# Energy Monitoring PICtail™ Plus Daughter Board User's Guide

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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 online help files.**

## INTRODUCTION

This chapter contains general information that will be useful to know before using the Energy Monitoring PICtail™ Plus Daughter Board. 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 Energy Monitoring PICtail™ Plus Daughter Board 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 on the Energy Monitoring PICtail™ Plus Daughter Board, including a getting started section that describes wiring the line and load connections.
- **Chapter 2. “Hardware”** – This chapter details the function blocks of the meter, including the analog front end design, Phase Lock Loop (PLL) circuitry and power supply design.
- **Chapter 3. “Calculation Engine and Register Description”** – This section describes the digital signal flow for all power output quantities such as RMS current, RMS voltage, active power and apparent power. This section also includes the calibration registers detail.
- **Appendix A. “Schematic and Layouts”** – Shows the schematic and layout diagrams.
- **Appendix B. “Bill of Materials (BOM)”** – Lists the parts used to build the Energy Monitoring PICtail™ Plus Daughter Board.

## 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 | <u>*File>Save*</u> |
| 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)`<br>`{ ...`<br>`}` |

## RECOMMENDED READING

This user's guide describes how to use the Energy Monitoring PICtail™ Plus Daughter Board. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

**PIC18F87J72 Family Data Sheet, *"80-Pin, High-Performance Microcontrollers with Dual Channel AFE, LCD Driver and nanoWatt Technology"* (DS39979)**

This data sheet provides detailed information regarding the PIC18F87J72 device.

**AN994 Application Note *"IEC61036 Meter Design using the MCP3905A/06A Energy Metering Devices"* (DS00994)**

This application note documents the design decisions associated with using the MCP390X devices for energy meter design and IEC compliance, which are directly related to the PIC18F87J72 and other PIC® microcontroller-based meter designs.

***"Single-Phase Energy Meter Calibration User's Guide"* (DS51964)**

This document describes the software and calibration methods associated to the PIC18F87J72 and how to communicate to, and use the device registers described in this document for energy monitoring and calibration.

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- **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
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- 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 (June 2011)

- Initial Release of this Document.

# ENERGY MONITORING PICtail™ PLUS DAUGHTER BOARD USER'S GUIDE

# Chapter 1. Product Overview

## 1.1 INTRODUCTION

The Energy Monitoring PICtail™ Plus Daughter Board is a power monitor circuit that uses the highly integrated PIC18F87J72 single chip energy meter IC. This low-cost design does not use any transformers and requires few external components. It includes both an isolated USB connection for meter calibration and access to the device power calculation, and an isolated PICtail Plus connection for Explorer 16 Development Board and other board developments.

The system calculates the Active Energy, Reactive Energy (both forward and reverse), Active Power, Reactive Power, Apparent Power, Root Mean Square Voltage ($V_{RMS}$), Root Mean Square Current ($I_{RMS}$), and other typical power quantities.

The Microchip Energy Meter 1-Phase Software used with this board calibrates and monitors the system. It can also be used to create custom calibration setups. For some accuracy requirements only a single point calibration may be required. The software offers an automated step by step calibration process that can be used to quickly calibrate energy meters.

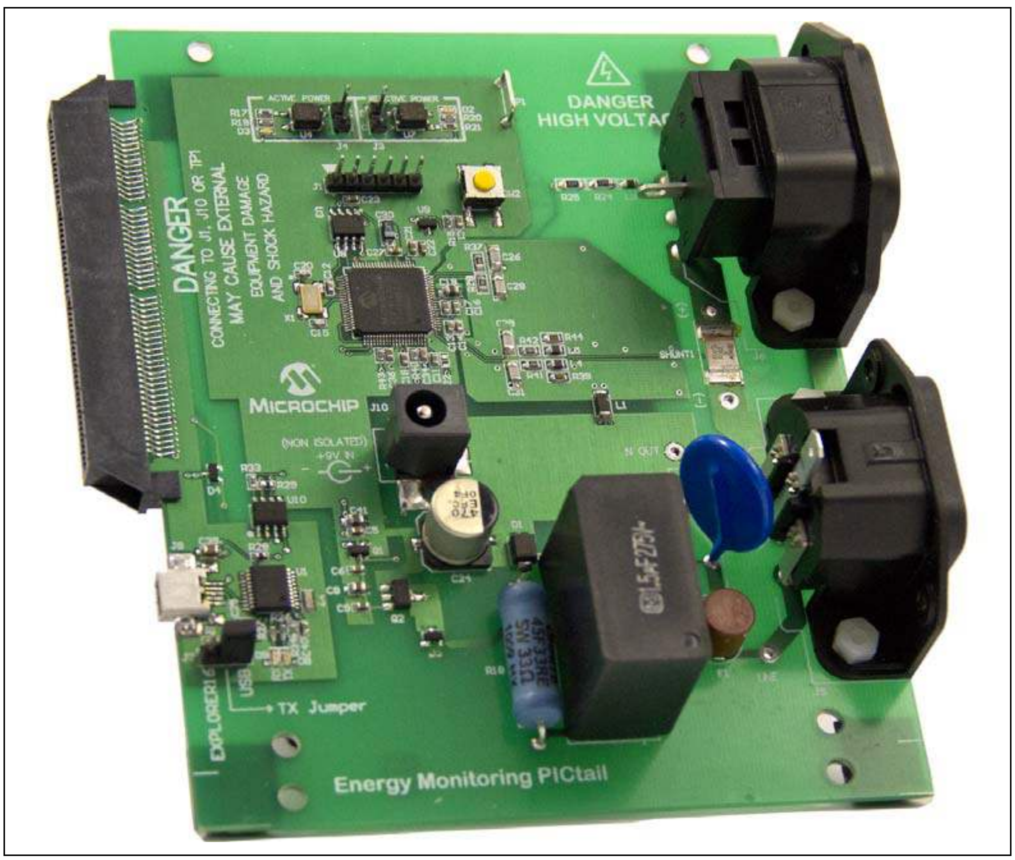



***FIGURE 1-1:*** *Energy Monitoring PICtail™ Plus Daughter Board.*

## 1.2 WHAT THE ENERGY MONITORING PICtail™ PLUS DAUGHTER BOARD USER’S GUIDE KIT INCLUDES

The Energy Monitoring PICtail™ Plus Daughter Board Kit includes:

- Energy Monitoring PICtail™ Plus Daughter Board (102-00330)
- Important Information Sheet

## 1.3 GETTING STARTED

The Energy Monitoring PICtail™ Plus Daughter Board uses a 2A load for calibration current, and a maximum current ($I_{MAX}$) of 15A.

All connections described in this section are dependent on the choice of the current sensing element. A secondary external transformer may be required in higher current meter designs.

To test a calibrated meter, the following connections apply for a two-wire connection.

### 1.3.1 Step 1: Wiring connections

J5 and J6 are the line and load connections of the meter.

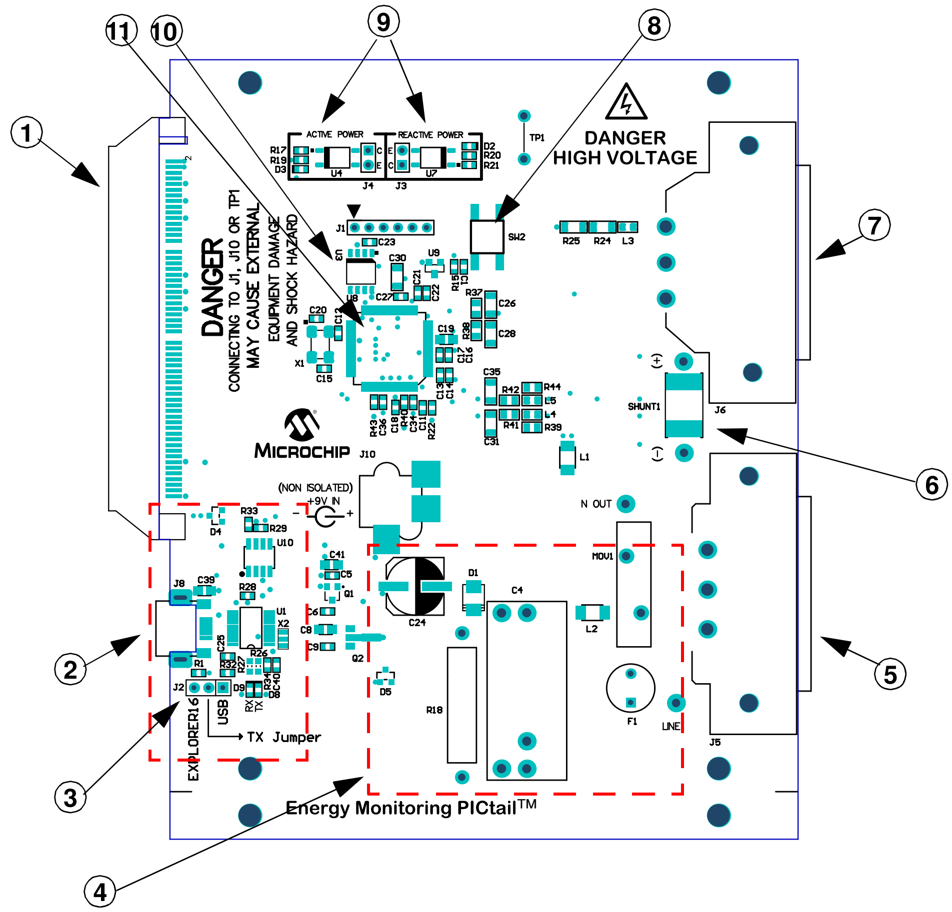
### 1.3.2 Step 2: Connect the board to a PC running the energy meter software

The meter will turn on when the line connection has 110V–240V connected. The PC software will show the total energy accumulated.

# Chapter 2. Hardware

## 2.1 OVERVIEW

Figure 2-1 shows the Energy Monitoring PICtail Plus Daughter Board:




**Legend:**

| | | |
|---|---|---|
| 1 | = | PICtail™ Plus connector (isolated) |
| 2 | = | USB connection for “Energy Meter Software” on PC (isolated) |
| 3 | = | Serial Connection Selection (Explorer 16 or USB) |
| 4 | = | High voltage power supply (non-isolated) |
| 5 | = | Line connection (male - 110 → 240V) |
| 6 | = | Shunt, 3000 µW |
| 7 | = | Load connection (female) |
| 8 | = | Reset switch for PIC18F87J72 |
| 9 | = | Output Pulses for calibration in units of imp/kWh (calibrated to 3200 imp/kWh) |
| 10 | = | EEPROM for calibration and energy meter usage storage |
| 11 | = | PIC18F87J72 |

***FIGURE 2-1:*** *Hardware Components.*

Figure 2-2 shows the digital connections of the Energy Monitoring PICtail Plus Daughter Board.

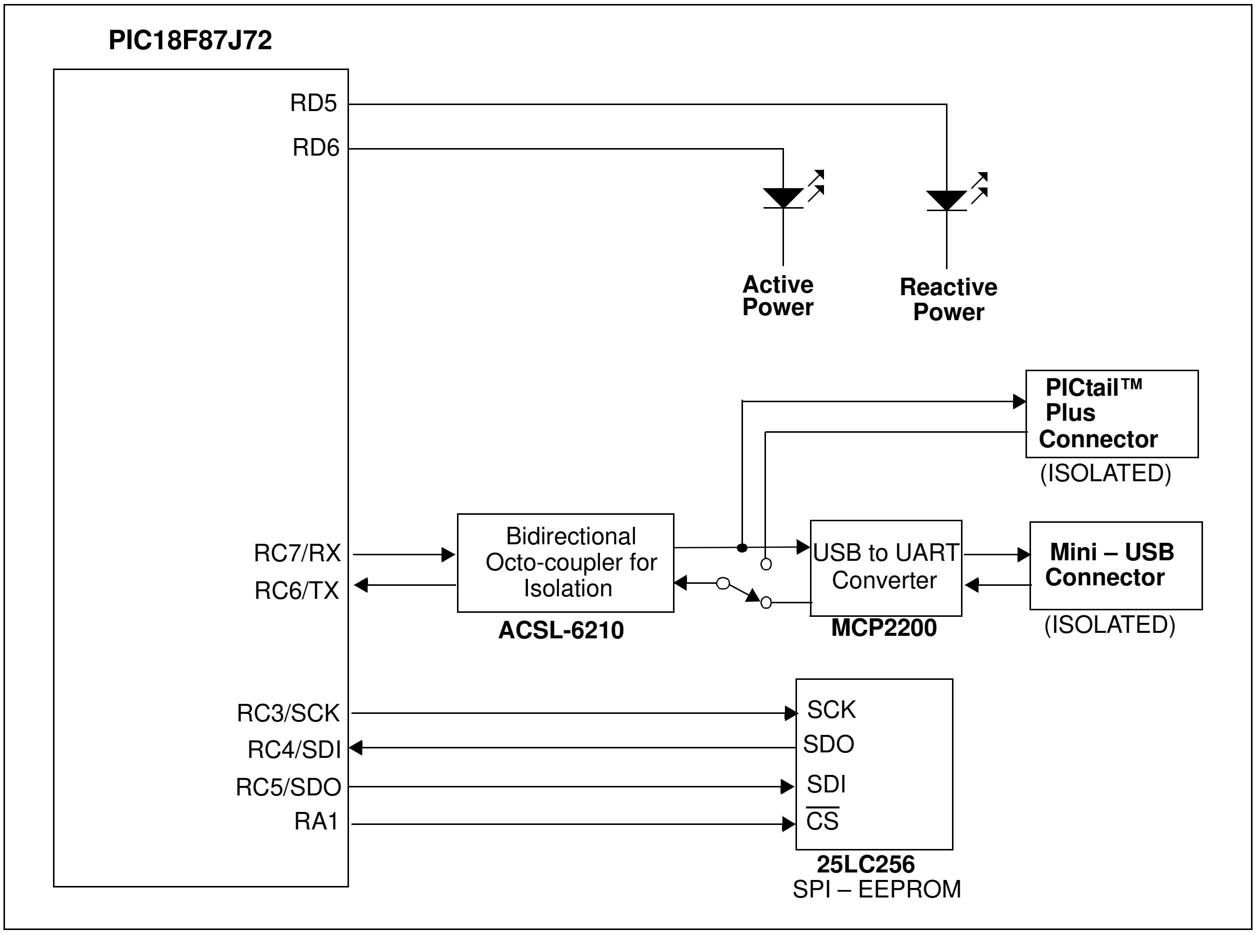
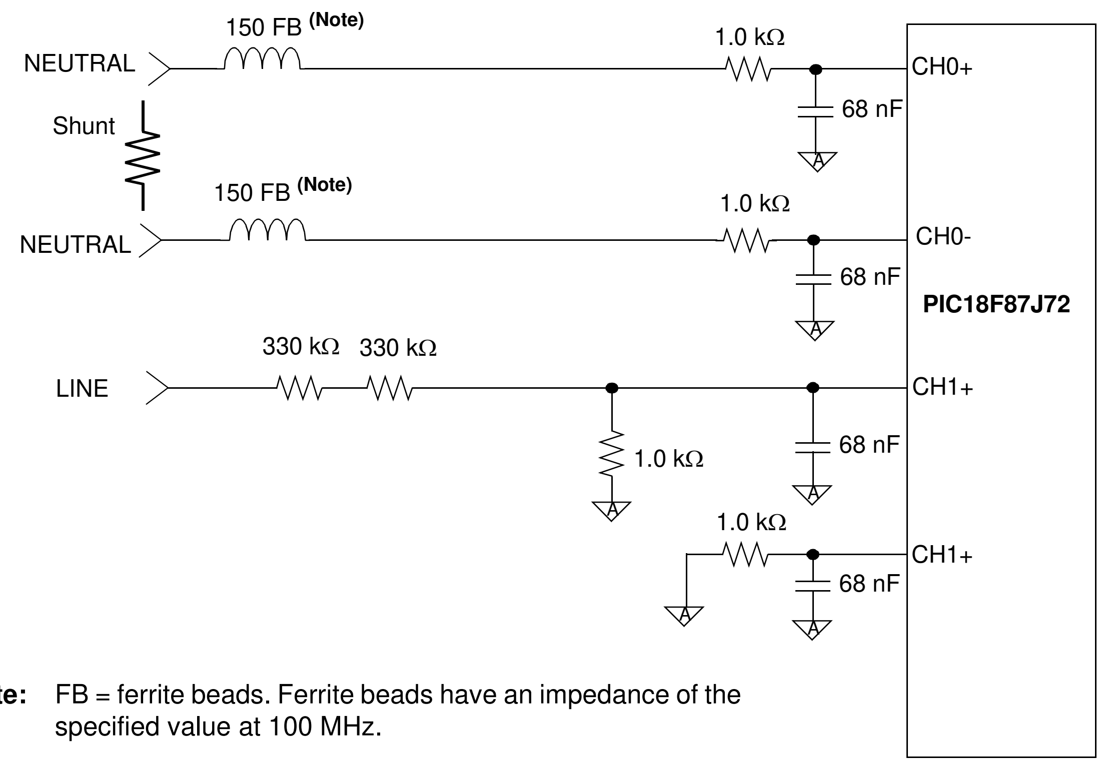



***FIGURE 2-2:*** *Simplified Schematic for Digital Connections.*

## 2.2 INPUT AND ANALOG FRONT END

The Energy Monitoring PICtail Plus Daughter Board comes populated with components designed for 110–240V line voltage. The shunt sits on the low or neutral side of a two-wire system.

The line of phase side of the two-wire system goes into a resistor divider on the voltage channel input. Anti-aliasing low-pass filters will be included on both differential channels. The voltage channel uses two 330 kΩ resistors to achieve a divider ratio of 664:1. For a line voltage of 230 $V_{RMS}$, the channel 1 input signal size will be 490 $mV_{PEAK}$.




**Note:** FB = ferrite beads. Ferrite beads have an impedance of the specified value at 100 MHz.

***FIGURE 2-3:*** *Analog Input Circuitry.*

## 2.3 POWER SUPPLY CIRCUIT

The power supply circuit for the Energy Monitoring PICtail Plus Daughter Board uses a half-wave rectified signal, a single +5V voltage regulator and a 3.3V LDO.

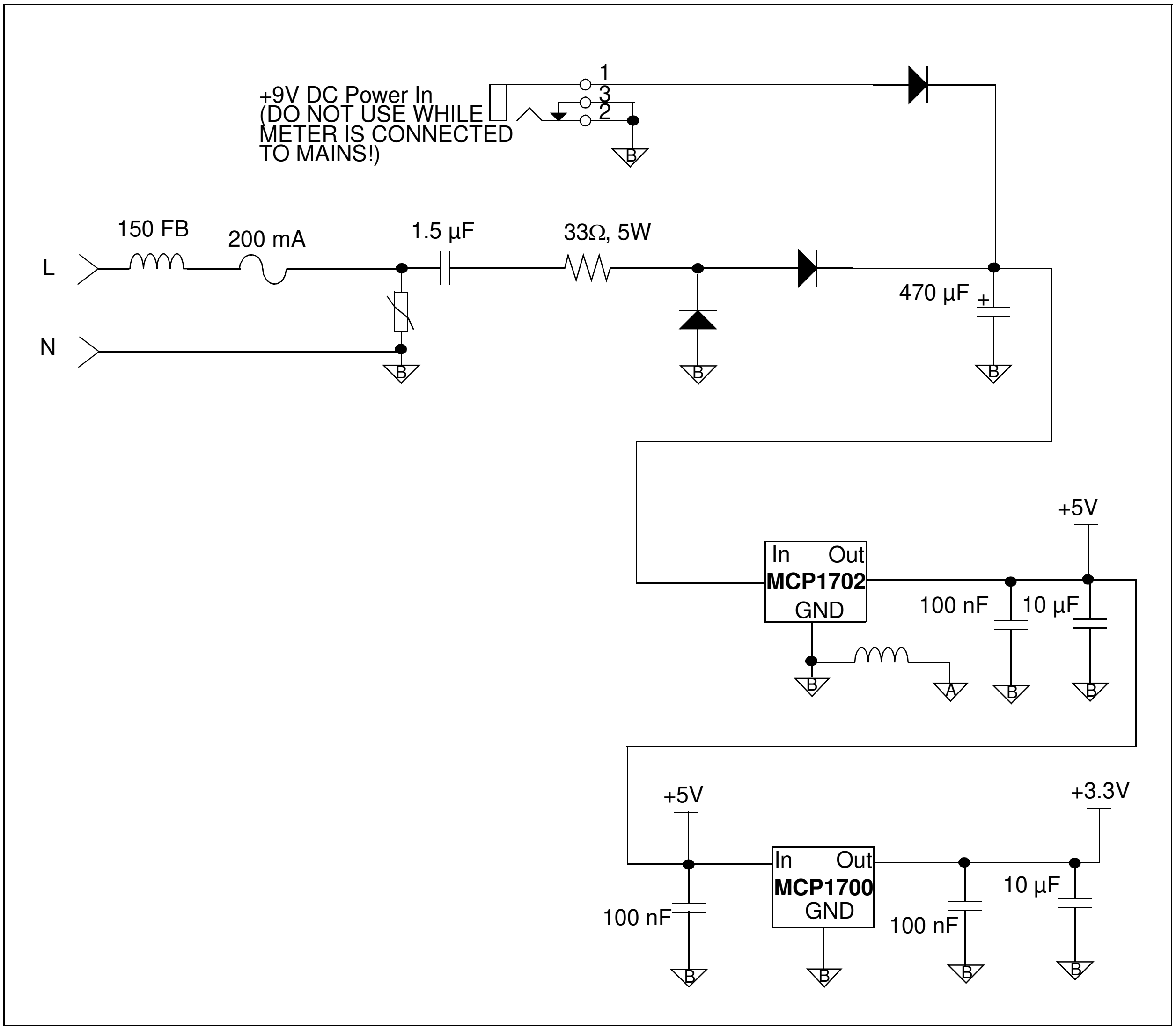



***FIGURE 2-4:*** *Simplified Power Supply Circuit.*

# Chapter 3. Calculation Engine and Register Description

## 3.1 CALCULATION ENGINE SIGNAL FLOW SUMMARY

RMS voltage, RMS current, Active Power and Apparent Power, and the calibration output pulse are all calculated through the following process described in Figure 3-1. The calibration registers for each calculation are shown as well as the output registers.

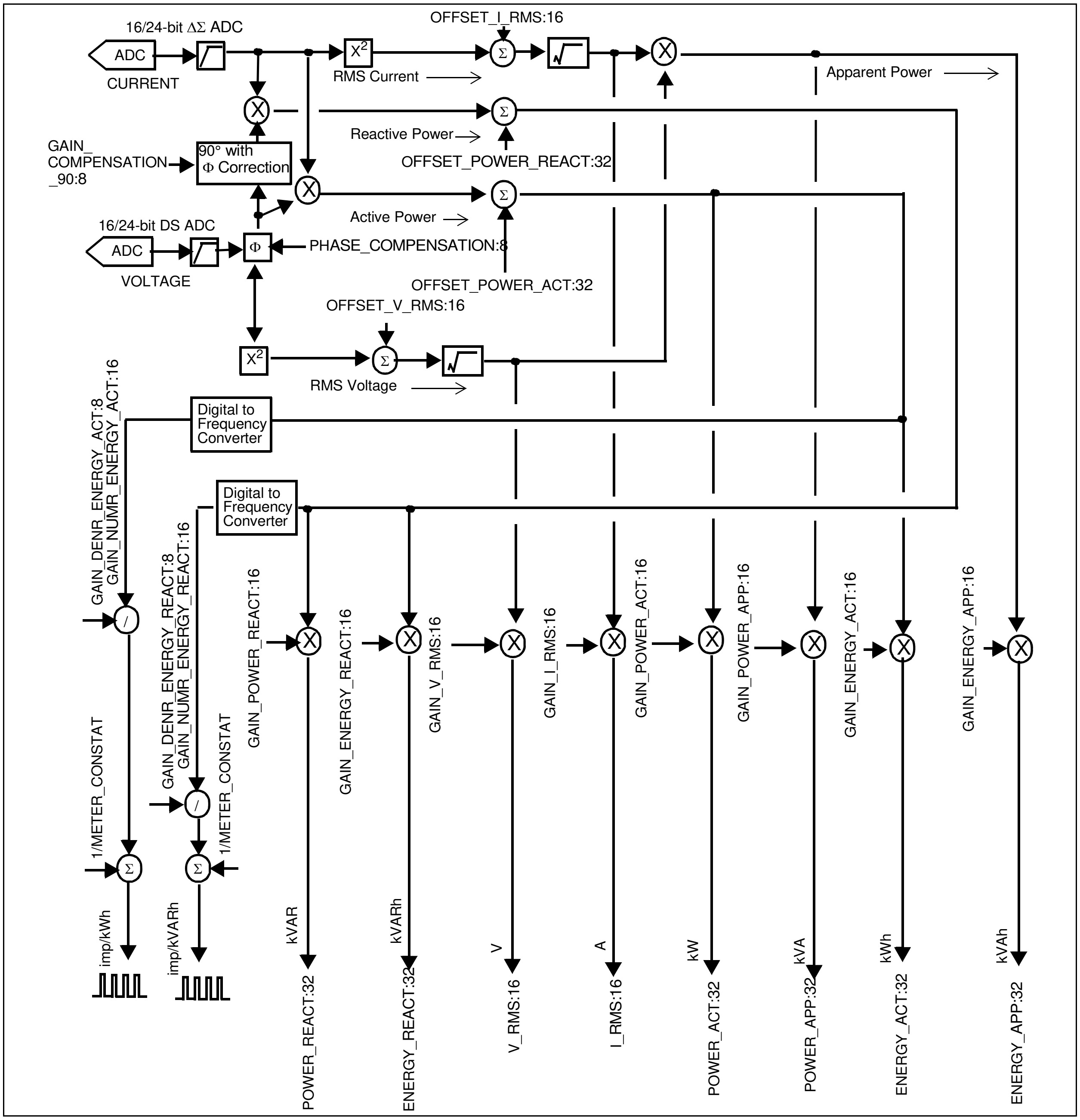



***FIGURE 3-1:*** *PIC18F87J72 Calculation Engine Signal Flow*

## 3.2 COMPLETE REGISTER LIST

**TABLE 3-1: INTERNAL REGISTER SUMMARY**

| Name | Bits | R/W | Description |
|---|---|---|---|
| MODE | 8 | R/W | Configuration register for operating mode of the meter. |
| STATUS | 8 | R | STATUS register. |
| CAL_CONTROL | 8 | R/W | Configuration register for calibration control. |
| LINE_CYC | 16 | R/W | $2^n$ number of line cycles to be used during energy accumulation. |
| LINE_CYC_CNT | 16 | R | Counter for number of line cycles. |
| RAW2_I_RMS | 64 | R | $Raw^2$ RMS value from the current A/D converter in LSBs. |
| RAW_I_RMS | 16 | R | Raw RMS value from the current A/D converter in LSBs. |
| I_RMS | 16 | R | RMS value of the current, post Calibration. |
| RAW2_V_RMS | 64 | R | $Raw^2$ RMS value from the voltage A/D converter in LSBs. |
| RAW_V_RMS | 16 | R | Raw RMS value from the voltage A/D converter in LSBs. |
| V_RMS | 16 | R | RMS value of the voltage, post Calibration. |
| LINE_FREQUENCY | 16 | R | Line Frequency. |
| RAW_POWER_ACT | 64 | R | Raw Active Power. |
| POWER_ACT | 32 | R | Final Active Power, units in watts (W). |
| POWER_APP | 32 | R | Final Apparent Power, units in volt-amperes (VA). |
| RAW_POWER_REACT | 64 | R | Raw Reactive Power. |
| POWER_REACT | 32 | R | Final Reactive Power, units in volt-amperes-reactive (VAR). |
| PERIOD | 32 | R | Period register. |
| ENERGY_ACT | 32 | R | Final Active Energy accumulated. |
| RAW_ENERGY_ACT | 64 | R | Raw Active Energy accumulated. |
| ENERGY_APP | 32 | R | Final Apparent Energy accumulated. |
| RAW_ENERGY_APP | 64 | R | Raw Apparent Energy accumulated. |
| I_ABS_MAX | 8 | R | Not implemented. |
| V_ABS_MAX | 8 | R | Not implemented. |
| ENERGY_REACT | 32 | R | Final Reactive Energy accumulated. |
| RAW_ENERGY_REACT | 64 | R | Final Reactive Energy accumulated. |
| PHASE_COMPENSATION | 8 | R/W | Phase compensation between voltage and current. |
| OFFSET_I_RMS | 16 | R/W | Offset adjustment for RMS current reading. |
| OFFSET_V_RMS | 16 | R/W | Offset adjustment for RMS voltage reading. |
| GAIN_I_RMS | 16 | R/W | Gain adjustment for RMS current. |
| GAIN_V_RMS | 16 | R/W | Gain adjustment for RMS voltage. |
| OFFSET_POWER_ACT | 32 | R/W | Active Power offset. |
| GAIN_POWER_ACT | 16 | R/W | Active Power gain adjust. |
| OFFSET_POWER_REACT | 32 | R/W | Offset correction for Reactive Power. |
| GAIN_POWER_REACT | 16 | R/W | Reactive Power gain adjust to produce X VAR/LSB. |
| GAIN_ENERGY_ACT | 16 | R/W | Not implemented. |
| GAIN_ENERGY_APP | 16 | R/W | Not implemented. |
| GAIN_ENERGY_REACT | 16 | R/W | Not implemented. |
| CF_PULSE_WIDTH | 8 | R/W | Defines CF pulse width from 0 to 255 x 0.8192 ms (0.209s). |
| GAIN_DENR_ENERGY_ACT | 8 | R/W | Active Energy Pulse Output correction factor. |
| GAIN_NUMR_ENERGY_ACT | 16 | R/W | Active Energy Pulse Output correction factor. |
| MODE1_DEF | 16 | R/W | Power-Up Configuration Register. |
| CAL_STATUS | 16 | R/W | Calibration Status. |

**TABLE 3-1: INTERNAL REGISTER SUMMARY (CONTINUED)**

| Name | Bits | R/W | Description |
|---|---|---|---|
| MAXIMUM CURRENT | 16 | R/W | Maximum current of the meter ($I_{MAX}$). |
| CALIBRATION_VOLTAGE | 16 | R/W | Calibration Voltage of the meter ($V_{CAL}$). |
| CALIBRATION_CURRENT | 16 | R/W | Calibration Current of the meter ($I_{CAL}$). |
| CALIBRATION_FREQUENCY | 16 | R/W | Calibration Frequency of the meter. |
| METER_CONSTANT | 16 | R/W | Meter Constant in imp/kWh or imp/kVARh. |
| CALIBRATION_LINE_CYCLE | 16 | R/W | Number of line cycles for calibration. |
| GAIN_DENR_ENERGY_REACT | 8 | R/W | Reactive Energy Pulse Output correction factor. |
| GAIN_NUMR_ENERGY_REACT | 16 | R/W | Reactive Energy Pulse Output correction factor. |
| PHASE_COMPENSATION_90 | 8 | R/W | Phase delay for Reactive Power. |
| CREEP_THRSHOLD_MINUTE | 8 | R/W | No Load threshold time (minutes). |
| CREEP_THRSHOLD_SECOND | 8 | R/W | No Load threshold time (seconds). |
| ENERGY_ACT_FORWARD | 32 | R/W | Forward Active Energy. |
| ENERGY_ACT_REVERSE | 32 | R/W | Reverse Active Energy. |
| ENERGY_REACT_INDUCTIVE | 32 | R/W | Inductive Reactive Energy. |
| ENERGY_REACT_CAPACITIVE | 32 | R/W | Capacitive Reactive Energy. |

## 3.3 MODE

The MODE register controls the operation of the energy meter. The bit functions are defined by the table below.

**REGISTER 3-1: MODE REGISTER**

| U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | CF | ABSOLUTE | PHASE | CREEP |
| bit 7 | | | | | | | bit 0 |

| Legend: | | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as ‘0’ | |
| -n = Value at POR | ‘1’ = Bit is set | ‘0’ = Bit is cleared | x = Bit is unknown |

bit 7-4 **Unimplemented:** Read as ‘0’.

bit 3 **CF:** Active Energy CF Phase Enable bit
1 = Bit = 1 Phase is enabled to be accumulated into the total energy registers or CF pulse output
0 = Bit = 0 Phase is DISABLED and is not accumulated into the total energy registers or CF pulse output

bit 2 **ABSOLUTE** Positive Only Energy Accumulation Mode bit
1 = Bit = 1 Positive energy only
0 = Bit = 0 Both negative and positive energy accumulated (negative energy is subtracted)

bit 1 **PHASE:** Phase bit
1 = Single Point Phase Correction
0 = Multi-Point Phase Correction (future)

bit 0 **CREEP:** No-Load Threshold bit
1 = Enabled
0 = Disabled

## 3.4 STATUS

The STATUS register contains the operational status of the energy meter. The bit functions are defined in the table below.

**REGISTER 3-2: STATUS REGISTER**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | PH_S | — |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' | |
| -n = Value at POR | '1' = Bit is set | '0' = Bit is cleared | x = Bit is unknown |

bit 7-2 **Unimplemented:** Read as '0'

bit 1 **PH_S:** Phase Sign bit
1 = CT may be in backward (if enabled)
0 = Operation normal

bit 0 **Unimplemented:** Read as '0'

## 3.5 CAL_CONTROL

This is the Calibration mode control register. Bit 0 enables the Calibration mode. In this mode, the power meter operates as normal, but no updates are made to the voltage, current, power or energy registers as long as bit 1 is low. When bit 1 is set high, the registers are updated for LINE_CYC line cycles (only power and energy registers are updated). After this time, bit 1 is set low by the PIC18F87J72 and the update of the registers will stop. This allows the calibration software to set bit 0, clear the registers, set bit 1 and start reading the desired registers, as well as the CAL_CONTROL register, to check the status of bit 1. When bit 1 goes low, the LINE_CYC line cycles have passed and the registers are final. Note that bit 0 takes effect immediately, and bit 1 will take effect on the very next line cycle. When bit 1 goes low, all registers will be ready to read.

**REGISTER 3-3: CAL_CONTROL REGISTER (NOTE 1)**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | Reserved | CAL_UPDATE | CAL_MODE |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as ‘0’ | |
| -n = Value at POR | ‘1’ = Bit is set | ‘0’ = Bit is cleared | x = Bit is unknown |

bit 7-3 **Unimplemented:** Read as ‘0’

bit 2 **Reserved:**

bit 1 **CAL_UPDATE:** Calibration Update bit

Power and energy registers updated for LINE_CYC line cycles when cleared. Bit must be set for registers to begin updating, which starts on the next line cycle after bit is set.

1 = When the CAL_MODE bit is set, set the CAL_UPDATE bit to enable update of power and energy registers starting on next line cycle. Bit = 1 Single Point Phase Correction

0 = When the CAL_MODE bit is set and the CAL_UPDATE bit has been set, the CAL_UPDATE bit will be cleared after LINE_CYC line cycles. At that point, all registers will be updated and no further updates will be done until the CAL_UPDATE bit is set again, or the CAL_MODE bit is cleared.

bit 0 **CAL_MODE:** Calibration Mode bit

This bit enables Calibration mode.

1 = Calibration mode enabled

0 = Calibration mode disabled

**Note 1:** This register is used in Multi-Point and Single Point Calibration modes only.

## 3.6 LINE_CYC

| Name | Bits | Cof |
|---|---|---|
| LINE_CYC | 16 | R/W |

Number of line cycles as a power of two. A setting of 0 indicates $2^0$ or one line cycle. A setting of 1 is two line cycles ($2^1$), a setting of 2 is four lines cycles ($2^2$), up to a setting of eight, which is 256 line cycles. When written, this register will not take effect until the previous number of line cycles has been acquired.

## 3.7 LINE_CYC_CNT

| Name | Bits | Cof |
|---|---|---|
| LINE_CYC_CNT | 16 | R |

This register counts from 0 and finishes at $2^{(LINE\_CYC - 1)}$. Then re-starts at 0, where LINE_CYC represents the value in the LINE_CYC register.

## 3.8 RAW2_I_RMS

| Name | Bits | Cof |
|---|---|---|
| RAW2_I_RMS | 64 | R |

This register is the square of the raw RMS value from the current A/D converter in LSBs. By definition, this register will always contain a positive value, including the situation where power is negative from a backwards CT or otherwise. This register is overwritten every LINE_CYC line cycle and is written only once, if the calibration is enabled.

## 3.9 RAW_I_RMS

| Name | Bits | Cof |
|---|---|---|
| RAW_I_RMS | 16 | R |

This register is the raw RMS value from the current A/D converter in LSBs (square root of the top 32-bits of (RAW2_I_RMS + OFFSET_I_RMS). By definition, this register will always contain a positive value (even if the CT is in backwards). This register is overwritten every LINE_CYC line cycle and is written only once, if the calibration is enabled.

## 3.10 I_RMS

| Name | Bits | Cof |
|---|---|---|
| I_RMS | 16 | R |

This register is the RMS value of phase A current in X A/LSB, as determined by the value in the GAIN_I_RMS register. When displaying the RMS current, multiply the (decimal) value in these registers by X to get the display value in Amperes. This register is overwritten every LINE_CYC line cycle (written only once if the calibration is enabled).

## 3.11 RAW2_V_RMS

| Name | Bits | Cof |
|---|---|---|
| RAW2_V_RMS | 64 | R |

This register is the square of the raw RMS value from the voltage A/D converter in LSBs. By definition, it will always contain a positive value. This register is overwritten every LINE_CYC line cycle (written only once if the calibration is enabled).

## 3.12 RAW_V_RMS

| Name | Bits | Cof |
|---|---|---|
| RAW_V_RMS | 16 | R |

This is the raw RMS value from the voltage A/D converter in LSBs (square root of the top 32-bits of RAW2_V_RMS + OFFSET_V_RMS. By definition, this register will always contain a positive value. The register is overwritten every LINE_CYC line cycle (written only once if the calibration is enabled).

## 3.13 V_RMS

| Name | Bits | Cof |
|---|---|---|
| V_RMS | 16 | R |

This register is the RMS value of the voltage, in X 0.01 V/LSB, as determined by the value in the GAIN_V_RMS register. When displaying the RMS voltage, assume a calibrated meter exists and multiply the (decimal) value in these registers by X to get the display value in Volts. This register is overwritten every LINE_CYC line cycle (written only once if the calibration is enabled).

## 3.14 LINE_FREQUENCY

| Name | Bits | Cof |
|---|---|---|
| LINE_FREQUENCY | 16 | R |

This register holds the measured line frequency using the zero crossing technique.

## 3.15 RAW_POWER_ACT

| Name | Bits | Cof |
|---|---|---|
| RAW_POWER_ACT | 64 | R |

This register is the raw active power, as it represents the sum of current A/D value times voltage A/D value results over LINE_CYC line cycles (each line cycle has 128 results). Each current times voltage multiplication results in a 32-bit word. There are up to 256 line cycles with each line cycle being 128 results, and each result being 32-bit. Thus, 48 bits are needed. This is the register to be read during calibration for calculating the offset and gain values associated with active power, OFFSET_POWER_ACT and GAIN_POWER_ACT. This register is overwritten every line cycle, however if the calibration is enabled, the updates will stop once the LINE_CYC line cycles have elapsed.

## 3.16 POWER_ACT

| Name | Bits | Cof |
|---|---|---|
| POWER_ACT | 32 | R |

This register is the value for active power. The goal of the calibration is to get this register value to equal X W/LSB. This is done with the OFFSET_POWER_ACT and GAIN_POWER_ACT registers. When displaying the power, multiply the (decimal) value in this register by X to get the display value in Watts. This register is overwritten every LINE_CYC line cycle (written only once if the calibration is enabled).

## 3.17 POWER_APP

| Name | Bits | Cof |
|---|---|---|
| POWER_APP | 32 | R |

This is the value of the apparent power. The goal of the calibration is to get this value to equal X VA/LSB. This is done with the GAIN_POWER_APP registers. When displaying the power for phase A, multiply the (decimal) value in this register by X to get the display value in Watts. This register is overwritten every LINE_CYC line cycle (written only once if the calibration is enabled).

## 3.18 RAW_POWER_REACT

| Name | Bits | Cof |
|---|---|---|
| RAW_POWER_REACT | 64 | R |

This is the raw reactive power. This register is read during the calibration for calculating the gain values associated with the reactive power and GAIN_POWER_REACT. This register is overwritten every LINE_CYC line cycle (written only once if the calibration is enabled). This register is accumulated once a line-cycle basis.

### 3.19 POWER_REACT

| Name | Bits | Cof |
|---|---|---|
| POWER_REACT | 32 | R |

This is the value for reactive power. The goal is to get this value to equal X VAR/LSB. This is done with the GAIN_POWER_REACT register. When displaying the power, multiply the (decimal) value in this register by X to get the display value in Watts. This register is overwritten every LINE_CYC line cycle (written only once if the calibration is enabled).

### 3.20 PERIOD

| Name | Bits | Cof |
|---|---|---|
| PERIOD | 32 | R |

This 32-bit register represents the total number of clock ticks that elapsed over the most recent LINE_CYC line cycle. Each LSB represents 1.6 µs with a 40 MHz clock on the microcontroller. This register is overwritten every LINE_CYC line cycle (written only once if the calibration is enabled).

### 3.21 ENERGY_ACT

| Name | Bits | Cof |
|---|---|---|
| ENERGY_ACT | 32 | R |
| RAW_ENERGY_ACT | 64 | R |

The design updates the Energy register using the CF Pulse blink output count. In this method, the Energy registers increments every pulse by a value equal to 1/(METER_CONSTANT).

ENERGY_W = ENEGRY_W + (1/METER_CONSTANT)

The gain calibration registers GAIN_NUMR_ENERGY_ACT and GAIN_DENR_ENERGY_ACT hold good for this method also.

### 3.22 ENERGY_APP

| Name | Bits | Cof |
|---|---|---|
| ENERGY_APP | 32 | R |
| RAW_ENERGY_APP | 64 | R |

These two registers represent the total apparent energy accumulated so far.

## 3.23 I_ABS_MAX

| Name | Bits | Cof |
|---|---|---|
| I_ABS_MAX | 8 | R |

NOT IMPLEMENTED IN THIS FIRMWARE/SOFTWARE RELEASE.

## 3.24 V_ABS_MAX

| Name | Bits | Cof |
|---|---|---|
| V_ABS_MAX | 8 | R/W |

NOT IMPLEMENTED IN THIS FIRMWARE/SOFTWARE RELEASE.

## 3.25 ENERGY_REACT

| Name | Bits | Cof |
|---|---|---|
| ENERGY_REACT | 32 | R |
| RAW_ENERGY_REACT | 64 | R |

The design updates the reactive energy registered using the CF Pulse blink output count too. In this method, the Energy registers increments every pulse by a value equal to 1/(METER_CONSTANT).

ENERGY_REACT = ENERGY_REACT + (1/METER_CONSTANT)

The gain calibration registers GAIN_NUMR_ENERGY_ACT and GAIN_DENR_ENERGY_ACT hold good for this method also.

## 3.26 PHASE_COMPENSATION

| Name | Bits | Cof |
|---|---|---|
| PHASE_COMPENSATION | 8 | R/W |

Phase delay, signed 8-bit value, provides the phase compensation by sampling time/2.

## 3.27 OFFSET_I_RMS

| Name | Bits | Cof |
|---|---|---|
| OFFSET_I_RMS | 16 | R/W |

Square of the offset for RMS current reading, signed 16-bit value. Note that this value should be similar to the ADC's noise squared. At a gain of 1, the noise will be about 1 LSB, 2 LSBs at a gain of 2, 6 LSBs at a gain of 8, 11 LSBs at a gain of 16, and 22 LSBs at a gain of 32. There may be other sources of noise. Using the square of the offset allows for higher accuracy. The value will be added before the square root is taken when calculating the final RMS value.

## 3.28 OFFSET_V_RMS

| Name | Bits | Cof |
|---|---|---|
| OFFSET_V_RMS | 16 | R/W |

Square of offset for RMS voltage reading, signed 8-bit value. Note that this value should be similar to the ADC's noise squared. For the voltage channel, the noise will be about 1 LSB. There may be other sources of noise. Using the square of the offset allows for higher accuracy. The value will be added before the square root is taken when calculating the final RMS value.

## 3.29 GAIN_I_RMS

| Name | Bits | Cof |
|---|---|---|
| GAIN_I_RMS | 16 | R/W |

Current gain to produce X A/LSB. The value is always less than one (for example, 32,767 = 0.9999695).

## 3.30 GAIN_V_RMS

| Name | Bits | Cof |
|---|---|---|
| GAIN_V_RMS | 16 | R/W |

Voltage gain to produce 0.1 V/LSB in the V_RMS register. The value is always less than one (for example, 32,767 = 0.9999695).

## 3.31 OFFSET_POWER_ACT

| Name | Bits | Cof |
|---|---|---|
| OFFSET_POWER_ACT | 32 | R/W |

Active power offset (this is a straight offset, not the square, as with voltage and current). A much larger value is needed because the power is a running sum. This is a 32-bit signed value.

## 3.32 GAIN_POWER_ACT

| Name | Bits | Cof |
|---|---|---|
| GAIN_POWER_ACT | 16 | R/W |

Active power gain to produce X W/LSB. The value is always less than one (for example, 32,767 = 0.9999695).

## 3.33 OFFSET_POWER_REACT

| Name | Bits | Cof |
|---|---|---|
| OFFSET_POWER_REACT | 32 | R/W |

Reactive power offset (this is a straight offset, not the square, as with voltage and current). A much larger value is needed because the power is a running sum. This is a 32-bit signed value.

## 3.34 GAIN_POWER_REACT

| Name | Bits | Cof |
|---|---|---|
| GAIN_POWER_REACT | 16 | R/W |

Reactive power gain to produce X W/LSB. The value is always less than one (for example, 32,767 = 0.9999695).

## 3.35 GAIN_ENERGY_ACT

| Name | Bits | Cof |
|---|---|---|
| GAIN_ENERGY_ACT | 16 | R/W |

Active energy gain to produce X Wh/LSB. The value is always less than one (for example, 32,767 = 0.9999695).

## 3.36 GAIN_ENERGY_APP

| Name | Bits | Cof |
|---|---|---|
| GAIN_ENERGY_APP | 16 | R/W |

Apparent energy gain to produce X VAh/LSB. The value is always less than one (for example, 32,767 = 0.9999695).

## 3.37 GAIN_ENERGY_REACT

| Name | Bits | Cof |
|---|---|---|
| GAIN_ENERGY_REACT | 16 | R/W |

Reactive energy gain to produce X VARh/LSB. The value is always less than one (for example, 32,767 = 0.9999695).

## 3.38 CF_PULSE_WIDTH

| Name | Bits | Cof |
|---|---|---|
| CF_PULSE_WIDTH | 8 | R/W |

Defines the CF pulse width from 0 to 255. Length of width is valued
* 8 * (1/LINE_FREQUENCY)/128) ms. A maximum of 0.266 seconds for 60 Hz and 0.319 seconds for 50 Hz.

If the value is 0, no CF pulse is produced.

## 3.39 GAIN_DENR_ENERGY_ACT

| Name | Bits | Cof |
|---|---|---|
| GAIN_DENR_ENERGY_ACT | 8 | R/W |

8-bit signed value. Represents the number of shifts for active power energy register ENERGY_ACT before GAIN_DENR_ENERGY_ACT is applied.

## 3.40 GAIN_NUMR_ENERGY_ACT

| Name | Bits | Cof |
|---|---|---|
| GAIN_NUMR_ENERGY_ACT | 16 | R/W |

Active power gain to produce a specified pulses per watt-hour. The value is always less than one (for example, 32,767 = 0.9999695).

## 3.41 MODE1_DEF

| Name | Bits | Cof |
|---|---|---|
| MODE1_DEF | 16 | R/W |

MODE default power-up settings. On power-up, this register will be read and placed into the MODE register.

## 3.42 CAL_STATUS

The CAL_STATUS register holds the calibration status for each individual phase. Broken down by phase, these are the values that can be calibrated. Each bit has the status of `0` = NOT Calibrated, `1` = CALIBRATED.

**REGISTER 3-4: CAL_STATUS REGISTER**

| R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PHASE_COMPENSATION | OFFSET_I_RMS | OFFSET_V_RMS | — | — | GAIN_I_RMS | GAIN_V_RMS | OFFSET_POWER_ACT |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | U-0 | U-0 | U-0 | R/W-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | GAIN_POWER_ACT | — | — | — | GAIN_POWER_REACT | — | — |
| bit 7 | | | | | | | bit 0 |

| Legend: | | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' | |
| -n = Value at POR | '1' = Bit is set | '0' = Bit is cleared | x = Bit is unknown |

bit 15-0 **All bits:** Calibration Register Status bits
`1` = This register has been calibrated
`0` = This register is NOT calibrated

## 3.43 MAXIMUM CURRENT

| Name | Bits | Cof |
|---|---|---|
| MAXIMUM_CURRENT | 16 | R/W |

This register holds the maximum current for the meter ($I_{MAX}$).

## 3.44 CALIBRATION_VOLTAGE

| Name | Bits | Cof |
|---|---|---|
| CALIBRATION_VOLTAGE | 16 | R/W |

This register holds the calibration voltage of the meter ($V_{CAL}$).

## 3.45 CALIBRATION_CURRENT

| Name | Bits | Cof |
|---|---|---|
| CALIBRATION_CURRENT | 16 | R/W |

This register holds the calibration current of the meter ($I_{CAL}$).

## 3.46 CALIBRATION_FREQUENCY

| Name | Bits | Cof |
|---|---|---|
| CALIBRATION_FREQUENCY | 16 | R/W |

This register holds the calibration frequency of the meter.

## 3.47 METER_CONSTANT

| Name | Bits | Cof |
|---|---|---|
| METER_CONSTANT | 16 | R/W |

This register holds the meter constant in imp/kWh or imp/kVARh.

## 3.48 CALIBRATION_LINE_CYCLE

| Name | Bits | Cof |
|---|---|---|
| CALIBRATION_FREQUENCY | 16 | R/W |

This register holds the number of line cycles used during the calibration.

## 3.49 GAIN_DENR_ENERGY_REACT

| Name | Bits | Cof |
|---|---|---|
| GAIN_DENR_ENERGY_REACT | 8 | R/W |

8-bit signed value. Represents the number of shifts for reactive power energy register, before GAIN_NUMR_ENERGY_REACT is applied.

## 3.50 GAIN_NUMR_ENERGY_REACT

| Name | Bits | Cof |
|---|---|---|
| GAIN_NUMR_ENERGY_REACT | 16 | R/W |

Reactive power gain to produce a specified pulse per VAR-hour. The value is always less than one (for example, 32,767 = 0.9999695).

## 3.51 PHASE_COMPENSATION_90

| Name | Bits | Cof |
|---|---|---|
| PHASE_COMPENSATION_90 | 8 | R/W |

Phase delay for reactive power, signed 8-bit value, sampling time/2.

## 3.52 CREEP_THRSHOLD_MINUTE

| Name | Bits | Cof |
|---|---|---|
| CREEP_THRSHOLD_MINUTE | 8 | R/W |

This 8-bit register holds the decimal representation of the creep threshold time in minutes (total creep is minutes + seconds register).

## 3.53 CREEP_THRSHOLD_SECOND

| Name | Bits | Cof |
|---|---|---|
| CREEP_THRSHOLD_SECOND | 8 | R/W |

This 8-bit register holds the decimal representation of the creep threshold time in seconds (total creep is minutes + seconds register).

## 3.54 ENERGY_ACT_FORWARD

| Name | Bits | Cof |
|---|---|---|
| ENERGY_ACT_FORWARD | 32 | R/W |

This 32-bit register is the accumulated active energy in the forward direction only.

The design updates the Energy register using the CF Pulse blink output count. In this method, the Energy registers increments every pulse by a value equal to 1/(METER_CONSTANT).

## 3.55 ENERGY_ACT_REVERSE

| Name | Bits | Cof |
|---|---|---|
| ENERGY_ACT_REVERSE | 32 | R/W |

This 32-bit register is the accumulated active energy in the reverse direction only.

The design updates the Energy register using the CF Pulse blink output count. In this method, the Energy registers increments every pulse by a value equal to 1/(METER_CONSTANT).

## 3.56 ENERGY_REACT_INDUCTIVE

| Name | Bits | Cof |
|---|---|---|
| ENERGY_REACT_INDUCTIVE | 32 | R/W |

This 32-bit register is the accumulated reactive energy in the inductive quadrants only.

The design updates the Energy register using the CF Pulse blink output count. In this method, the Energy registers increments every pulse by a value equal to 1/(METER_CONSTANT).

## 3.57 ENERGY_REACT_CAPACITIVE

| Name | Bits | Cof |
|---|---|---|
| ENERGY_REACT_CAPACITIVE | 32 | R/W |

This 32-bit register is the accumulated reactive energy in the capacitive quadrants only.

The design updates the Energy register using the CF Pulse blink output count. In this method, the Energy registers increments every pulse by a value equal to 1/(METER_CONSTANT).

**NOTES:**

# Appendix A. Schematic and Layouts

## A.1 INTRODUCTION

This appendix contains the following schematics and layouts for the Energy Monitoring PICtail™ Plus Daughter Board User's Guide:

- Board – Schematic
- Board – Schematic Isolation
- Board – Top Silk
- Board – Top Traces and Pads
- Board – Top Traces and Silk
- Board – Bottom Traces and Pads
- Board – Bottom Silk

## A.2 SCHEMATICS AND PCB LAYOUT

The layer order is shown in Figure A-1.

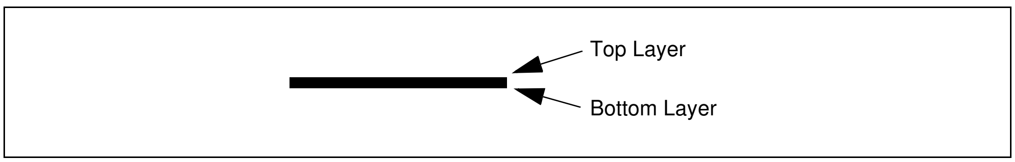
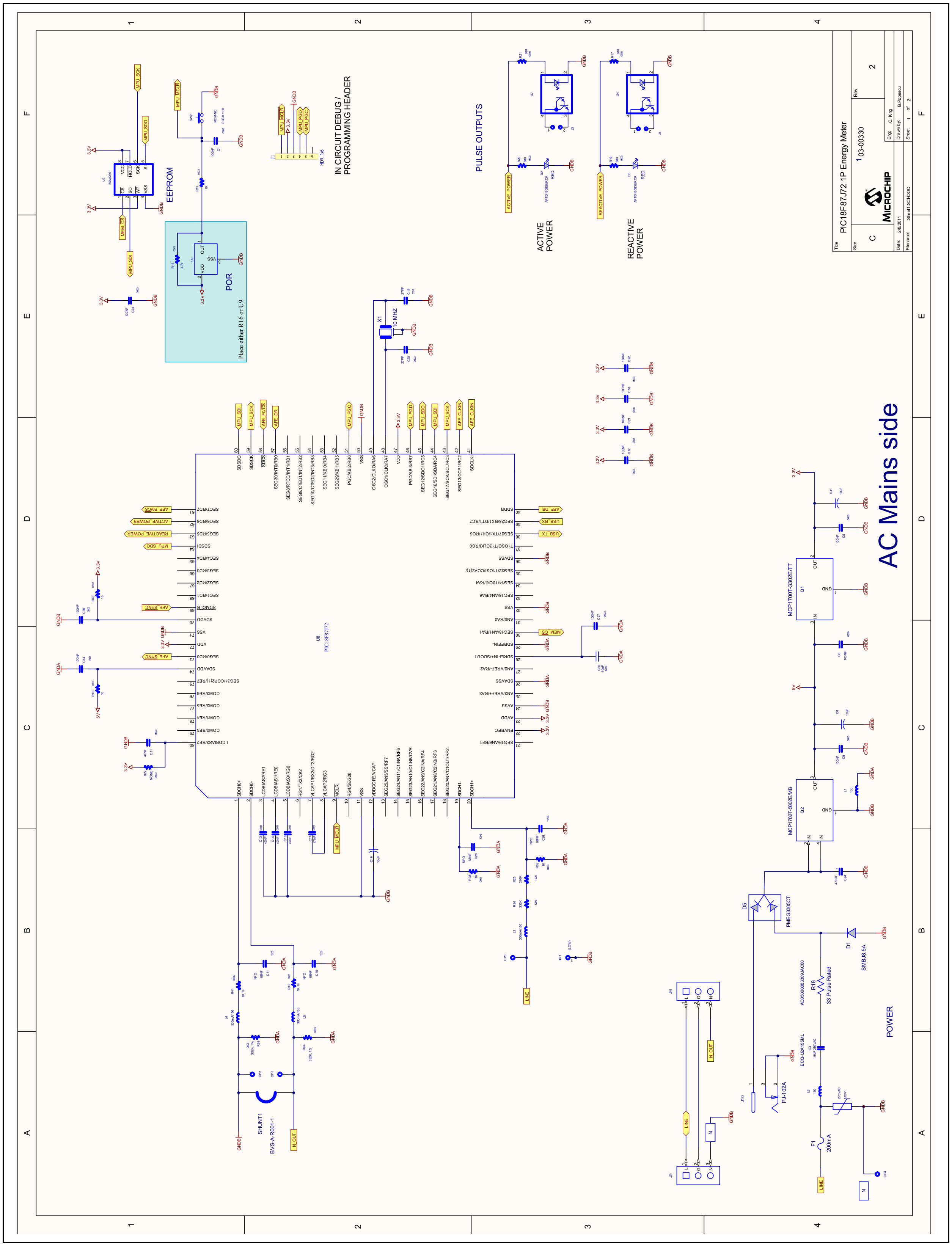
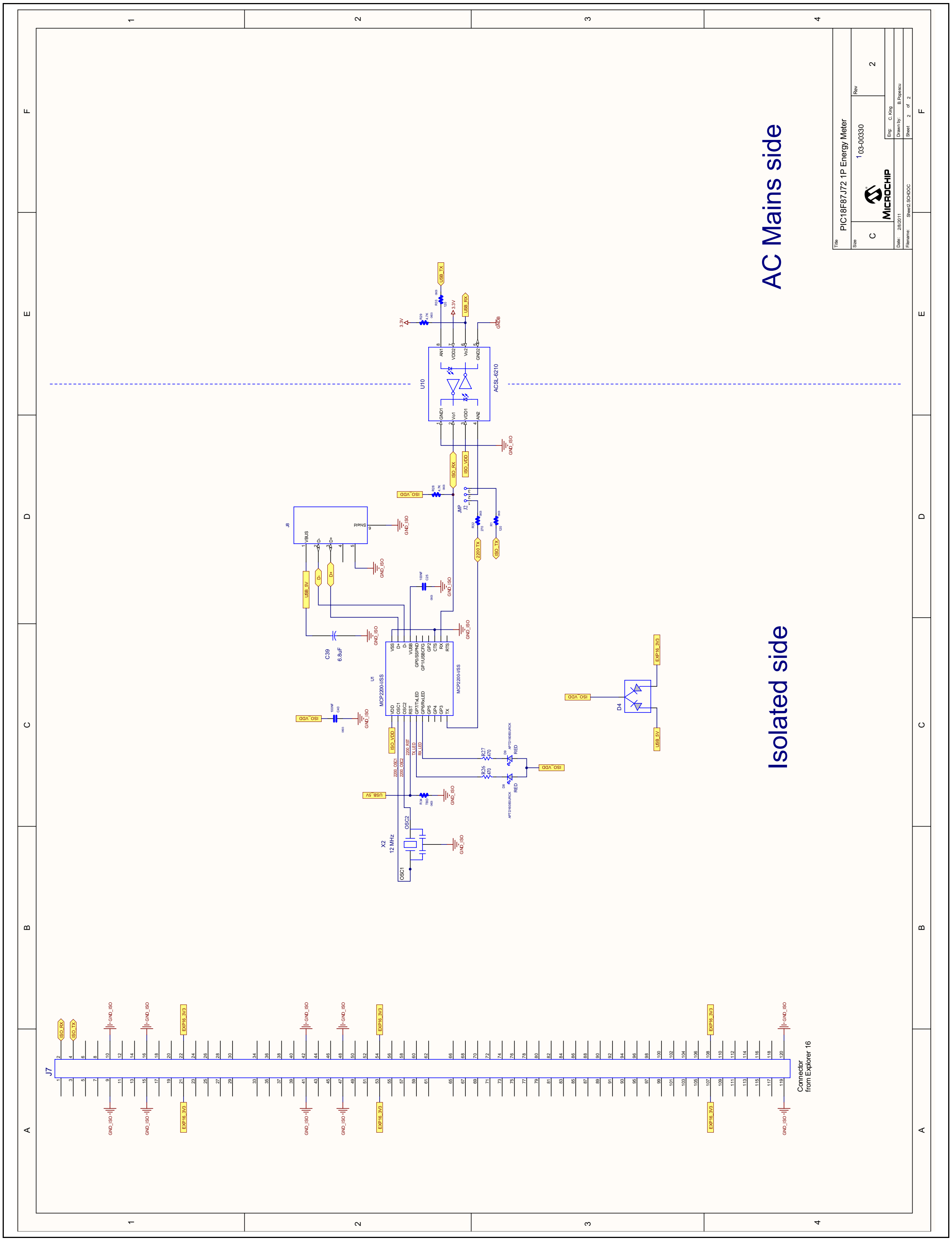



***FIGURE A-1:*** *Layer Order.*

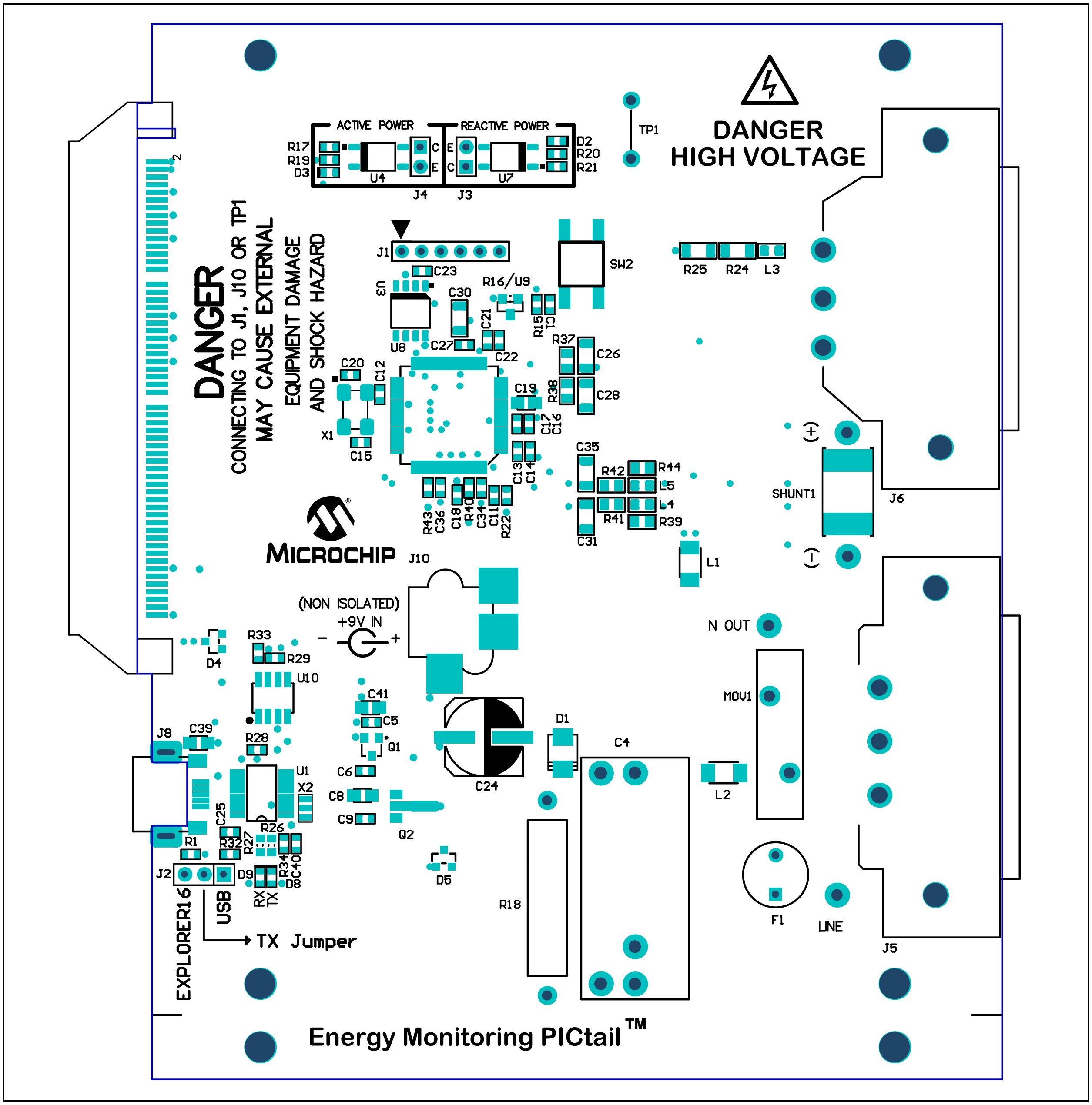
## A.3 BOARD – SCHEMATIC



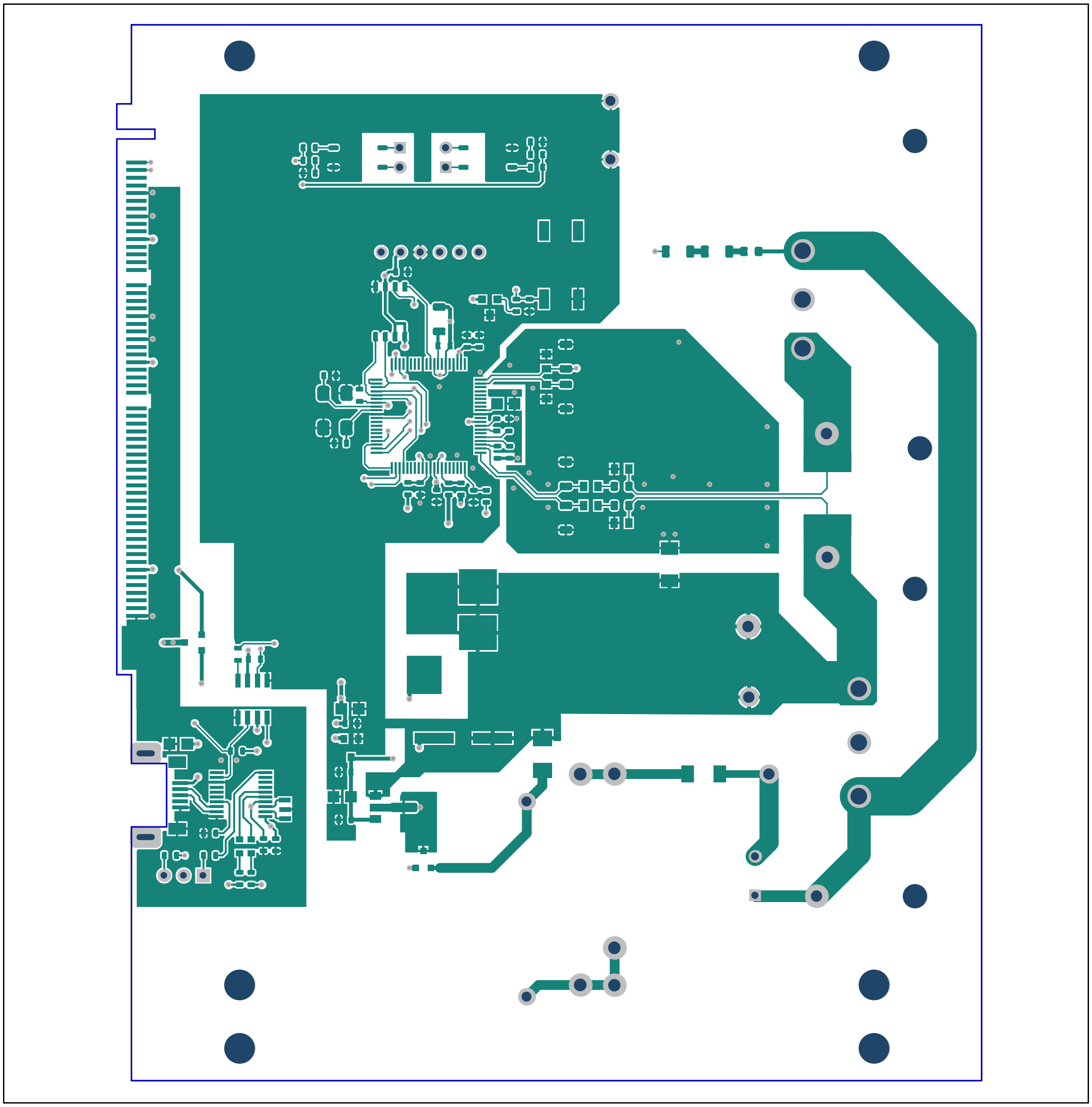
## A.4 BOARD – SCHEMATIC ISOLATION



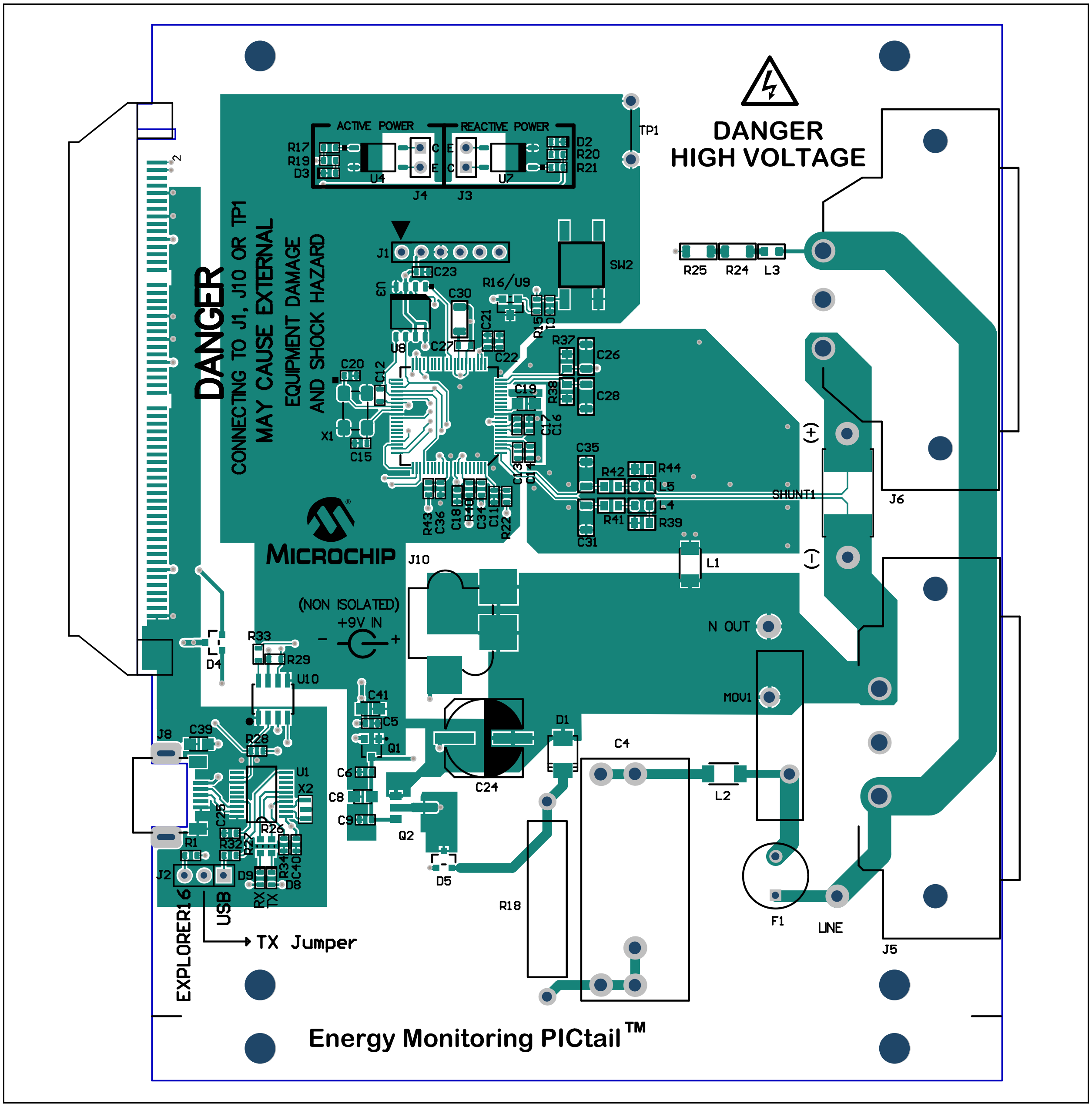
## A.5 BOARD – TOP SILK



## A.6 BOARD – TOP TRACES AND PADS

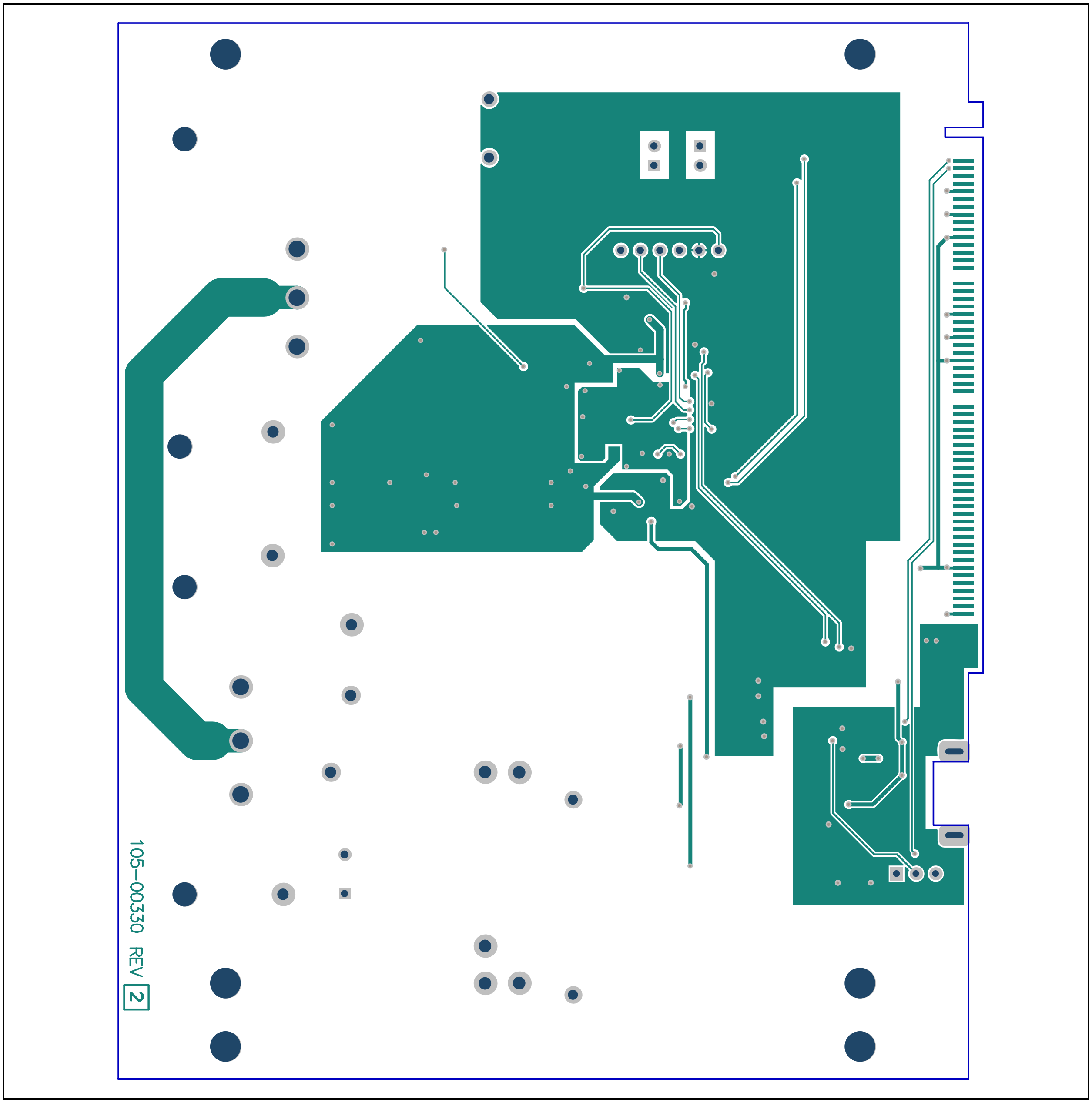


## A.7 BOARD – TOP TRACES AND SILK

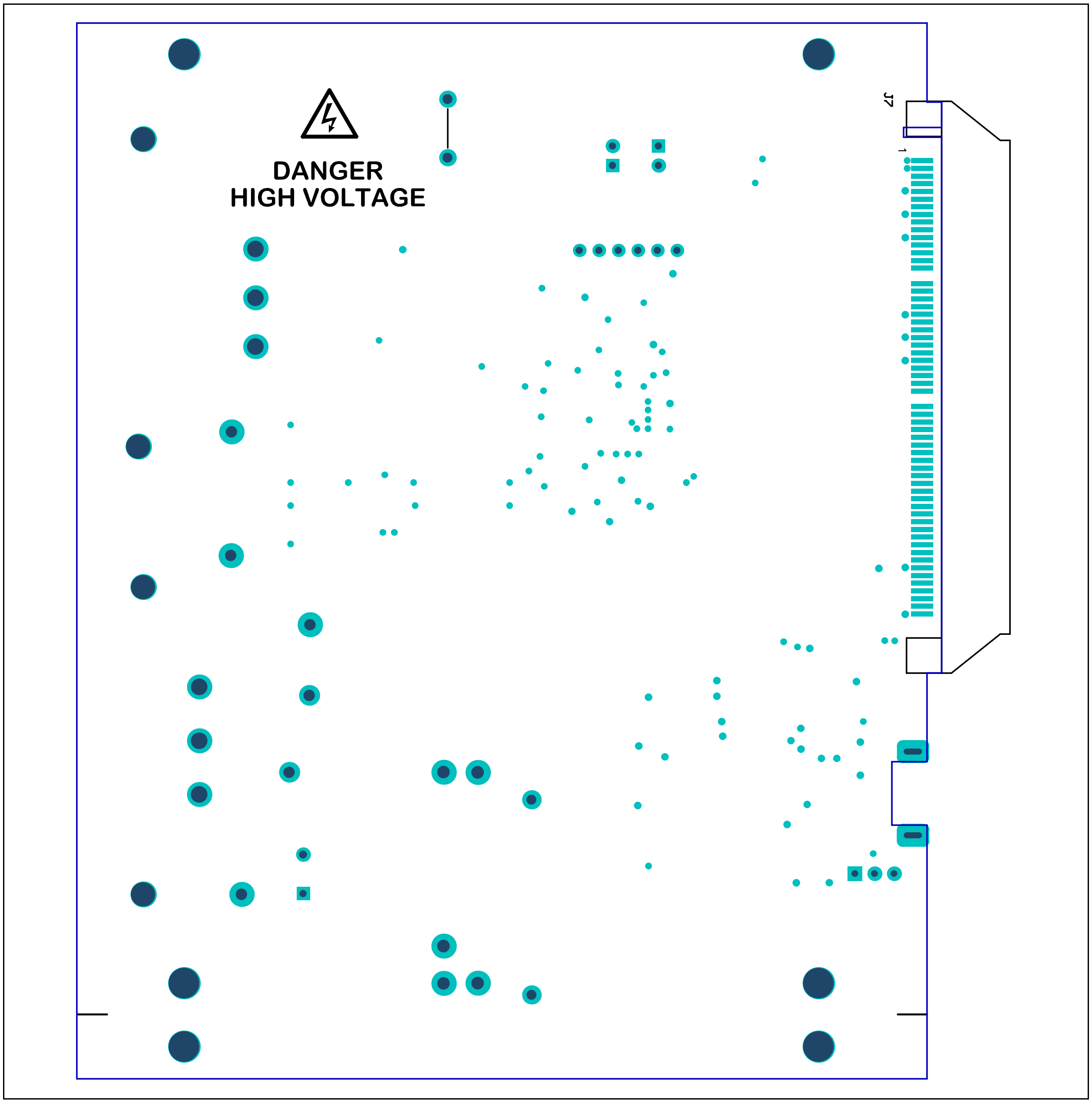


## A.8 BOARD – BOTTOM TRACES AND PADS



## A.9 BOARD – BOTTOM SILK



# Appendix B. Bill of Materials (BOM)

**TABLE B-1: BILL OF MATERIALS (BOM)**

| Qty | Reference | Description | Manufacturer | Part Number |
|---|---|---|---|---|
| 15 | C1, C5, C6, C9, C12, C18, C21, C22, C23, C25, C27, C34, C36, C40 | CAP .1UF 16V CERAMIC Y5V 0603 | Panasonic® – ECG | ECJ-1VF1C104Z |
| 1 | C4 | CAP 1.5UF 250/275VAC ECQ-UL | Panasonic – ECG | ECQ-U2A155ML |
| 3 | C8, C19, C41 | CAP CER 10UF 6.3V Y5V 0805 | Murata Manufacturing Co., Ltd. | GRM21BF50J106ZE01L |
| 5 | C11, C13, C14, C16, C17 | CAP CER 47000PF 25V 10% X7R 0603 | Murata Manufacturing Co., Ltd. | GRM188R71E473KA01D |
| 2 | C15, C20 | CAP CERAMIC 27PF 50V NP0 0603 | Kemet | C0603C270J5GACTU |
| 2 | C24 | CAP 470UF 25V ELECT FC SMD | Panasonic – ECG | EEV-FC1E471P |
| 4 | C26, C28, C31, C35 | CAP CER 6800PF 50V 5% C0G 1206 | Murata Manufacturing Co., Ltd. | GRM3195C1H682JA01D |
| 1 | C30 | CAP Tantalum A 10uF 6.3V | AVX Corporation | TAJA106M006RNJ |
| 1 | C39 | CAP CERAMIC 6.8UF 6.3V X5R 0805 | Kemet | C0805C685K9PACTU |
| 1 | D1 | Transient Voltage Suppressors 8.5V, Peak Pulse 600W, 41.7A | Littelfuse® Inc. | SMBJ8.5A |
| 4 | D2, D3, D8, D9 | LED – SMD Helios SMD Red | Kingbright Corporation | APTD1608SURCK |
| 1 | D4 | SCHOTTKY DIODE G3010BER/SOD | NXP Semiconductors | PMEG3005CT,215 |
| 1 | D5 | SCHOTTKY DIODE G3010BER/SOD | NXP Semiconductors | 3005CT,215 |
| 1 | F1 | Fuses 250V IEC LL .200A TR5 | Littelfuse Inc. | 37002000000 |
| 1 | J1 | 6 X 1 Header 2.54mm on center 6 mm/2.5mm | Samtec, Inc | TSW-106-07-G-S |
| 1 | J2 | 3 x 1 Header 2.54mm | — | — |
| 0 | J3, J4 | CONN HEADER 2POS .100 VERT TIN | Molex® Electronics | 22-28-4020 |
| 1 | J5 | MOD INLET ANG GND W/M3 HOLE PCB | Schurter Electronic Components | GSP1.9103.1 |
| 1 | J6 | MODULE PWR OUTLET F SCREW-ON PCB | Schurter Electronic Components | 6182.0033 |
| 1 | J7 | MINI EDGE CARD CONNECTOR 1.MM | Samtec, Inc | MEC1-160-02-S-D-EM2 |

**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 | J8 | CONN RCPT USB MINI B MID MOUNT | Hirose Electric Co., Ltd. | UX60SD-MB-5S55 |
| 1 | J10 | CONN PWR JACK 2.5X5.5MM VERT SMD | CUI Inc. | PJ-006B-SMT |
| 1 | JMP | SHUNT ECONOMY 2POS .100 TIN (for J2) | Tyco Electronics | 2-382811-1 |
| 2 | L1, L2 | FERRITE 300MA 150 OHM 1806 SMD | Laird Technologies® | LI1806C151R-10 |
| 3 | L3, L4, L5 | FERRITE 800MA 150 OHM 0805 SMD | Laird Technologies | LI0805H151R-10 |
| 1 | MOV1 | VARISTOR 275V RMS 20MM RADIAL | EPCOS AG. | S20K275E2 |
| 1 | PCB | RoHS Compliant Bare PCB, Energy Monitoring PICtail™ Plus Daughter Board (PIC18F87J72) | — | 104-00330 |
| 1 | Q1 | IIC LDO REG 200MA 3.3V SOT-23-3 | Microchip Technology Inc. | MCP1700T-3302E/TT |
| 1 | Q2 | IC REG LDO 5V 250MA SOT-89-3 | Microchip Technology Inc. | MCP1702T-5002E/MB |
| 2 | R1, R33 | RES SMT, 120-OHM 1/10W 5% 0603 | Panasonic – ECG | ERJ-3GEYJ121V |
| 1 | R15 | RES SMT, 1K-OHM 1/10W 5% 0603 | Panasonic – ECG | ERJ-3GEYJ102V |
| 2 | R17, R21 | RES 680 OHM 1/10W 5% 0603 SMD | Stackpole Electronics Inc. | RMCF0603JT680R |
| 1 | R18 | RESISTOR SILICONE 33 OHM 5W | Ohmite® Mfg. Co. | 45F33RE |
| 2 | R19, R20 | RES SMT, 330-OHM 1/10W 5% 0603 | Panasonic – ECG | ERJ-3GEYJ331V |
| 0 | R22 | DO NOT POPULATE | — | — |
| 2 | R24, R25 | RES 330K OHM 1/4W 5% 1206 SMD | Stackpole Electronics Inc | RMCF 1/8 330K 5% R |
| 2 | R26, R27 | RES SMT, 470-OHM 1/10W 5% 0603 | Panasonic – ECG | ERJ-3GEYJ471V |
| 2 | R16, R28, R29 | RES SMT, 4.7K-OHM 1/10W 5% 0603 | Panasonic – ECG | ERJ-3GEYJ472V |
| 1 | R32 | RES SMT, 270-OHM 1/10W 5% 0603 | Panasonic – ECG | ERJ-3GEYJ271V |
| 0 | R34 | DO NOT POPULATE | — | — |
| 4 | R37, R38, R41, R42 | RES 1.00K OHM 1/8W 1% 0805 SMD | Rohm Semiconductor | MCR10EZHF1001 |
| 2 | R39, R44 | RES 332K OHM 1/8W 1% 0805 SMD | Rohm Semiconductor | MCR10EZPF3323 |
| 2 | R40, R43 | RES SMT, 10-OHM 1/10W 5% 0603 | Panasonic – ECG | ERJ-3GEYJ100V |
| 1 | SHUNT1 | Precision Current Sensing Resistors 3 mΩ, 3W, tolerance:1.0% | ISOTEK Corporation | BVS-A-R003-1.0 |

**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 | SW2 | SWITCH TACT 6MM SMD MOM 230GF | Omron Corporation | B3S-1002 BY OMZ |
| 1 | TP1 | Wire Test Point 0.3" Length | Component Corporation® | PJ-202-30 |
| 1 | U2 | IC USB TO UART 20-SSOP | Microchip Technology Inc. | **MCP2200-I/SS** |
| 1 | U3 | IC EEPROM 256 KBIT 10 MHz 8-SOIC | Microchip Technology Inc. | **25AA256-I/SN** |
| 2 | U4, U7 | PHOTOCOUPLER DARL OUT 4-SMD | Sharp® Electronics Corporation | PC365NJ0000F |
| 1 | U8 | PIC18F Microcontroller with 32K bytes of Flash, 2048 bytes of RAM | Microchip Technology Inc. | **PIC18F87J72-80I/PT** |
| 1 | U9 | DO NOT POPULATE | Microchip Technology Inc. | **MCP130T-270I/TT** |
| 1 | U10 | OPTOCOUPLER DUAL BI 15MBD 8-SOIC | Avago Technologies | ACSL-6210-00RE |
| 1 | X1 | CRYSTAL 10.0000 MHz 10PF SMD | Abracon Corporation | ABM3B-10.000MHZ-10-1-U-T |
| 1 | X2 | RESONATOR 12.0 MHz CERAMIC | Murata Manufacturing Co., Ltd. | CSTCE12M0G55-R0 |
| 4 | Ea Conner and center of PCB | BUMPON HEMISPHERE .63X.31 BLACK | 3M | SJ-5027 (BLACK) |

**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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