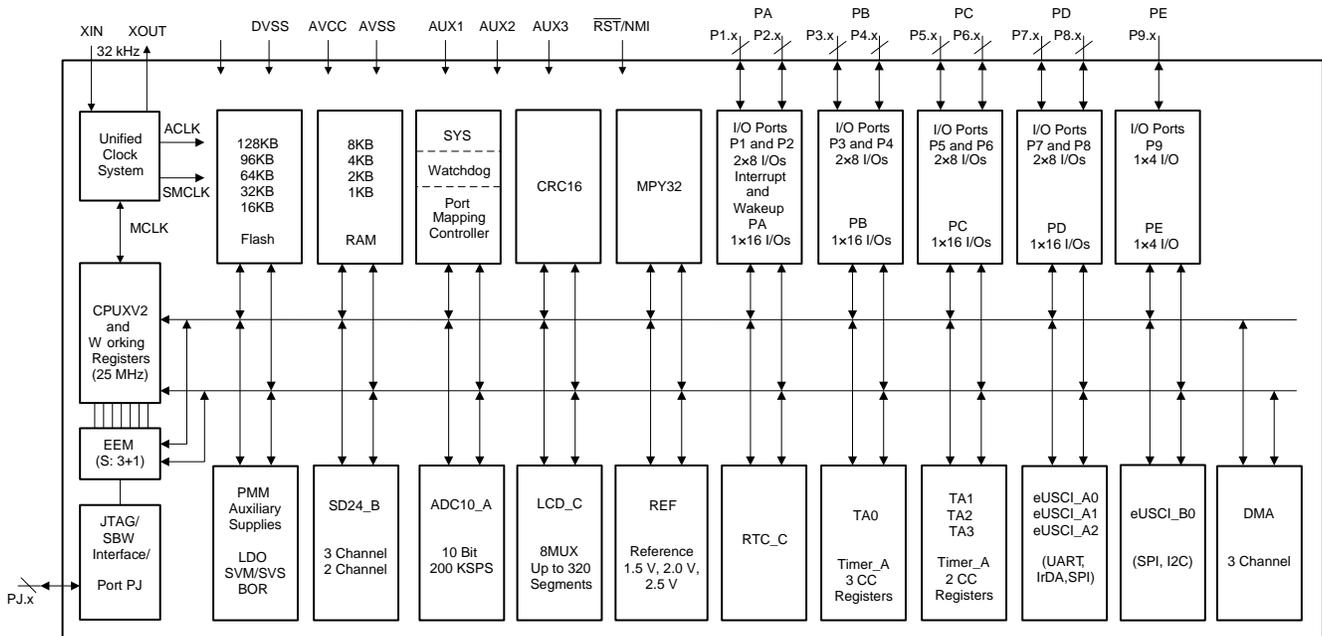


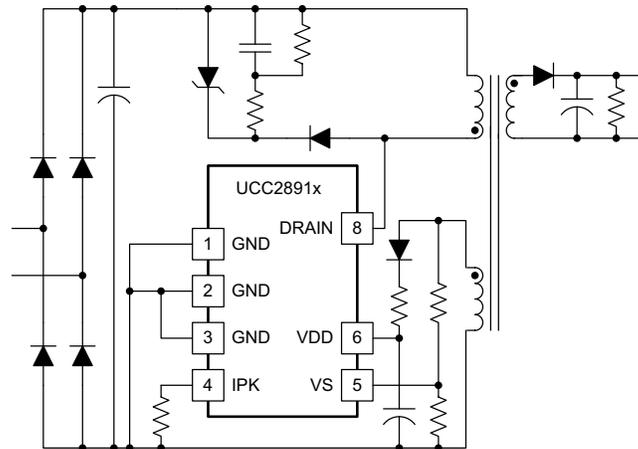
Figure 4. MSP430F6736 Block Diagram

- Low supply voltage range: 3.6 V down to 1.8 V
- Ultralow-power consumption
 - Active mode (AM)
 - All system clocks active
 - 265 μ A/MHz at 8 MHz, 3.0 V, flash program execution (typical)
 - 140 μ A/MHz at 8 MHz, 3.0 V, RAM program execution (typical)
 - Standby mode (LPM3)
 - Real-time clock with crystal, watchdog, supply supervisor operational, full RAM retention, and fast wakeup
 - 1.7 μ A at 2.2 V, 2.5 μ A at 3.0 V (typical)
 - Off mode (LPM4)
 - Full RAM retention, supply supervisor operational, and fast wake-up
 - 1.6 μ A at 3.0 V (typical)
 - Shutdown RTC mode (LPM3.5)
 - Shutdown mode, active real-time clock (RTC) with crystal
 - 1.24 μ A at 3.0 V (typical)
 - Shutdown mode (LPM4.5)
 - 0.78 μ A at 3.0 V (typical)
- Wake-up from standby mode in 3 μ s (typical)
- 16-bit RISC architecture, extended memory, up to 25-MHz system clock
- Flexible power-management system
 - Fully integrated LDO with programmable regulated core supply voltage
 - Supply voltage supervision, monitoring, and brownout
 - System operation from up to two auxiliary power supplies

- Unified clock system
 - Frequency-locked loop (FLL) control loop for frequency stabilization
 - Low-power low-frequency internal clock source (VLO)
 - Low-frequency trimmed internal reference source (REFO)
 - 32-kHz crystals (XT1)
- One 16-bit timer with three capture and compare registers
- Three 16-bit timers with two capture and compare registers each
- Enhanced universal serial communication interfaces
 - eUSCI_A0, eUSCI_A1, and eUSCI_A2: enhanced universal asynchronous receiver/transmitter (UART) supports auto-baudrate detection, IrDA encoder and decoder, and synchronous SPI
 - eUSCI_B0: I2C with multi-slave addressing, synchronous SPI
- Password-protected RTC with crystal offset calibration and temperature compensation
- Separate voltage supply for backup subsystem o 32-kHz low-frequency oscillator (XT1)
 - Real-time clock
 - Backup memory (4 bits x 16 bits)
- Three 24-bit $\Delta\Sigma$ ADCs with differential PGA inputs
- Integrated liquid-crystal display (LCD) driver with contrast control for up to 320 segments in 8-mux mode
- Hardware multiplier supports 32-bit operations
- 10-bit 200-kSPS A-D converter
 - Internal reference
 - Sample-and-hold, auto-scan feature
 - Up to six external channels and two internal channels (including temperature sensor)
- Three-channel internal DMA
- Serial onboard programming, no external programming voltage required
- Available in 100-pin and 80-pin LQFP packages

2.1.3 UCC28910D

Figure 5 shows the UCC28910D simplified schematic.



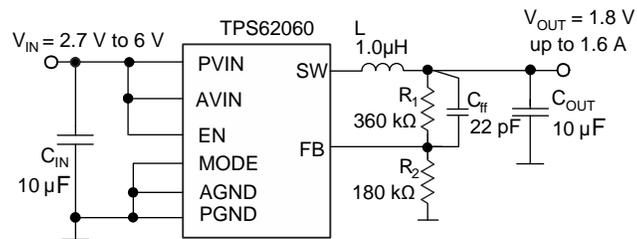
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Figure 5. UCC28910D Simplified Schematic

- Constant-voltage (CV) and constant-current (CC) output regulation without optical-coupler
- $\pm 5\%$ output-voltage regulation accuracy
- $\pm 5\%$ output-current regulation with AC line and primary-inductance tolerance compensation
- 700-V start-up and smart power management enables $< 30\text{-mW}$ standby power
- 115-kHz maximum switching frequency design for high-power density
- Valley switching and frequency dithering to ease electromagnetic interference (EMI) compliance
- Thermal shutdown
- Low line and output overvoltage protection

2.1.4 TPS62063

Figure 6 shows the TPS62063 schematic.



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Figure 6. TPS62063 Schematic

- 3-MHz switching frequency
- V_{IN} range from 2.7 V to 6 V
- 1.6-A output current
- Up to 97% efficiency
- Power save mode and 3-MHz fixed PWM mode
- Output voltage accuracy in PWM mode $\pm 1.5\%$
- Output discharge function
- Typical 18- μ A quiescent current
- 100% duty cycle for lowest dropout
- Voltage positioning
- Clock dithering
- Supports a maximum of 1-mm height solutions
- Available in a 2-mm \times 2-mm \times 0.75-mm WSON

2.1.5 OPA171

- Supply range
 - 2.7 V to 36 V, ± 1.35 V to ± 18 V
- Low noise
 - 14 nV/ $\sqrt{\text{Hz}}$
- Low offset drift
 - ± 0.3 $\mu\text{V}/^\circ\text{C}$ (typical)
- RFI filtered inputs
- Input range includes negative supply
- Input range operates to positive supply
- Rail-to-rail output (RRO)
- Gain bandwidth
 - 3 MHz
- Low quiescent current: 475 μA for each amplifier
- High common-mode rejection
 - 120 dB (typical)
- Low-input bias current
 - 8 pA

2.1.6 LM7322

Figure 7 shows the LM7322 package layout.

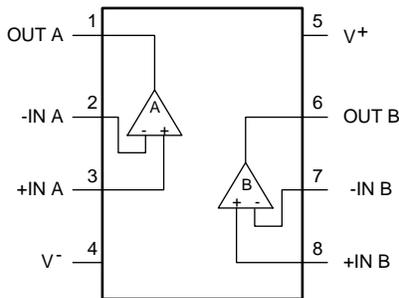


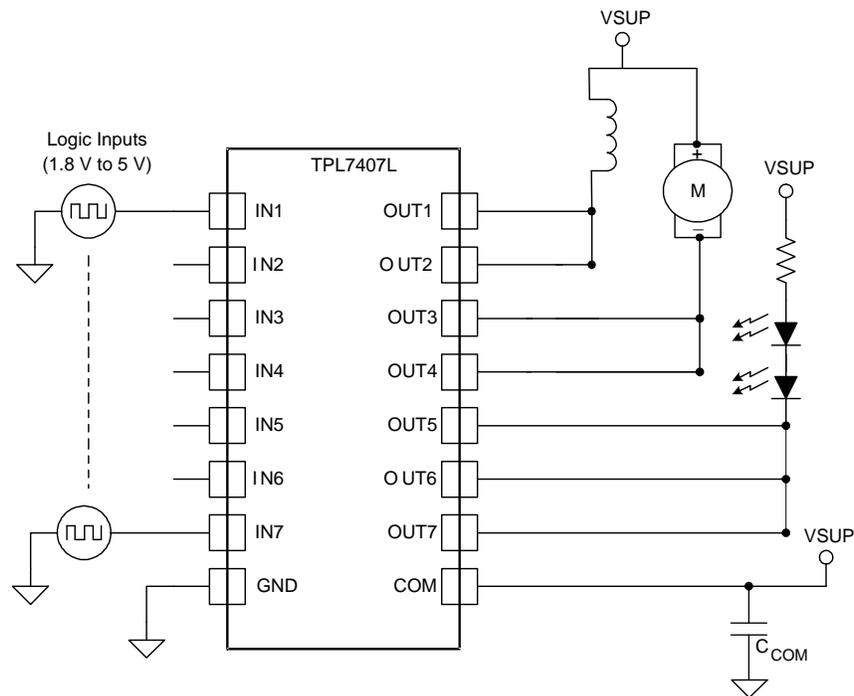
Figure 7. LM7322 Package Layout

The LM732xx devices are automotive grade products that are AEC-Q100 grade 1 qualified. The typical values, unless specified, are $V_S = \pm 15$ and $T_A = 25^\circ\text{C}$.

- Wide supply voltage range
 - 2.5 V to 32 V
- Output current
 - +65 mA or –100 mA
- Gain bandwidth product
 - 20 MHz
- Slew rate
 - 18 V/ μs
- Unlimited capacitive load tolerance
- Input common-mode voltage
 - 0.3 V beyond rails
- Input-voltage noise
 - 15 nV/ $\sqrt{\text{Hz}}$
- Input-current noise
 - 1.3 pA/ $\sqrt{\text{Hz}}$
- Supply current and channel
 - 1.1 mA
- Distortion THD and Noise
 - –86 dB
- Temperature range
 - -40°C to $+125^\circ\text{C}$
- Tested at -40°C , $+25^\circ\text{C}$, and $+125^\circ\text{C}$ at 2.7 V, ± 5 V, and ± 15 V

2.1.7 TPL7407L

Figure 8 shows the TPL7407L sample application schematic.



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Figure 8. TPL7407L Sample Application Schematic

- 600-mA rated drain current (for each channel)
- CMOS pin-to-pin improvement of 7-channel Darlington array (for example, ULM2003A)
- Power efficient (low V_{OL})
 - Less than four times lower V_{OL} at 100 mA than Darlington array
- Low output leakage
 - < 10 nA for each channel
- Extended ambient-temperature range
 - $T_A = -40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$
- High voltage outputs 40 V
- Compatible with 1.8- to 5.0-V MCUs and logic interfaces
- Internal free-wheeling diodes for inductive kickback protection
- Input-pulldown resistors allow a tri-state condition of the input driver
- Input RC-snubber eliminates spurious operation in noisy environments
- Inductive load-driver applications
- Electrostatic-discharge (ESD) protection exceeds JESD 22
 - 2-kV HBM, 500-V CDM

3 System Design Theory

3.1 Pilot Signal Interface

The pilot signal is the primary method that a J1772 compliant EVSE uses to communicate with a vehicle. The pilot signal is based on a 1-kHz, ± 12 -V PWM signal that is transmitted to a vehicle through the charge cord. The vehicle can then respond by placing various loads on the line, affecting the voltage (the EVSE measures this).

3.1.1 J1772 Duty Cycle

The duty cycle of the pilot signals communicates the limit of current the EVSE is capable of supplying to the vehicle. The vehicle then uses up to the limit of current for the charging circuitry. This current rating is determined by the electromechanical components in the EVSE, such as conductors, relays, contactors, and the service connection.

The relationship between duty cycle and current is defined by two difference equations according to the current range that is specified. For a 6- to 51-A service, use [Equation 1](#).

$$\text{Duty Cycle} = \frac{\text{Amps}}{0.6} \quad (1)$$

For a 51- to 80-A service, use [Equation 2](#).

$$\text{Duty Cycle} = \left(\frac{\text{Amps}}{2.5} \right) + 64 \quad (2)$$

[Table 2](#) shows some of the common service ratings.

Table 2. Pilot Wire Example Duty Cycles

AMPS	DUTY CYCLE
5	8.3 %
15	25%
30	50%
40	66.6%
65	90%
80	96%

In this design, the PWM is generated by a timer module on the MSP430 MCU. Because the current rating is tightly coupled to the external hardware, the current rating can be set as the permanent value in the firmware.

Advanced EVSEs with a human machine interface (HMI) can enable the current to be derated if the service line cannot provide sufficient current with a stable voltage. A significant voltage drop is possible because of wire loss in high-current applications.

3.1.2 Pilot Signal States

The EVSE connection and negotiation occurs through several states of the PWM signal and load resistances of the vehicle. [Table 3](#) shows the states of the PWM.

Table 3. States of the PWM

STATE	PILOT HIGH VOLTAGE	PILOT LOW VOLTAGE	FREQUENCY	RESISTANCE	DESCRIPTION
State A	12 V	N/A	DC	N/A	Not connected
State B	9 V	-12 V	1 kHz	2.74 k Ω	EV connected, ready to charge
State C	6 V	-12 V	1 kHz	882 Ω	EV charging
State D	3 V	-12 V	1 kHz	246 Ω	EV charging, ventilation required
State E	0 V	0 V	N/A	—	Error
State F	N/A	-12 V	N/A	—	Unknown error

States A, B, and C are the core functionality and they define the normal operation. An EVSE performs several self tests upon powering on and then enters State A. When the EVSE is ready, the normal connection process follows several steps.

1. The EVSE puts 12 V on the pilot wire. This transmission signals the vehicle when the plug has been connected.
2. The vehicle places a 2.74-k Ω load on the pilot line when the plug is connected (this drops the voltage to 9 V).
3. The EVSE moves to State B and enables the PWM that signals the vehicle how much current it can draw. The EVSE closes the relays, providing power to the vehicle.
4. The vehicle draws power and switches to the 822- Ω load, dropping the voltage to 6 V and signaling the EVSE that charging has begun.
5. The charging process ends when the cable is unplugged, returning the voltage to 12 V (most vehicles continue to pull low amounts of power in State C even when fully charged). The EVSE measures this process and closes the relays and returns to State A.

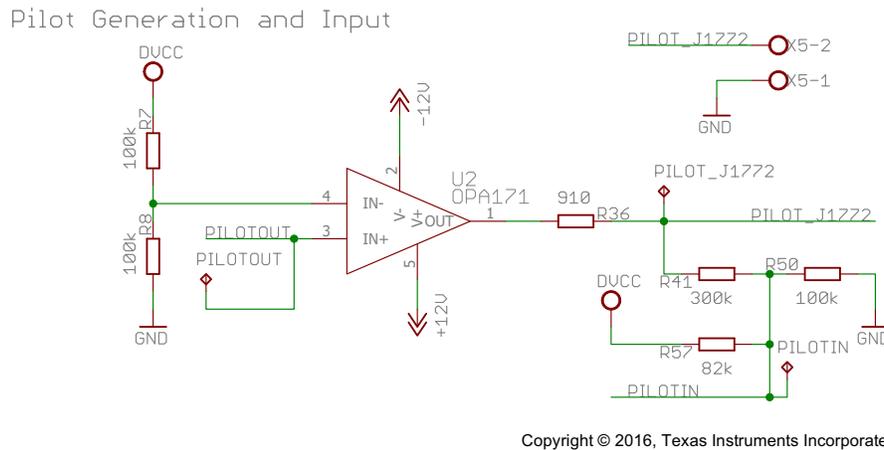
Additional error handling, such as missing diodes in the vehicle or an improper connection, can be detected and resolved by the EVSE by cutting the power.

3.1.3 Pilot Signal Circuit

The pilot signal is required to travel through several meters of cable and a load resistance. The pilot signal is a bipolar $\pm 12\text{-V}$ signal that requires special consideration.

To accommodate these parameters, select an amplifier that has a wide input range and reasonable power output. The OPA171 has a voltage rating of $\pm 18\text{ V}$ and a current rating of 475 mA , making it suitable for this application. Most EVSEs do not require an automotive qualification, but a Q1-rated variant of the OPA171 exists if this feature is required.

The amplification circuit is a simple rail-to-rail output configuration of the OPA171 device, where the MCU I/O drives the positive input. The output of the pilot amplifier is also fed into a simple voltage divider so the MCU can measure the voltage during operation and detect the load resistance of the vehicle. Figure 9 shows the schematic of this subsystem.



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Figure 9. Pilot Signal Generation and Input

To validate the architecture, the design was tested with the TINA-TI™ software (spice-based simulation tool). The resistor load states of the EVSE are included in these tests to simulate the response to the state changes. The simulation files are in the design download packages.

Figure 10 shows an example result of the simulation for a State B condition.

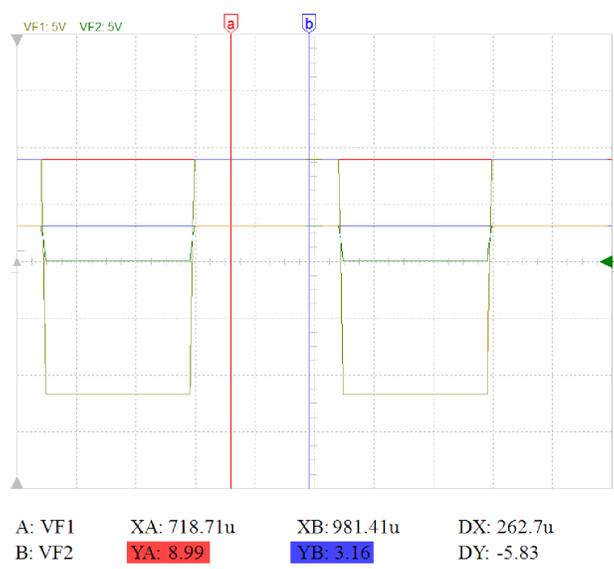


Figure 10. Pilot Signal TINA-TI™ Software Simulation

This capture (Figure 10) has a 5-V per division Y-axis. VF1 is the line-out channel, and VF2 is the MCU ADC channel. Marker A (on VF1) measures 8.99 V, and marker B (on VF2) measures 3.16 V. VF1 also shows that the -12-V side is intact and that VF2 does not drop to less than 0 V, which could damage the MCU. The pilot output is correct for this application and the MCU can measure the incoming signal.

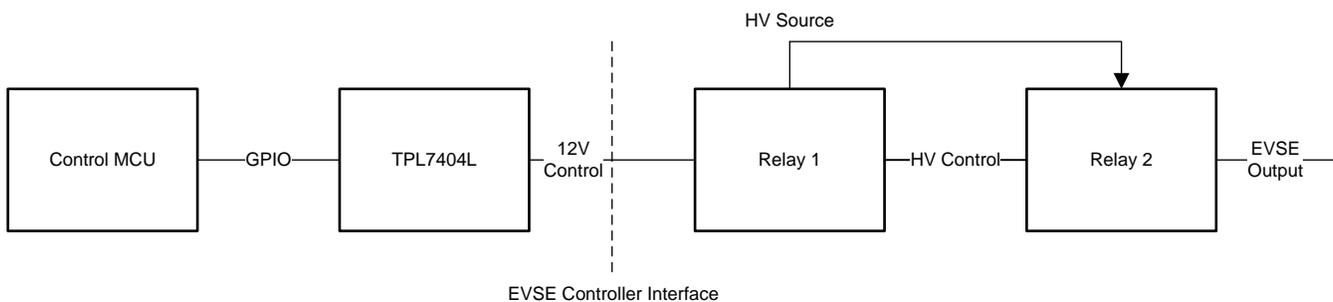
3.2 Relay Drive and Latch Detect

The primary functionality of the EVSE is the reliable control of large currents that are directed toward an EV at the voltage of the main. In a normal-use case, the relay must be held closed for several hours to fully charge a vehicle, but the relays cannot be latching type because of safety concerns. If something fails in the control system, the relays must fail open. These high-current relays can draw tens to hundreds of milliamps as an inductive load, requiring specific drive architectures.

Because of the amount of time that a relay requires to remain powered on, an efficient-drive solution is preferred instead of the Darlington array or a discrete transistor configuration. The TPL7404L has high-efficiency, integrated-diode protection for inductive loads and has a wide-voltage output capability to match most electromechanical relays. The design defaults to a 5-V output, but an external voltage can be used depending on the relay configuration.

The relay configuration used for design testing contains a two-stage approach. The EVSE board controls the first relay through a 12-V signal from the TPL7404L device. This relay switches a 120-V signal into a larger relay that is capable of supporting the required currents of the EVSE. This configuration is not uncommon because many large contactors or high-amplifier relays are 120 V. This configuration also reduces power-supply requirements because a lower current is required to drive a smaller first relay.

Figure 11 shows a simple diagram of the relay configuration.



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Figure 11. Relay Configuration

3.3 Energy Metering

The energy measurement section of this TI Design has been emulated from the existing portfolio of residential e-meter designs of TI, specifically the *Class 0.2 Single-Phase E-Meter* (see [1]). this design offers a high-accuracy energy measurement through the MSP430F6736 MCU. The MCU is fully programmable and has been adopted to run the software that controls the EVSE system. For more information about the metering solution, refer to [1].

4 Getting Started Hardware

4.1 Hardware Overview

The control system for the TIDC-EVSE-WIFI EVSE Reference Design is fully implemented in a single PCB. Figure 12 shows the top view of the board.

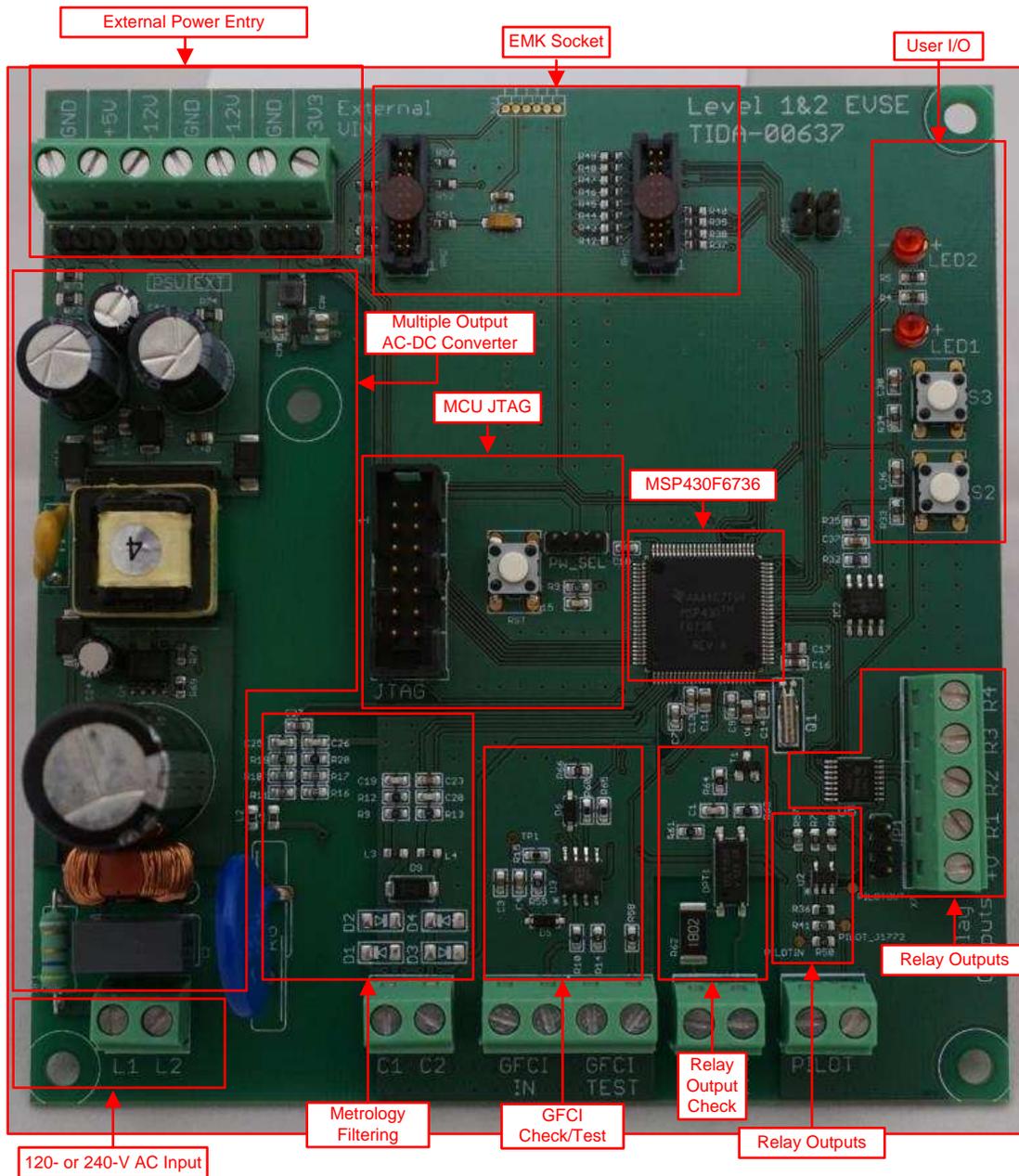


Figure 12. Top View of EVSE PCB

The EVSE has the following functional blocks:

- External power entry – Several screw terminals are available to evaluate alternative-power options with the PCB. The system requires at least ± 12 V and 3.3 V to operate, and has an optional 5-V input available. Each input has a jumper option to enable selection between the internal and external power.
- EMK socket – A standard TI EMK socket enables the easy addition of wireless cards that are produced by TI. The board also provides a second, dedicated communication power for EZ-RF boards or other UART compatible devices.
- User I/O – Two onboard buttons and two light-emitting diodes (LEDs) provide a simple user interface with the system. The buttons do not have mapped functions and the LEDs signal error states for the GFCI and pilot-line systems.
- MSP430F6736 – The F6736 series MSP430 is the MCU that controls the EVSE.
- MCU JTAG – A standard MSP430 14-pin JTAG connector is available for programming the device. A power-selection jumper (to enable the MCU to be powered from the MSPFET) and reset push button are included.
- Multiple output AC-DC converter – The onboard AC-DC converter is capable of producing ± 12 V and 5 V from a 120- or 240-V AC input. A small footprint DC-DC converter produces the 3.3-V rail from the 5-V output. All of these rails can be bypassed and powered externally through the external-power entry block.
- 120- to 240-V AC input – The AC power entry terminal supports a wide-input voltage (V_{IN}) and feeds the onboard power supply and the metrology section of the system.
- Metrology filtering – The signal filtering for the energy metering is based on *Class 0.2 Single-Phase E-Meter* (see [1]). The design is a simple passive filter for AC voltage and a current transformer input through the terminal blocks. An external 0.05% CT is required to meet the high-accuracy specification with the appropriate burden-resistor tuning. [Section 5.2](#) contains more information on the functionality of this hardware.
- GFCI check and GFCI test – Filtering for the GFCI input signal and the test signal output is supplied here. [Section 5.3](#) contains more information on the hardware connections and setup.
- Relay output check – The AC output of the relay can be fed through the EVSE for monitoring, enabling a quick check of the relay functionality.
- Pilot interface – A screw terminal is available to make a connection between the pilot signal to the amplification and filtering block. [Section 5.4](#) contains more information on the functionality of this hardware.
- Relay outputs – Output capability is provided for up to four discrete relay signals. An onboard jumper is available to use the onboard power supply to drive the relay and the TPL7407 or to use an external voltage. [Section 5.5](#) contains more information on the functionality of this hardware.

4.2 Main Power and Metrology

The power entry block on the TIDA-00637 reference design powers the system and provides a signal to the metrology filters to be measured by the MCU. On a single-phase feeder the terminal assignment is: Live \rightarrow L1 and Neutral \rightarrow L2. On a split-phase connection the terminal connection does not have a specific polarity. A ground connection is required for a single-phase feeder and a split-phase connection, but only for the pilot-wire signal (see [Section 5.4](#)).

The terminal block (C1 and C2) inputs the current output of a current transformer to measure the current that the vehicle is drawing. The system has an integrated 13- Ω burden resistor, and a 2000 to 1 ratio CT gives accurate metrology measurements of up to 100 A with a 2000 to 1 dynamic range. If a lower ceiling on the current range is required, a CT with a lower current rating can be used, but the burden resistor must match and the software must be updated with the new ranging information. See [1] for more information.

4.3 Pilot Wire

The fourth and smaller wire on a standard J1772 cable is the pilot line. This line can be electrically connected to the right side of the PILOT terminal block on the EVSE system design. The EV interacts with the pilot signal by placing a resistance between the pilot pin and the ground connection on the cable. While the ground connection is not used for the power elements in this design, it is required as an electrical reference for the pilot signal. To set the ground connection to act as the electrical reference, the left connection of the PILOT terminal block must be connected to the earth ground on the EVSE cable.

4.4 Relays

The relay terminal block on the EVSE system design has output support for four relays, with a fifth terminal for a positive voltage output from the onboard supply (or external supply unit). The four relay connectors have been setup to enable low-side switching of the relays without the requirement for external-snubber diodes. Having the diodes in place does not affect operation.

For normal connection of a relay using the onboard 12-V rail, the relay coil is connected between the +V port and the associated relay port on the terminal block, shown in [Figure 15](#).

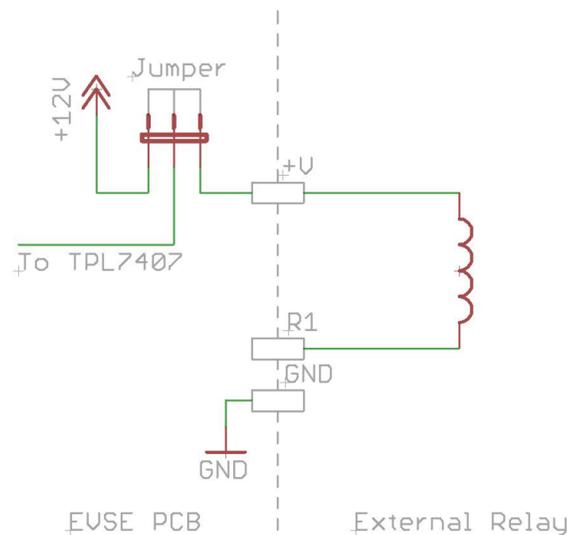


Figure 15. Normal Relay Connection

To use an external supply, the positive rail must connect to the +V port, ground to the GND port, and the relay to the associated control port, shown in [Figure 16](#).

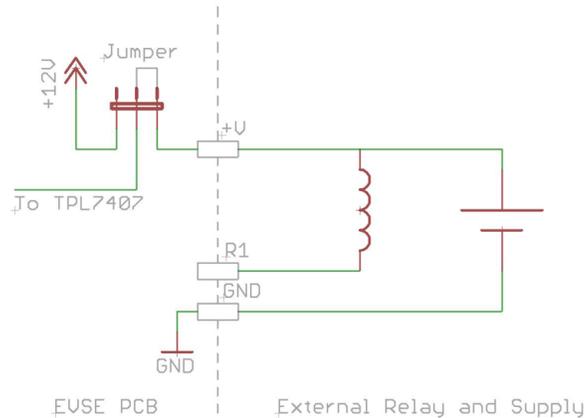


Figure 16. Relay With External Supply

A relay that is able to switch the amount of current required for an EVSE requires a significant level of switching current to latch. High current relays or contactors mitigate this requirement by using line-level AC voltage on the coil. To control this style of relay or contactor, a smaller relay with a low-voltage control level can be switched by the EVSE, switching the line voltage to the high-current control.

4.5 CC3100 Daughter Card Interface

Connect the CC3100BOOST BoosterPack to the EVM to add Wi-Fi capabilities to the TIDC-EVSE-WIFI. Because the CC3100BOOST uses the BoosterPack connectors instead of the EM connectors, the CC3100_EM_BP_ADAPTER adapter must connect the pins on the RF connector of the TIDC-EVSE-WIFI to the pins on the CC3100BOOST. [Figure 17](#) and [Figure 18](#) show the EM and BoosterPack sides of the CC3100_EM_BP_ADAPTER adapter board.

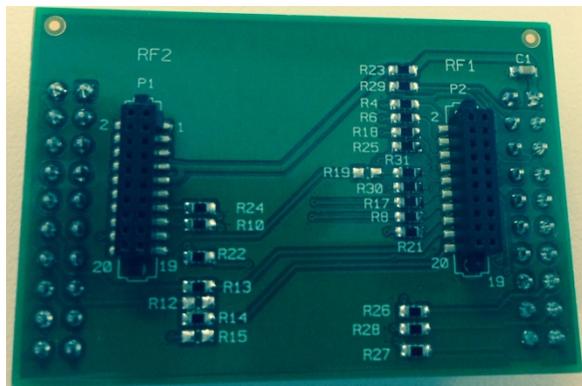


Figure 17. CC3100_EM_BP_ADAPTER EM Female Connection



Figure 18. CC3100_EM_BP_ADAPTER BoosterPack Male Connection

To connect the CC3100BOOST to the EVM, the EM female connector is placed in the RF connector of the TIDC-EVSE-WIFI and the BoosterPack male connector is connected to the BoosterPack female connector of the CC3100BOOST. To properly orient the CC3100BOOST to the adapter, connect J1 on the adapter to P1 and P3 of the CC3100BOOST and J2 to P4 and P2 of the CC3100BOOST. Because the BoosterPack connections are not keyed, ensure that each pin of the CC3100BOOST is connected to the proper pin of the adapter and that the CC3100BOOST does not have the wrong orientation with respect to the adapter. To connect the TIDC-EVSE-WIFI to the adapter, connect RF1 of the adapter to RH1 of the TIDC-EVSE-WIFI and RF2 of the adapter to RH2 of the TIDC-EVSE-WIFI.

Figure 19 shows the connections from the TIDC-EVSE-WIFI to the male EM connectors, and Figure 20 shows the connections from the adapter onto the female EM connectors.

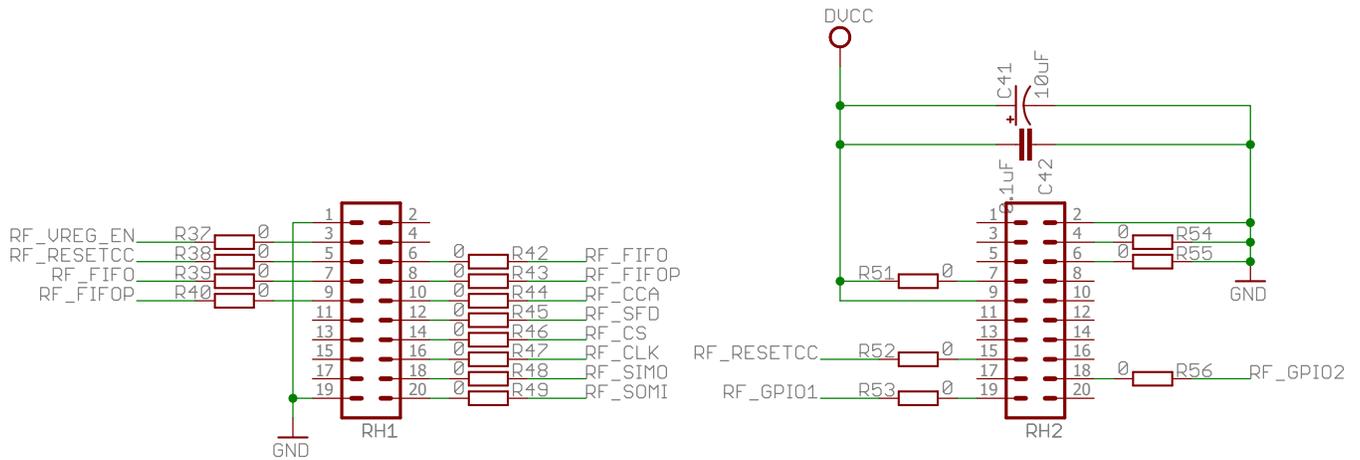


Figure 19. Connections on TIDC-EVSE-WIFI Male Connectors

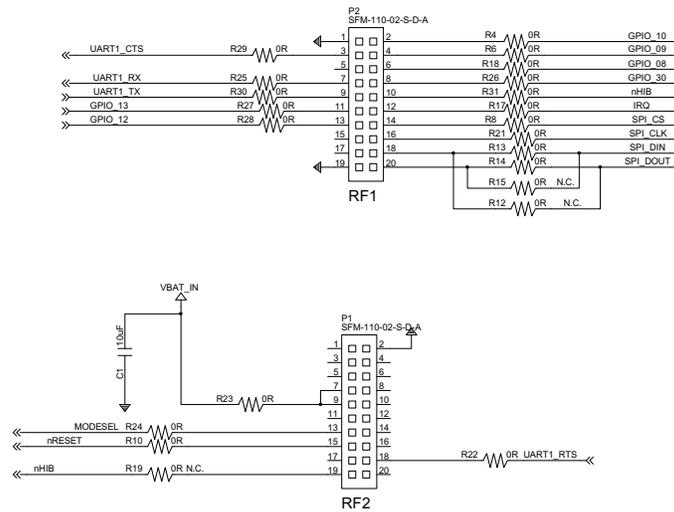


Figure 20. Connections on CC3100_EM_BP_ADAPTER EM Female Connectors

Figure 21 shows the connections from the adapter to the male BoosterPack headers and Figure 22 shows the connections from the CC3100BOOST to the female BoosterPack headers.

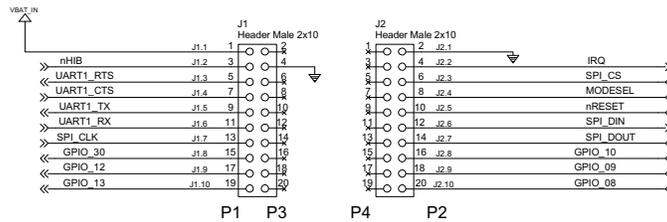


Figure 21. Connections on CC3100_EM_BP_ADAPTER BoosterPack Male Connectors

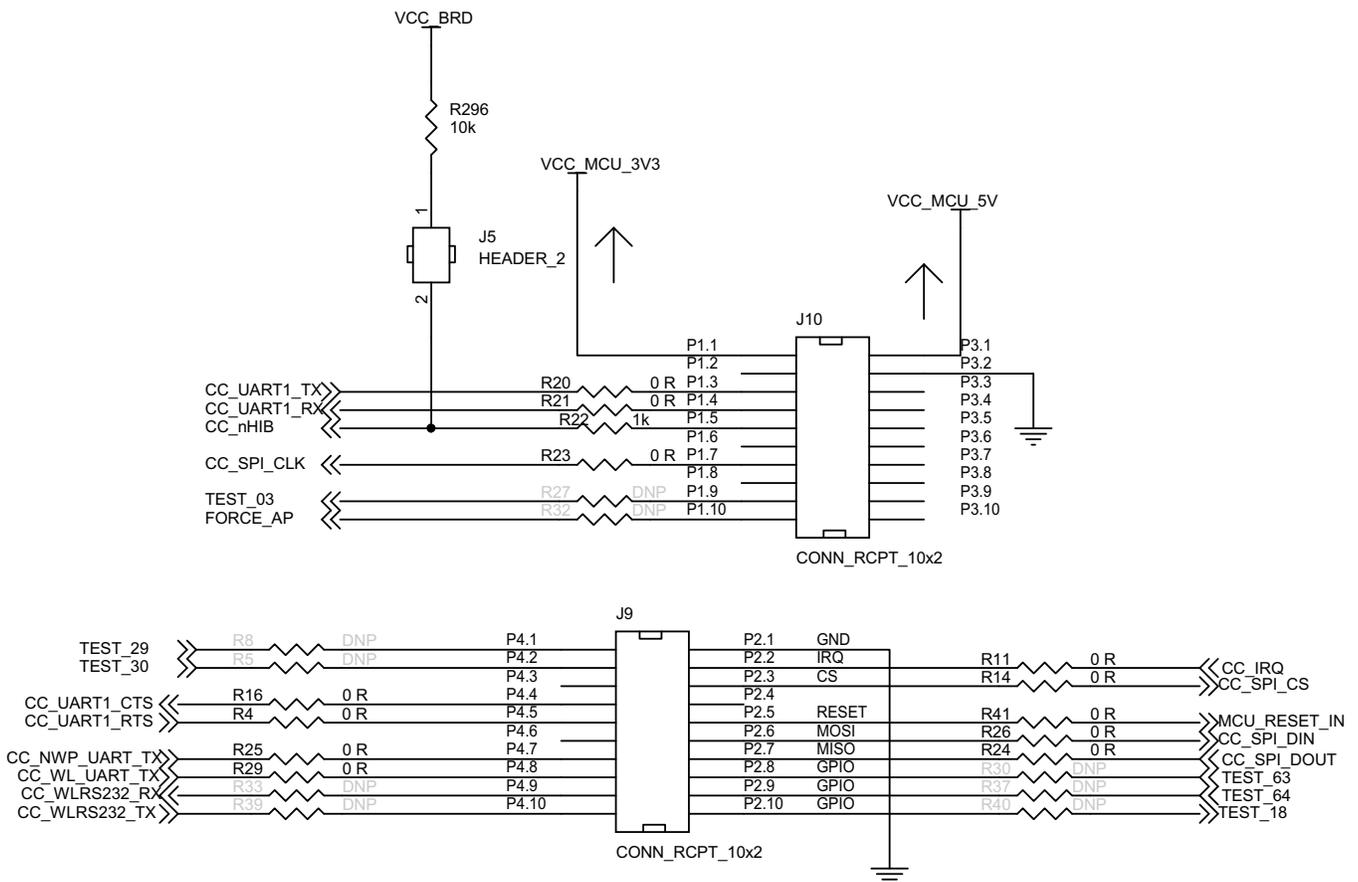


Figure 22. Connections on CC3100BOOST BoosterPack Female Connectors

The mapping between the TIDC-EVSE-WIFI and the CC3100BOOST is shown in [Table 4](#). Each row in [Table 4](#) represents a mapping between a pin of the EM header to the corresponding pin on the CC3100BOOST. The highlighted rows represent the connections that are used for communication between the MSP430F6736 and the CC3100. Pins that do not have a mapping in [Table 4](#) are denoted with a dash.

Table 4. Mapping Between TIDC-EVSE-WIFI and CC3100BOOST

TIDC-EVSE-WIFI CONNECTION	TIDC-EVSE-WIFI CONNECTION NAME	CC3100BOOST CONNECTION	ADAPTER CONNECTION NAME
RH1, pin 1	DGND	P3, pin 2 and P2, pin 1	GND
RH1, pin 3	RF_VREG_EN	P1, pin 4	CC_UART1_TX
RH1, pin 5	RF_RESETCC	--	--
RH1, pin 7	RF_FIFO	P1, pin 6	Not Connected To CC3100
RH1, pin 9	RF_FIFOP	P1, pin 5	CC_nHIB
RH1, pin 11	Not Connected To F6736	P1, pin 10	Not Connected To CC3100
RH1, pin 13	Not Connected To F6736	P1, pin 9	Not Connected To CC3100
RH1, pin 15	Not Connected To F6736	--	--
RH1, pin 17	Not Connected To F6736	--	--
RH1, pin 19	DGND	P3, pin 2 and P2, pin 1	GND
RH1, pin 2	Not Connected To F6736	P2, pin 8	Not Connected To CC3100
RH1, pin 4	Not Connected To F6736	P2, pin 9	Not Connected To CC3100
RH1, pin 6	RF_FIFO	P2, pin 10	Not Connected To CC3100
RH1, pin 8	RF_FIFOP	P1, pin 8	Not Connected To CC3100
RH1, pin 10	RF_CCA	P3, pin 2	Not Connected To CC3100
RH1, pin 12	RF_SFD	P2, pin 2	CC_IRQ
RH1, pin 14	RF_CS	P2, pin 3	CC_SPI_CS
RH1, pin 16	RF_CLK	P1, pin 7	CC_SPI_CLK
RH1, pin 18	RF_SIMO	P2, pin 6	CC_SPI_DIN
RH1, pin 20	RF_SOMI	P2, pin 7	CC_SPI_DOUT
RH2, pin 1	Not Connected To F6736	--	--
RH2, pin 3	Not Connected To F6736	--	--
RH2, pin 5	Not Connected To F6736	--	--
RH2, pin 7	DVCC	P1, pin 1	CC_MCU_3V3
RH2, pin 9	DVCC	P1, pin 1	CC_MCU_3V3
RH2, pin 11	Not Connected To F6736	--	--
RH2, pin 13	Not Connected To F6736	P2, pin 4	Not Connected To CC3100
RH2, pin 15	RF_RESETCC	P2, pin 5	MCU_RESET_IN
RH2, pin 17	Not Connected	--	--
RH2, pin 19	RF_GPIO1	P1, pin 2	Not Connected To CC3100
RH2, pin 2	DGND	P3, pin 2 and P2, pin 1	GND
RH2, pin 4	DGND	--	--
RH2, pin 6	DGND	--	--
RH2, pin 8	Not Connected To F6736	--	--
RH2, pin 10	Not Connected To F6736	--	--
RH2, pin 12	Not Connected To F6736	--	--
RH2, pin 14	Not Connected To F6736	--	--
RH2, pin 16	Not Connected To F6736	--	--
RH2, pin 18	RF_GPIO2	P1, pin 3	CC_UART1_TX
RH2, pin 20	Not Connected To F6736	--	--
--	--	P3, pin 1	VCC_MCU_5V
--	--	P3, pin 3	Not Connected To CC3100

Table 4. Mapping Between TIDC-EVSE-WIFI and CC3100BOOST (continued)

TIDC-EVSE-WIFI CONNECTION	TIDC-EVSE-WIFI CONNECTION NAME	CC3100BOOST CONNECTION	ADAPTER CONNECTION NAME
--	--	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

5 Getting Started Firmware

The software package provided with this TI Design is used to implement the basic structure of the J1772 signaling protocol and to evaluate the functionality of design features. The software is not production ready, but the principles can be leveraged to build a final application.

The software was built on top of the legacy MSP430-Energy-Library (Please see the Energy Measurement Design Center [Energy Measurement Design Center](#) for an updated library). This library has been proven for use in electricity meters and provides an excellent framework for adding the EVSE application state machine.

5.1 Workspace Setup

The software in this TI Design requires the latest version of the Code Composer Studio™ (CCS) IDE from TI with the MSP430 plugins. Users can download the software from www.ti.com.

Ensure that all of the directory structures remain unchanged when extracting the software. Select the `ccs_workspace` directory that is extracted from the archive when opening CCS (or switching workspaces). The following example in [Figure 23](#) shows the placement of the files in the `C:\EVSE-Software\` directory.

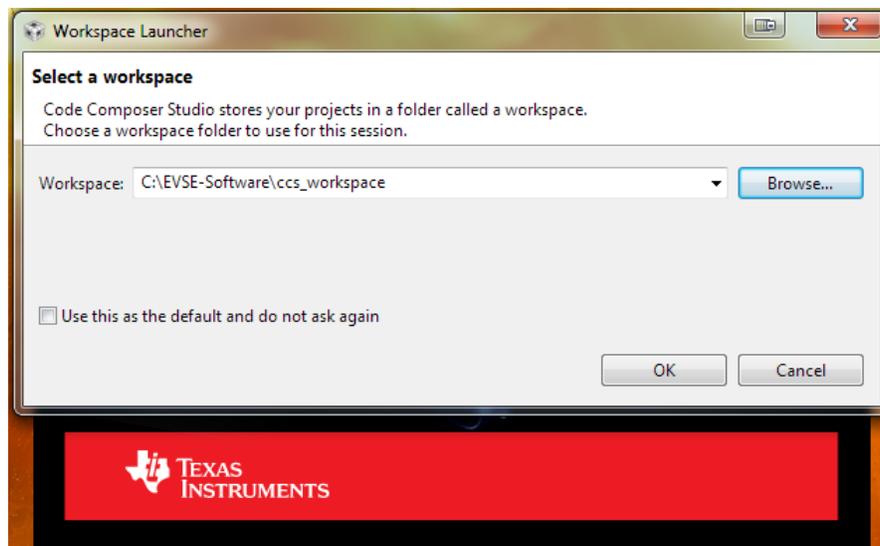


Figure 23. Opening CCS Workspace

Three projects become visible when launching the workspace.

- **Emeter-app-6736** – This workspace contains the application level code, including peripheral setup and foreground state machines and the driver for the CC3100.
- **Emeter-metrology-6736** – This workspace is located one level below and contains all of the metrology functionality. This functionality includes the ADC ISRs, metrology DSP calculations, and data-access routines.
- **Emeter-toolkit-6736** – This workspace has many low-level functions that accelerate processing for specific data types used in the metrology-processing engine.

Users must set a global variable to reference files when opening the workspace for the first time. To set this variable:

1. Navigate to **Window**→**Preferences** in the File menu on the task bar.
2. Navigate through the sidebar to **General**→**Workspace**→**Linked Resources** when the Preferences window appears.

3. Edit the resource *EMETER_SOURCES* to be one directory above the *ccs_workspace* directory. The directory in step three is *C:\EVSE-Software* in this example (see [Figure 24](#))

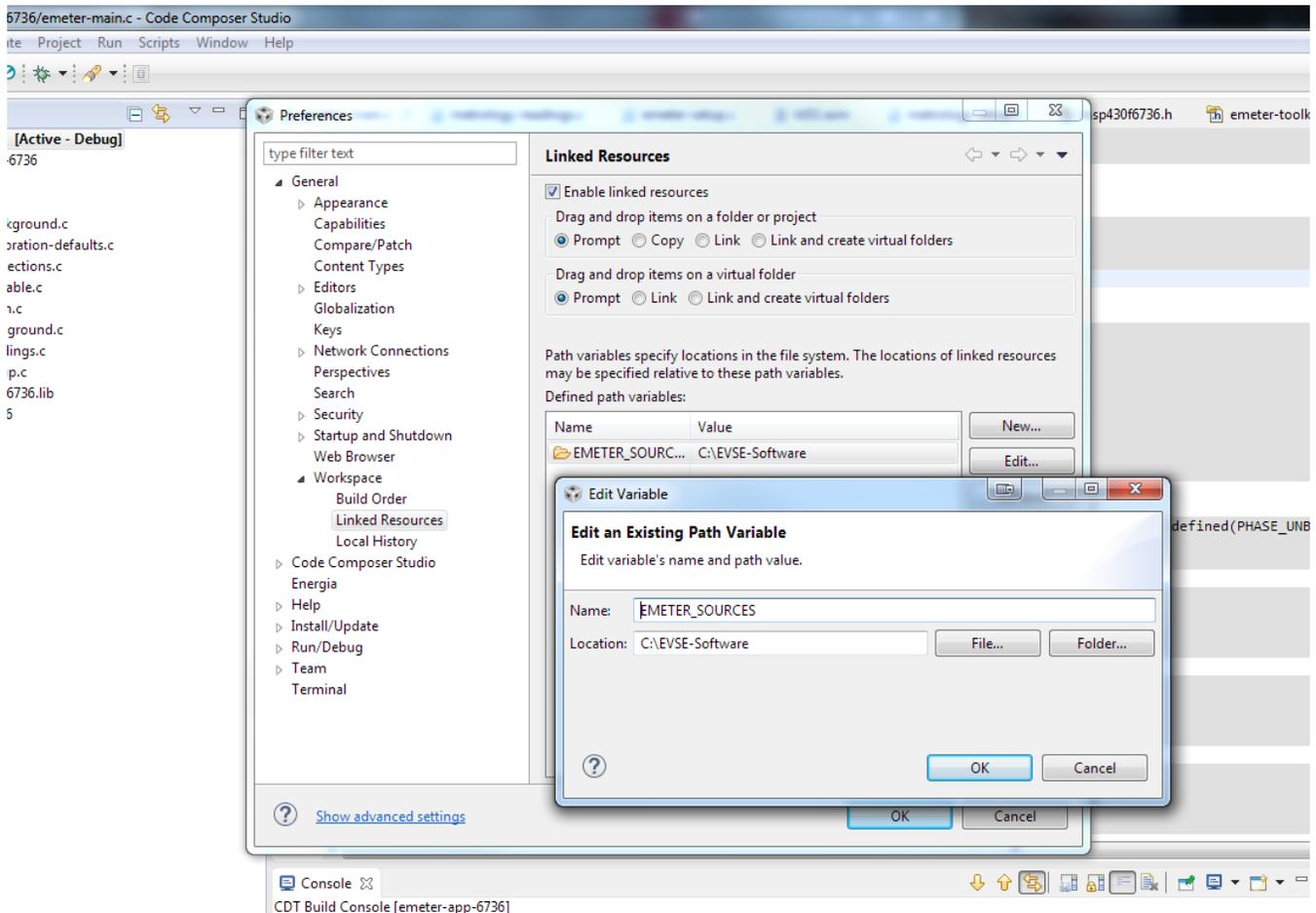


Figure 24. Changing EMETER_SOURCES Resource

Test the directory change by opening one of the C:\ drive files and recompiling the projects in the workspace.

When browsing the source code, major changes to the base library are flagged with the following comment block, allowing users to quickly find and discern the core functionality:

```
/* ----- */
/* EVSE Specific functionality */
/* ----- */
```

The firmware can be flashed to evaluate functionality by initiating a debug of the *emeter-app-6736* project. Any changes made to the individual projects must be propagated by recompiling the higher level projects because the *emeter-toolkit-6736* is used by *emeter-metrology-6736*, and then used by *emeter-app-6736*.

5.2 CC3100BOOST Preparation

To view the metrology parameters using Wi-Fi, the EVM and CC3100BOOST must be configured. This configuration must only be completed once if the configuration settings are not changed. Use the following instructions to configure the CC3100BOOST and EVM.

1. Load the metrology Web page onto the CC3100BOOST.
 1. Connect the CC3100BOOST to the CC31XXEMUBOOST (see [2]) so the arrows pointing to P1.1 on the CC3100BOOST and CC31XXEMUBOOST are aligned with each other.
 2. Connect the jumper on J8 of the CC3100BOOST to select the MCU option so the CC3100BOOST can be powered from the CC31XXEMUBOOST.
 3. Install CCS UniFlash for the CC3100 and CC3200 (see [3]). Ensure that the required drivers for the CC31XXEMUBOOST are installed.
 4. Open CCS UniFlash.
 5. Click on File→OpenConfiguration.
 1. Select the `http_server.ucf` file located in the `Webpages\uniflash_template` directory in the software folder.
 2. Press Open, then press OK (the screen in Figure 25 should appear).

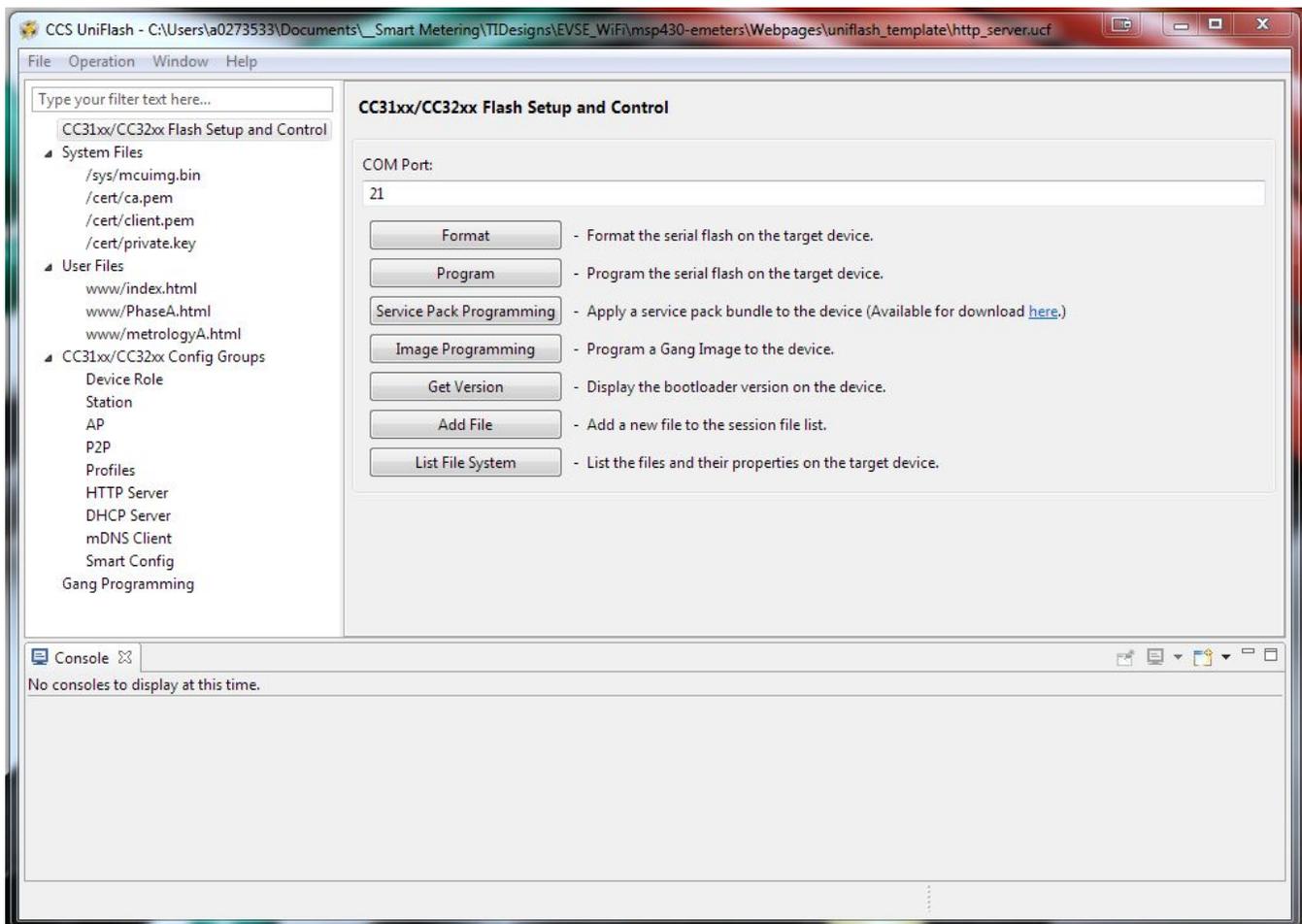


Figure 25. UniFlash CC31x Flash Setup and Control Window

Verify that the Web pages detailed in Table 4 are shown in the left pane.

NOTE: `main.html` is renamed to `index.html`

- Click on each Web page that is listed and modify the URL field (see [Figure 26](#)) to point to the absolute location of the corresponding Web page. Each page is located in the *Webpages\html* directory in the design software folder. Ensure that the Web page names are properly mapped to the corresponding Web page location.

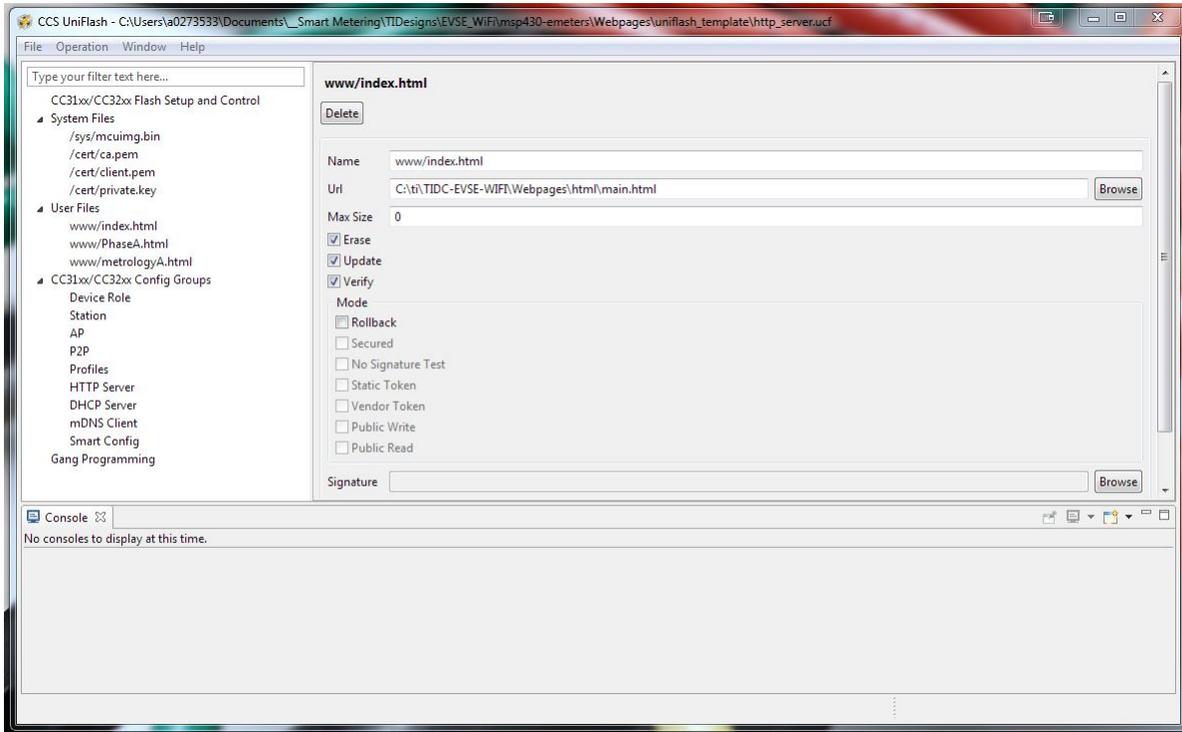


Figure 26. UniFlash CC31x Flash Setup and Control Window

- Connect the CC31XXEMUBOOST to a computer by connecting a USB cable to connector J6 of the CC31XXEMUBOOST; four new COM ports should appear in Device Manager (see [Figure 27](#)).

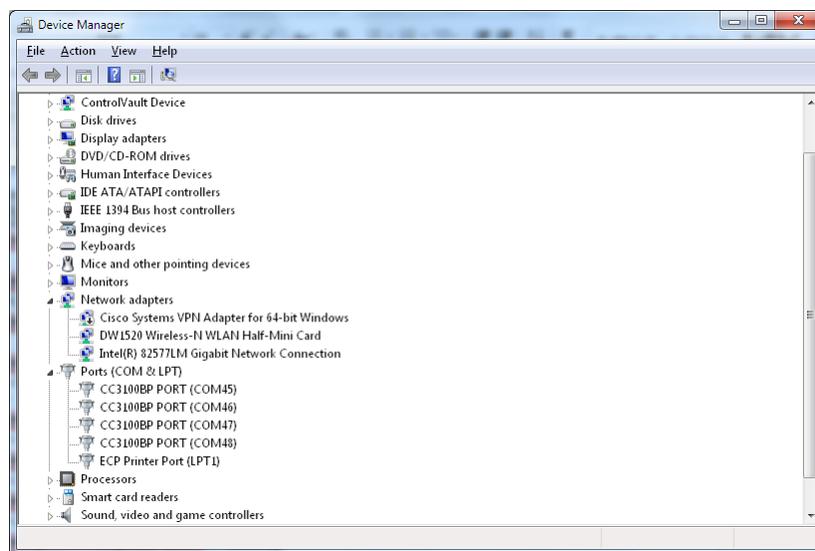


Figure 27. Device Manager

The third new COM port in [Figure 27](#) (COM47) is used for programming in this example.

8. Click on the CC31xx Flash Setup and Control label on the left window pane.
On the screen that appears, change the COM PORT value to the COM port associated with programming (COM47 in this example).
 9. Click Format to format the device.
A message will appear in the console that asks to restart the device. After this message appears, press the RST(SW2) switch on the CC3100BOOST.
 10. Click Program after the formatting is complete.
A message will appear in the console that asks to restart the device. After this message appears, press the RST(SW2) switch on the CC3100BOOST. The metrology Web pages should be loaded onto the CC3100 device after it has restarted.
2. Configure the CC3100BOOST power-selection jumper for the intended power source.
If the CC3100BOOST is powered from the EVM, connect the jumper resistor of the CC3100BOOST that connects VDD_ANA2 and VCC_LDO_3V3 (R35) to VBAT_CC (R50).
 3. Open the CCS workspace.
 4. Modify the SSID_NAME macro in CC3100config.c to the desired network name for the EVM.
 5. Load this software onto the TIDC-EVSE-WIFI, then turn off the EVM.
 6. Connect the CC3100_EM_BP_ADAPTER to the TIDC-EVSE-WIFI.
 7. Connect the CC3100BOOST to the CC3100_EM_BP_ADAPTER.
 8. Configure the jumper settings on the TIDC-EVSE-WIFI for the intended power source (see [Section 4.1](#)).

5.3 Energy Measurement

The energy measurement functionality of the TIDA-00637 reference design is based on the MSP430 Energy Library (see [\[4\]](#)). Users should also reference [\[1\]](#).

5.4 Hardware Specific Setup

All pins on the MSP430 device are set at the application launch according to the functionality defined in the emeter-template.h file. The three core registers required to initialize a pin for each I/O module (PxDIR, PxSEL, and PxOUT) are defined in the .h file and applied in the system_setup() register. Leave all clocking and power options on the default settings (defined in [\[4\]](#)).

The only additional required setup that is not covered by the basic I/O settings is the pilot-signal generation, GFCI interrupt, and ADC10 configuration.

5.4.1 Pilot Signal Setup

Because the pilot signal requires a steady 1-kHz PWM, the hardware uses a built-in timer module on the MSP430 device (TA2.1). The standard method of PWM generation on the MSP430 is to use one timer-capture register to set the PWM frequency and another (with the appropriate output tied to a pin) as the PWM duty cycle.

The existing energy library-clocking schema sets the SMLCK pin to match the MCLK pin at 25.16 MHz. Using an SMCLK with a divider of 25160 gives the appropriate timer frequency of 1 kHz. The PWM duty cycle only needs to be set once because it is static through the operation of the EVSE. Use [Equation 1](#) and [Equation 2](#) to determine the value for the TA2.1 trigger register as a percentage of 25160.

In the provided source code, the maximum current value is defined in a header. This current value can be set programmatically if a variable value is required.

To set the system output of 12 V on the pilot wire, a logic high must be set on the MCU to the pilot circuitry; set the MCU to output from the I/O module instead of the timer module on startup. The signal output transpires in the application state machine when required.

5.5 Wi-Fi® Stack

5.5.1 Software Overview

To add Wi-Fi capabilities to the TIDC-EVSE-WIFI device, a CC3100 host driver is integrated into the TIDC-EVSE-WIFI software. This extra software is in the CC3100 folder of the software .zip file associated with this design. These files are also in the emeter-app-6736 folder in the CCS workspace. This host driver has a portion that is platform independent and platform dependent. The platform-independent portion is in the SimpleLink folder. Because this portion is platform independent, it can be copied to other devices and other applications without making file changes.

The platform-dependent portion is in the Driver folder. The files in this folder are designed specifically for the TIDC-EVSE-WIFI, but the chip-specific details have been abstracted so it is easy to port to other MSP430 devices. [Table 5](#) shows different files and file descriptions.

Table 5. TIDC-EVSE-WIFI Driver Files

FILENAME	DESCRIPTION
board.c	This file defines the functions required to enable and disable the CC3100 and to receive interrupts from the CC3100 device. The file also maps the interrupt driver of the host driver to the events associated to the MSP430 port pin that the CC3100 interrupt-request pin (IRQ) is connected to.
board.h	To make the TIDC-EVSE-WIFI driver files more portable to other devices, an additional level of abstraction was added so 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. For example, to disable 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 the board.h file. From this file the following mappings can be configured: spi channel name (for example, UCA0, UCB1, and more), 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 (see Section 5.1). This file also declares the function prototypes for the functions in board.c.
CC3100config.c	This file contains the required code for running the desired Wi-Fi application. For this design, the code is configured for creating an http Web server, but 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 TIDC-EVSE-WIFI, similar to the http Web server example used for this design.
CC3100config.h	This file declares the function prototypes for the functions in spi.h.
spi.c	This file defines the SPI driver functions required by the platform-independent portion of the software to properly communicate with the CC3100. In this code, the SPI is configured for a 3-pin, 8-bit SPI with a 4-MHz SPI clock and the F6736 is configured as the SPI master.
spi.h	This file 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.

5.5.2 Startup Sequence

After the TIDC-EVSE-WIFI is powered and the peripherals are configured, the CC3100 is configured for operation by the EVM. The CC3100 automatically configures to the default state. Because of this configuration, all of the persistent settings of the CC3100 that were stored in nonvolatile memory will be replaced with default settings. By putting the device in the default state, it is put in a known state that will be used as a base state for later configuration actions. The device is configured for WLAN AP mode without security. When configuring the network, the resulting network SSID name is set to a user-defined value. After resetting the device for the new configurations to take place and after 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.

5.5.3 Communication Between CC3100 and TIDC-EVSE-WIFI

Metrology pages are located in the serial-flash system of the CC3100. When the client enters the website for one of these Web pages, the CC3100 sends the Web page that is stored in memory to the client. To support Web pages that have dynamically-updated content, the CC3100 allows user-defined tokens to be present in the .html file. Once the CC3100 has a request to send a Web page that has a user-defined token in it that is not in the list of predefined tokens, the CC3100 invokes a callback function in the EVM software. When this function is invoked, the EVM sends the token value that corresponds to the requested token to the CC3100. After providing the proper token value to the CC3100, the CC3100 replaces the token name in the .html page with the value that was sent by the F6736. This feature of the CC3100 updates the metrology Web pages with the metrology parameter values.

The length of a token value must be less than 64 bytes. Only one page and one token is used in this example, but additional pages can be added using unique tokens. [Table 6](#) shows a description of each Web page. The internal Web pages have no content besides the raw token value of the corresponding token. These internal Web pages query the values of the parameters to update the six metrology Web pages.

Table 6. Web Page Descriptions

WEB PAGE NAME	DESCRIPTION
main.html	Defines the navigation bar that has links to each metrology Web page and other default settings used in the display of each page.
metrologyA.html	Metrology Web page that has the metrology-value parameters for Phase A. This page gets these parameters by querying PhaseA.html. Because this internal Web page 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.
PhaseA.html	Internal Web page that is queried for the metrology parameters associated with Phase A. This Web page 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. This value does not get updated unless the Web page is manually refreshed.
PhaseB.html	Internal Web page that is queried for the metrology parameters associated with Phase B. This Web page 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. This value does not get updated unless the Web page is manually refreshed.

When the metrology page is requested, the entire page loads with unfilled metrology parameters. By using JavaScript, the metrology Web page completes a new http request for an internal Web page every second. The requested internal Web page always corresponds to the token associated with the metrology Web page.

If the request for the internal Web page is successful, the result is only the token values because the internal Web pages do not have any other content. The received data is verified to ensure the data is valid. If the data is valid, it is parsed to find the values of each metrology parameter so it can be displayed on the Web page. If invalid data is received consecutively for a token value, an alert is sent to the browser stating that invalid data was received and that the connection should be checked.

Figure 28 shows the formatting of valid token values for all tokens. In this messaging format, every parameter is represented by the string representation of the numerical value.

NOTE: This representation must have the decimal point for each parameter because the Web page does not add a decimal point after parsing data. Each string representation of the metrology value must have a semicolon after it to parse one metrology parameter to another.

Only the current portion of the token value has a value. The other parameters for the neutral channel have a space character to represent it. Table 7 shows the expected units of the parameters sent from the F6736 to the CC3100.

Voltage	;	Current	;	Active Power	;	Reactive Power	;	Apparent Power	;	Power Factor	;	Frequency	;	EVSE Status	;
---------	---	---------	---	--------------	---	----------------	---	----------------	---	--------------	---	-----------	---	-------------	---

Figure 28. Token and Data Format for Metrology and EVSE State

Table 7. Token and Data Format for Metrology and EVSE State

METROLOGY PARAMETER	EXPECTED UNITS
Voltage	Volts
Current	Amps
Active power	Watts
Reactive power	Var
Apparent power	VA
Power factor	No unit; this value should be a value between 0-1.
Frequency	Hz
EVSE status	ASCII character related to current EVSE status: 0: Idle 6: Ready to Charge 8: Charging

To operate the button functionality from the Web page, the JavaScript sets a separate token from the original data request. The token value `__SL_P_ULD` is defined to inform the EVSE that there is an incoming command. The default command is to change the charger state so the static string `__SL_P_ULD=ChargeState` is set. This command informs the EVSE that there is an incoming command and that it is related to the charger state.

Depending on the known current state of the EVSE, the JavaScript code will send a start or stop command. This command is completed by concatenating `_Start` or `_Stop` to the end of the token. An example final token string is `__SL_P_ULD=ChargeState_Start`. When received, the EVSE will unlink the string to determine the appropriate action and use a series of calls to the EVSE state machine to set the new parameter.

5.5.4 Connection Block Diagram

Figure 29 is a block diagram that shows the high-level interface used for a three-phase energy meter application using the F677x. A three-phase four-wire star connection to the AC mains is shown. Current sensor are connected to each of the current channels and a simple-voltage divider is used for corresponding voltages. The current transfer (CT) has an associated burden resistor that has to be connected at all times to protect the measuring device. Choose the CT and the burden resistor according to the manufacturer and current range required for energy measurements. The CTs can be replaced by Rogowski coils with minimal changes to the front end. The 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 MSP430 $\Sigma\Delta$ 24. Refer to the MSP4305xx and MSP4306xx user guides and device specific data sheets for these numbers.

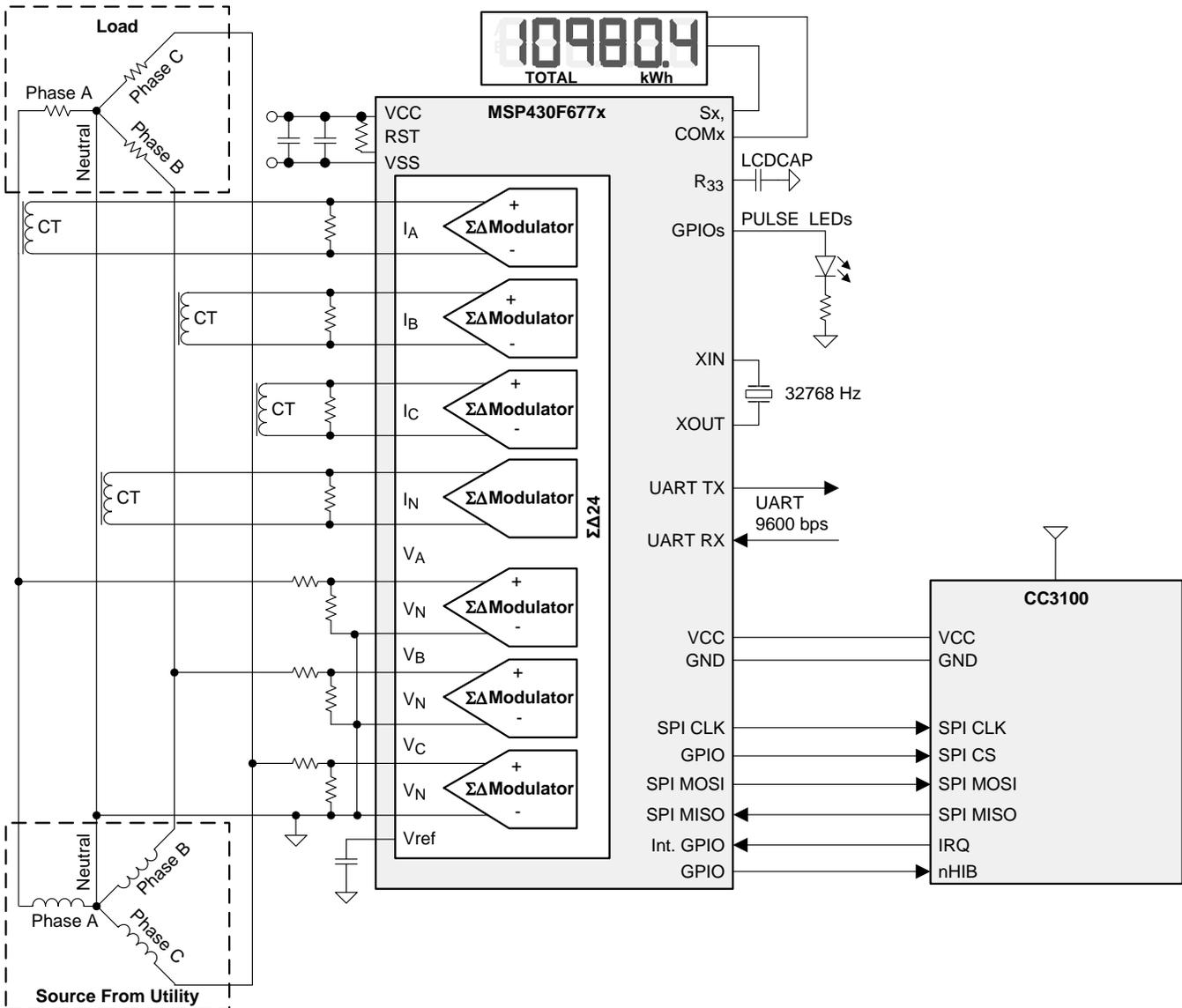


Figure 29. TIDC-3PHMTR-WIFIXR System Block Diagram

Other signals in Figure 29 are used to transmit active and reactive energy pulses used for accuracy measurement and calibration. 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 F6736 using SPI, where the F6736 is the master device. A GPIO output pin must be connected to the nHIB line of the CC3100BOOST. This pin enables or disables the CC3100. A GPIO pin that has interrupt capability must be connected to the IRQ pin of the CC3100 to provide an event interrupt from the CC3100 to the F6736. All port-1 and port-2 pins are viable options for connecting to the IRQ pin of the CC3100.

5.6 EVSE Application State Machine

The core functionality of the EVSE is moving between different states of the J1772 pilot-signal protocol. The simplest method of facilitating this movement is by implementing a simple state machine that has been built in the foreground of the energy library. The energy library has a function in the application layer that runs once per second (based on the number of SD24 samples that are collected) and provides the basis for the state machine. [Figure 30](#) shows the basic layout of the implemented state machine.

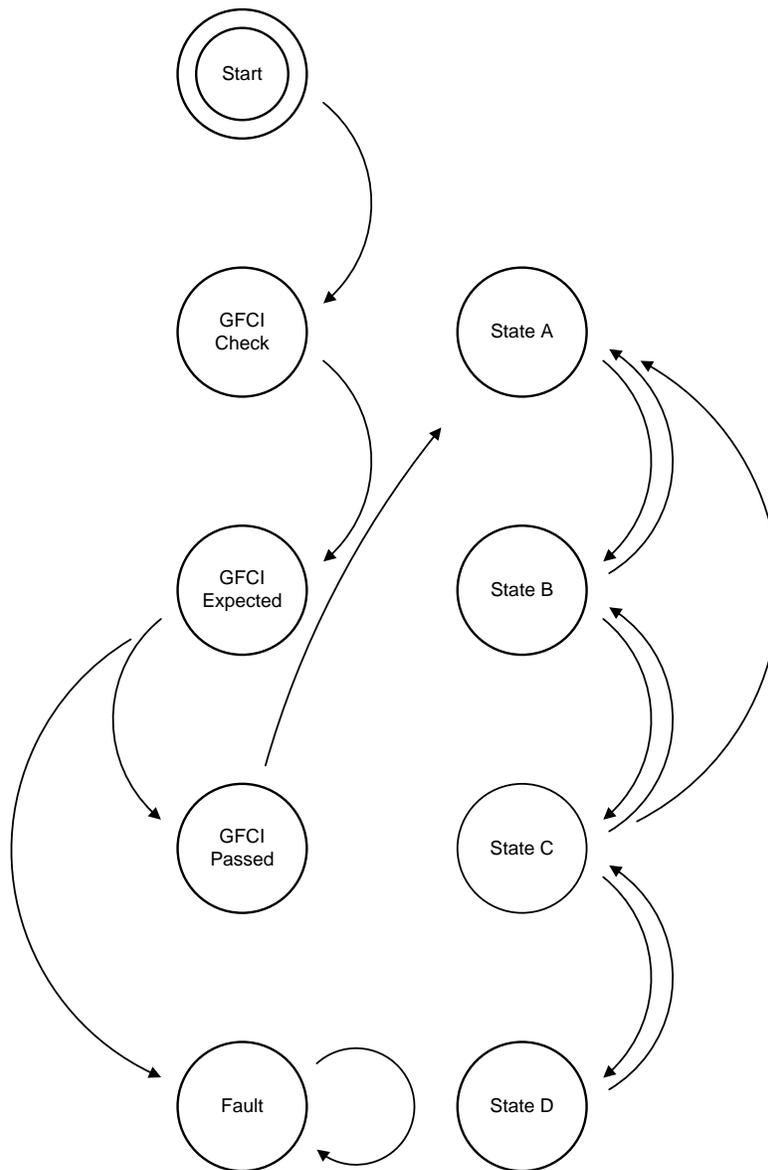


Figure 30. State Machine Overview

The following list details the process of the implemented state machine.

- **Start** – This is the state-machine entry point. Additional initialization can be put here.
- **GFCI Check** – This state initializes a GFCI check by setting a flag for the ISR and outputting a pulse to the check coil. The pulse triggers the GFCI ISR, which does not trigger a fault if the check expected flag has been set.
- **GFCI Expected** – Check that the GFCI test has been properly detected here. Trigger a GFCI Check fault and move to the fault state if necessary. If passed, move to the GFCI Passed state.
- **GFCI Passed** – The pass state is a mostly empty state to facilitate any additional functionality that may be required to run before starting the J1772 signaling.
- **State A** – To start the signaling, the pilot line is brought high at the beginning of State A. The only possible exit from here is to State B when the voltage drop on the pilot line has been signaled by the ADC10 ISR in the background. If a different voltage has been detected, this state can exit to the Fault state with a J1772 condition.
- **State B** – State B enables the PWM output on the pilot line. From here, the only possible exit is to State C (indicating that the vehicle has changed to resistance to signal that it is ready to accept charge voltage), State A (indicating that the connector has been unplugged), or a J1772 fault condition that has been detected in the background.
- **State C** – State C enables the charge voltage by closing the relay. Possible exits include State B (indicating that the vehicle has changed the resistance to signal that it is done charging), State A (indicating that the connector has been unplugged from the vehicle), State D (indicating that venting is required), or a J1772 fault condition that has been detected in the background.
- **State C** – State C enables the charge voltage by closing the relay. Possible exits include State B (indicating that the vehicle has changed the resistance to signal that it is done charging), State A (indicating that the connector has been unplugged from the vehicle), State D (indicating that venting is required), or a J1772 fault condition that has been detected in the background.
- **Fault** – The primary faults that can be triggered by the system are GFCI check failed, GFCI triggered, relay stuck, or a J1772 pilot signal fault. These faults are all critical and require a system restart to clear.

The primary mechanism for shifting between various states is the pilot-wire measurement on the ADC10 module. When a voltage change is measured, the foreground state machine detects the voltage change and moves appropriately. This setup limits the response rate to 1 s because the foreground operates at 1 Hz (sufficient response rate for this application).

6 Test Setup

The test setup for the TIDC-EVSE-WIFI mimis the TIDA-00637. the only alteration is the addition of the CC3100BOOST and the CC3100_EM_BP_ADAPTER.

7 Test Data

The core functionality of the EVSE was tested and can be viewed at [TIDA-00637](#).

7.1 Viewing EVSE Web Pages

To view the EVSE Web pages:

1. Power on the CC3100BOOST and the EVM.
If the CC3100BOOST is not powered from the EVM, ensure that the CC3100BOOST is powered on before the EVM. On power up, the CC3100 should broadcast the SSID in AP mode. The name of this network is set to the SSID macro value in the EVM software.
2. Connect to the network created by the CC3100 by using a computer or a smart phone. If this network is not viewable in the wireless networks, refresh the network list.
3. Open a Web browser from the station that is connected to the network of the CC3100BOOST and type in mysimplelink.net or 192.168.1.1 into the URL bar of the browser, then hit Enter.

If a window similar what is shown in [Figure 31](#) appears, type admin in the User Name and Password sections and click Log In.

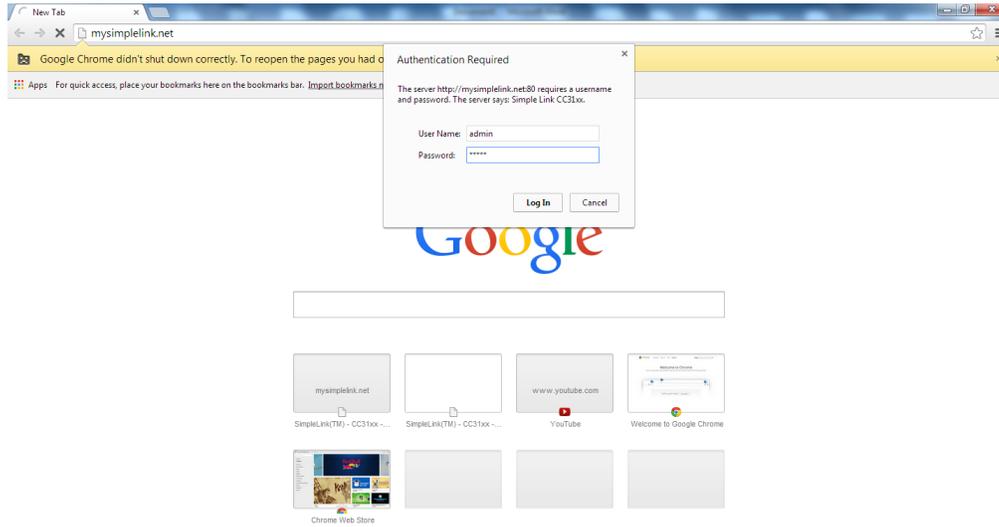


Figure 31. Authentication Page for Accessing Metrology Data

After clicking Log In, the page shown in [Figure 32](#) should appear.

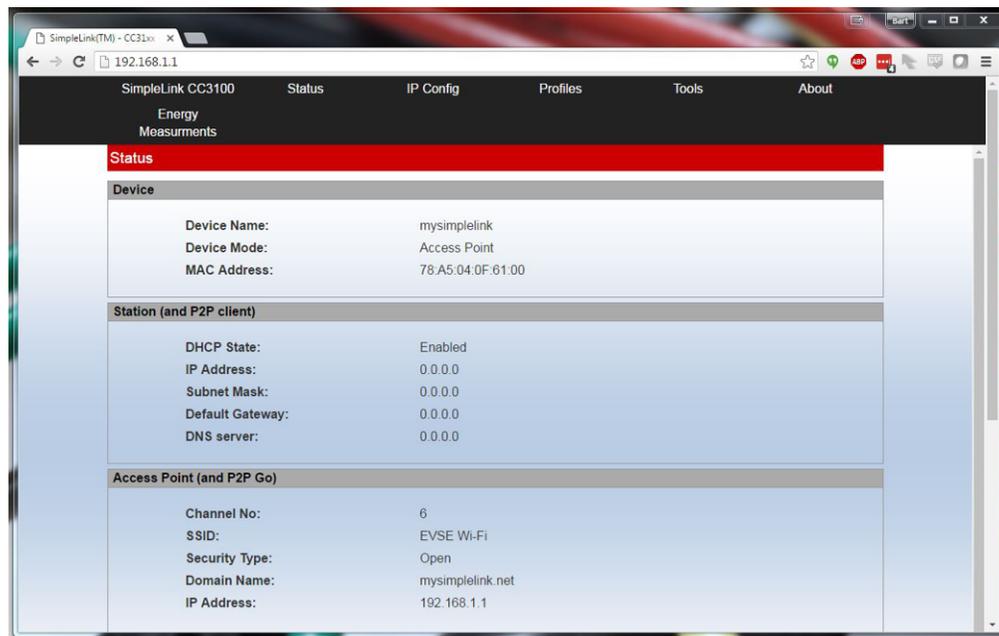


Figure 32. Index.html Web Page

By clicking on Energy Measurements in the second row, the status and control functionality should appear. [Figure 33](#) and [Figure 34](#) show the displays of energy measurements and EVSE states.



Figure 33. EVSE Web Page Showing Charging State

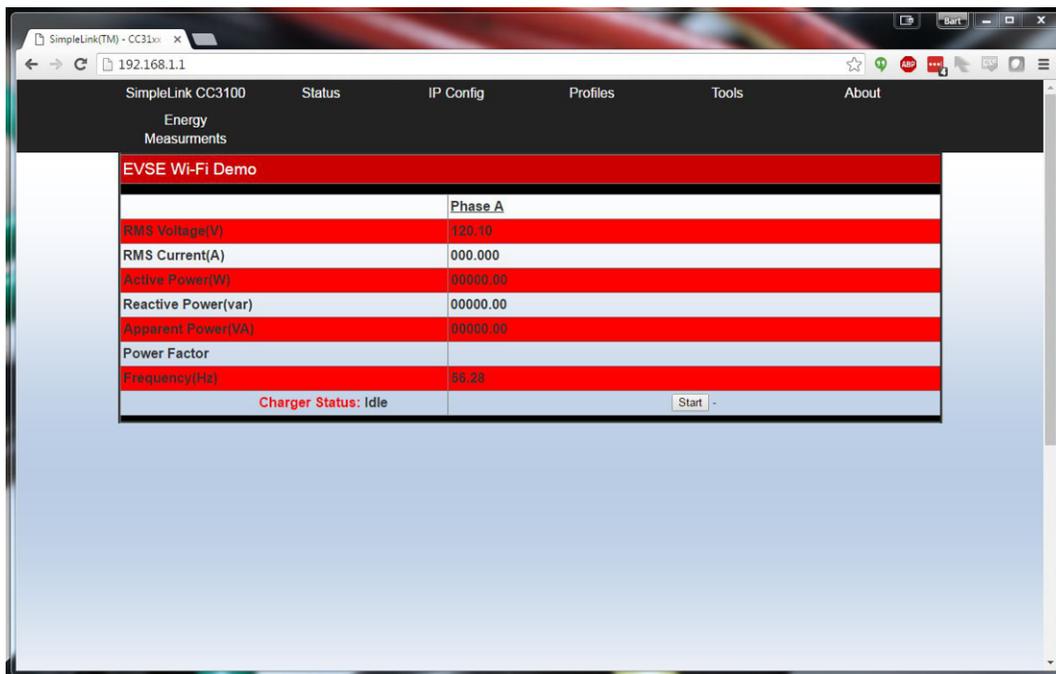


Figure 34. EVSE Web Page Showing Idle State

7.2 Energy Measurement

The energy measurement accuracy results for this design are identical to the results in [1]. Reference [1] for a full analysis of results.

7.3 Power Supply

For a full analysis of the power supply, see [TIDUAB3](#).

8 Design Files

8.1 Schematics

To download the schematics, see the design files at [TIDA-00637](#).

8.2 Bill of Materials

To download the bill of materials (BOM), see the design files at [TIDA-00637](#).

8.3 PCB Layout Recommendations

8.3.1 Layout Prints

To download the layer plots, see the design files at [TIDA-00637](#).

8.4 EagleCAD Project

To download the EagleCAD project files, see the design files at [TIDA-00637](#).

8.5 Gerber Files

To download the Gerber files, see the design files at [TIDA-00637](#).

8.6 Assembly Drawings

To download the assembly drawings, see the design files at [TIDA-00637](#).

9 Software Files

To download the software files, see the design files at [TIDA-00637](#).

10 References

1. Texas Instruments, *Class 0.2 Single-Phase E-Meter*, Application Note ([SLAA517](#))
2. Texas Instruments, *Advanced Emulation BoosterPack for SimpleLink™ Wi-Fi® CC3100 BoosterPack™ plug-in module*, Tool ([CC31XXEMUBOOST](#))
3. Texas Instruments, *CCS UniFlash - CC3100/CC3200 Edition*, ([UniFlash](#))
4. Texas Instruments, *MSP430 Energy Library (legacy)*, see the Energy Measurement Design Center [Energy Measurement Design Center](#) for an updated library

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11 Terminology

EVSE – Electric Vehicle Service Equipment

EV – Electric Vehicle

Pilot Line and Pilot Wire – One-wire communication between an EVSE and an EV

12 About the Author

BART BASILE is a systems architect in the Grid Infrastructure Solutions Team at Texas Instruments, focusing on renewable energy and EV infrastructure. Bart works across multiple product families and technologies to leverage the best solutions possible for system level application designs. Bart received his Bachelor's of Science in Electronic Engineering from Texas A&M University.

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