



Energy Monitoring PICtail™ Plus Daughter Board User's Guide

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ENERGY MONITORING PICtail™ PLUS DAUGHTER BOARD USER'S GUIDE

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ENERGY MONITORING PICTail™ PLUS DAUGHTER BOARD 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 “DSXXXXA”, where “XXXX” 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	<i>MPLAB[®] IDE User's Guide</i>
	Emphasized text	...is the <i>only</i> 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><i>File>Save</i></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	<i>file.o</i> , where <i>file</i> can be any valid filename
Square brackets []	Optional arguments	mcc18 [options] <i>file</i> [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 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.

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

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://support.microchip.com>

DOCUMENT REVISION HISTORY

Revision A (June 2011)

- Initial Release of this Document.

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.

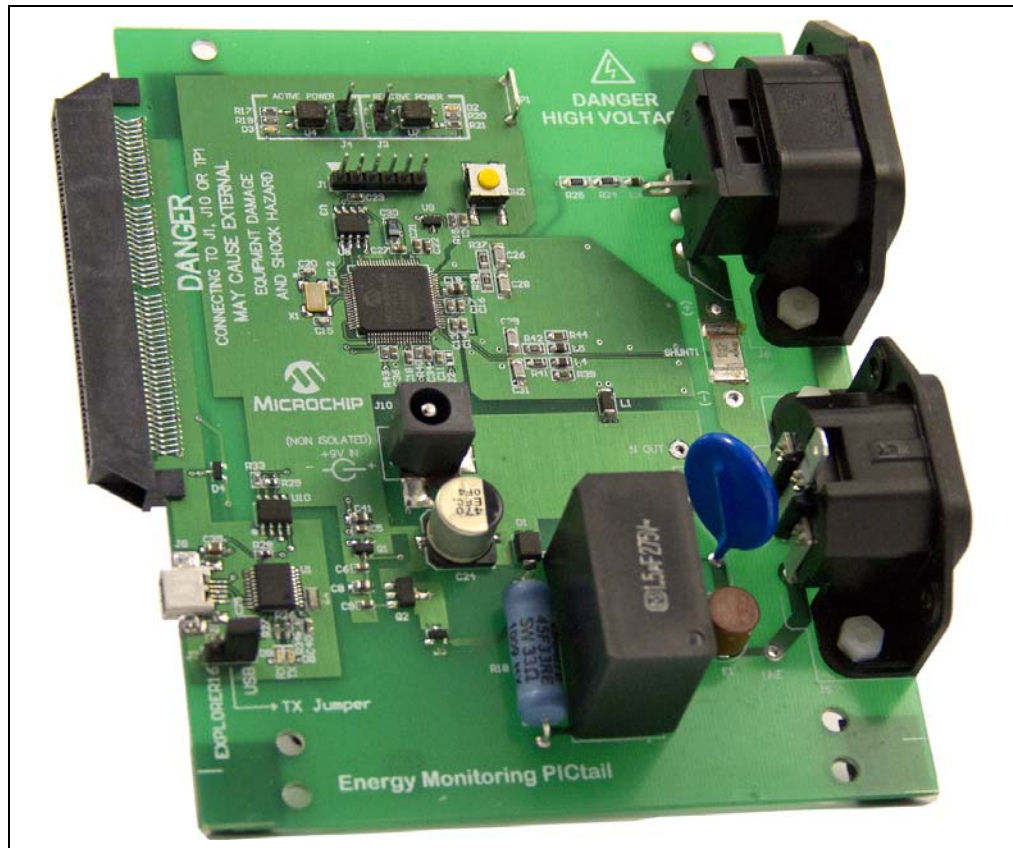


FIGURE 1-1: Energy Monitoring PICTail™ Plus Daughter Board.

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.

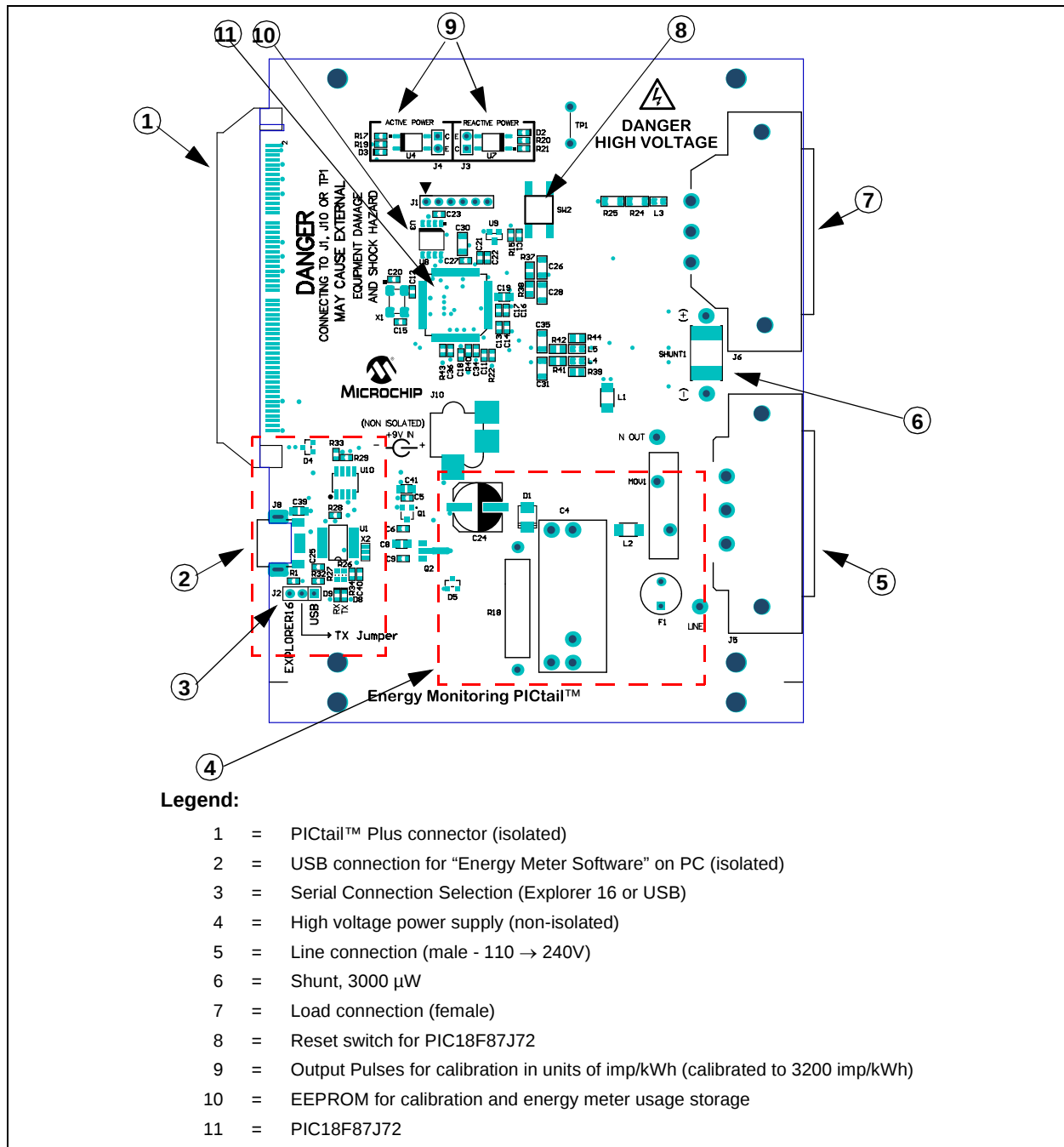
1.3.2 Step 2: Connect the board to a PC running the energy meter software

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:



Energy Monitoring PICtail™ Plus Daughter Board User's Guide

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

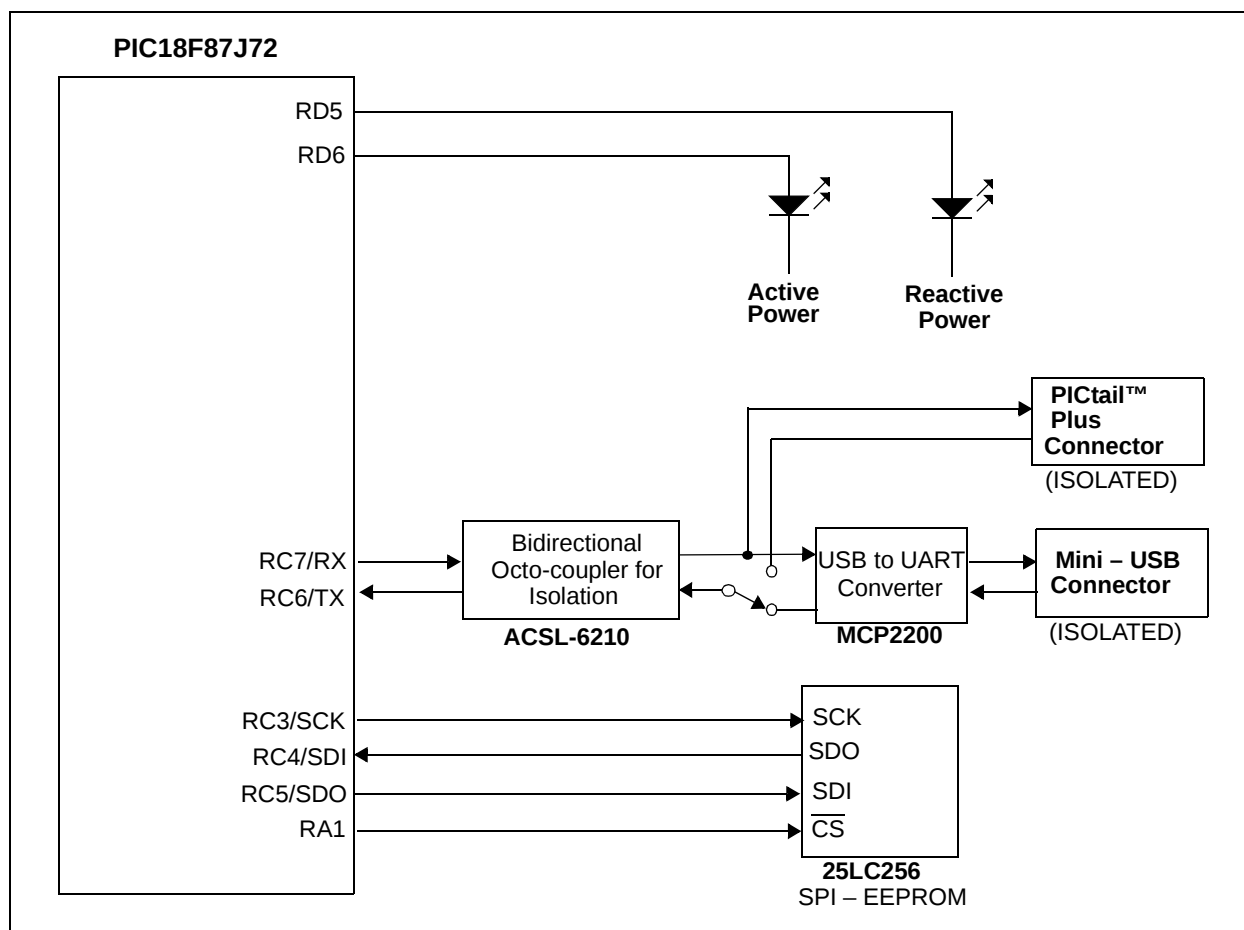


FIGURE 2-2: Simplified Schematic for Digital Connections.

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 k Ω 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}.

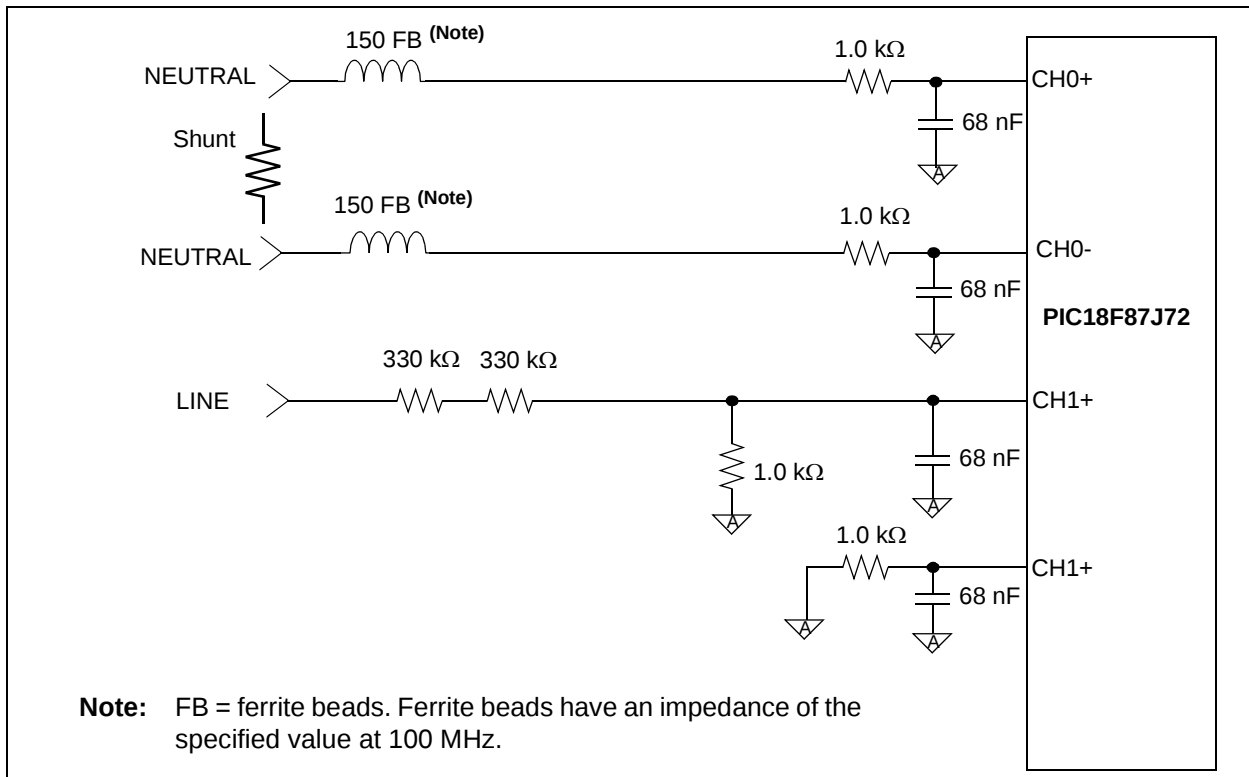


FIGURE 2-3: Analog Input Circuitry.

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.

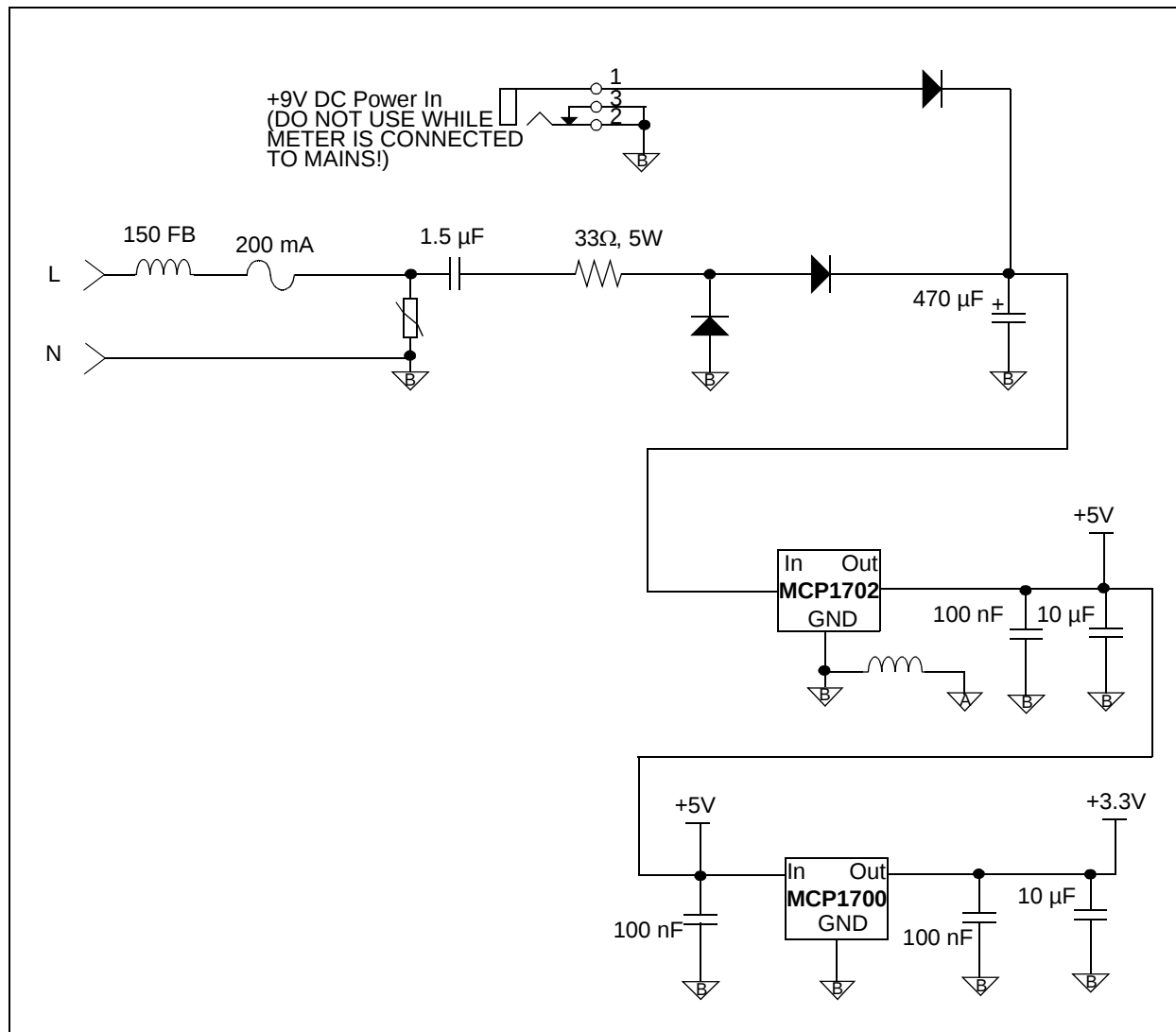


FIGURE 2-4: Simplified Power Supply Circuit.

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.

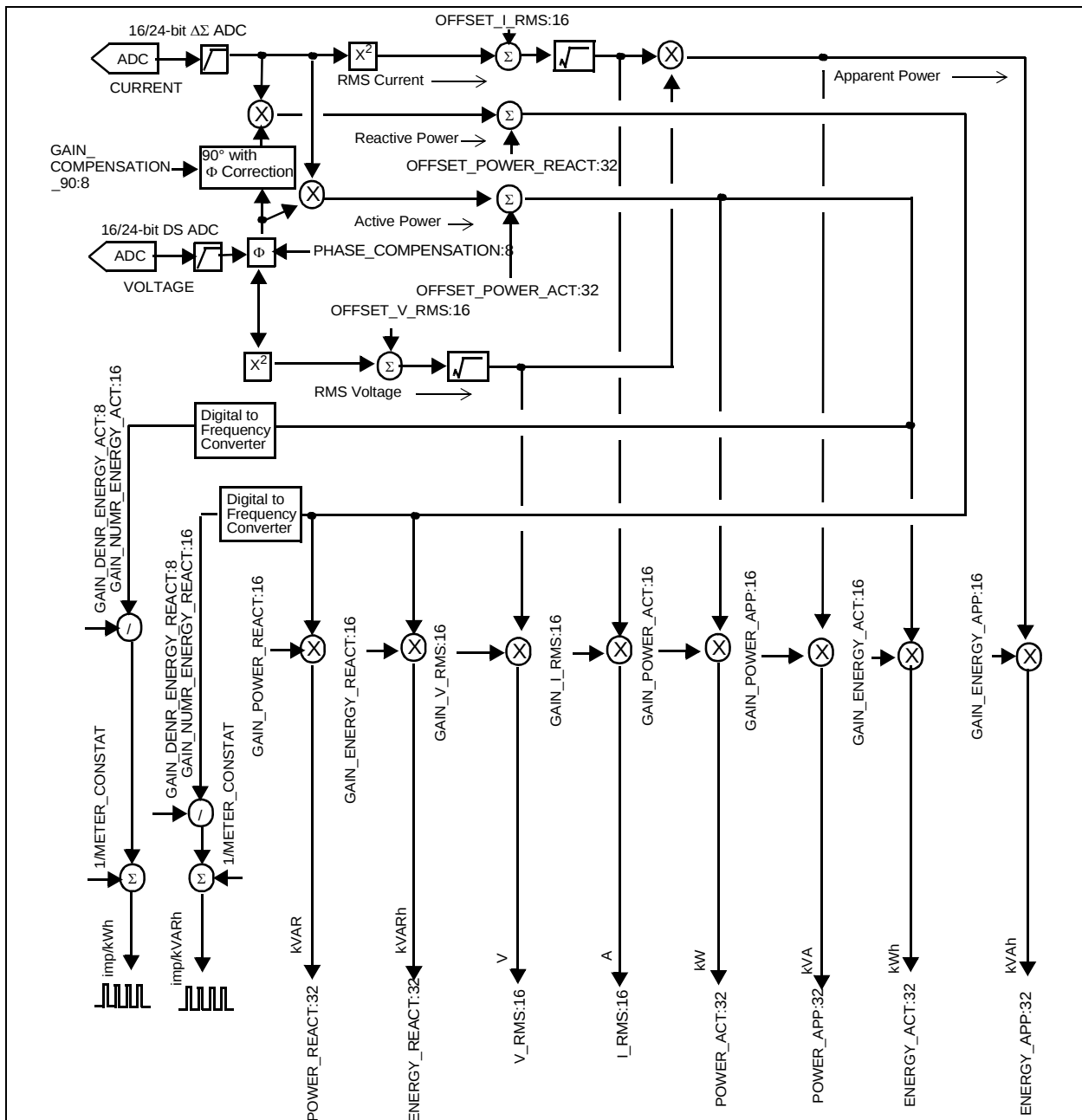


FIGURE 3-1: PIC18F87J72 Calculation Engine Signal Flow

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.

Calculation Engine and Register Description

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_THRESHOLD_MINUTE	8	R/W	No Load threshold time (minutes).
CREEP_THRESHOLD_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'

Calculation Engine and Register Description

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 line 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 $2^{(\text{LINE_CYC} - 1)}$. 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).

Calculation Engine and Register Description

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 $X \text{ W/LSB}$. 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 $X \text{ VA/LSB}$. 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.

Calculation Engine and Register Description

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 μ s 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 $1/(\text{METER_CONSTANT})$.

$$\text{ENERGY_W} = \text{ENERGY_W} + (1/\text{METER_CONSTANT})$$

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 $1/(\text{METER_CONSTANT})$.

$\text{ENERGY_REACT} = \text{ENERGY_REACT} + (1/\text{METER_CONSTANT})$

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.

Calculation Engine and Register Description

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, $32,767 = 0.9999695$).

Calculation Engine and Register Description

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_COM PENSATION	OFFSET_I_ RMS	OFFSET_V_ RMS	—	—	GAIN_I_RMS	GAIN_V_RMS	OFFSET_PO WER_ACT
bit 15							bit 8

U-0	R/W-0	U-0	U-0	U-0	R/W-0	U-0	U-0
—	GAIN_POW ER_ACT	—	—	—	GAIN_POWE R_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}).

Calculation Engine and Register Description

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 $1/(\text{METER_CONSTANT})$.

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 $1/(\text{METER_CONSTANT})$.

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 $1/(\text{METER_CONSTANT})$.

Calculation Engine and Register Description

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 $1/(\text{METER_CONSTANT})$.

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.

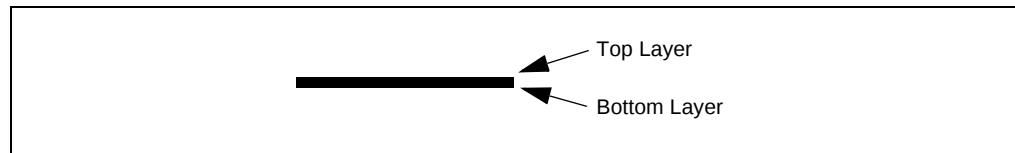
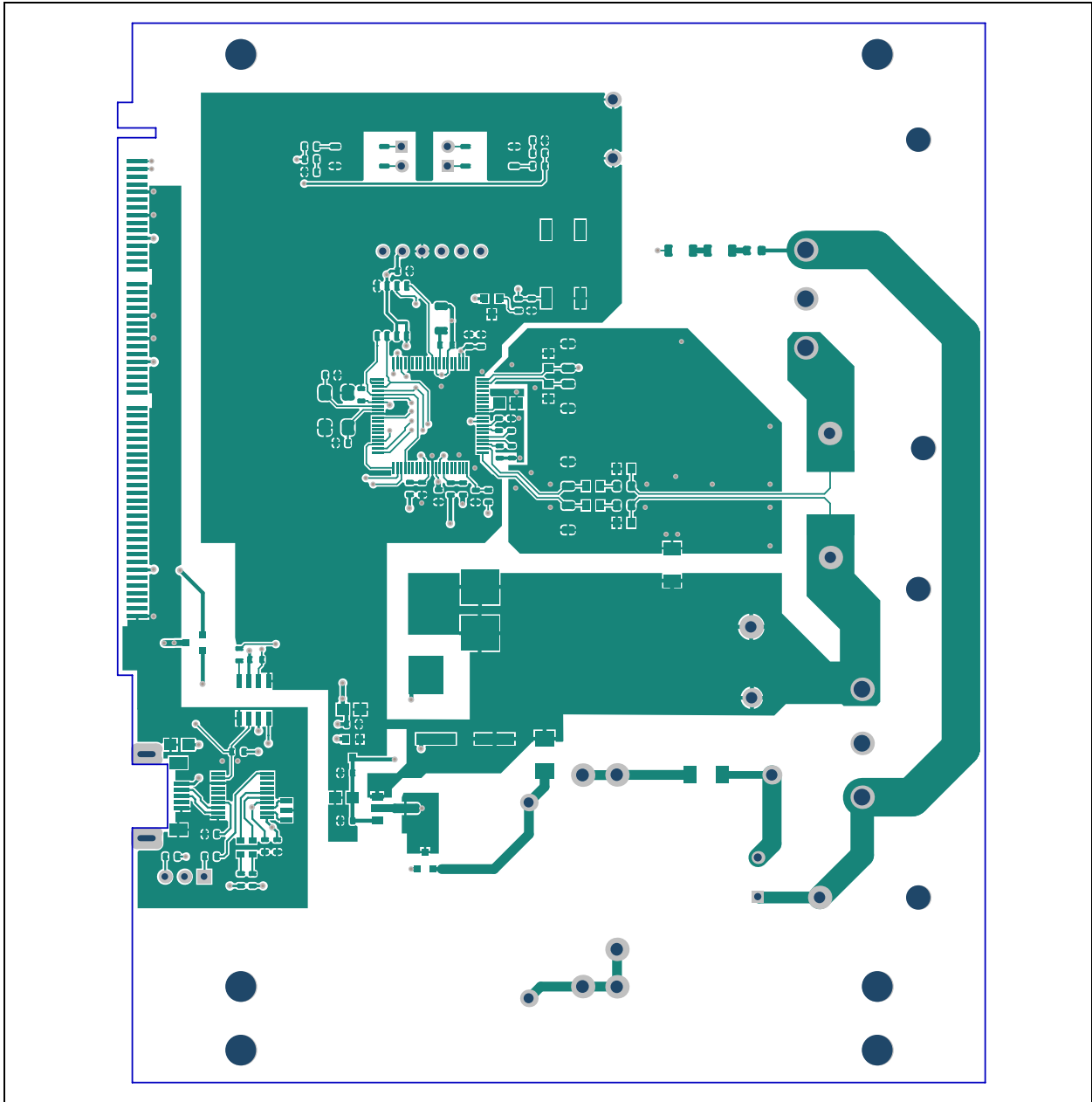
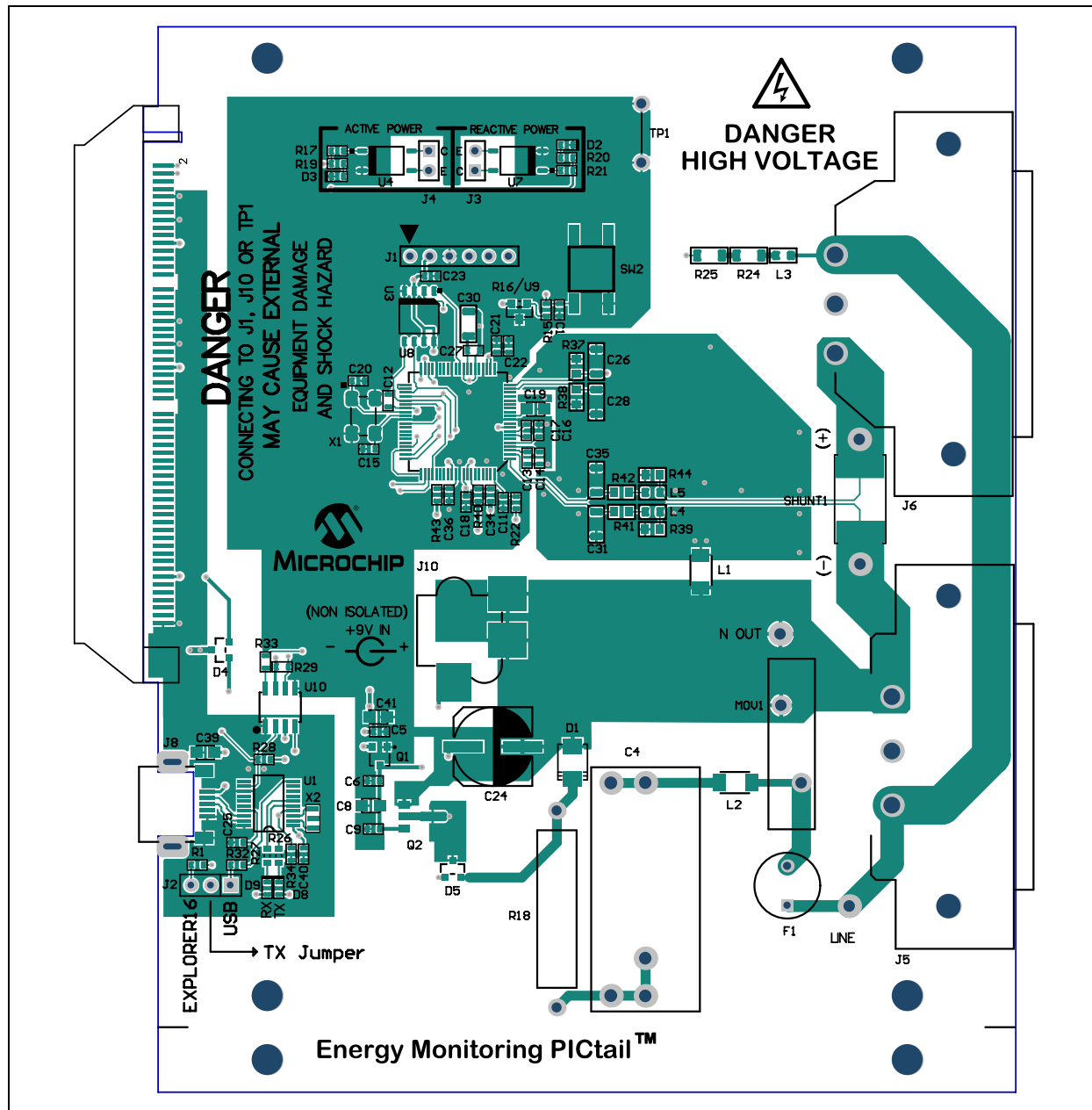


FIGURE A-1: Layer Order.

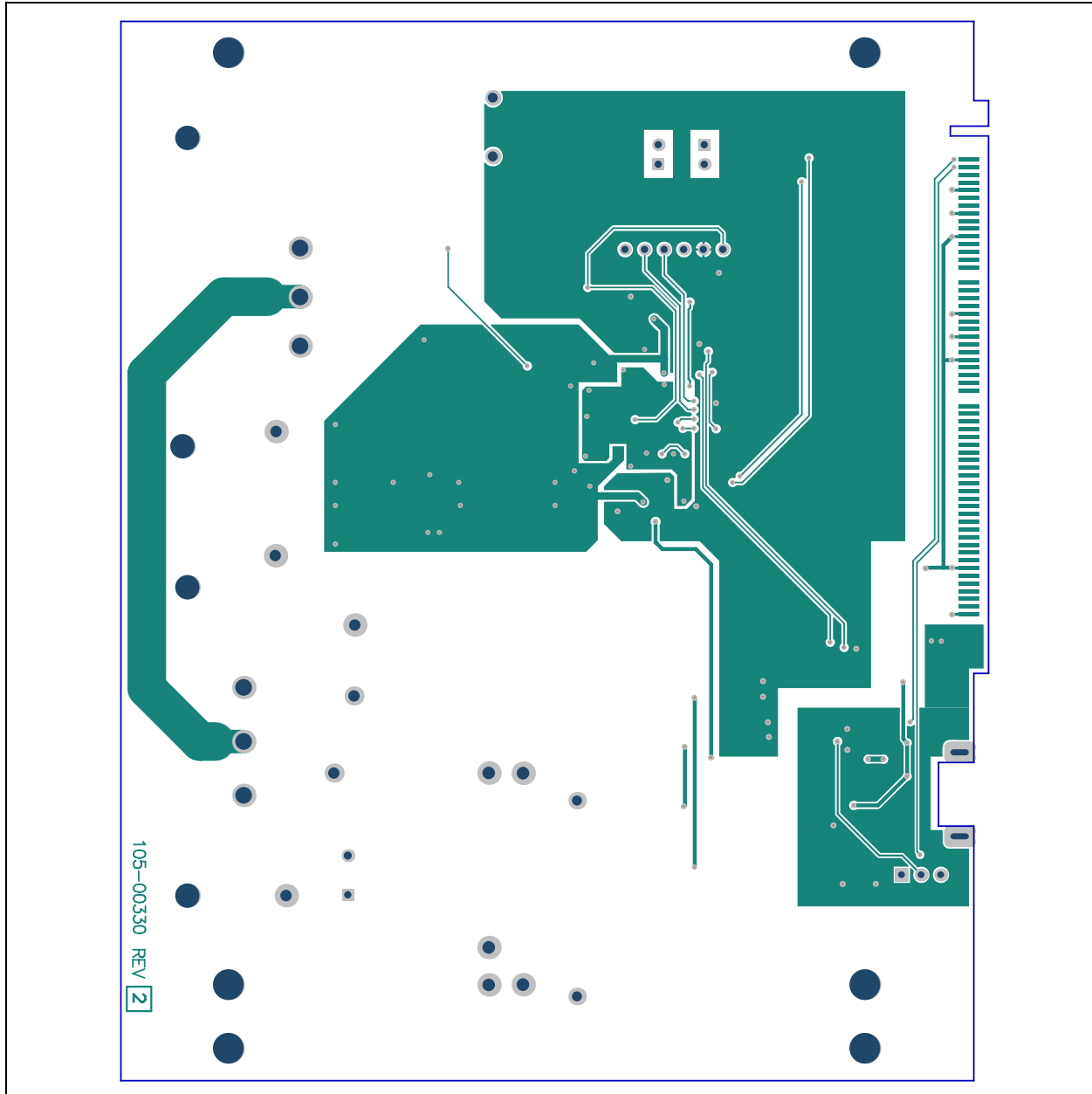
A.6 BOARD – TOP TRACES AND PADS



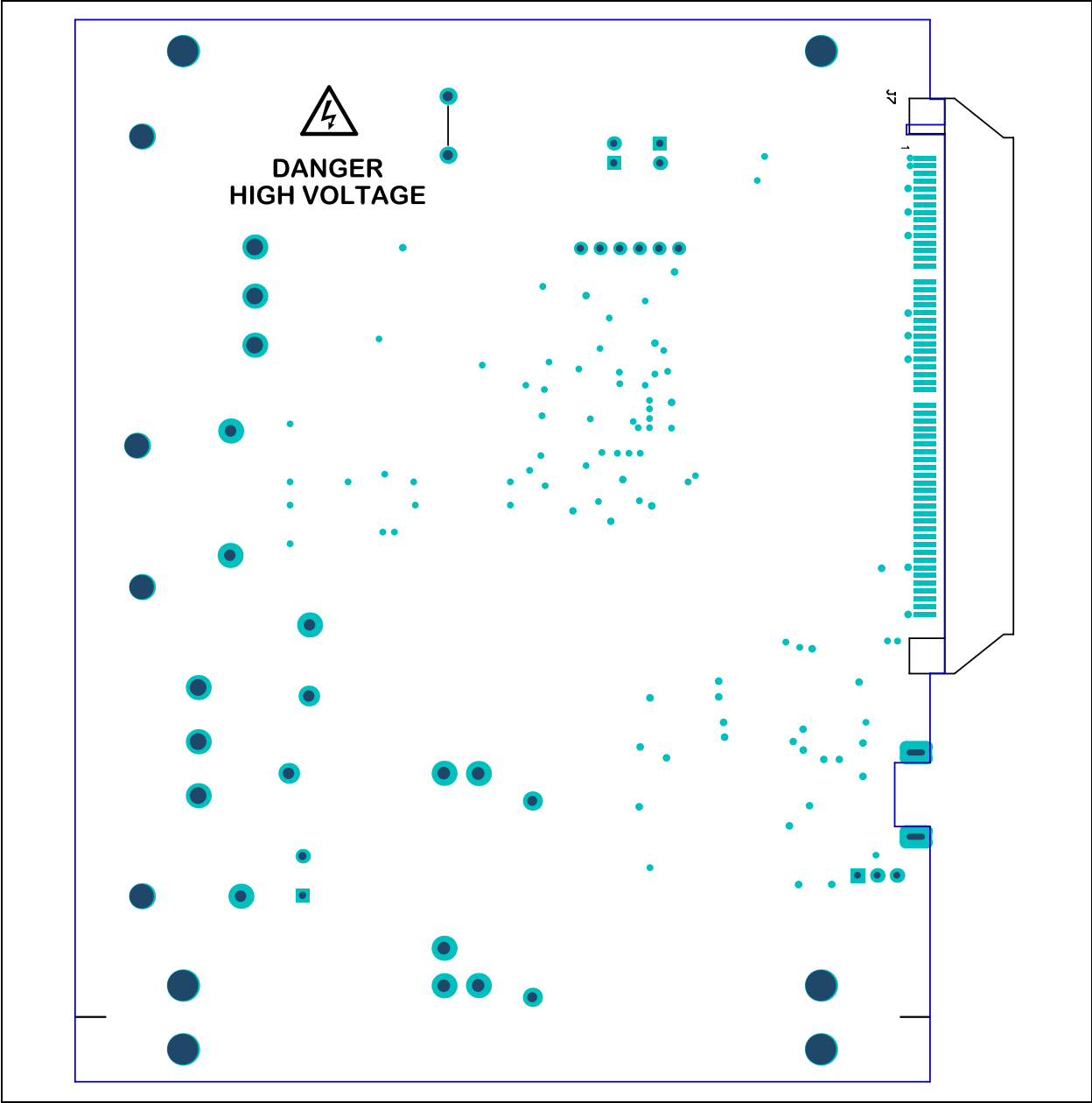
A.7 BOARD – TOP TRACES AND SILK



A.8 BOARD – BOTTOM TRACES AND PADS



A.9 BOARD – BOTTOM SILK





ENERGY MONITORING PICTail™ PLUS DAUGHTER BOARD USER'S GUIDE

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.

Energy Monitoring PICtail™ Plus Daughter Board User's Guide

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.

Bill of Materials (BOM)

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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