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FDAS-20-01 Heterodyning to produce a HI-FI grid

FDAS-20-01 Heterodyning to produce a HI-FI grid

Heterodyne means "other power".

The power grid is collection in interconnected oscillators meant to efficiently transmit power to loads.

The "other power" that can aid the grid's fidelity is the control of loads to modulate voltage and frequency in real-time.

The grid's ability to efficiently transmit power is challenged by many factors that affect voltage, frequency, and synchronization of the interconnected oscillators (power plants).

Latency of systems that rely on setting prices and notifying end users to favorably adjust their usage to satisfy the grids needs to continue to provide power to all end users is likely to be unreliable and may lead to unintended hazards.

Early warning that can be done instantly anywhere on the grid can surpass any system that relies on real-time setting of prices for watt-hours and communicating said prices to customers to control loads.

Monitoring voltage and frequency of the grid at service connections (points of end use) can provide control data to aid in ensuring high fidelity of voltage and frequency of the grid.

No other communication network is required, no radios, no communication standards, no need to collect and communicate product pricing. The signal for control has always existed, modern electronics can turn that signal in to actionable information for control in a cost effective way at the load or collection of loads.

Automation can be implemented to meet the requirements of the grid for every load type. Some loads are inductive and can be asked to choke unwanted parts of the waveform of the grid. Some loads are resistive and can be asked to change resistivity to change the waveform of the grid. Some loads have capacitance or inductance and can fill in missing parts of the waveform of the grid. This type of real-time control of the waveform of the grid is superheterodyning.

High speed signal processing and power control devices implemented on the same semiconductor device (single chip smart power) will make this process cost effective. These devices may be added to replaceable components of existing loads, allowing

MCP39F511
Smart Plug Reference Kit
User's Guide

ISBN: 978-1-5224-2114-6

Object of Declaration: MCP39F511 Smart Plug Reference Kit

EU Declaration of Conformity

This declaration of conformity is issued by the manufacturer.
The development/evaluation tool is designed to be used for research and development in a laboratory environment. This development/evaluation tool is not a Finished Appliance, nor is it intended for incorporation into Finished Appliances that are made commercially available as single functional units to end users under EU EMC Directive 2004/108/EC and as supported by the European Commission's Guide for the EMC Directive 2004/108/EC (8th February 2010).
This development/evaluation tool complies with EU RoHS2 Directive 2011/65/EU.
This development/evaluation tool, when incorporating wireless and radio-telecom functionality, is in compliance with the essential requirement and other relevant provisions of the R&TTE Directive 1999/5/EC and the FCC rules as stated in the declaration of conformity provided in the module datasheet and the module product page available at www.microchip.com.
For information regarding the exclusive, limited warranties applicable to Microchip products, please see Microchip's standard terms and conditions of sale, which are printed on our sales documentation and available at www.microchip.com.
Signed for and on behalf of Microchip Technology Inc. at Chandler, Arizona, USA.

Rodger Richey
Director of Development Tools

4/4/17
Date

NOTES:

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MCP39F511 SMART PLUG REFERENCE KIT USER'S GUIDE

Preface

NOTICE TO CUSTOMERS

All documentation becomes dated, and this manual is no exception. Microchip tools and documentation are constantly evolving to meet customer needs, so some actual dialogs and/or tool descriptions may differ from those in this document. Please refer to our web site (www.microchip.com) to obtain the latest documentation available.

Documents are identified with a "DS" number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is "DSXXXXXXXXA", where "XXXXXXXX" is the document number and "A" is the revision level of the document.

For the most up-to-date information on development tools, see the MPLAB® IDE online help. Select the Help menu, and then Topics, to open a list of available online help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using the MCP39F511 Smart Plug Reference Kit. Items discussed in this chapter include:

- Document Layout
- Conventions Used in this Guide
-
- Recommended Reading
- The Microchip Web Site
- Customer Support
- Document Revision History

DOCUMENT LAYOUT

This document describes how to use the MCP39F511 Smart Plug Reference Kit as a development tool to emulate and debug firmware on a target board. The manual layout is as follows:

- **Chapter 1. "Product Overview"** – Important information about the MCP39F511 Smart Plug Reference Kit.
- **Chapter 2. "Installation and Operation"** – Includes instructions on how the MCP39F511 Smart Plug Reference Kit works.
- **Chapter 3. "Meter Calibration"** - Describes the steps for meter calibration.
- **Chapter 4. "Android Application"** - Presents the Android application.
- **Appendix A. "Schematic and Layouts"** – Shows the schematic and layout diagrams for the MCP39F511 Smart Plug Reference Kit.
- **Appendix B. "Bill of Materials (BOM)"** – Lists the parts used to build the MCP39F511 Smart Plug Reference Kit.
- **Appendix C. "Accuracy Data"** – Lists accuracy data for the MCP39F511 Smart Plug Reference Kit.

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

<table>
<tr><th>Description</th><th>Represents</th><th>Examples</th></tr>
<tr><td colspan="3">Arial font:</td></tr>
<tr><td rowspan="2">Italic characters</td><td>Referenced books</td><td>MPLAB® IDE User's Guide</td></tr>
<tr><td>Emphasized text</td><td>...is the only compiler...</td></tr>
<tr><td rowspan="3">Initial caps</td><td>A window</td><td>the Output window</td></tr>
<tr><td>A dialog</td><td>the Settings dialog</td></tr>
<tr><td>A menu selection</td><td>select Enable Programmer</td></tr>
<tr><td>Quotes</td><td>A field name in a window or dialog</td><td>"Save project before build"</td></tr>
<tr><td>Underlined, italic text with right angle bracket</td><td>A menu path</td><td><u>File>Save</u></td></tr>
<tr><td rowspan="2">Bold characters</td><td>A dialog button</td><td>Click OK</td></tr>
<tr><td>A tab</td><td>Click the Power tab</td></tr>
<tr><td>N'Rnnnn</td><td>A number in verilog format, where N is the total number of digits, R is the radix and n is a digit.</td><td>4'b0010, 2'hF1</td></tr>
<tr><td>Text in angle brackets < ></td><td>A key on the keyboard</td><td>Press <Enter>, <F1></td></tr>
<tr><td colspan="3">Courier New font:</td></tr>
<tr><td rowspan="7">Plain Courier New</td><td>Sample source code</td><td>#define START</td></tr>
<tr><td>Filenames</td><td>autoexec.bat</td></tr>
<tr><td>File paths</td><td>c:\mcc18\h</td></tr>
<tr><td>Keywords</td><td>_asm, _endasm, static</td></tr>
<tr><td>Command-line options</td><td>-Opa+, -Opa-</td></tr>
<tr><td>Bit values</td><td>0, 1</td></tr>
<tr><td>Constants</td><td>0xFF, 'A'</td></tr>
<tr><td>Italic Courier New</td><td>A variable argument</td><td>file.o, where file can be any valid filename</td></tr>
<tr><td>Square brackets [ ]</td><td>Optional arguments</td><td>mcc18 [options] file [options]</td></tr>
<tr><td>Curly brackets and pipe character: { | }</td><td>Choice of mutually exclusive arguments; an OR selection</td><td>errorlevel {0|1}</td></tr>
<tr><td rowspan="2">Ellipses...</td><td>Replaces repeated text</td><td>var_name [, var_name...]</td></tr>
<tr><td>Represents code supplied by user</td><td>void main (void)
{ ...
}</td></tr>
</table>

RECOMMENDED READING

This user's guide describes how to use the MCP39F511 Smart Plug Reference Kit. Other useful documents are listed below. The following Microchip document is available and recommended as a supplemental reference resource:

MCP39F511 Data Sheet – *"Power-Monitoring IC with Calculation and Energy Accumulation"* (DS20005393B)

This data sheet provides detailed information regarding the power-monitoring device.

PIC24FJ64GA104 Family Data Sheet – *"28/44-Pin, 16-Bit General Purpose Flash Microcontrollers with nanoWatt XLP Technology"* (DS39951C)

This data sheet provides detailed information regarding the MCU.

RN4020 Data Sheet – *"Bluetooth® Low Energy Module"* (DS50002279B)

This data sheet provides detailed information regarding the BTLE module.

THE MICROCHIP WEB SITE

Microchip provides online support via our web site at www.microchip.com. This web site is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the web site contains the following information:

- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

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CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or field application engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the web site at:
http://www.microchip.com/support.

DOCUMENT REVISION HISTORY

Revision A (August 2017)

- Initial Release of this Document.

Chapter 1. Product Overview

1.1 INTRODUCTION

The MCP39F511 Smart Plug is a fully functional power meter capable of transmitting its data over a Bluetooth® interface to an Android phone or tablet.

The free Android application for the MCP39F511 Smart Plug can be found on the Google Play Store under "Microchip Smart Plug".

The system calculates the real-time values of the RMS current, RMS voltage, frequency, active, reactive and apparent power, power factor and also the energy consumption.

The MCP39F511 Smart Plug allows remote power control to save energy when the user turns an unused device off, instead of keeping it in stand-by (still consuming power).

It also offers an easy way of monitoring the electrical behavior of home devices and appliances, allowing early detection of malfunctions if an overpower or overcurrent event is observed.

The MCP39F511 Smart Plug is designed to stand between the wall outlet and any electronic device that the user wants to control and monitor remotely.

1.2 CHARACTERISTICS

- Nominal input voltage: 120V/230V [RMS]
- Nominal frequency: 50/60 Hz
- Latching relay for loads up to 10A [RMS]
- Wireless reporting of all power and energy quantities
- Factory calibrated
- BTLE range up to 100m
- Two LEDs for status indication
- Button for turning the wireless module OFF

FIGURE 1-1: *MCP39F511 Smart Plug Picture (North American Version).*

1.3 SYSTEM OVERVIEW

The MCP39F511 Smart Plug is assembled out of three PCBs.

The North American plug board is used as support for the other two boards, the power board and the BTLE MCU board, which are mounted vertically.

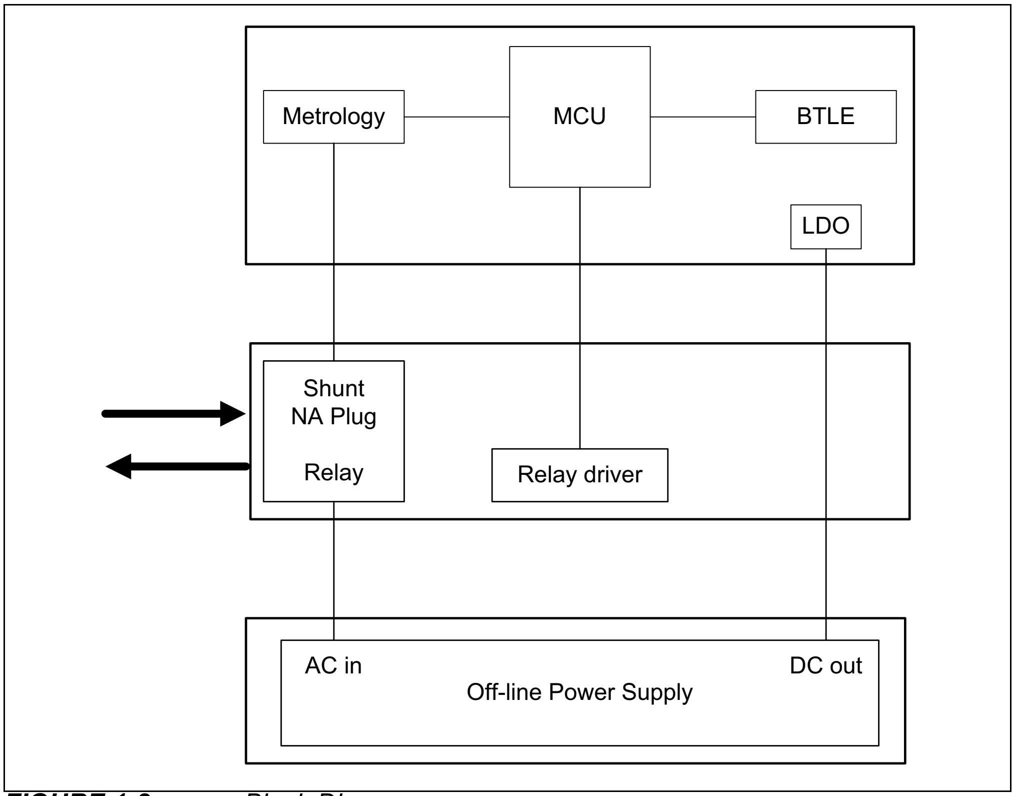


FIGURE 1-2: *Block Diagram.*

1.3.1 North American plug board

The North American plug board contains the output socket, the relay, the relay driver and the two LEDs.

A shunt resistor is used as a current sensor for the current channel and two high-voltage resistors, which are part of the resistive divider, provide the voltage input for the voltage channel.

The North American plug board is connected to the BTLE MCU board through two 90-degree male headers (3-pin and 6-pin) as shown next, soldered directly on both PCBs.

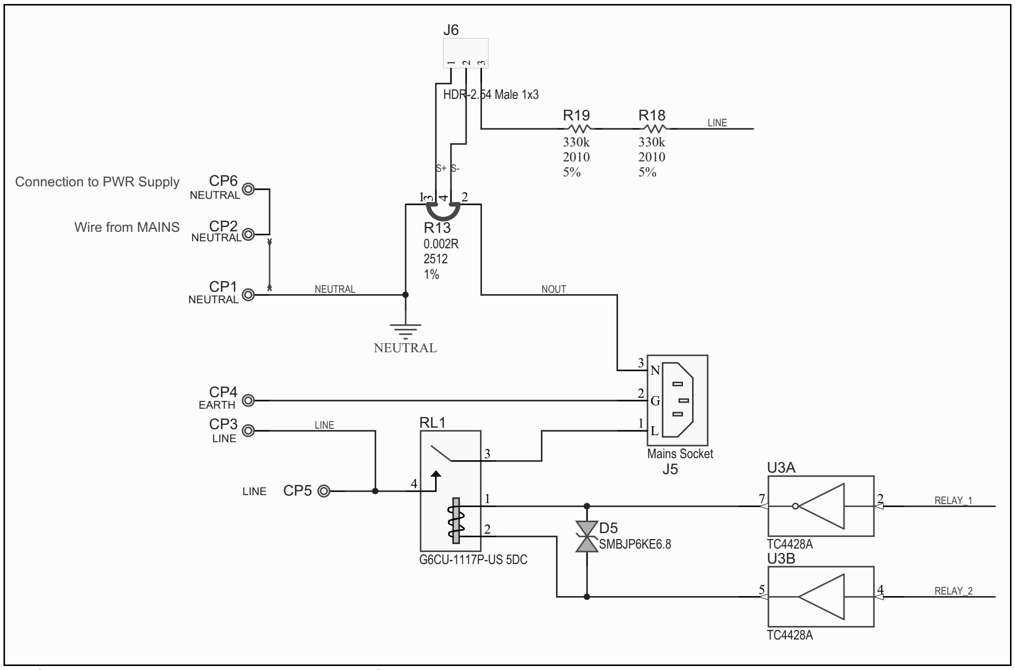


FIGURE 1-3: *Metrology Sensing.*

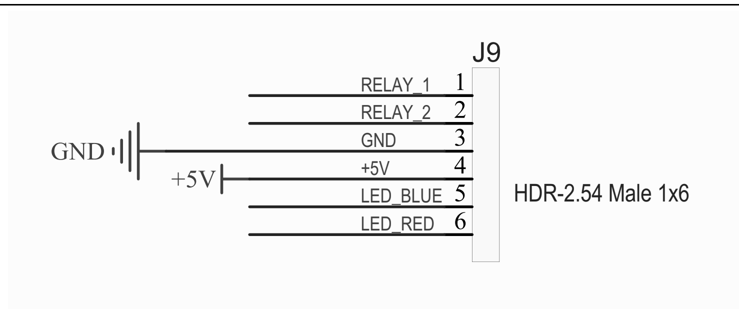


FIGURE 1-4: *Digital Signals Connector.*

1.3.2 Relay

The relay is a latching-type relay, which offers the advantage that it consumes no power in either ON or OFF state, but only during the transition between states.

This is a very important feature for a device like the MCP39F511 Smart Plug.

1.3.3 Status LEDs

The RED LED shows the status of the relay (it is off when the relay state is OFF).

The BLUE LED shows the status of the BTLE module (it is off when the BTLE module is turned OFF).

When the BTLE module is ON, but the connection to the Android application is not made, the BLUE LED emits a short light pulse every 5 seconds.

The BLUE LED is solidly lit as long as the Bluetooth® connection is maintained.

1.3.4 Power Board

The power board contains the AC-to-DC converter used as the power supply for the entire system.

It is connected to the North American plug board through two 90-degree, 3-pin male headers with the middle pin removed (AC input and +5V DC output), soldered directly on both PCBs.

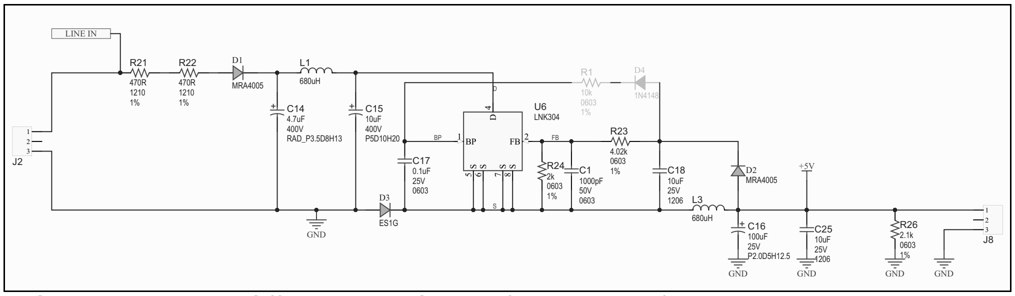


FIGURE 1-5: Offline Power Supply (Non-Isolated).

1.3.5 BTLE MCU Board

The BTLE MCU board contains the most important devices: the MCP39F511 power monitoring IC, BTLE module and the MCU. There is also an LDO that provides a stable +3.3V DC power supply for all the low-voltage components.

The MCP39F511 power-monitoring IC is a complex device in itself, because it includes a dual-channel Delta-Sigma ADC with PGA front-end, a 16-bit calculation engine and an UART interface.

The 16-bit calculation engine takes care of all the real-time measurements, meaning no metrology firmware is required on the MCU.

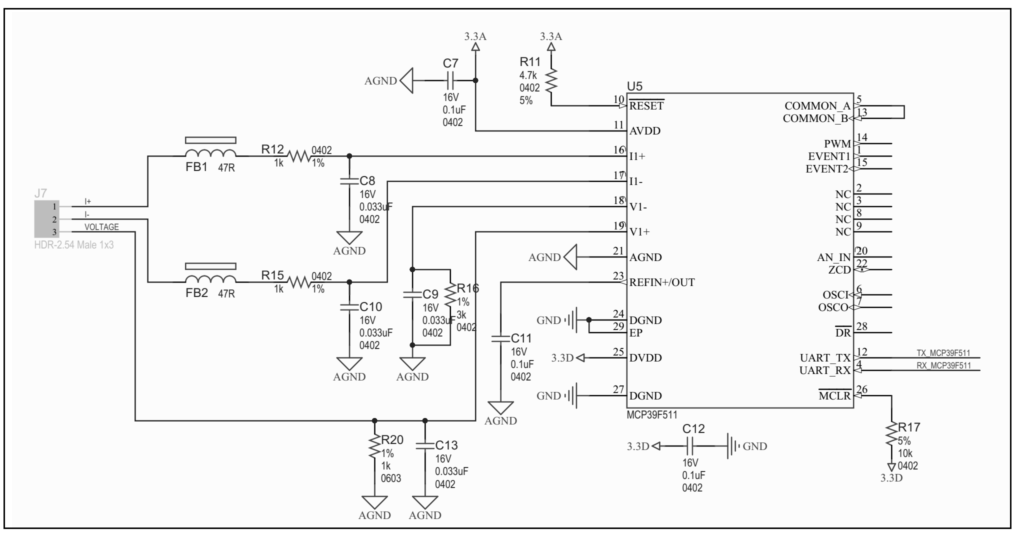


FIGURE 1-6: MCP39F511 Power Monitoring IC.

For calibration purposes, the J2 connector can be used to gain access to the MCP39F511 registers on the UART1 interface.

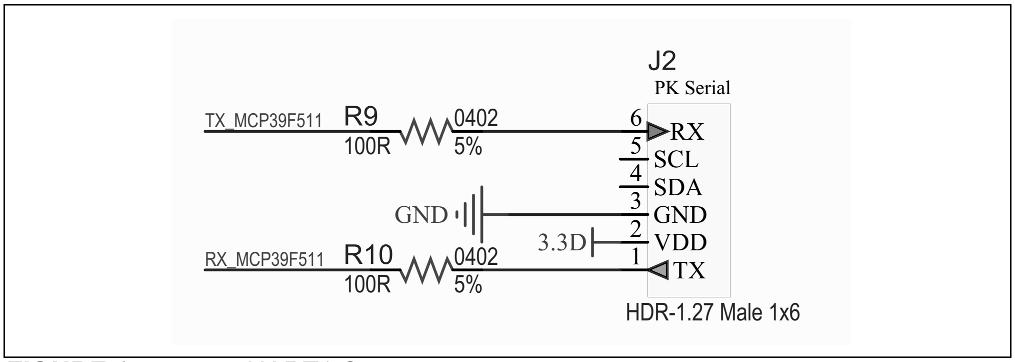


FIGURE 1-7: *UART1 Connector.*

The PIC24FJ32GA102 MCU is a low-cost, general-purpose microcontroller, equipped with two UART modules and an internal oscillator.

The button mounted on the board allows the BTLE module to be turned ON or OFF.

The MCU can be programmed by using the dedicated ICSP connector (J1).

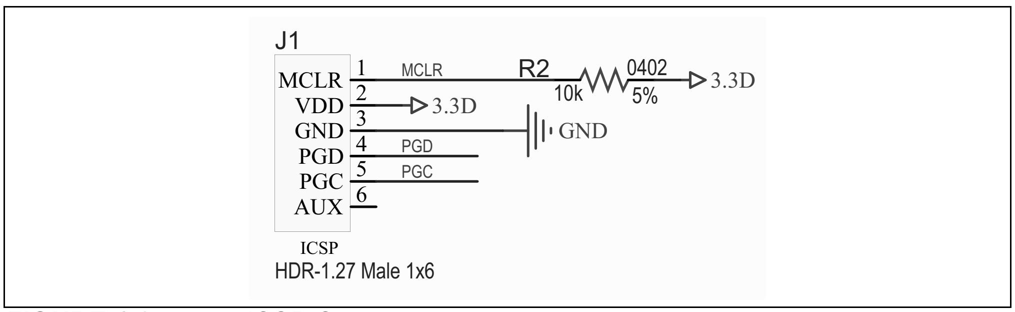


FIGURE 1-8: *ICSP Connector.*

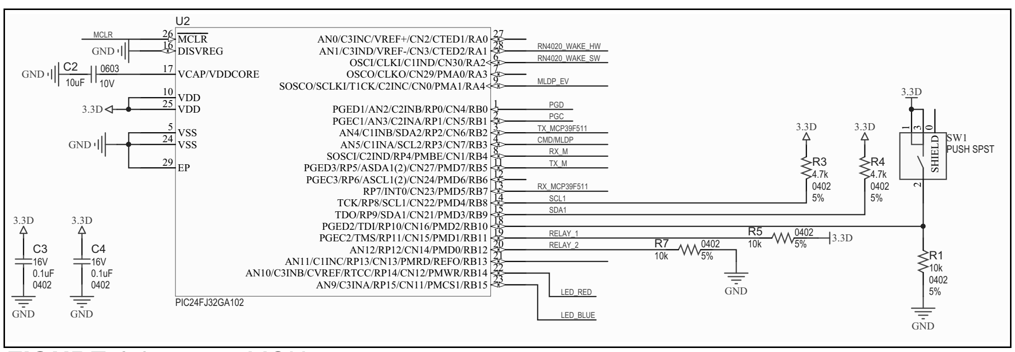


FIGURE 1-9: *MCU.*

The RN4020 is a fully certified Bluetooth® version 4.1 module.

This device integrates RF, a baseband controller and a command API processor, making it a complete Bluetooth® low-energy solution.

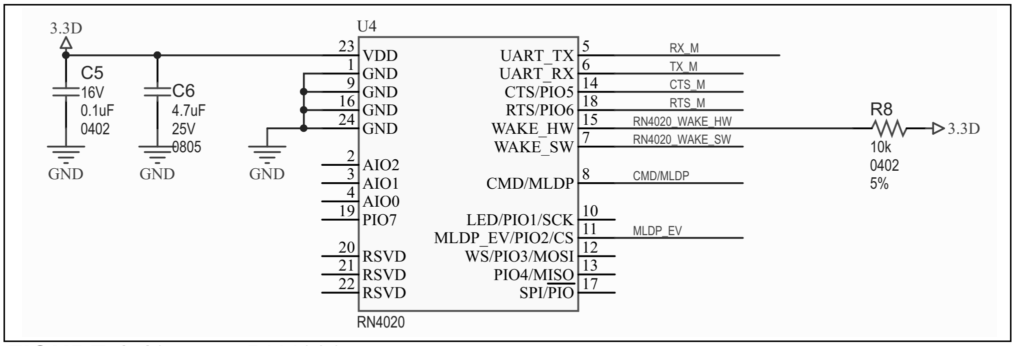


FIGURE 1-10: *RN4020.*

The BTLE module sends the data via a wireless connection and the information is displayed on the Android phone or tablet.

1.4 WHAT DOES THE MCP39F511 SMART PLUG REFERENCE KIT CONTAIN?

This MCP39F511 Smart Plug Reference Kit includes:

- The MCP39F511 Smart Plug Unit (ADM00642)
- Information Sheet

Chapter 2. Installation and Operation

2.1 OVERVIEW

The MCU is the heart of the system, expanding the power monitoring functionality over wireless connectivity.

When the application is in Meter State or Energy State, it asks for new data once every second.

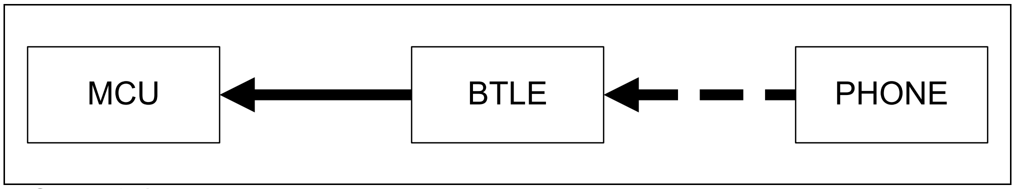


FIGURE 2-1: *The User Asks For Data.*

The MCU receives the request via wireless and sends a read command frame to the MCP39F511 power monitoring IC on the UART1 interface.

In Meter State, the MCU requests the reading of 24 bytes, starting from address 0x0006 (Voltage RMS register).

In Energy State, the MCU requests the reading of 32 bytes, starting from address 0x001E (Import Active Energy Counter).

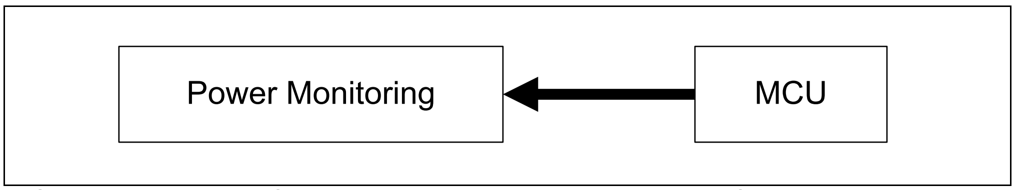


FIGURE 2-2: *MCU Interrogates the Power Monitoring IC.*

In response, MCP39F511 power-monitoring IC sends back the values of the internal registers containing the results of the calculations (performed every four line cycles in a continuous loop).

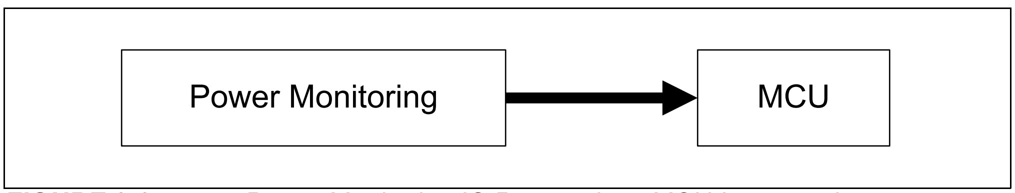


FIGURE 2-3: *Power Monitoring IC Responds to MCU Interrogation*

The MCU sends the requested data to the BTLE module on the UART2 interface.

The data is then wirelessly sent by the BTLE module and displayed in real time on the screen.

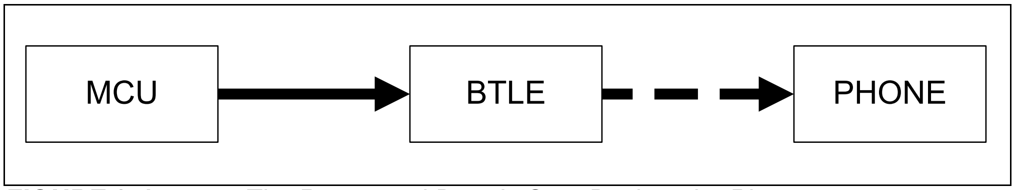


FIGURE 2-4: The Requested Data Is Sent Back to the Phone.

2.2 WIRELESS COMMANDS

Each command sent to the MCP39F511 Smart Plug by the application contains two bytes.

After receiving, decoding and executing the command, the MCU sends back one byte in response and the application displays a confirmation message.

TABLE 2-1: WIRELLES COMMANDS

Command Group (Byte 1)	Command Group (Byte 2)	Reply
Relay commands		
0x10	0x11 – Relay ON	0x1 1 – if relay is correctly set or no reply if the command fails
	0x12 – Relay OFF	0x1 2 – if relay is correctly set or no reply if the command fails
Calibration Commands		
0x20	0x21 - Frequency calibration and gains calibration at PF = 1	0x20 - Calibration successful
		0x28 - Set range command failed
		0x29 - Frequency calibration failed
		0x2A - Gain calibration failed
		0x2D - Save to flash command failed
	0x22 - Reactive power calibration at PF = 0.5	0x2F - Reactive power gain calibration failed
Data Request Commands		
0x30	0x31 – Read meter state	30-byte reply:
		0x31,0xFE, No of data bytes (27), 27 bytes of data representing the measured values of the voltage, current, frequency, active power, reactive power, apparent power and power factor
	0x32 – Read energy state	38-byte reply:
		0x32, 0xFE, No of data bytes(35), 35 bytes of data representing the energy counters
	0x34 – Reset energy counters	0x34 – counters reset

Chapter 3. Meter Calibration

3.1 OVERVIEW

The MCP39F511 Smart Plug is factory-calibrated, so no calibration is required.

The calibration is done by connecting the MCP39F511 power-monitoring IC to a PC via an isolated UART to USB adapter, and using the MCP39F511 Power Monitor Utility provided free of charge on the Microchip website.

The J2 connector provides all the necessary signals for this operation.

Once the MCP39F511 Smart Plug is assembled, it is harder to gain external access to the UART signals of the MCP39F511 power monitoring IC, because the MCU is already connected on the same UART pins.

The solution is to place the MCU in reset by pulling the MCLR pin down, which causes the internal UART port pins to be kept in high impedance.

This is done by placing a header with MCLR and GND pins shorted on the ICSP connector (J1).

The calibration is performed with lab grade equipment capable of generating an accurate high voltage and simulating a current load at 50/60 Hz.

After calibration, the MCU is released from reset by removing the header placed on J1.

3.2 STEP BY STEP CALIBRATION PROCEDURE USING THE GUI

- Apply the calibration AC voltage, without a load.
- Wait for a computational cycle (a minimum of 80 ms).
- Manually adjust the AC offset registers (current, active power and reactive power) for minimal offset values.
- Apply the calibration load current, PF = 1. A calibration load current of 1/3 of the maximum current is suggested.
- Wait for a computational cycle (a minimum of 80 ms).
- Press the Calibrate Gains button; this sets the range and target values, then performs the frequency, voltage, current and active power-gain calibration.
- Change the power factor to 0.5.
- Wait for a computational cycle (a minimum of 80 ms).
- Press the Calibrate Phase button; this calibrates the phase compensation coefficient.
- Wait for a computational cycle (a minimum of 80 ms).
- Press the Calibrate Reactive button; this calibrates the reactive power gain.
- Press the Save to Flash button.

Note: The default calibration values are:

- Voltage = 220V
- Current = 5A
- Frequency = 50 Hz

NOTES:

Chapter 4. Android Application

4.1 OVERVIEW

The Android App is free to download and can be found on the Google Play Store:

https://play.google.com/store/apps/details?id=com.microchip.smartplug

The first time you run the application, you will be prompted to accept the License Agreement.

Press **Accept** to agree with the terms to start using the application.

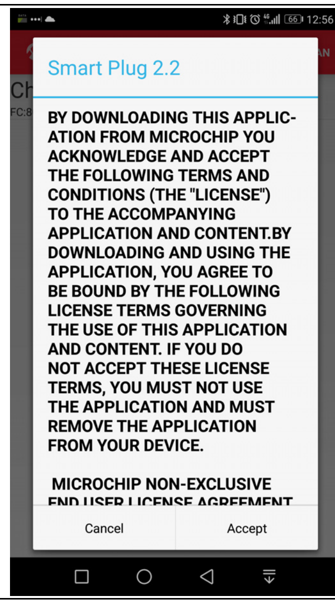


FIGURE 4-1: *License Agreement.*

The application needs permission to use the device's Bluetooth® and also the Location.

For Android 7 and higher, the Bluetooth® scan will not find any devices unless the Location permission is granted.

The first screen shown is the device list.

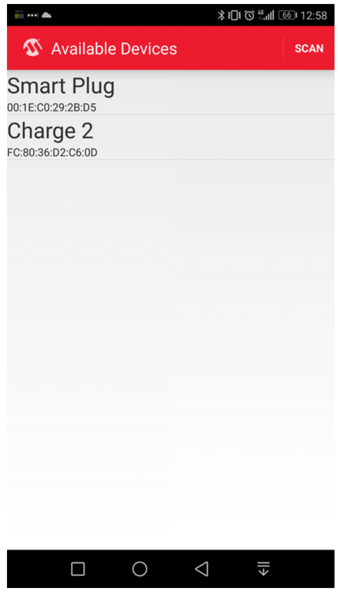


FIGURE 4-2: Device List.

The application scans for available Bluetooth® devices and displays them.

Touching the **Scan** button starts the search process again and updates the list.

Select the Smart Plug from the list to connect to it.

Once the connection is established, the blue light on the MCP39F511 Smart Plug will light up and the Meter State screen will be shown.

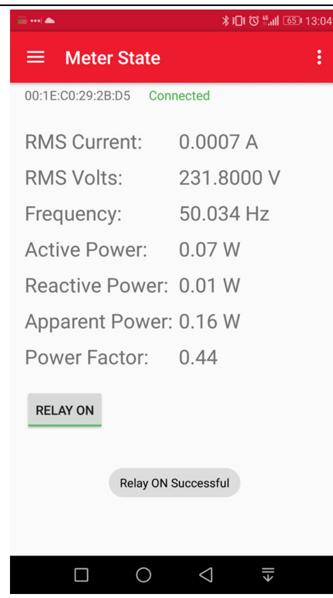


FIGURE 4-3: Meter State (No Load).

The Meter State screen contains information about the current consumption, voltage, frequency, active power, reactive power, apparent power and power factor value read from the meter and allows controlling the power output at a touch of a button using the onboard relay.

Switching the relay off cuts the power to any electrical device that is plugged in.

The result of the operation will briefly be displayed on screen.

The side menu allows access to the Energy State, where the total energy consumption is displayed.

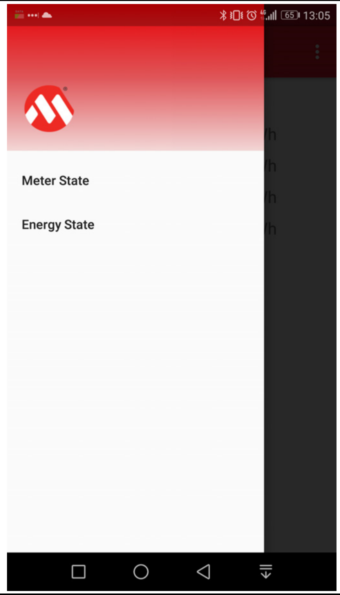


FIGURE 4-4: *Side Menu.*

The user has the option of resetting the energy counters, a useful feature for monitoring the energy consumption of a different consumer.

The energy-counting feature is turned on by default after resetting the counters.

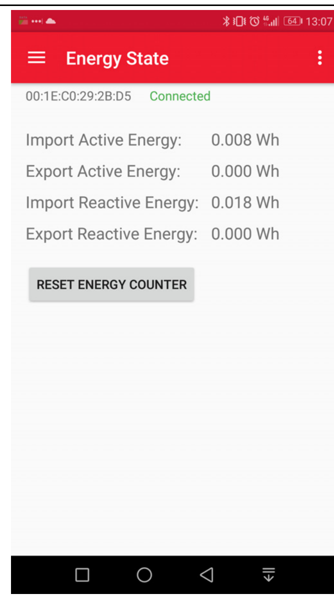


FIGURE 4-5: *Energy State.*

The side menu allows accessing the calibration menu.

Pressing the Microchip Logo five times in rapid succession (within a 3-second interval) will display the calibration screen.

Pressing the **Calibrate PF 1** button should be done after applying the appropriate voltage and current calibration signals at PF = 1.

This operation allows the calibration of the frequency, current, voltage and active power gains.

After changing the PF to 0.5, pressing the **Calibrate PF 0.5** button allows the calibration of the reactive power gain.

The new gain coefficients are saved to flash automatically after a successful calibration.

Disclaimer: The calibration procedure is irreversible and should only be carried out by trained personnel with the appropriate calibration equipment.

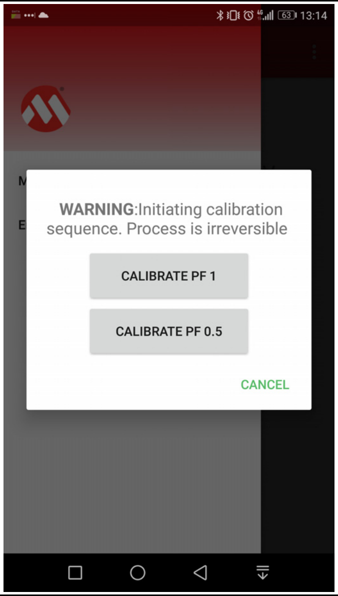


FIGURE 4-6: *Calibration Menu.*

To disconnect from the MCP39F511 Smart Plug, press the back button until you return to the Scan screen, or select **Disconnect** from the top-right menu on any of the screens.

The firmware, schematics and the layout files can be found on the MCP39F511 Smart Plug web page at www.microchip.com/smartplug.

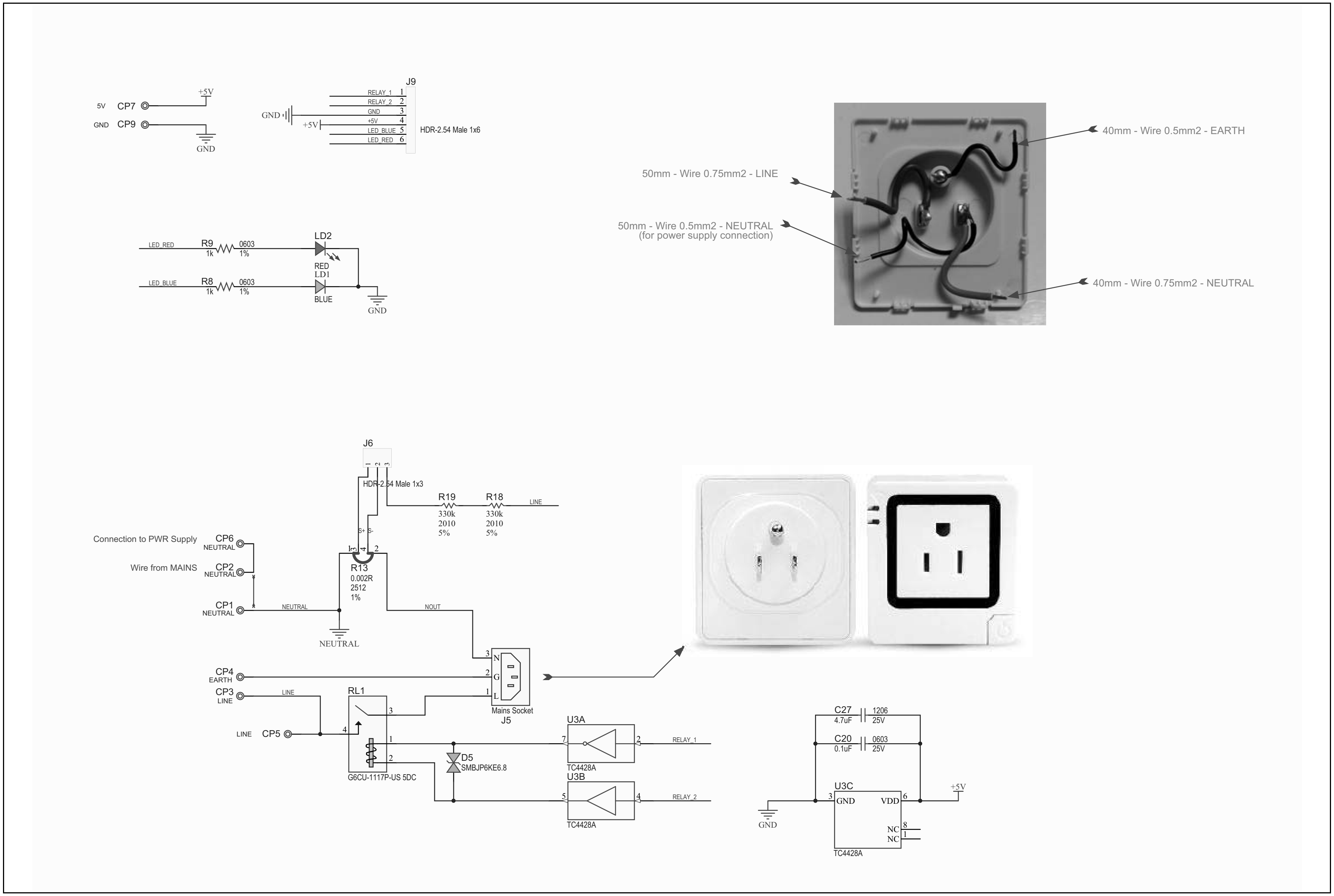
Appendix A. Schematic and Layouts

A.1 INTRODUCTION

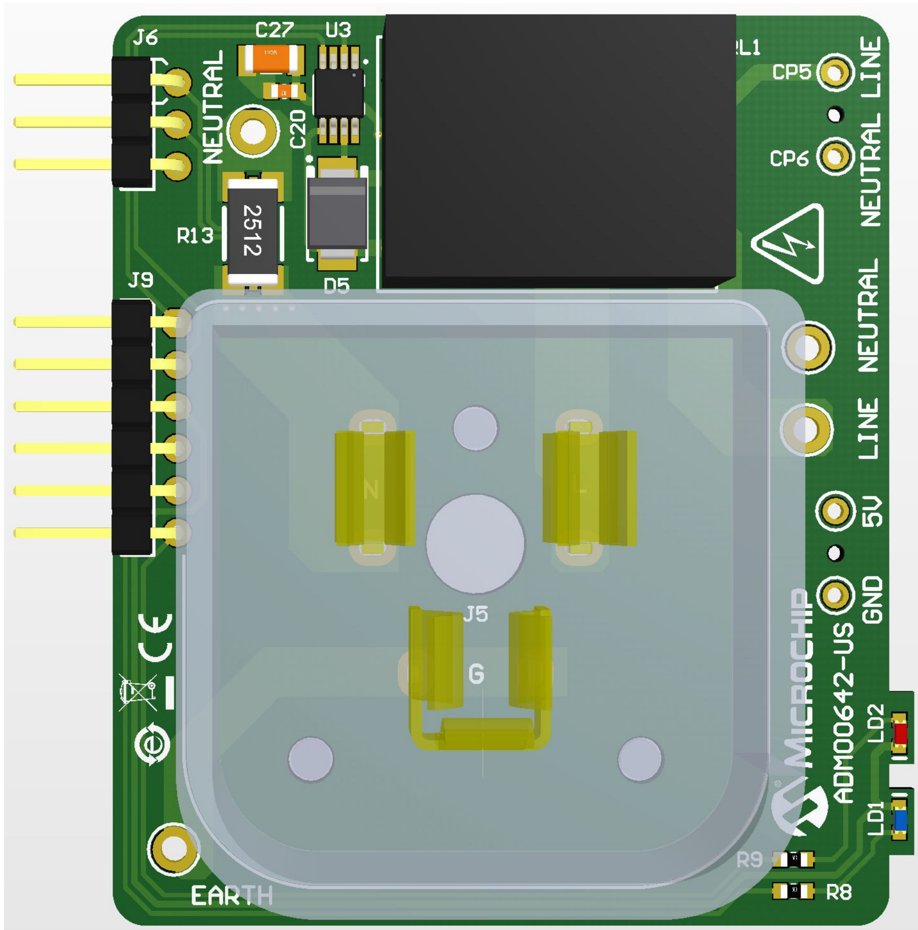
This appendix contains the following schematics and layouts for the MCP39F511 Smart Plug revision 3 boards:

- North American Plug Module Board - Schematic
- North American Plug Module Board - Top View
- North American Plug Module Board - Bottom View
- Power Module Board - Schematic
- Power Module Board - Top View
- Power Module Board - Bottom View
- BTLE MCU Module Board - Schematic
- BTLE MCU Module Board - Top View
- BTLE MCU Module Board - Bottom View

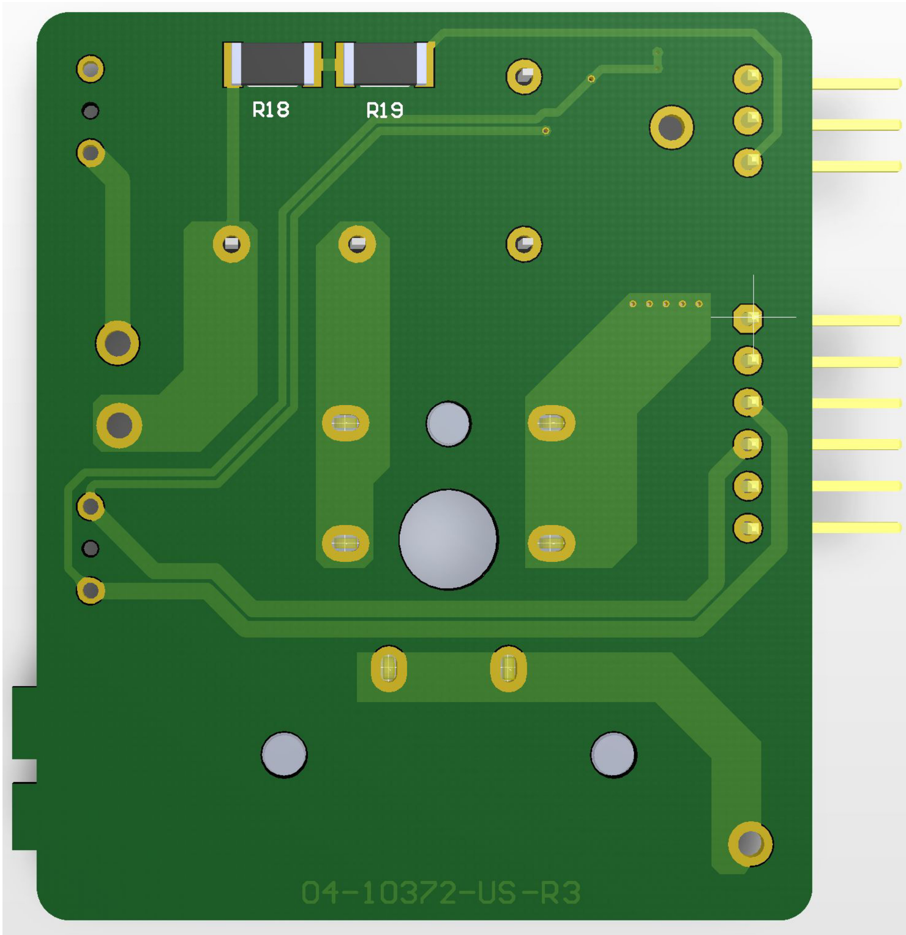
A.2 NORTH AMERICAN PLUG MODULE BOARD - SCHEMATIC



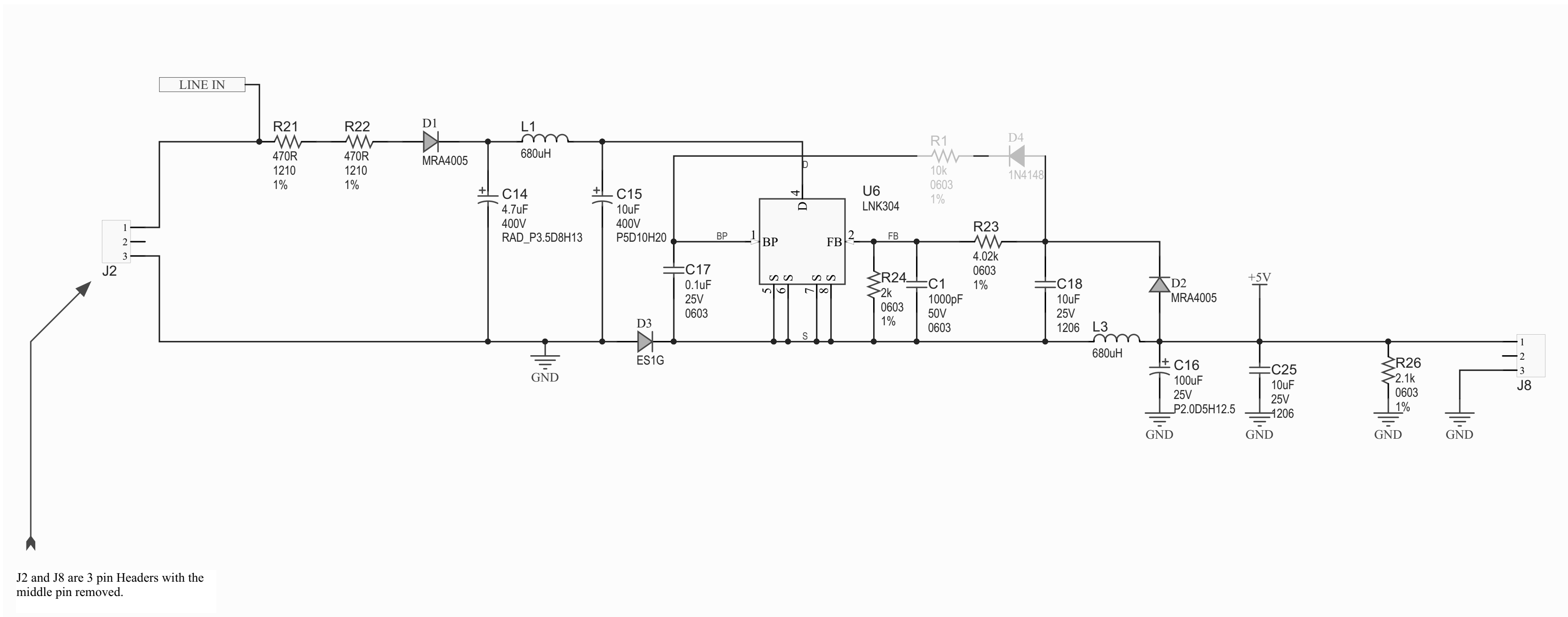
A.3 NORTH AMERICAN PLUG MODULE BOARD - TOP VIEW



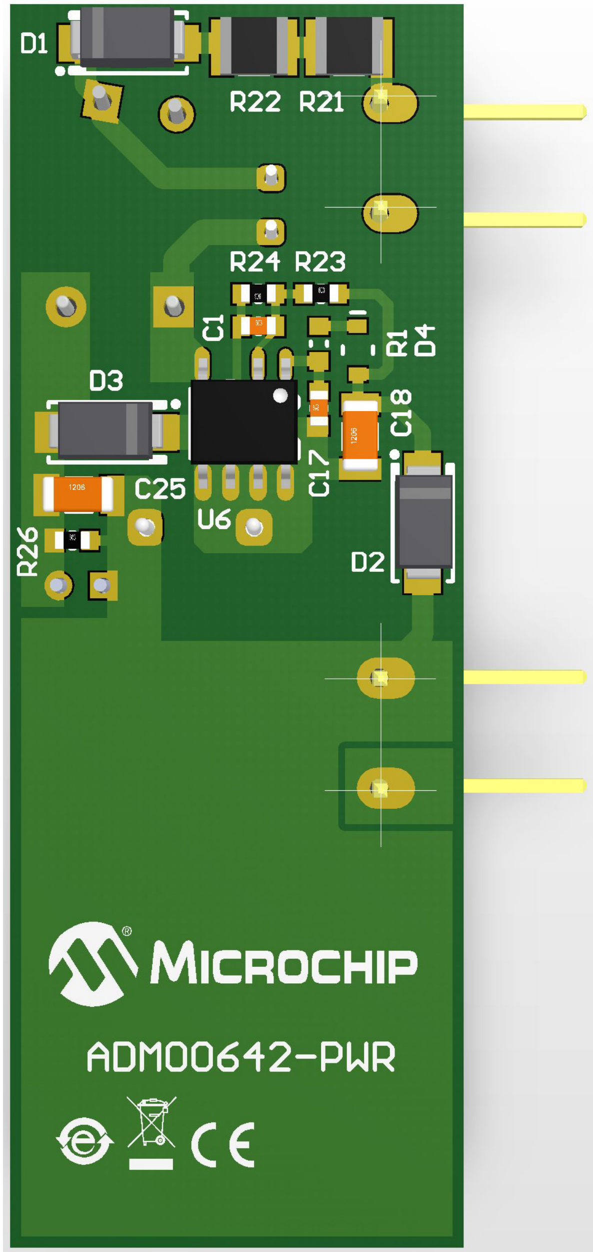
A.4 NORTH AMERICAN PLUG MODULE BOARD - BOTTOM VIEW



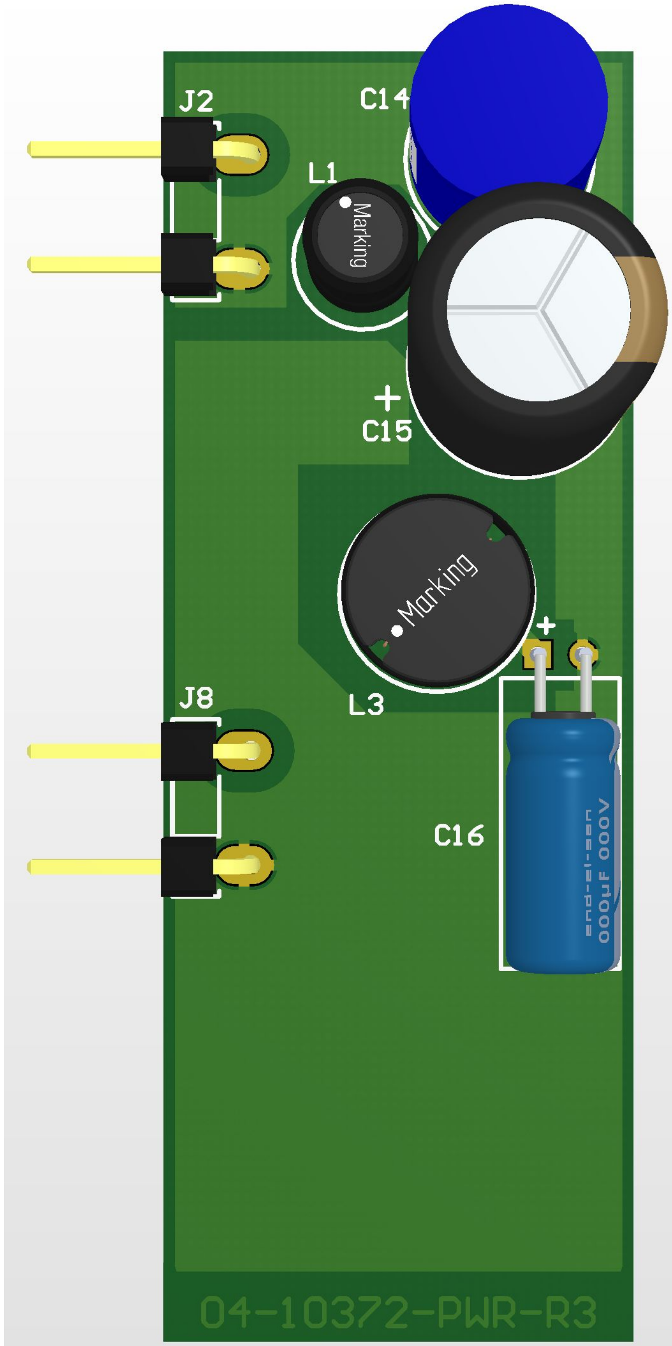
A.5 POWER MODULE BOARD - SCHEMATIC



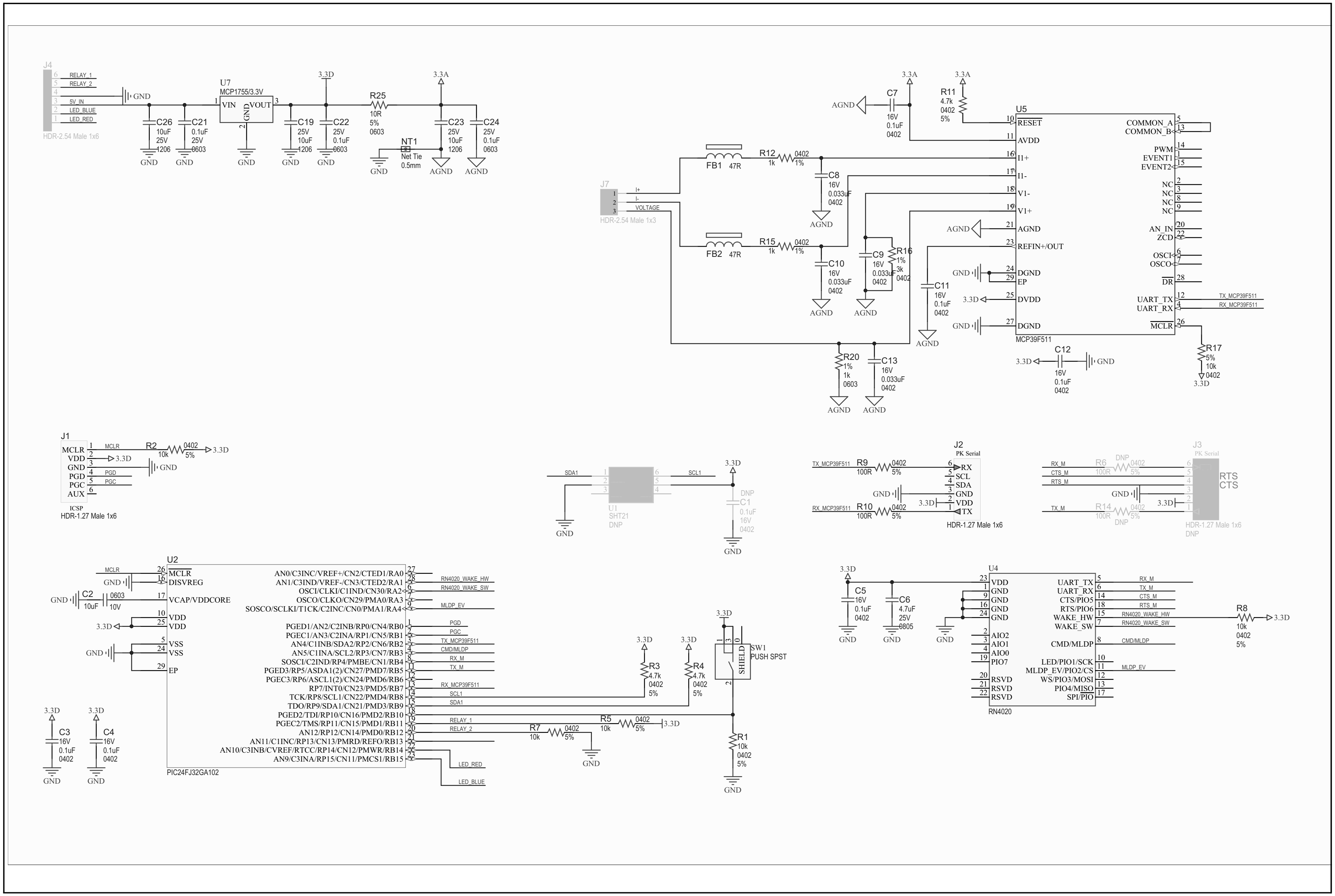
A.6 POWER MODULE BOARD - TOP VIEW



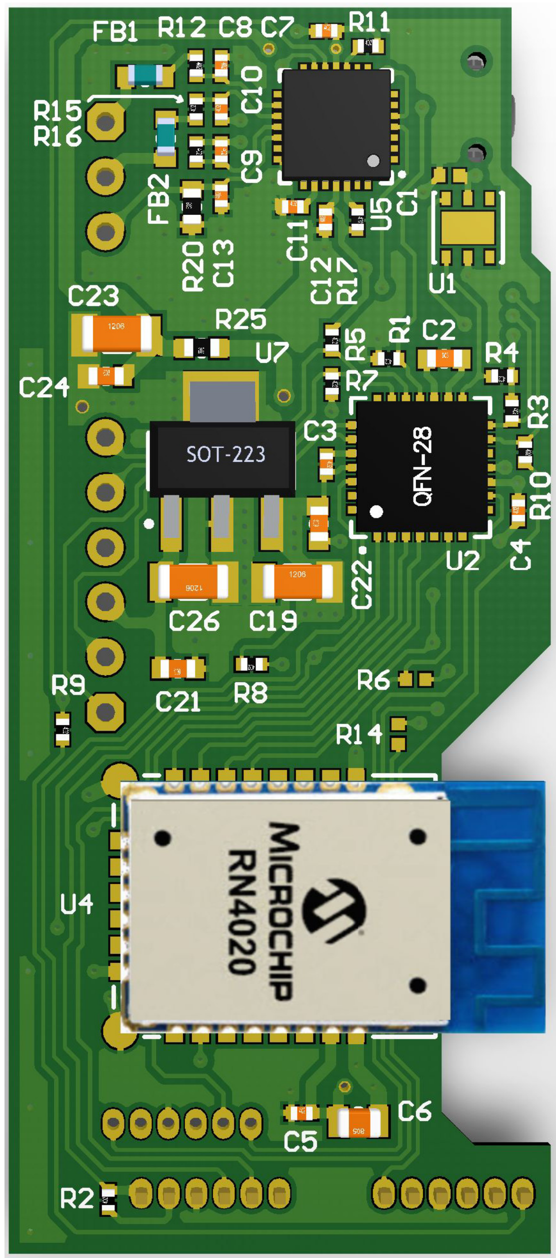
A.7 POWER MODULE BOARD - BOTTOM VIEW



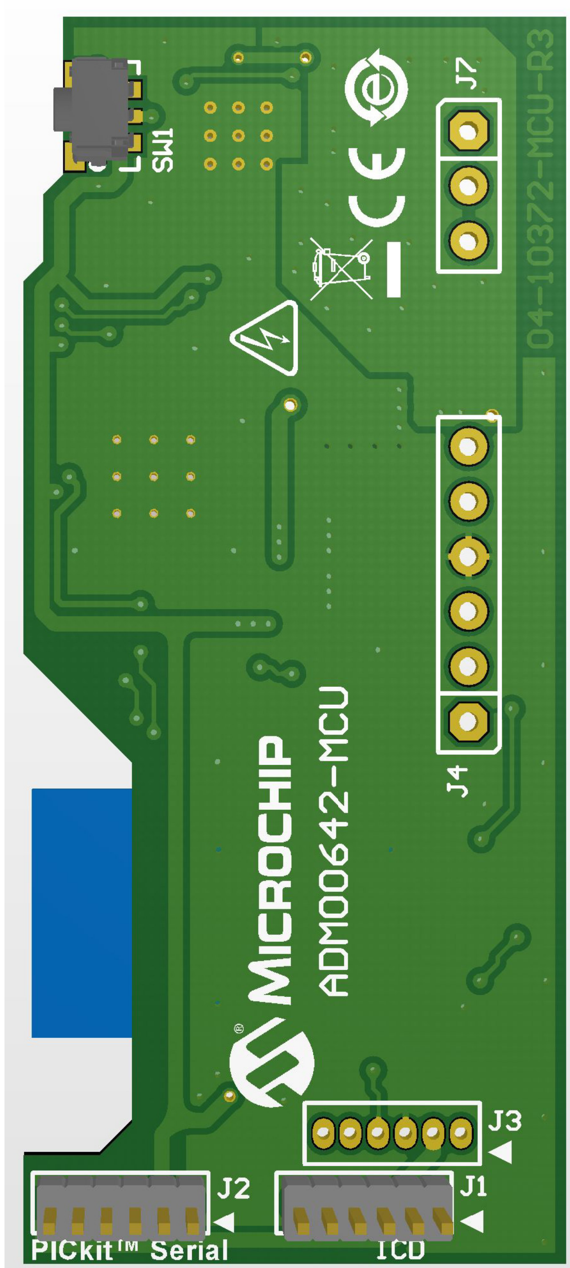
A.8 BTLE MCU MODULE BOARD - SCHEMATIC



A.9 BTLE MCU MODULE BOARD - TOP VIEW



A.10 BTLE MCU MODULE BOARD - BOTTOM VIEW



Appendix B. Bill of Materials (BOM)

TABLE B-1: BILL OF MATERIALS (BOM)(1) - NORTH AMERICAN PLUG MODULE BOARD (ADM00642-US)

Qty.	Reference	Description	Manufacturer	Part Number
1	C20	CAP CER 0.1uF 25V 10% X7R SMD 0603	Murata Electronics®	GRM188R71E104KA01D
1	C27	CAP CER 4.7uF 25V 10% X5R SMD 1206	TDK Corporation	C3216X5R1E475K
1	D5	DIO TVS SMBJP6KE6.8CA 5.8V 600W DO-214AA_SMB	Micro Commercial Components	SMBJP6KE6.8CA-TP
1	J5	Enclosure Aolaisite CZ660-US	Shenzhen Aolaisite Plastic Electronics Co., Ltd.	CZ660-US
1	J6	CON HDR-2.54 Male 1x3 Gold 5.84MH TH R/A	Samtec, Inc.	TSW-103-08-F-S-RA
1	J9	CON HDR-2.54 Male 1x6 Gold 5.84MH TH R/A	FCI	68016-106HLF
1	LD1	DIO LED BLUE 3.2V 20mA 140mcd Clear SMD 0603	Dialight Corporation	598-8091-107F
1	LD2	DIO LED RED 1.95V 30mA 700mcd Clear SMD 0603	Kingbright Electronic Co., Ltd.	APTD1608SURCK
1	PCB	North American Plug Module Printed Circuit Board	**Microchip Technology Inc.**	**04-10372-US-R3**
2	R8, R9	RES TKF 1k 1% 1/10W SMD 0603	Panasonic® - BSG	ERJ-3EKF1001V
1	R13	RES SHUNT MF 0.002R 1% 2W 2512	Stackpole Electronics, Inc.	CSNL2512FT2L00
2	R18, R19	RES TKF 330k 5% 1/2W SMD 2010	ROHM Semiconductor	MCR50JZHJ334
1	RL1	RELAY POWER SPST-NO LATCH-ING 5V 10A 250VAC TH	OMRON Corporation	G6CU-1117P-US 5DC
1	U3	MCHP ANALOG FET DRIVER Dual-Non/Inverting TC4428AE-UA713 MSOP-8	**Microchip Technology Inc.**	**TC4428AEUA713**

Note 1: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

TABLE B-2: BILL OF MATERIALS (BOM)(1) - POWER MODULE BOARD (ADM00642-PWR)

Qty.	Reference	Description	Manufacturer	Part Number
1	C1	CAP CER 1000pF 50V 10% X7R SMD 0603	Cal-Chip Electronics Inc.	GMC10X7R102K50NTL_F
1	C14	CAP ALU 4.7uF 400V 20% RAD_P3.5D8H13	Nichicon Corporation	UVC2G4R7MPD1TD
1	C15	CAP ALU 10uF 400V 20% TH P5D10H20	Panasonic® - ECG	EEU-EE2G100

Note 1: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

TABLE B-2: BILL OF MATERIALS (BOM)[1] (CONTINUED)- POWER MODULE BOARD

Qty.	Reference	Description	Manufacturer	Part Number
1	C16	CAP ALU 100uF 25V 20% RAD P2.0D5H12.5	Rubycon Corporation	25PX100MEFC5X11
1	C17	CAP CER 0.1uF 25V 10% X7R SMD 0603	Murata Electronics®	GRM188R71E104KA01D
1	C18	CAP CER 10uF 25V 10% X7R SMD 1206	Taiyo Yuden Co., Ltd.	TMK316B7106KL-TD
1	C25	CAP CER 10uF 25V 10% X7R SMD 1206	Murata Electronics North America, Inc.	GRM31CR71E106KA12L
2	D1, D2	DIO RECT MRA4005 1.1V 1A 600V DO-214AC_SMA	ON Semiconductor®	MRA4005T3G
1	D3	DIO RECT ES1G 1.25V 1A 400V SMD DO-214AC_SMA	Diodes Incorporated®	ES1G-13-F
2	J2, J8	CON HDR-2.54 Male 1x3 Gold 5.84MH TH R/A	Samtec, Inc.	TSW-103-08-F-S-RA
1	L1	INDUCTOR 680uH 250mA10% TH P2.5D6H8.5	Wurth Elektronik	7447462681
1	L3	INDUCTOR 680uH 330mA 10% TH RAD P5D8.5H5.5	Wurth Elektronik	7447412681
1	PCB	Power Module Printed Circuit Board	**Microchip Technology Inc.**	**104-10372-PWR-R3**
2	R21, R22	RES TKF 470R 1% 1/2W SMD 1210	Vishay/Dale	CRCW1210470RFKEA
1	R23	RES TKF 4.02K 1% 1/10W SMD 0603	Stackpole Electronics, Inc.	RMCF0603FT4K02
1	R24	RES TKF 2k 1% 1/10W SMD 0603	Panasonic® - ECG	ERJ-3EKF2001V
1	R26	RES TKF 2.1k 1% 1/10W SMD 0603	Panasonic® - ECG	ERJ-3EKF2101V
1	U6	IC SWITCHER LNK304 SO-8C	Power Integrations™	LNK304DG-TL

Note 1: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

TABLE B-3: BILL OF MATERIALS (BOM)[1] - BTLE MCU MODULE (ADM00642-MCU)

Qty.	Reference	Description	Manufacturer	Part Number
1	C2	CAP CER 10uF 10V 20% X5R SMD 0603	Panasonic® - ECG	ECJ-1VB1A106M
6	C3, C4, C5, C7, C11, C12	CAP CER 0.1uF 16V 10% X7R SMD 0402	Murata Electronics®	GRM155R71C104KA88D
1	C6	CAP CER 4.7uF 25V 10% X7R SMD 0805	TDK Corporation	C2012X7R1E475K125AB
4	C8, C9, C10, C13	CAP CER 0.033uF 16V 10% X7R SMD 0402	TDK Corporation	CGA2B2X7R1C333K050BA
3	C19, C23, C26	CAP CER 10uF 25V 10% X7R SMD 1206	Murata Electronics North America, Inc.	GRM31CR71E106KA12L
3	C21, C22, C24	CAP CER 0.1uF 25V 10% X7R SMD 0603	Murata Electronics®	GRM188R71E104KA01D

Note 1: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

TABLE B-3: BILL OF MATERIALS (BOM)[(1)] (CONTINUED)- BTLE MCU MODULE

Qty.	Reference	Description	Manufacturer	Part Number
2	FB1, FB2	FERRITE 47R@100MHz 500mA SMD 0603	Laird-Signal Integrity Products	LI0603E470R-10
2	J1, J2	CON HDR-1.27 Male 1x6 Gold 3MH TH VERT	Sullins Connector Solutions	GRPB061VWVN-RC
1	PCB	Bluetooth Module Printed Circuit Board	**Microchip Technology Inc.**	**04-10372-MCU-R3**
6	R1, R2, R5, R7, R8, R17	RES TKF 10k 5% 1/10W SMD 0402	Panasonic® - ECG	ERJ-2GEJ103X
3	R3, R4, R11	RES TKF 4.7k 5% 1/10W SMD 0402	Panasonic® - ECG	ERJ-2GEJ472X
2	R9, R10	RES TKF 100R 5% 1/16W SMD 0402	Yageo Corporation	RC0402JR-07100RL
2	R12, R15	RES TKF 1k 1% 1/10W SMD 0402	Panasonic® - ECG	ERJ-2RKF1001X
1	R16	RES SMD 3K 1% 1/10W 0402	Panasonic® - ECG	ERJ-2RKF3001X
1	R20	RES TKF 1k 1% 1/10W SMD 0603	Panasonic® - ECG	ERJ-3EKF1001V
1	R25	RES TKF 10R 5% 1/10W SMD 0603	Panasonic® - ECG	ERJ-3GEYJ100V
1	SW1	SWITCH PUSH SPST-NO 12V 0.05A TL3340 SMD	E-Switch®, Inc.	TL3340AF160QG
1	U2	MCHP MCU 16-BIT 32MHz 32KB 8KB PIC24FJ32GA102-I/ML QFN-28	**Microchip Technology Inc.**	**PIC24FJ32GA102-I/ML**
1	U4	MCHP RF BLUETOOTH 4.0 RN4020-V/RM MODULE-24	**Microchip Technology Inc.**	**RN4020-V/RM**
1	U5	MCHP ANALOG ENERGY MEASUREMENT 4000:1 MCP39F511-E/MQ QFN-28	**Microchip Technology Inc.**	**MCP39F511-E/MQ**
1	U7	MCHP ANALOG LDO 3.3V MCP1755ST-3302E/DB SOT-223-3	**Microchip Technology Inc.**	**MCP1755ST-3302E/DB**

Note 1: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

NOTES:

Appendix C. Accuracy Data

TABLE C-1: RMS CURRENT (AT 120V, 60Hz)

Applied Current [A]	Measured Current [A]	Error in %
10	9.9971	-0.029
5	5.0015	0.03
2	1.9999	-0.005
1	0.9995	-0.05
0.5	0.4997	-0.06
0.2	0.1995	-0.25
0.1	0.0997	-0.3
0.05	0.0494	-1.2

TABLE C-2: ACTIVE POWER (AT 120V, 60 Hz, PF = 1)

Expected Power (W)	Measured Active Power [W]	Error in %
1200	1197.62	-0.198333333
600	599.25	-0.125
240	239.83	-0.070833333
120	119.95	-0.041666667
60	59.97	-0.05
24	23.97	-0.125
12	11.98	-0.166666667
6	5.97	-0.5

TABLE C-3: ACTIVE POWER (AT 120V, 60 Hz, PF = 0.5)

Expected Power (W)	Measured Active Power [W]	Error in %
600	597.11	-0.481666667
300	299.26	-0.246666667
120	119.84	-0.133333333
60	59.95	-0.083333333
30	29.97	-0.1
12	11.97	-0.25
6	5.98	-0.333333333
3	2.98	-0.666666667

TABLE C-4: ENERGY COUNTING (AT 220V, 50 Hz)

Expected (Wh)	Measured [Wh]	Error in %
10000	10016.858	0.16858
1000	1003.648	0.3648
100	100.226	0.226
10	10.035	0.35
1	1.002	0.2

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