



MICROCHIP

PIC18F87J72
Single-Phase Energy Meter
Reference Design

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PIC18F87J72 SINGLE-PHASE 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 “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 PIC18F87J72 Single-Phase 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

PIC18F87J72 Single-Phase Energy Meter Reference Design

DOCUMENT LAYOUT

This document describes how to use the PIC18F87J72 Single-Phase 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 on using the PIC18F87J72 Single-Phase Energy Meter Reference Design including a getting started section that describes wiring the line and load connections.
- **Chapter 2. “Hardware”** – Includes detail on the function blocks of the meter including the analog front end design, 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 PIC18F87J72 Single-Phase 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	<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) { ... }

PIC18F87J72 Single-Phase Energy Meter Reference Design

RECOMMENDED READING

This user's guide describes how to use the PIC18F87J72 Single-Phase Energy Meter Reference Design. 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.

“Single-Phase Energy Meter Calibration User's Guide” (DS51964)

THE MICROCHIP WEB SITE

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

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

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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 (March 2011)

- Initial Release of this Document.

Chapter 1. Product Overview

1.1 INTRODUCTION

The PIC18F87J72 Single-Phase Energy Meter Reference Design is a fully functional single-phase meter based on the highly integrated PIC18F87J72 single-chip energy meter IC. This low-cost design does not use any transformers and requires few external components. The PIC18F87J72 directly drives the LCD, and includes both an isolated USB connection and a non-isolated RS-232 interface for meter calibration and access to the device power calculations. The system calculates active energy, active power, reactive energy, reactive power, RMS current, RMS voltage and other typical power quantities.

The Microchip Energy Meter 1-Phase Software is used to calibrate and monitor the system, and can be used to create custom calibration setups. For some accuracy requirements, only a single-point calibration may be needed. The energy meter software offers an automated step by step calibration process that can be used to quickly calibrate energy meters.



FIGURE 1-1: PIC18F87J72 Single-Phase Energy Meter.

PIC18F87J72 Single-Phase Energy Meter Reference Design

1.2 WHAT THE PIC18F87J72 SINGLE-PHASE ENERGY METER REFERENCE DESIGN KIT INCLUDES

The PIC18F87J72 Single-Phase Energy Meter Reference Design kit includes:

- PIC18F87J72 Single-Phase Energy Meter Reference Design (102-00280)
- Important Information Sheet

1.3 GETTING STARTED

To describe how to use the PIC18F87J72 Single-Phase Energy Meter Reference Design, the following example is given using a two-wire 1-phase, 220VAC line voltage and connections using an energy meter calibrator equipment, or other programmable load source. The meter design uses a 5A load for calibration current, and a maximum current (I_{MAX}) of 60A.

All connections described in this section are dependent upon 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

Figure 1-2 is identifying the line and load connections of the PIC18F87J72 Single-Phase Energy Meter Reference Design.

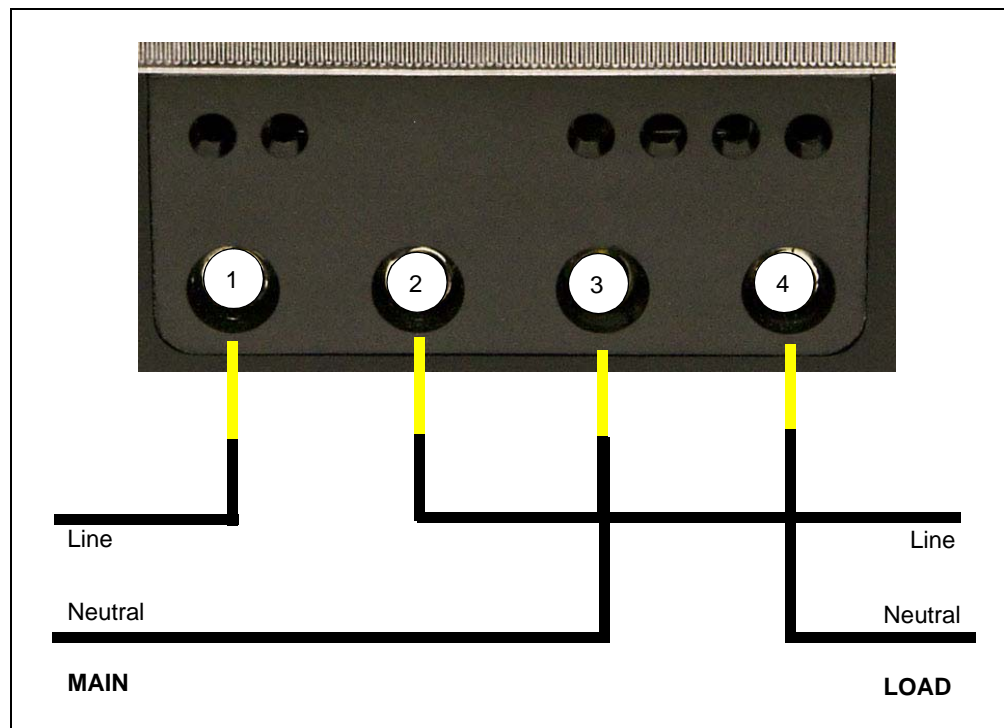


FIGURE 1-2: Example Connections using a Two-Wire System.

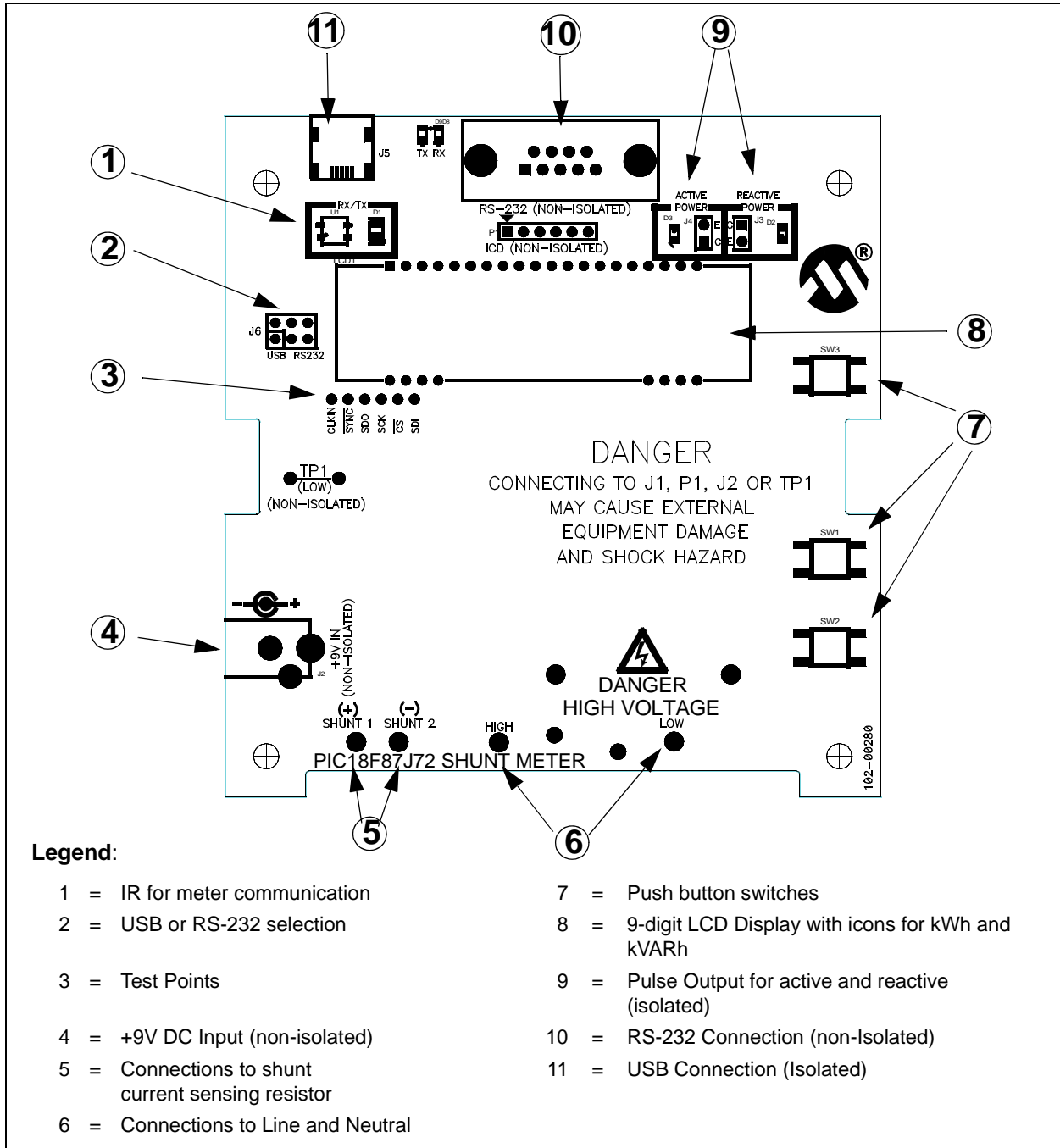
1.3.2 Step 2: Turn On Line/Load Power to the Meter (Power the Meter)

The meter will turn on when the line connection has 220V connected. The LCD display will show the total energy accumulated.

Chapter 2. Hardware

2.1 OVERVIEW

Figures 2-1 and 2-2 show the PIC18F87J72 Single-Phase Energy Meter Reference Design:



PIC18F87J72 Single-Phase Energy Meter Reference Design

FIGURE 2-1: Top View – Hardware Components.

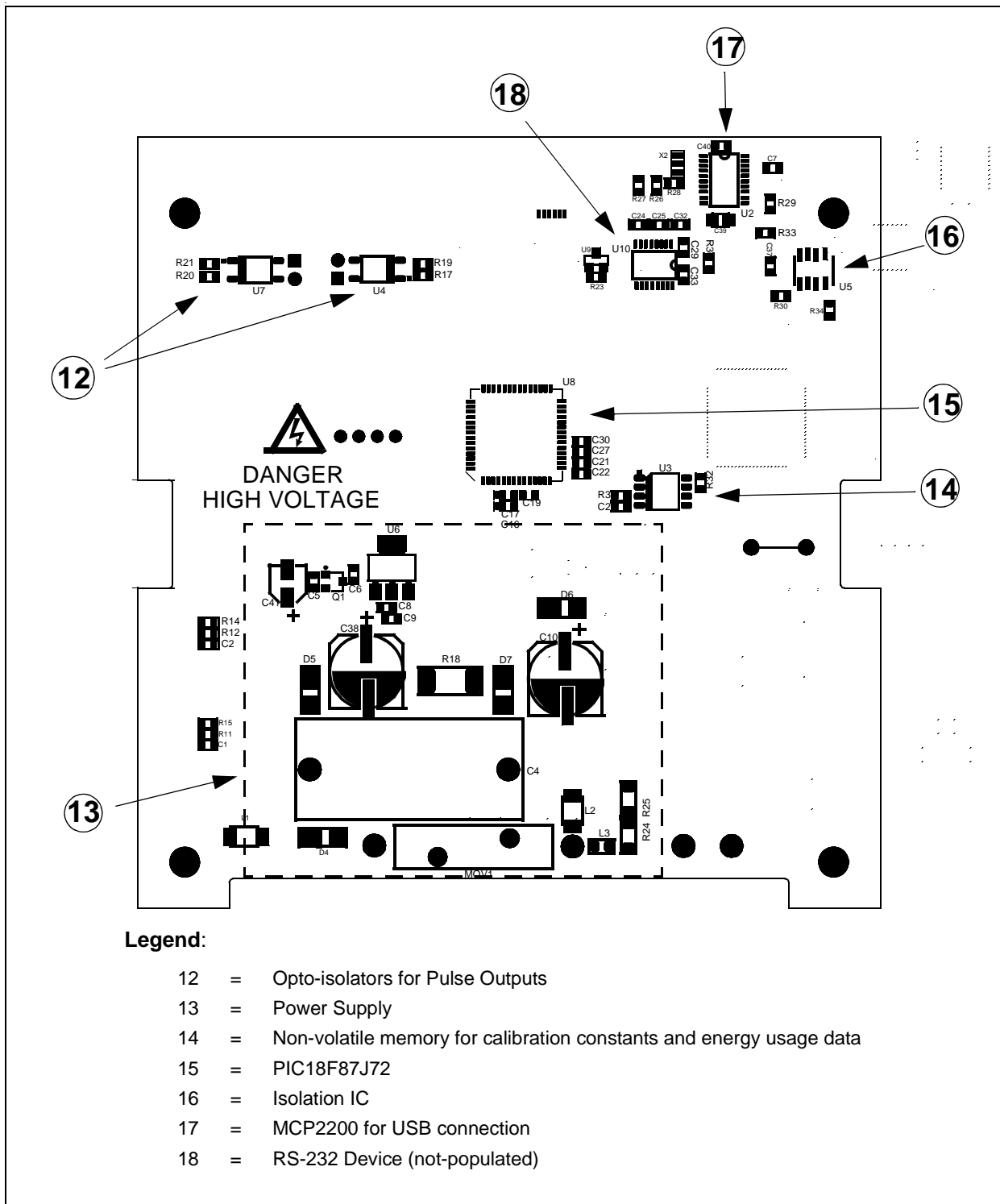


FIGURE 2-2: Bottom View – Hardware Components.

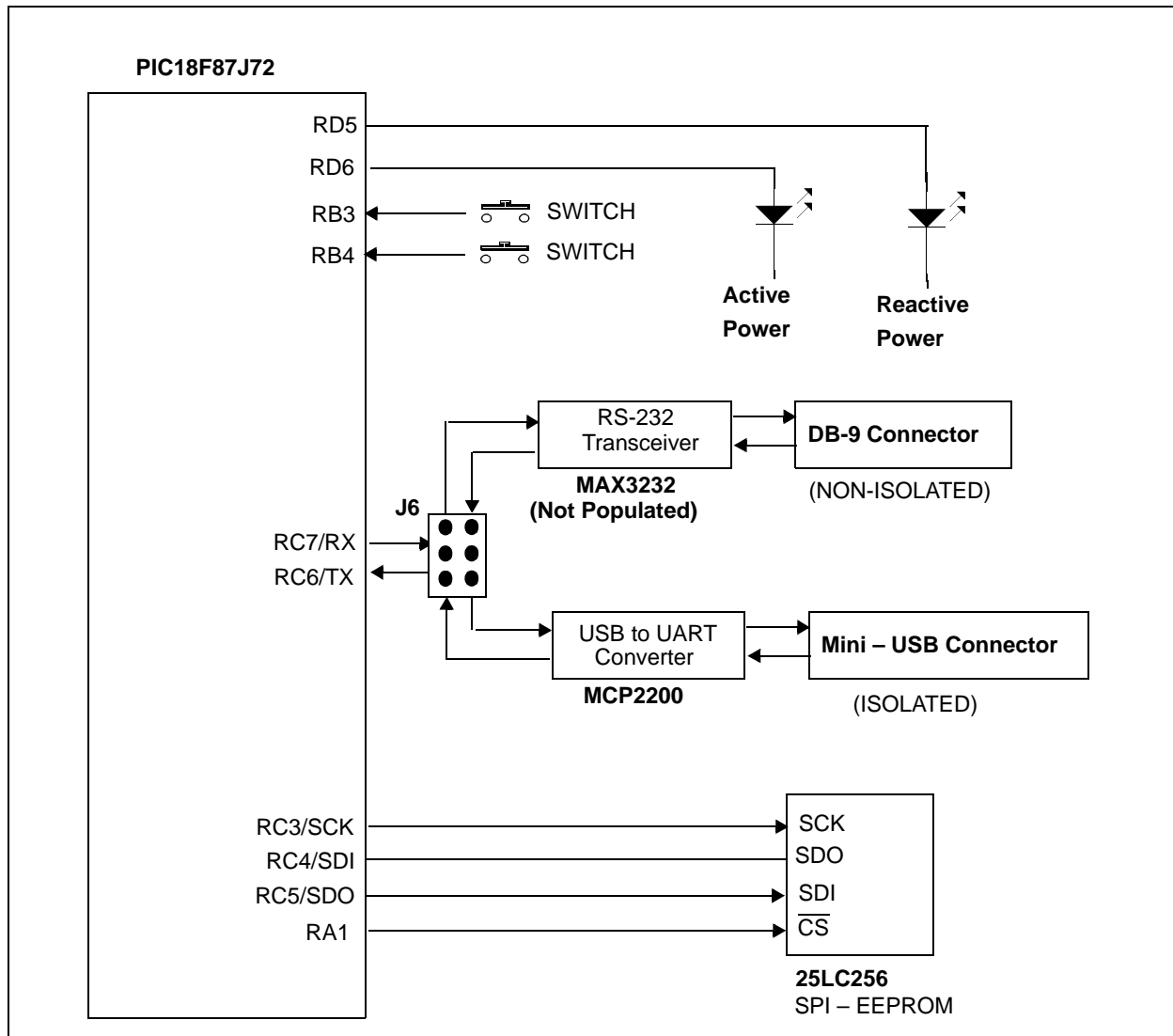


FIGURE 2-3: Digital Connections.

PIC18F87J72 Single-Phase Energy Meter Reference Design

2.2 INPUT AND ANALOG FRONT END

The PIC18F87J72 Single-Phase Energy Meter Reference Design comes populated with components designed for 220V line voltage. At the bottom of the main board are the high voltage line and neutral connections. There are four connections that are made from the PCB to the meter casing. They are labeled LINE, NEUTRAL, SHUNT1, and SHUNT2. The shunt sits on the high or line side of a two-wire system and the meter employs a hot or “live” ground. The wires going into the shunt to SHUNT1 and SHUNT2 should be twisted together. The wires going into the LINE and NEUTRAL side of the meter should be twisted together, and also kept away from the SHUNT1 and SHUNT2 wires if possible.

The neutral 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 332 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}. The current channel of each phase uses current transformer with a turns ratio of 2000:1 and burden resistance of 56.4 kΩ. The resulting channel 0 signal size is 340 mV_{PEAK} for 20A, or twice the rated maximum current of the meter, still within the input range of the A/D converter of the PIC18F87J72.

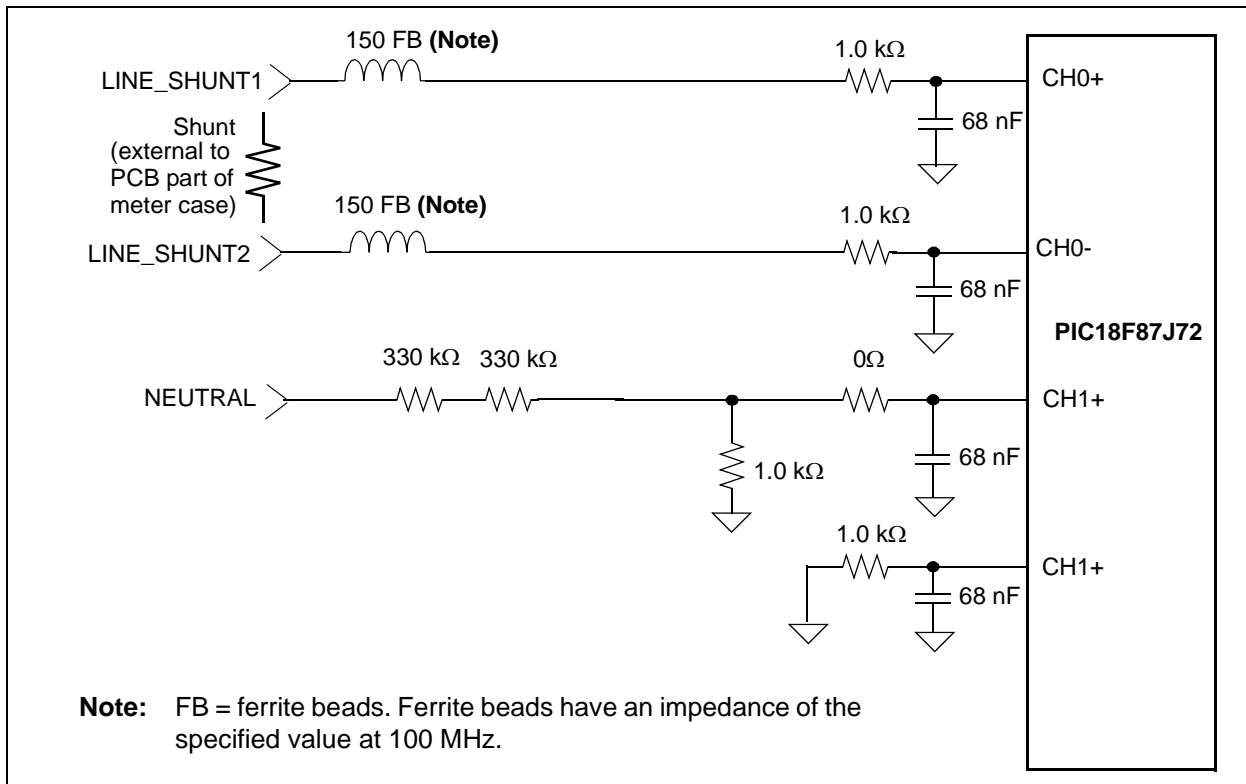


FIGURE 2-4: Analog Input Circuitry.

2.3 POWER SUPPLY CIRCUIT

The power supply circuit for the PIC18F87J72 Single-Phase Energy Meter Reference Design uses a half-wave rectified signal, a single +5V voltage regulator and a 3.3V LDO.

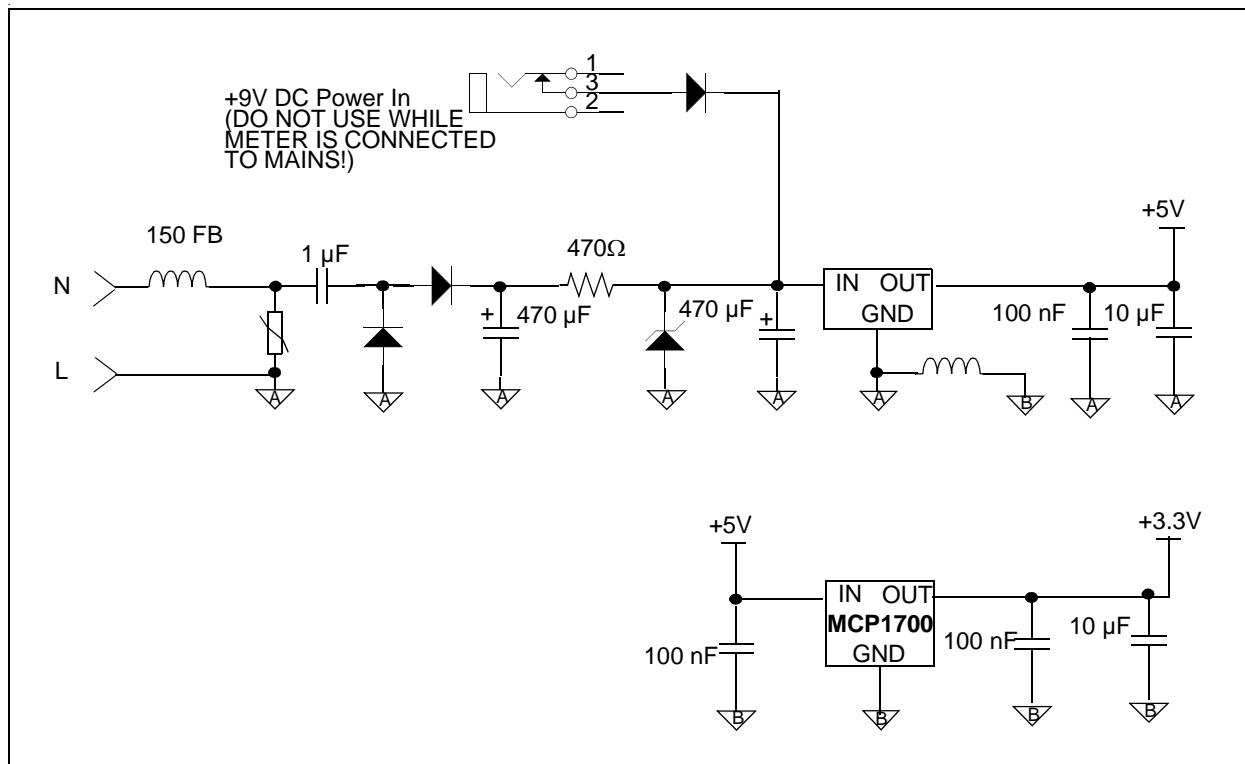


FIGURE 2-5: Low-Cost Power Supply Circuit.

PIC18F87J72 Single-Phase Energy Meter Reference Design

NOTES:

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.

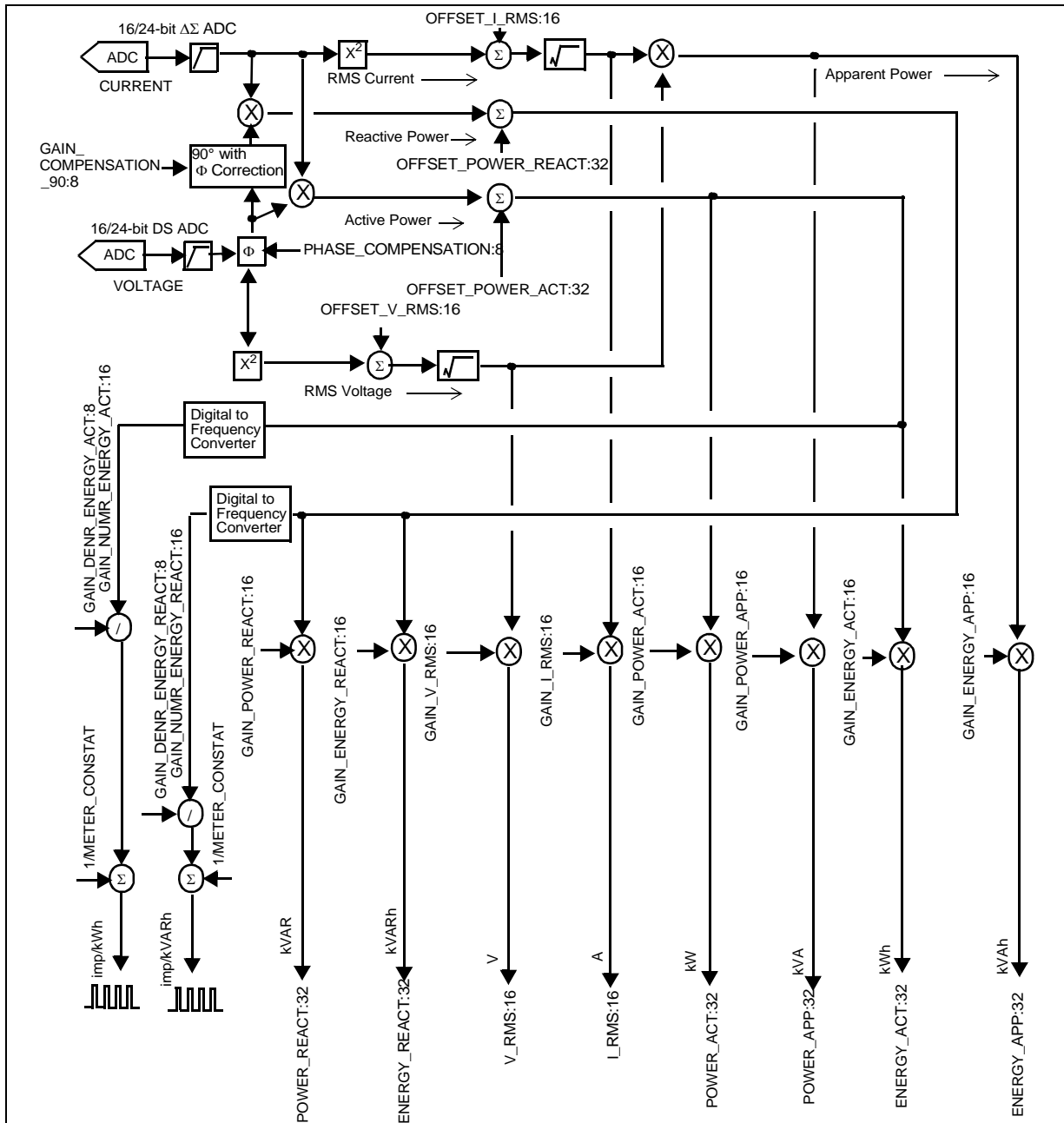


FIGURE 3-1: PIC18F87J72 Calculation Engine Signal Flow

PIC18F87J72 Single-Phase Energy Meter Reference Design

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
—	—	—	—	CREEP	PHASE	ABSOLUTE	CF
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 **CREEP:** No-Load Threshold bit

- 1 = Enabled
- 0 = Disabled

bit 2 **PHASE:** Phase bit

- 1 = Single-Point Phase Correction
- 0 = Multi-Point Phase Correction (future)

bit 1 **ABSOLUTE:** Positive Only Energy Accumulation Mode bit

- 1 = Positive energy only
- 0 = Both negative and positive energy accumulated (negative energy is subtracted)

bit 0 **CF:** Active Energy CF Phase Enable bit

- 1 = Phase is enabled to be accumulated into the total energy registers or CF pulse output
- 0 = Phase is DISABLED and is not accumulated into the total energy registers or CF pulse output

PIC18F87J72 Single-Phase Energy Meter Reference Design

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	R	U-0	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 7-3 **Unimplemented:** Read as '0'

bit 2 **PH_S:** Phase Sign bit

1 = CT may be in backward (if enabled)

0 = Operation normal

bit 1-0 **Unimplemented:** Read as '0'

Calculation Engine and Register Description

3.5 CAL_CONTROL

This is the CAL_CONTROL 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

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

0 = When CAL_MODE bit and CAL_UPDATE bit have been set, CAL_UPDATE bit will be cleared after the LINE_CYC line cycles. At that point, all registers will be updated and no further updates will be done until CAL_UPDATE bit is set again or 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: This register is used in "Multi-Point and Single-Point Calibration" modes only.

PIC18F87J72 Single-Phase Energy Meter Reference Design

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 (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 (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.

PIC18F87J72 Single-Phase Energy Meter Reference Design

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.

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.

PIC18F87J72 Single-Phase Energy Meter Reference Design

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 \pm 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 ADCs 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 ADCs 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, $32,767 = 0.9999695$).

PIC18F87J72 Single-Phase Energy Meter Reference Design

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 $* 8 * (1/\text{LINE_FREQUENCY})/128$ 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.

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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_COMP ENSATION	OFFSET_I_RMS	OFFSET_V_R MS	—	—	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}).

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, \pm sampling time/2 μ s.

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

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NOTES:

Appendix A. Schematic and Layouts

A.1 INTRODUCTION

This appendix contains the following schematics and layouts for hardware revision two of the PIC18F87J72 Energy Meter Reference Design:

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

A.2 SCHEMATICS AND PCB LAYOUT

The layer order is shown in Figure A-1.

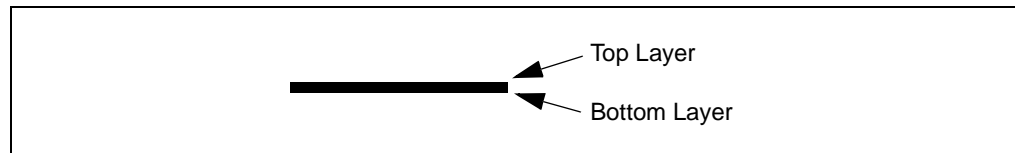
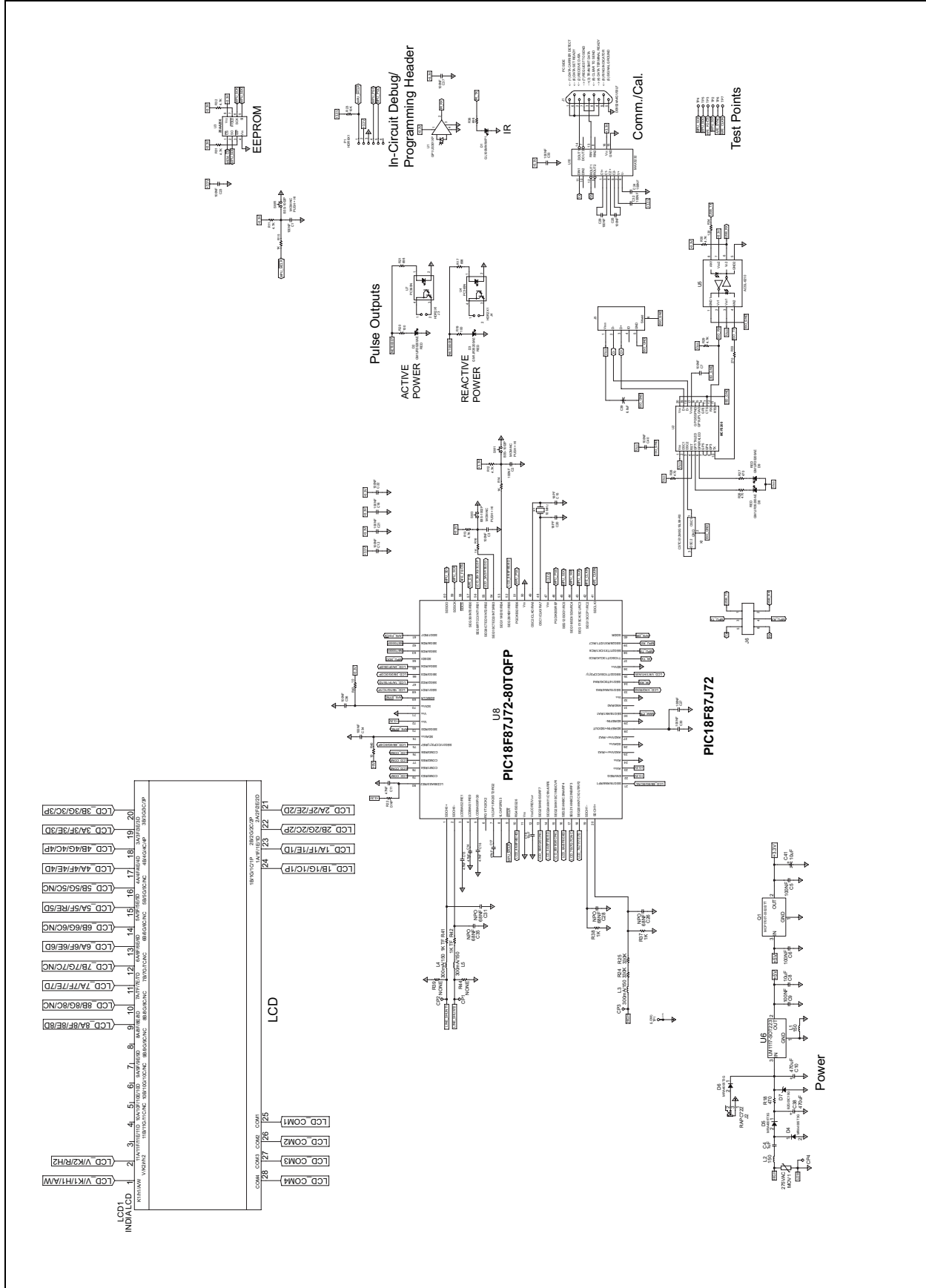


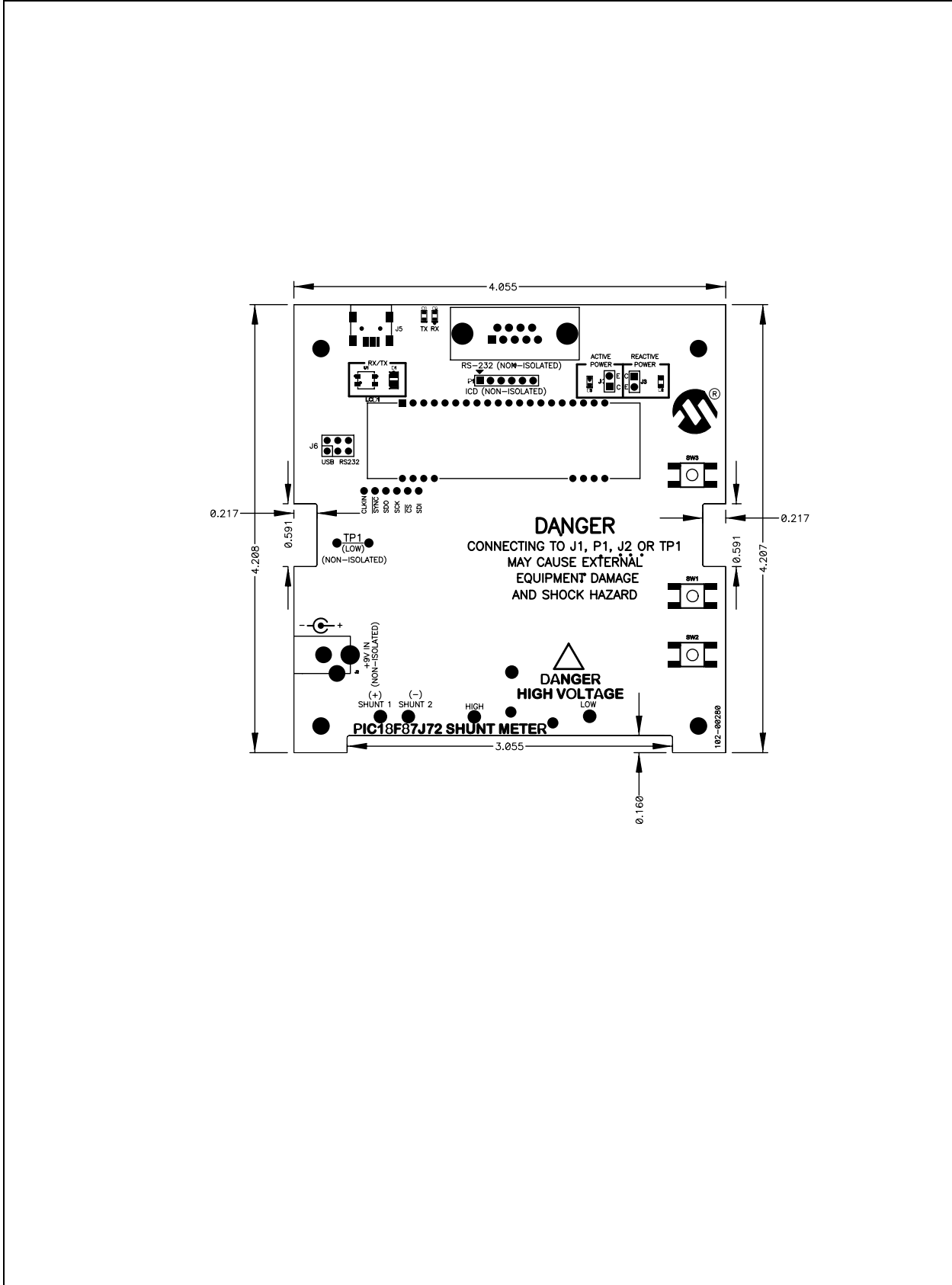
FIGURE A-1: *Layer Order.*

PIC18F87J72 Single-Phase Energy Meter Reference Design

A.3 BOARD – SCHEMATIC

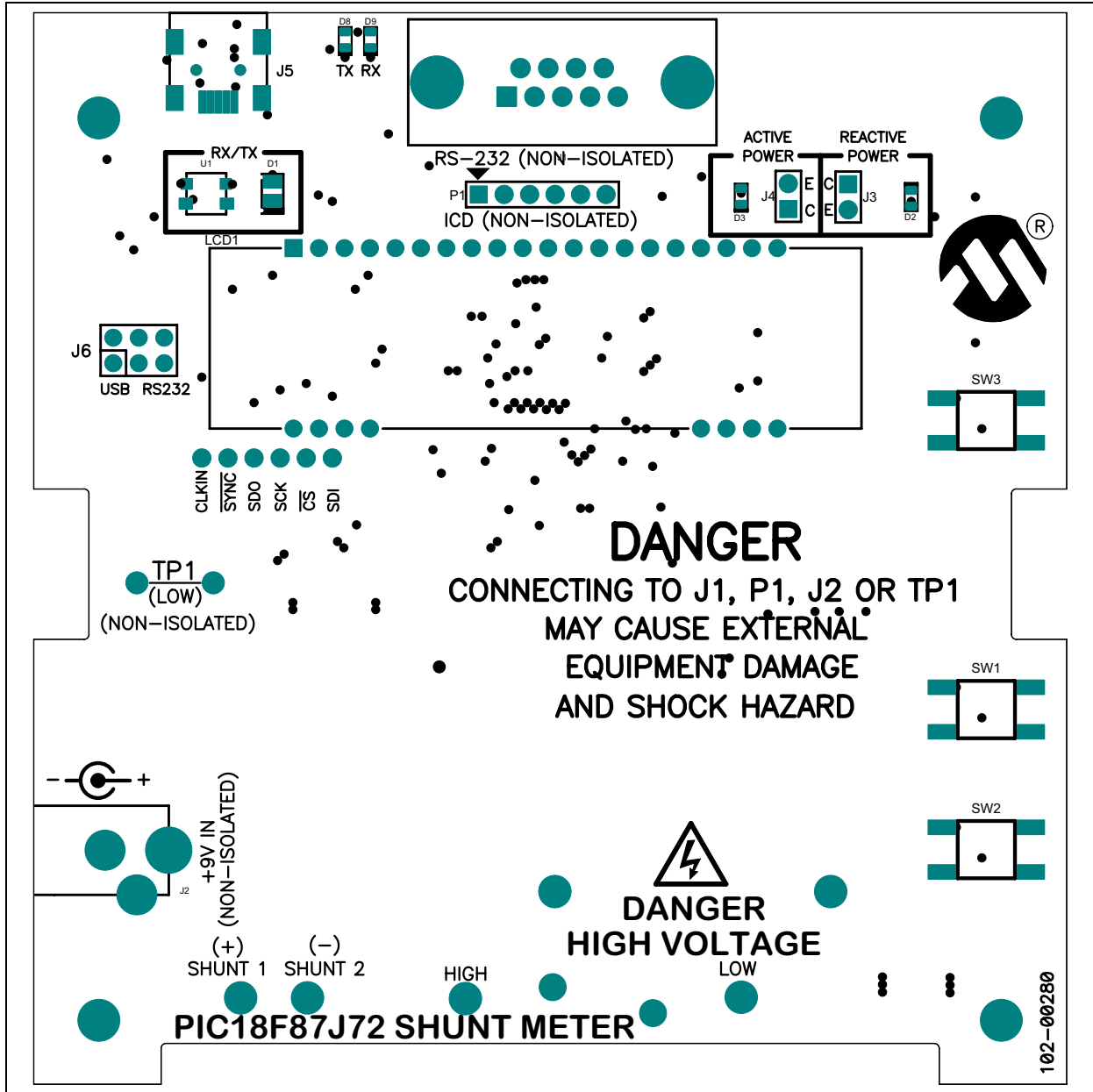


A.4 BOARD – SCHEMATIC TOP SILK AND BOARDER OUTLINE

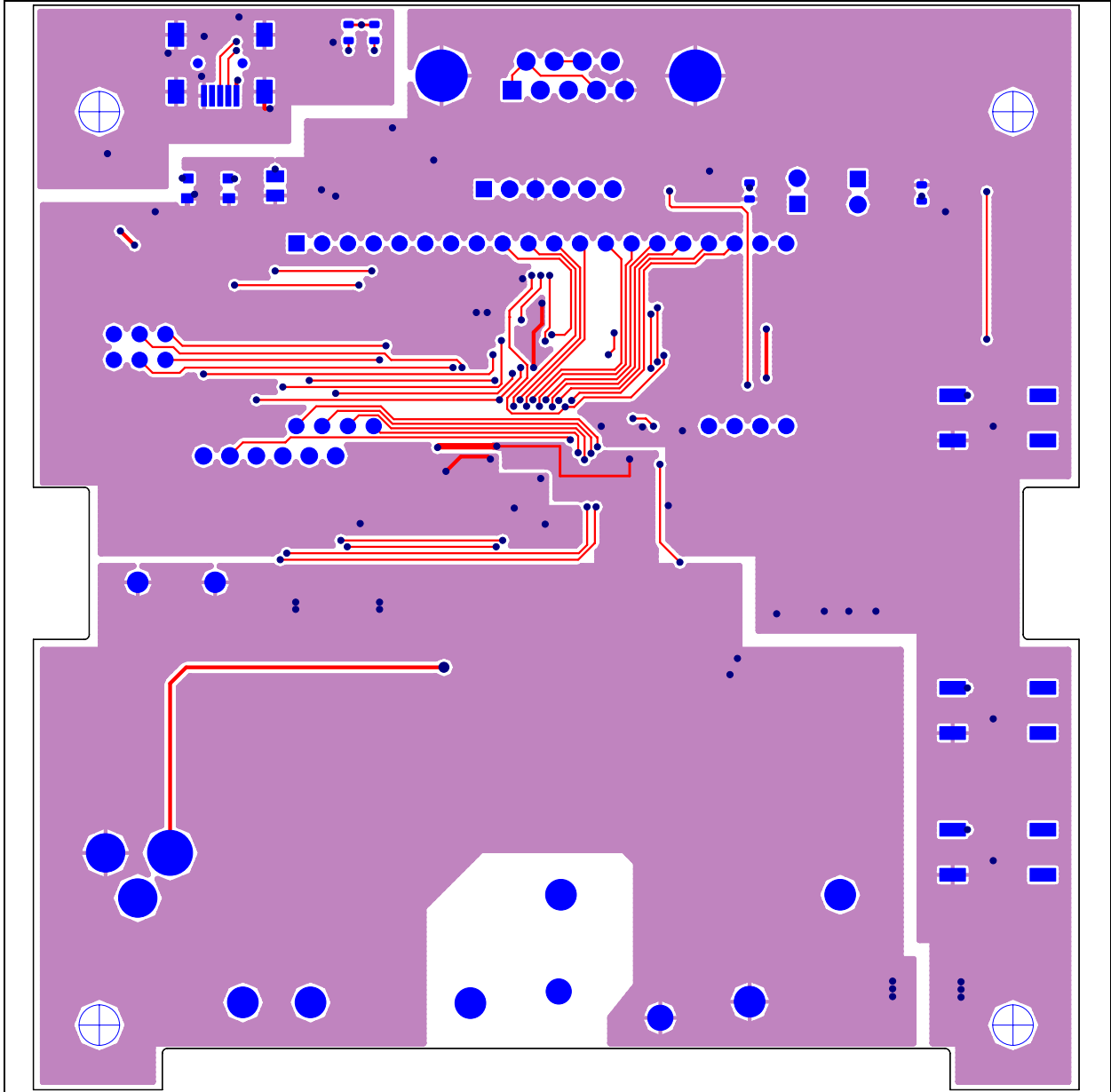


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A.5 BOARD – TOP SILK

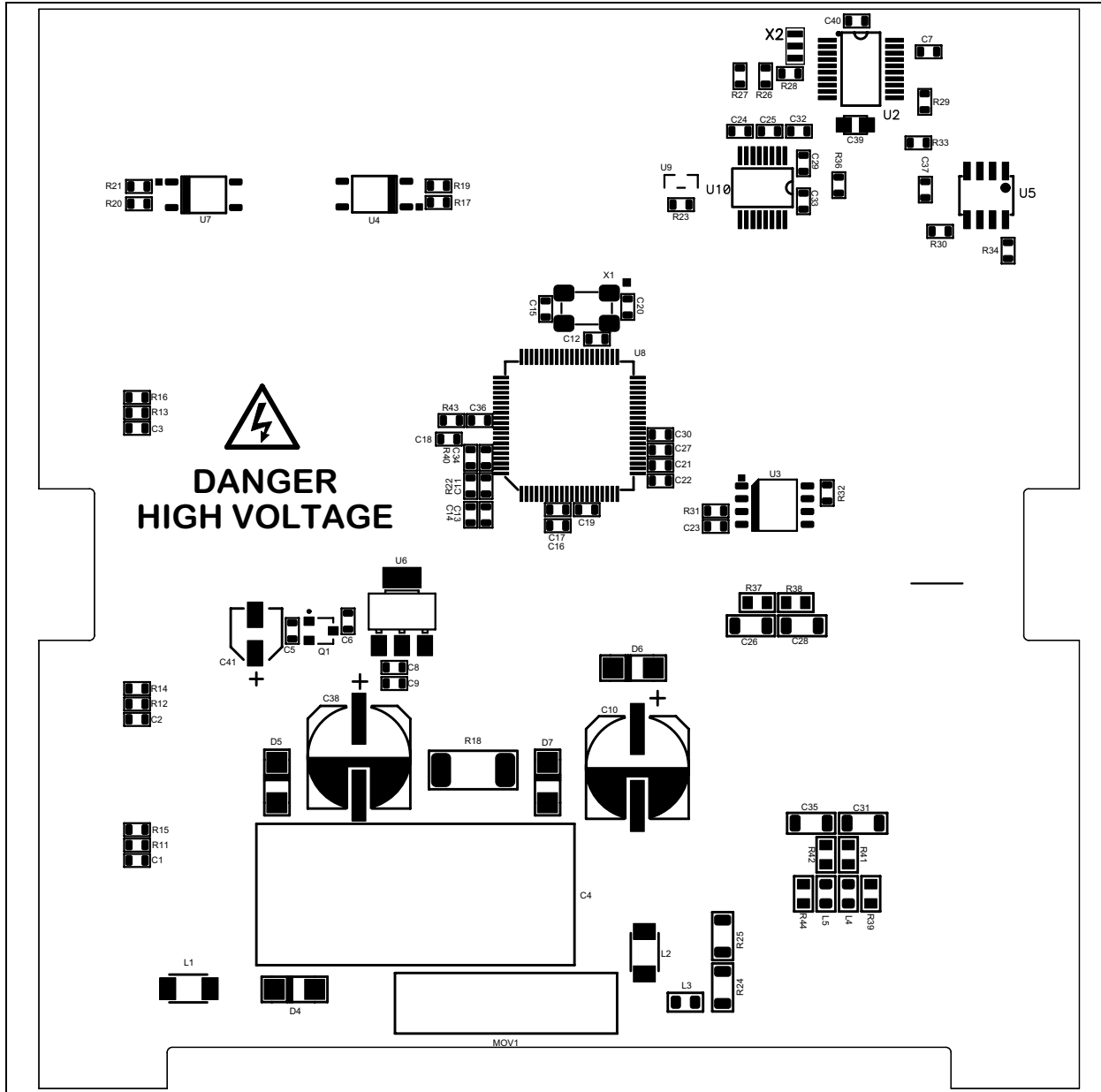


A.6 BOARD – TOP TRACE AND PADS

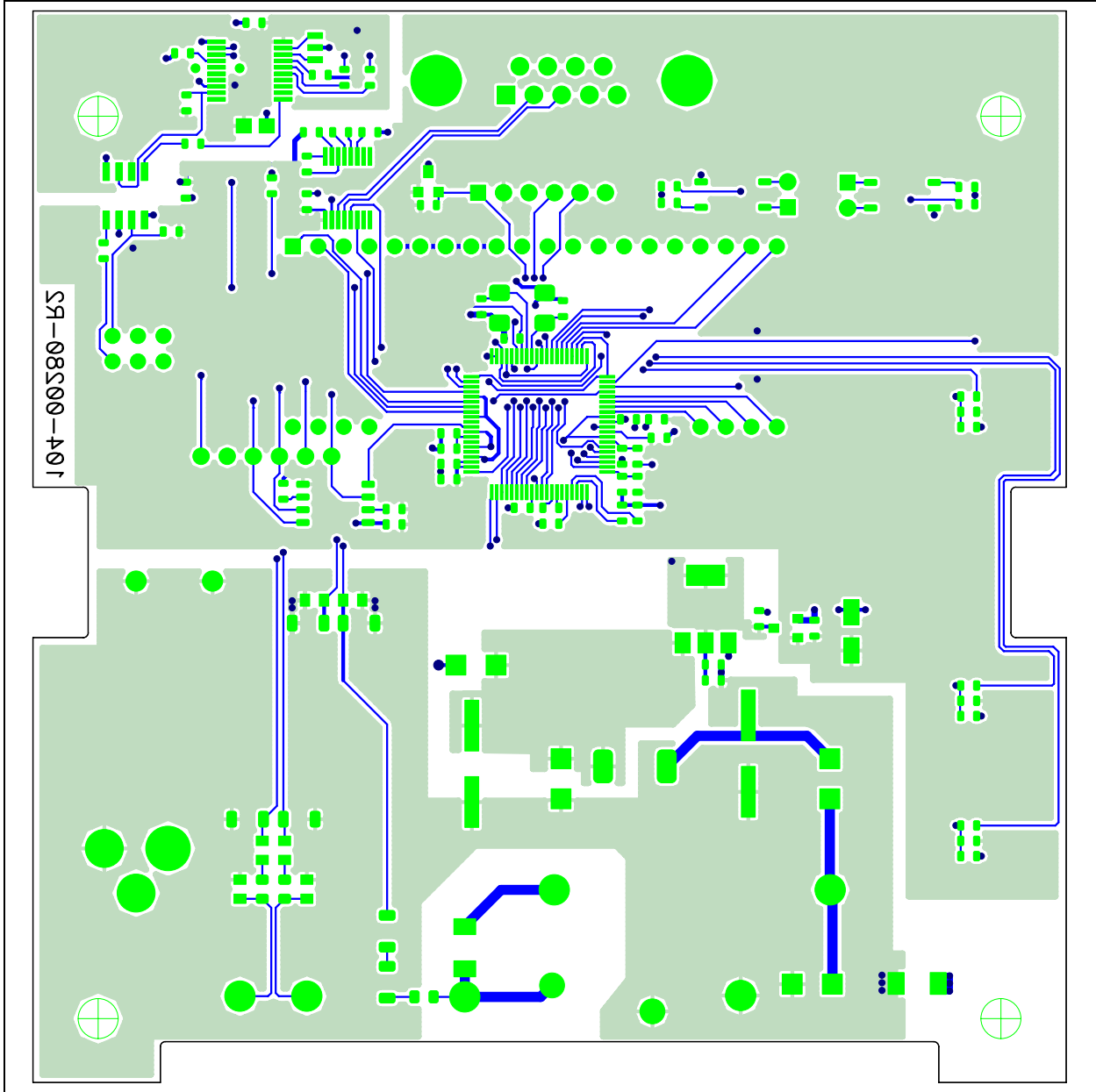


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A.7 BOARD – BOTTOM SILK



A.8 BOARD – BOTTOM TRACE AND PADS



PIC18F87J72 Single-Phase Energy Meter Reference Design

NOTES:



PIC18F87J72 SINGLE-PHASE ENERGY METER REFERENCE DESIGN

Appendix B. Bill of Materials (BOM)

TABLE B-1: BILL OF MATERIALS (BOM)

Qty	Reference	Description	Manufacturer	Part Number
23	C1, C2, C3, C5, C6, C7, C9, C12, C18, C21, C22, C23, C24, C25, C27, C29, C30, C32, C33, C34, C36, C40	CAP .10UF 16V CERAMIC Y5V 0603	Kemet	C0603C104Z4VACTU
1	C4	CAP 1.0UF 630V METAL POLYPRO	EPCOS Inc	B32614A6105J008
2	C8, C19	CAP CER 10UF 6.3V X5R 0603	Murata Manufacturing Co., Ltd.	GRM188R60J106ME47D
2	C10, C38	CAP 470UF 25V ELECT FC SMD	Panasonic® – ECG	EEV-FC1E471P
5	C11, C13, C14, C16, C17	CAP CER 47000PF 25V 10% X7R 0603	Murata Manufacturing Co., Ltd.	GRM188R71E473KA01D
2	C15, C20	CAP CER 18PF 50V 5% C0G 0603	Murata Manufacturing Co., Ltd.	GRM1885C1H180JA01D
4	C26, C28, C31, C35	CAP CER 6800PF 50V 5% C0G 1206	Murata Manufacturing Co., Ltd.	GRM3195C1H682JA01D
1	C39	CAP CERAMIC 6.8UF 6.3V X5R 0805	Kemet	C0805C685K9PACTU
1	C41	CAP 10UF 16V ELECT FC SMD	Panasonic – ECG	EEE-FC1C100R
10	CP1, CP2, CP3, CP4, TP2, TP3, TP4, TP5, TP6, TP7	DO NOT INSTALL	—	—
1	D1	DO NOT INSTALL	—	—
4	D2, D3, D8, D9	LED 1.6X0.8MM 625NM RED CLR SMD	Kingbright Electronics Co., Ltd.	APT1608EC
3	D4, D5, D6	DIODE SCHOTTKY 40V 1A SMB	ON Semiconductor®	MRA4005T3G
1	D7	DIODE ZENER 15V 1.5W SMA	ON Semiconductor	BZG03C15G
1	J1	CONN DSUB RCPT 9POS STR PCB SLD	FCI	D09S24A4GV00LF
1	J2	CONN POWERJACK MINI R/A T/H	CUI Inc.	PJ-102B
2	J3, J4	"DO NOT INSTALL	—	—
1	J5	CONN MINI USB RCPT RA TYPE B SMD	Tyco Electronics	1734035-2

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.

PIC18F87J72 Single-Phase Energy Meter Reference Design

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

Qty	Reference	Description	Manufacturer	Part Number
2	(two Shunts) at J6	SHUNT LP W/HANDLE 2 POS 30AU	Tyco Electronics	881545-2
1	J6	CONN HDR DUAL 6POS .100 SRT AU	Molex [®] Connector Corporation	10-89-7062
2	L1,L2	EMI/RFI Suppressors and Ferrites 150ohms 100 MHz .3A Monolithic 1806 SMD	Laird Technologies [®]	LI1806C151R-10
3	L3, L4, L5	EMI/RFI Suppressors and Ferrites 150ohms 100 MHz .8A Monolithic 0805 SMD	Laird Technologies	LI0805H151R-10
1	LCD 1	LCD Glass size 65.00 x 18.00	Xiamen Ocular Optics Co., Ltd.	DP076P
1	MOV 1	VARISTOR 275V RMS 20MM RADIAL	EPCOS Inc.	S20K275E2
1	P1	6 X 1 Header 2.54mm on center 6 mm/2.5mm	Samtec	TSW-106-07-G-S
1	PCB	RoHS Compliant Bare PCB, PIC18F87J72 Energy Meter Reference Design	—	104-00280
1	Q1	IIC LDO REG 200MA 3.3V SOT-23-3	Microchip Technology Inc.	MCP1700T-3302E/TT
5	R11, R12, R13, R31, R32	RES 4.70K OHM 1/10W 1% 0603 SMD	ROHM Co., Ltd.	MCR03EZPFX4701
3	R14, R15, R16	RES 1.00K OHM 1/10W 1% 0603 SMD	ROHM Co., Ltd.	MCR03EZPFX1001
3	R17, R21, R36	RES 698 OHM 1/10W 1% 0603 SMD	ROHM Co., Ltd.	MCR03EZPFX6980
1	R18	RES 470 OHM 1W 5% 2512 SMD	Panasonic – ECG	ERJ-1TYJ471U
2	R19, R20	RES 100 OHM 1/10W 1% 0603 SMD	ROHM Co., Ltd.	MCR03EZPFX1000
1	R22	DO NOT INSTALL	—	—
1	R23	RES 10.0K OHM 1/10W 1% 0603 SMD	ROHM Co., Ltd.	MCR03EZPFX1002
2	R24, R25	RES 330K OHM 1/4W 5% 1206 SMD	Stackpole Electronics Inc.	RMCF 1/8 330K 5% R
3	R26, R27, R28	RES SMT, 470-OHM 1/10W 5% 0603	Panasonic – ECG	ERJ-3GEYJ471V
2	R29, R30	RES 2.70K OHM 1/10W 1% 0603 SMD	ROHM Co., Ltd.	MCR03EZPFX2701
1	R33	RES SMT, 270-OHM 1/10W 5% 0603	Panasonic – ECG	ERJ-3GEYJ271V
1	R34	RES SMT, 120-OHM 1/10W 5% 0603	Panasonic – ECG	ERJ-3GEYJ121V
2	R37, R38	RES 1.00K OHM 1/8W 1% 0805 SMD	ROHM Co., Ltd.	MCR10EZHF1001
2	R39, R44	DO NOT INSTALL	—	—
2	R40, R43	RES 10.0 OHM 1/10W 1% 0603 SMD	ROHM Co., Ltd.	MCR03EZPFX10R0
2	R41, R42	RES 1.0K OHM .1% 1/4W 0805 SMD	Susumu Co., Ltd.	RGH2012-2E-P-102-B
3	SW1, SW2, SW3	SWITCH TACT 6MM 230GF H=4.3MM	OMRON	B3S-1002 BY OMZ

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	TP1	Wire Test Point 0.3" Length	Component Corporation	PJ-202-30
1	U1	DO NOT INSTALL	—	—
1	U2	MCP2200 USB to UART Serial Converter	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 Electronic Corporation	PC365NJ0000F
1	U5	OPTOCOUPLER DUAL BI 15MBD 8-SOIC	Avago Technologies	ACSL-6210-00RE
1	U6	IC REG LDO 800MA 5.0V SOT-223	National Semiconductor	LM1117MP-5.0/NOPB
1	U8	PIC18F Microcontroller with 32K bytes of Flash, 2048 bytes of RAM	Microchip Technology Inc.	PIC18F87J72-80/PT
1	U10	IC DRVR/RCVR MULTCH RS-232 16-SSOP	Texas Instruments	MAX3232CDBR
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

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.

PIC18F87J72 Single-Phase Energy Meter Reference Design

NOTES:

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NOTES:



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