

MCP3907
Energy Meter
Reference Design

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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 "DSXXXXXA", where "XXXXX" 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 on-line help. Select the Help menu, and then Topics to open a list of available on-line help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using the MCP3907 Energy Meter Reference Design. 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 MCP3907 Energy Meter Reference Design 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 MCP3907 Energy Meter Reference Design.
- **Chapter 2. "Installation and Operation"** – Includes instructions on how to get started with this board, with a detailed description of each block.
- **Appendix A. "Schematic and Layouts"** – Shows the schematic and layout diagrams for the MCP3907 Energy Meter Reference Design.
- **Appendix B. "Bill of Materials (BOM)"** – Lists the parts used to build the MCP3907 Energy Meter Reference Design.

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

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

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RECOMMENDED READING

This user's guide describes how to use MCP3907 Energy Meter Reference Design. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

MCP3905A/05L/06A Data Sheet – *"Energy Metering ICs with Active Real Power Pulse Output"* (DS22011)

MCP3907 Data Sheet – *"Precision Energy Metering IC with Active Power Output, SPI Interface and Internal Oscillator"* (DS22256)

MCP3909 Data Sheet – *"Energy Metering IC with SPI Interface and Active Power Pulse Output"*(DS22025)

This data sheet provides detailed information regarding the MCP3907 device.

AN994 – *"IEC Compliant Active Energy Meter Design using the MCP3905A/06A"* (DS00994)

This application note documents the design decisions associated with MCP3907 Energy Meter Reference Design. The design decisions for the MCP3905A/06A and MCP3909 are applicable to the MCP3907 device.

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- **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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- 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://support.microchip.com.

DOCUMENT REVISION HISTORY

Revision A (August 2010)

- Initial Release of this Document.

NOTES:

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Chapter 1. Product Overview

1.1 INTRODUCTION

This chapter provides an overview of the MCP3907 Energy Meter Reference Design and covers the following topics:

- What is the MCP3907 Energy Meter Reference Design?
- What the MCP3907 Energy Meter Reference Design Kit Includes

1.2 WHAT IS THE MCP3907 ENERGY METER REFERENCE DESIGN?

The MCP3907 Energy Meter Reference Design is a device energy metering IC that supplies *real power* information via a pulse output. The MCP3907 Energy Meter Reference Design device includes an internal oscillator for low cost meter designs. An external 3.58 MHz crystal is not required.

The MCP3907 Energy Meter Reference Design is used as a reference design for single phase residential meters. The MCP3907 Energy Meter Reference Design includes all the necessary PCB circuits and PCB layout tips required for IEC energy meter compliance.

1.3 WHAT THE MCP3907 ENERGY METER REFERENCE DESIGN KIT INCLUDES

This MCP3907 Energy Meter Reference Design kit includes:

- MCP3907 Energy Meter Reference Design, 102-00129
- Important Information Sheet

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NOTES:

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Chapter 2. Installation and Operation

2.1 INTRODUCTION

The MCP3907 Energy Meter Reference Design is a complete stand-alone single-phase residential meter design for energy meter manufacturers. This energy meter design does not require a crystal for a lower cost meter design. This design also serves as the design of the analog front end (AFE) for advanced meter products. The design includes a low cost DC power supply circuit and the necessary protection for IEC62053-21 EMC testing and IEC62053-21 accuracy.

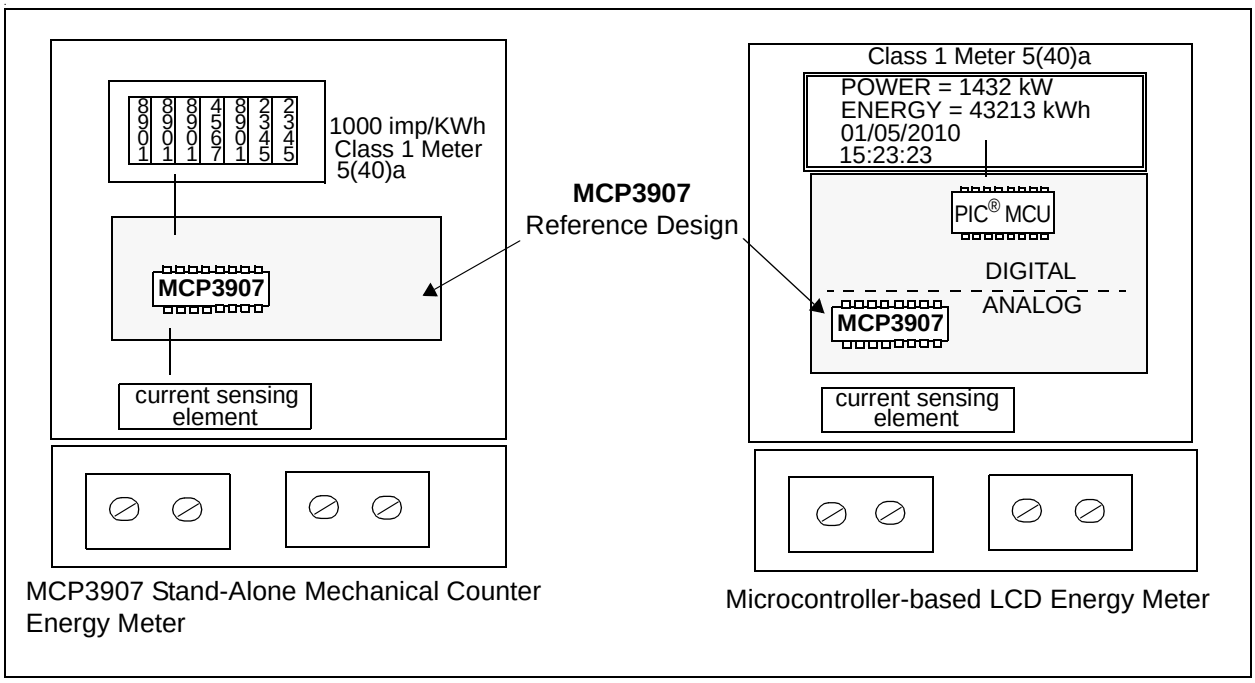


FIGURE 2-1: *MCP3907 Stand-Alone Energy Meter and Microcontroller-Based Energy-Using MCP3907 AFE Design.*

For more detailed information regarding design decisions and approach to IEC compliance using the circuitry in this board, please refer to AN994 application note (DS00994).

2.2 FEATURES

The MCP3907 Energy Meter Reference Design has the following features:

- Protection for IEC62053-21 Energy Meter EMC Immunity Tests
- On-board DC power supply
- Resistor divider circuit for single-point meter calibration
- Connections for current sensing shunt or other current sensing element
- Connection for voltage sensing and power supply biasing
- Connections for mechanical counter and calibration output
- Low noise PCB layout for small signal conversion, and IEC accuracy compliance for small shunt values
- Low cost design

2.3 GETTING STARTED

The MCP3907 Energy Meter Reference Design is a complete stand-alone energy meter compliant to IEC62053-21, IEC1036 and other legacy IEC energy meter specifications. This meter can be manufactured by performing the two steps detailed in this document. For the external connections, the following terms are used:

- “Phase” – refers to the hot or line side of the power supply lines
- “Neutral” – refers to the return wire or low side of the power supply lines

2.3.1 Step 1: External Connections

Connections are made to the phase and neutral wire for voltage detection and AC/DC power supply. The MCP3907 Energy Meter Reference Design is designed to be biased to the phase or hot side of a 2-wire power supply system.

Step 1a – Connect JP4 to the phase power supply line connection

Step 1b – Connect JP3 to the neutral line

Step 1c – Connect JP1 and JP2 across the shunt

Step 1d – Connect JP5 and JP6 to the mechanical counter

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2.3.2 Step 2: Calibration of the Frequency Output Using the Voltage Divider Calibration Circuit

Each meter must be calibrated using the voltage divider circuit going into channel 1 of the MCP3907 device. A known power is supplied to the meter (e.g 1000W), aiming the output frequency of 1000 imp/kWh as a goal. The resistor divider is then successively lowered until the output frequency is matched. For more detailed information regarding meter calibration and the PCB design approach used with the circuitry described in this document, please refer to AN994 application note.

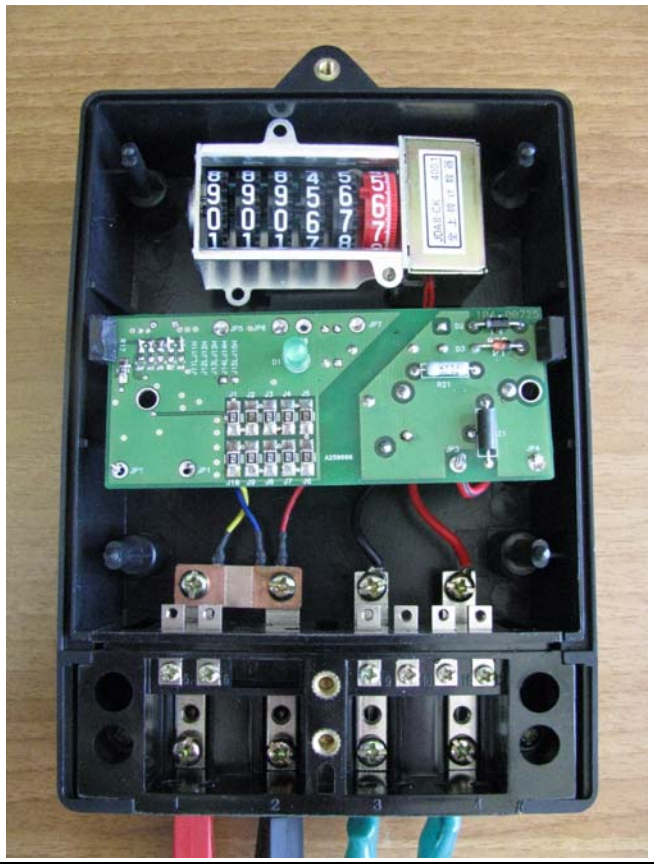


FIGURE 2-2: *Picture of Complete Stand-Alone MCP3907 Energy Meter Reference Design.*

2.4 MCP3907 ENERGY METER REFERENCE DESIGN OVERVIEW

This reference design can be used as either a complete stand-alone mechanical counter energy meter, or as the analog front-end design in advanced microcontroller based meter designs.

The analog front-end (AFE) design limits the overall meter accuracy. A low-noise, proven AFE circuit and layout is still required for a high accuracy meter. For both meter types the current sense input, voltage sense input, calibration scheme, jumper selection and power supply, the design blocks described here should apply.

This design keeps all of the major components on the back side of the PCB. This minimizes any environmental side effect when a meter case experiences failure. Only the necessary components for calibration, jumper selection and external connections are placed on the front side of the board. Keeping the larger DC power supply components on the back side of the board is also necessary, for installation in some meter cases with PCB stand-offs.

The major components on the front side of the MCP3907 Energy Meter Reference Design are listed below this paragraph. See descriptions in **Section 2.5 “Front side of the PCB – Detailed Description”**:

- Shunts for Gain and FC selection (J11–J15)
- Calibration Jumpers (J1–J10)
- Output Connections for Mechanical Counter and Calibration (JP5-JP7)
- Connection to Current Sensing Element (JP1, JP2)
- Connection to Voltage or Phase Line and Ground Reference Point (JP3, JP4)

The major components on the back side of the MCP3907 Energy Meter Reference Design are listed below. See descriptions in **Section 2.6 “Back Side of the PCB – Detailed Description”**.

- MCP3907 Device (U1)
- DC Power Supply (C17, C16, U2, C18, D2)
- Metal Oxide Varistor (MOV1)
- Optical Isolator(U3)
- The Analog Ground Plane, Power Supply Ground Plane, Moat

The following two sections give an overview of the blocks and their functionality. For more detailed information regarding design decisions and approach to IEC1036 compliance please refer to AN994 application note – *“IEC Compliant Active Energy Meter Design using the MCP3905A/06A”*. For a more detailed circuit schematic, refer to **Appendix A. “Schematic and Layouts”** and **Appendix B. “Bill of Materials (BOM)”**.

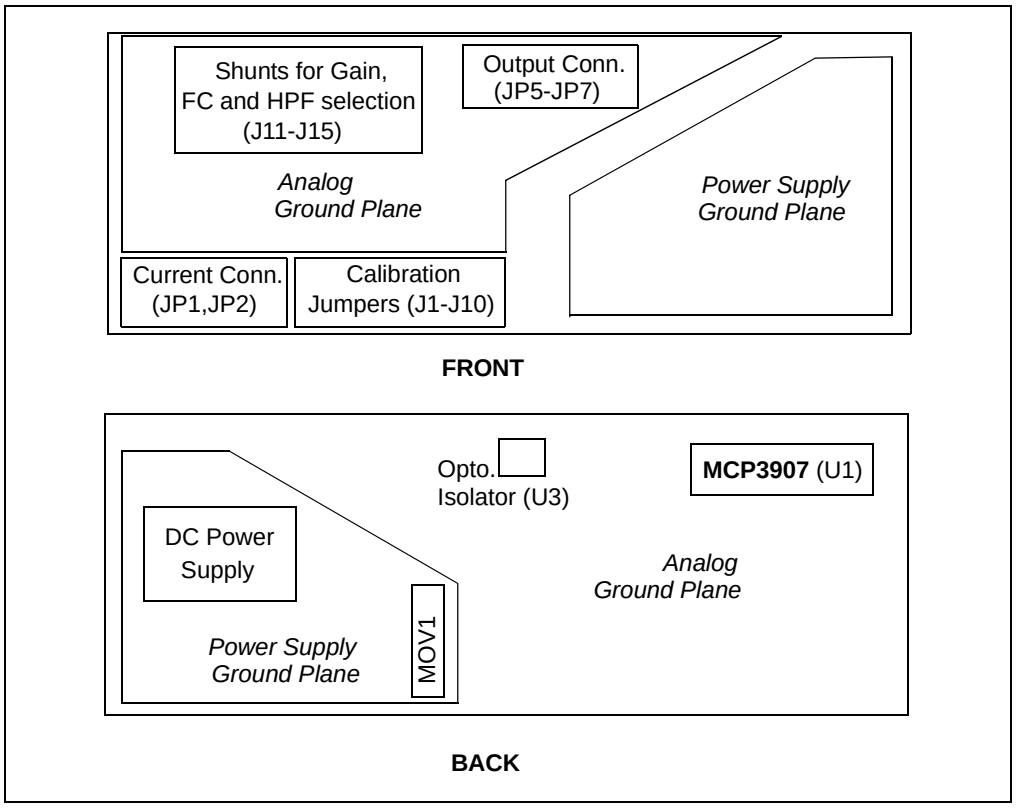


FIGURE 2-3: *MCP3907 Energy Meter Reference Design Block Diagram.*

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2.5 FRONT SIDE OF THE PCB – DETAILED DESCRIPTION

2.5.1 Shunts for Gain and FC selection (J11–J15)

Positions for both logic “high” and logic “low” are here for all gains and frequency constant selections. The logic “high” positions are labeled J1H, and the “low” positions are labeled J1L, as an example for Jumper 1. Do not short both the “high” and the “low” positions for any of the jumpers.

2.5.2 Calibration Jumpers (J1–J10)

Calibration resistors for each of these jumper locations are located directly beneath the associated jumper. When a shorting resistor or a jumper is in place, the associated calibration resistor is shortened and bypassed.

2.5.3 Output Connections for Mechanical Counter and Calibration (JP5-JP7)

JP5 and JP6 are the differential output drive for the mechanical counter.

JP7 is the calibration or microcontroller output that is connected to HF_{OUT} on the MCP3907 devices. An LED is supplied to assist in any optical calibration schemes.

2.5.4 Connection to Current Sensing Element (JP1, JP2)

These two connections lead directly through LRC filtering into Channel 0 of the MCP3907 device. The schematic in **Appendix A. “Schematic and Layouts”** uses a low cost shunt as current sensing element. The shunt resistance should be placed in parallel with these two connections, between JP1 and JP2.

2.5.5 Connection to Voltage or Phase Line and Ground Reference Point (JP3, JP4)

These two connections feed the DC power supply circuitry described in **Section 2.6.2 “DC Power Supply (C17, C16, U2, C18, D2)”**. JP4 is connected to the ground of the PCB, and JP3 to the high side of the DC power supply circuitry. JP3 is also connected to the resistor divider that feeds the analog input of Channel 1 of the MCP3907 device. This is the measuring voltage channel, connected to the differential input in a single-ended fashion. See **Section A.3 “Board – Schematic”** for further details.

2.6 BACK SIDE OF THE PCB – DETAILED DESCRIPTION

2.6.1 MCP3907 Device (U1)

The MCP3907 device is located on the right hand side of the back side of the board, where the analog ground plane exists. The MCP3907 device has appropriate bypass capacitors on V_{DD} coming from the DC power supply circuitry. The MCP3907 device has all its input logic pins connected to user selectable jumpers, with one exception, the HPF pin. For this system the HPF is turned on with this pin connected to V_{DD}; the device is in AC mode only. The REVP connection is not connected in this reference design, and this pin should be left floating. The other three output pins (F_{OUT0}, F_{OUT1}, HF_{OUT}) are connected to nodes JP5, JP6 and JP7, described in this document.

2.6.2 DC Power Supply (C17, C16, U2, C18, D2)

The DC power supply is created from a half-wave Zener diode-limited AC signal, feeding a 7805 +5V regulator. C17 and C16 divide the AC signal coming directly from the line (designed in this document for 220V), and Zener diode D2 limits the peak voltage to 15V. For more information regarding this power supply design see application note AN994 – *"IEC Compliant Active Energy Meter Design using the MCP3905A/06A"* (DS00994).

2.6.3 Metal Oxide Varistor (MOV1)

A Metal Oxide Varistor (MOV) is included in this design to suppress any high voltage transients coming through the power lines.

2.6.4 Optical Isolator(U3)

An optical isolator is included in the MCP3907 Energy Meter Reference Design as an additional level of protection for other circuitry used in advanced meter designs (PIC® microcontroller, DSP or otherwise). It is connected to the HF_{OUT} frequency output of the MCP3907 device. Depending on the meter design, this optical isolator may not be required. This design is a direct-connect meter that has the entire PCB referenced to the line side of the power supply, therefore any other circuitry would either need to be biased to the same point or isolated using this scheme. A pull-up resistor is required on the output of the optical isolator to allow the HF logic signal to appear.

2.6.5 The Analog Ground Plane, Power Supply Ground Plane, Moat

The MCP3907 energy meter reference design PCB is designed for low-noise performance and immunity to external influences, as required by IEC62053-21 and legacy IEC energy meter specifications, such as IEC61036. The DC power supply and digital outputs are connected to the power supply ground plane (front side, on the right of the board). The lower noise analog ground plane, including the MCP3907 connections, is on the opposite side of the board, separated by a moat between the two ground planes. An inductive choke connects the two grounds. For further information regarding low-noise PCB design for IEC compliance, see AN994 – *"IEC Compliant Active Energy Meter Design using the MCP3905A/06A"*.

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Appendix A. Schematic and Layouts

A.1 INTRODUCTION

This appendix contains the following schematics and layouts for the MCP3907 Energy Meter Reference Design:

- Board – Schematic
- Board – Top Silk and Pads
- Board – Top Layer
- Board – Bottom Silk and Pads
- Board – Bottom Layer

A.2 SCHEMATICS AND PCB LAYOUT

The layer order is shown in Figure A-1.

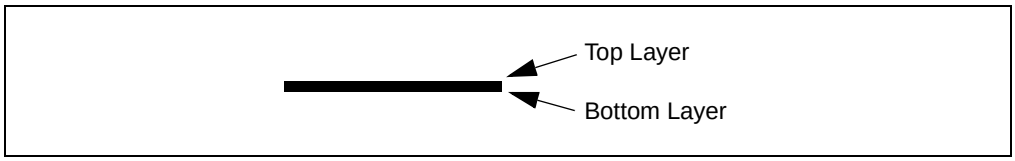
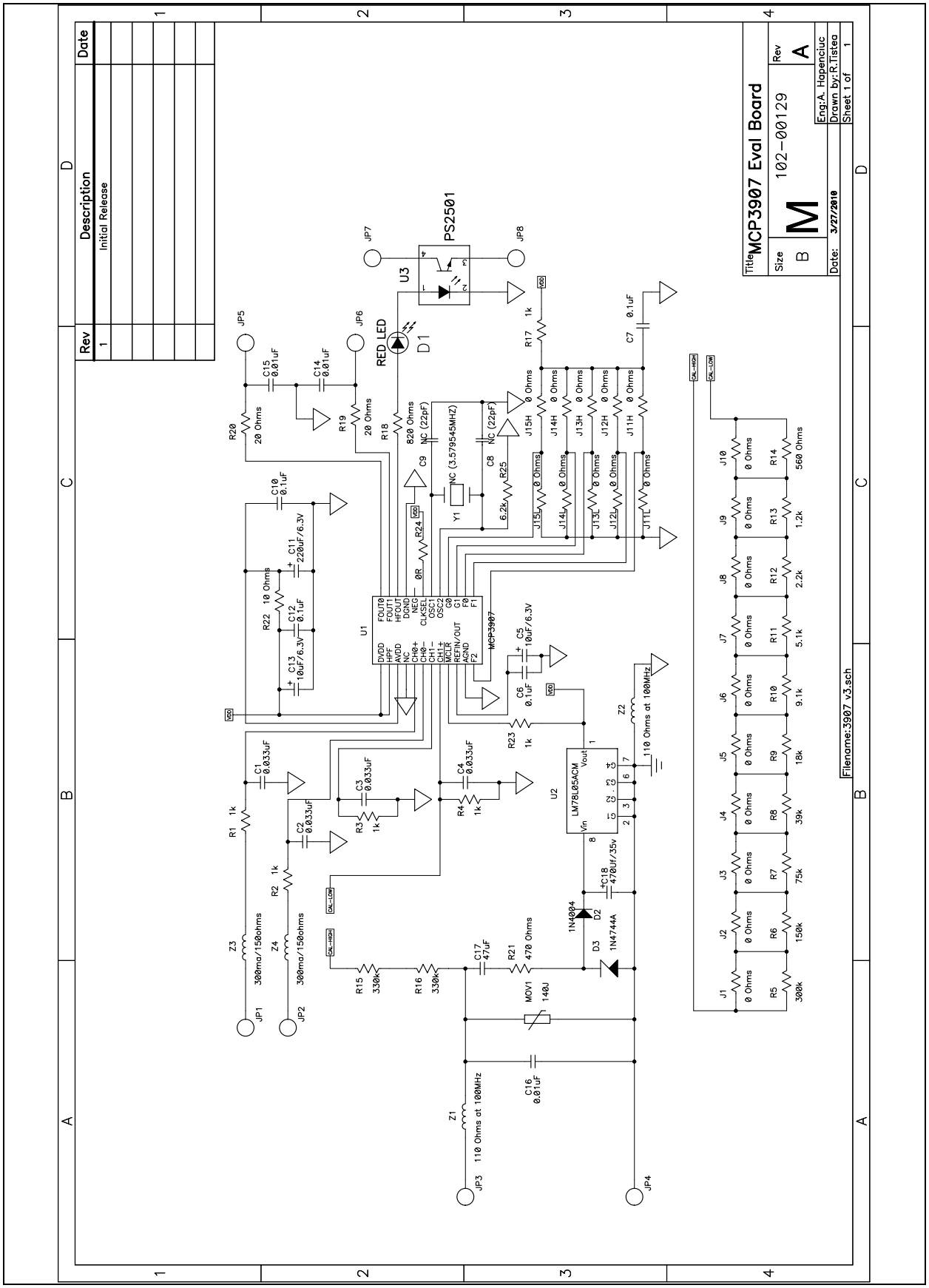


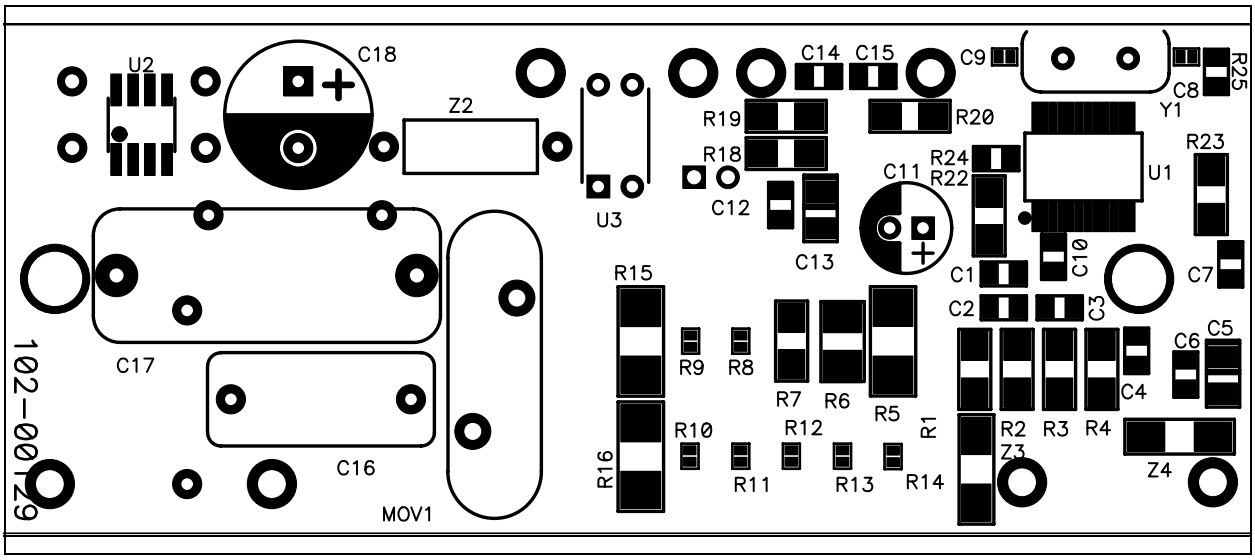
FIGURE A-1: *Layer Order.*

A.3 BOARD – SCHEMATIC

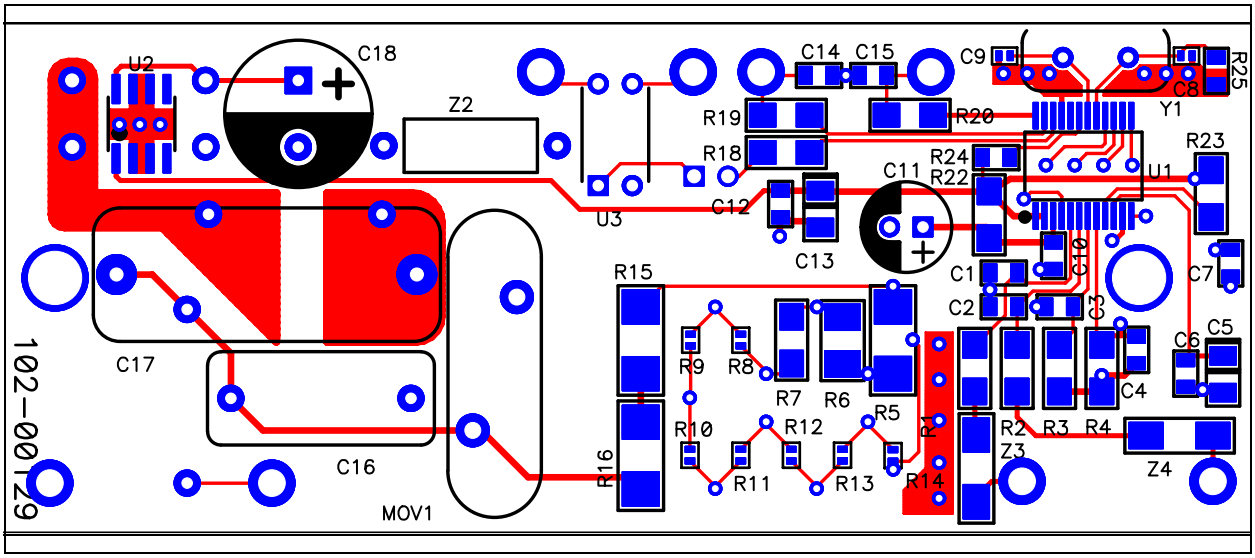


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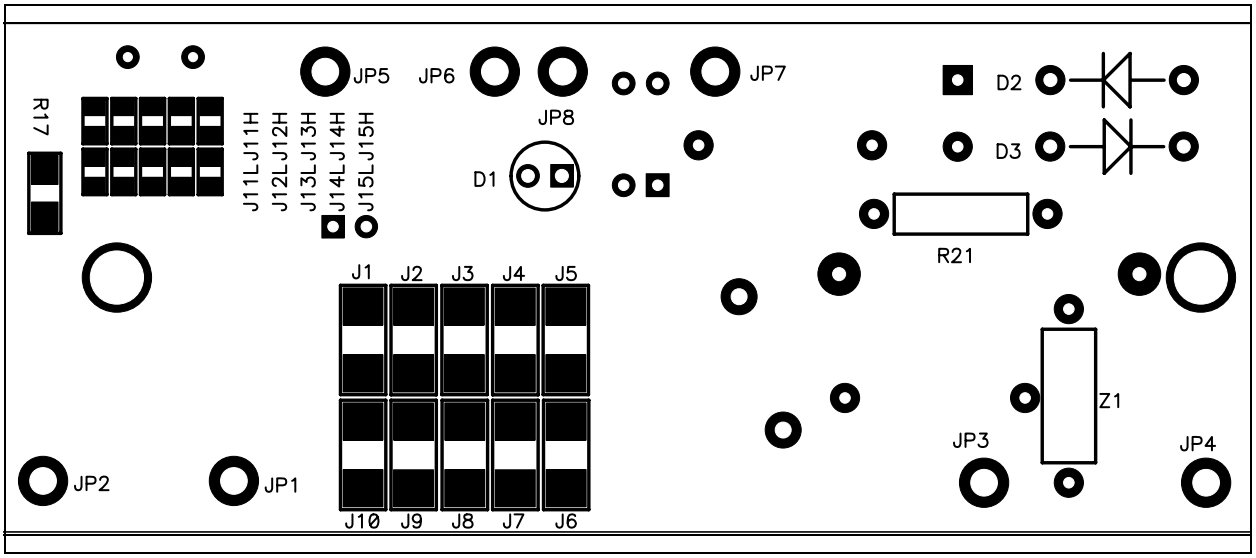
A.4 BOARD – TOP SILK AND PADS



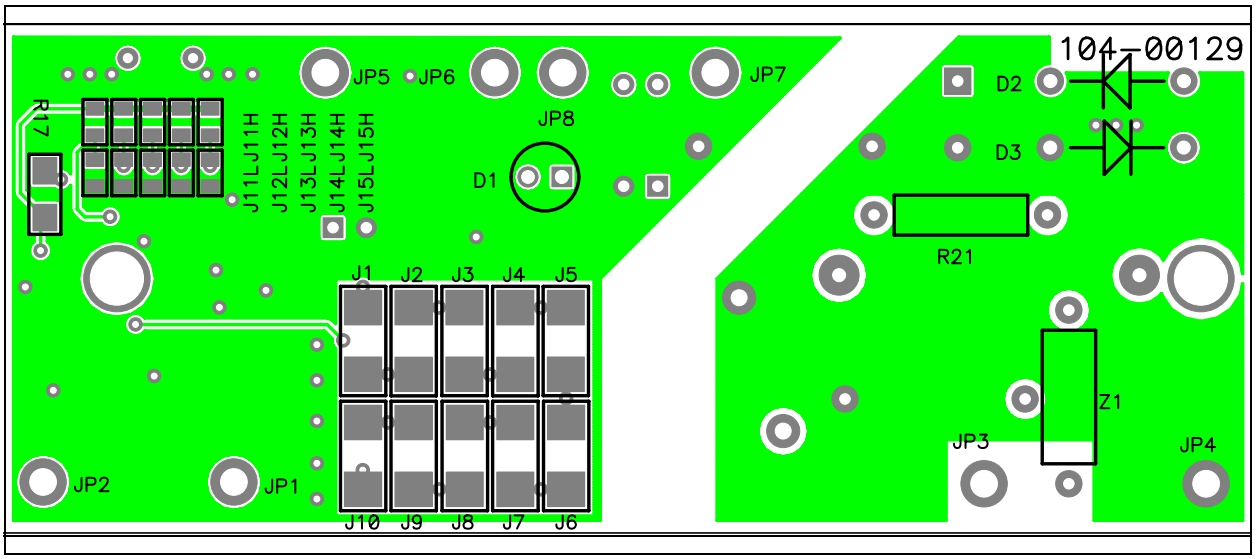
A.5 BOARD – TOP LAYER



A.6 BOARD – BOTTOM SILK AND PADS



A.7 BOARD – BOTTOM LAYER



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Appendix B. Bill of Materials (BOM)

TABLE B-1: BILL OF MATERIALS (BOM)

Qty	Reference	Description	Manufacturer	Part Number
4	C1, C2, C3, C4	CAP 33000PF 50V CERM X7R 0805	Panasonic® – ECG	ECJ-2VB1H333K
2	C5, C13	CAPACITOR TANT 10UF 6.3V 20% SMD	Kemet® Electronics Corp.	T491A106M006AS
6	C6, C7, C10, C12, C14, C15	CAP .1UF 16V CERAMIC X7R 0805	Panasonic – ECG	ECJ-2VB1C104K
2	C8, C9	CAP 22PF 50V CERAMIC 0402 SMD	Panasonic – ECG	ECJ-0EC1H220J
1	C11	CAP 220UF 10V ELECT FC RADIAL	Panasonic – ECG	EEU-FC1A221S
1	C16	01UF INTERFERFENCE METAL CAP	Panasonic – ECG	ECQ-U2A103MN
1	C17	47UF/630VDC METAL POLY CAP	Panasonic – ECG	ECQ-E6474KF
1	C18	CAP 470UF 35V ELECT FC RADIAL	Panasonic – ECG	EEU-FC1V471
1	D1	LED GREEN DIFFUSED ROUND LONG	Panasonic – SSG	LN31GPH
1	D2	RECTIFIER GPP 400V 1A DO-41	Diodes Inc	1N4004-T
1	D3	DIODE ZENER 15V 1W 5% DO-41	Diodes Inc	1N4744A-T
10	J1-J10	RES .1 OHM 1/4W 5% 1210 SMD	Panasonic – ECG	ERJ-14RSJR10U
6	J11H, J12H, J13H, J14H, J15H, R24	RES 0.0 OHM 1/8W 5% 0805 SMD	Panasonic – ECG	ERJ-6GEY0R00V
5	J11L, J12L, J13L, J14L, J15L	DO NOT POPULATE	—	—
8	JP1–JP8	PIN RECPT .032/.046 DIA 0328 SER	Mill-Max® Manufacturing Corp.	0328-0-15-15-34-27-10-0
1	MOV1	Suppressors; Clamping Voltage Max.:710V	EPCOS	SIOV-S20K275
1	PCB	RoHS Compliant Bare PCB, MCP3907 Energy Meter Reference Design	—	104-00129
3	R1, R2, R13	RES 1.2K OHM 1/16W 5% 0402 SMD	Panasonic – ECG	ERJ-2GEJ122X
4	R3, R4, R17, R23	RES 1.00K OHM 1/8W 1% 1206 SMD	Panasonic – ECG	ERJ-8ENF1001V
1	R5	RES 300K OHM 1/2W 5% 2010 SMD	Panasonic – ECG	ERJ-12ZYJ304U
1	R6	RES 150K OHM 1/4W 5% 1210 SMD	Panasonic – ECG	ERJ-14YJ154U
1	R7	RES 75K OHM 1/4W 5% 1206 SMD	Panasonic – ECG	ERJ-8GEYJ753V
1	R8	RES 39K OHM 1/16W 5% 0402 SMD	Panasonic – ECG	ERJ-2GEJ393X
1	R9	RES 18K OHM 1/16W 5% 0402 SMD	Panasonic – ECG	ERJ-2GEJ183X
1	R10	RES 9.1K OHM 1/16W 5% 0402 SMD	Panasonic – ECG	ERJ-2GEJ912X
1	R11	RES 5.1K OHM 1/16W 5% 0402 SMD	Panasonic – ECG	ERJ-2GEJ512X
1	R12	RES 2.2K OHM 1/16W 5% 0402 SMD	Panasonic – ECG	ERJ-2GEJ222X
1	R14	RES 560 OHM 1/16W 5% 0402 SMD	Panasonic – ECG	ERJ-2GEJ561X
2	R15, R16	RES 330K OHM 1/2W 5% 2010 SMD	Panasonic – ECG	ERJ-12ZYJ334U
1	R18	RES 820 OHM 1/4W 5% 1206 SMD	Panasonic – ECG	ERJ-8GEYJ821V
2	R19, R20	RES 20 OHM 1/4W 5% 1206 SMD	Panasonic – ECG	ERJ-8GEYJ200V

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-1: BILL OF MATERIALS (BOM) (CONTINUED)

Qty	Reference	Description	Manufacturer	Part Number
1	R21	RES 470 OHM 1W 5% METAL OXIDE	Panasonic – ECG	ERG-1SJ471
1	R22	RES 10 OHM 1/4W 5% 1206 SMD	Panasonic – ECG	ERJ-8GEYJ100V
1	R25	RES 4.7K OHM 1/16W 5% 0805 SMD	Panasonic – ECG	ERJ-2GEJ222X
1	U1	Energy Metering Device	Microchip Technology Inc.	**MCP3907**
1	U2	IC VOLT REG 5V 100MA 8-SOIC	National Semiconductor®	LM78L05ACM
1	U3	1 CHANNEL OPTO COUPLER TRANS DIP	NEC	PS2501-1
1	Y1	CRYSTAL 3.579545MHZ 17PF HC49/US	ECS Inc	ECS-35-17-4
2	Z1,Z2	BEAD CORE SINGLE 3.5X9MM AXIAL	Panasonic – ECG	EXC-ELSA39
2	Z3,Z4	FERRITE 300MA 150 OHM 1806 SMD	Steward	LI1806C151R-10

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.

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