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Single-Phase Energy Meter Solution for Advanced Applications

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Design Resources

TIDM-EMETER-CORTEXM3	Design Folder
F28M35H52C1	Product Folder
OPA4376	Product Folder
PGA112	Product Folder
AFE032	Product Folder
TLV1117-33	Product Folder
SN74LVC2G07	Product Folder

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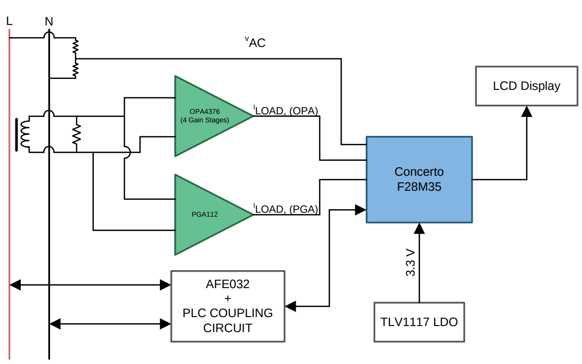
Design Features

- Single-Phase Energy Metering with ±0.5% Accuracy Using Concerto™ F28M35 MCU
- Independent Metrology Processing Core Frees Up Host Processor's (Cortex®-M3) Bandwidth for Communications, Diagnostics, Tamper Protection, and Display
- Integrated Independent C28x MCU Provides the CPU for Power-Line Communications, Which Support the Prime, G3, and IEEE-1901.2 Standards
- Dynamic Range of 6.67:1 per Gain Stage, or 2000:1 Using All Four Gain Stages
- Easy Calibration and Energy Metering: No Metrology Coding Required to Configure the Metrology Registers and Read the Results
- Optional PGA112 Provided to Increase Number of Gain Stages and Achieve Higher Dynamic Range and Accuracy

Featured Applications

- E-Meter with Integrated PLC for Monitoring
- E-Meters with Host Application, Metrology, and PLC on a Single Chip Requiring 32-Bit Processing Power
- Grid Infrastructure Meters



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1 System Description

This design, featuring the F28M35 Concerto dual-core microcontroller, implements a highly integrated solution for electricity metering featuring programmable metrology software and hardware. The metrology core is independent of the main core, freeing up the ARM® Cortex-M3's bandwidth to run communications, diagnostics, and any user-defined host application. Additional hardware is provided to support power-line communications using the C2000™ core of the Concerto and the AFE032 PLC front-end.

2 Design Features

The F28M35 Concerto microcontroller is a dual-core controller featuring an ARM Cortex-M3 and a C2000 core. Dedicated metrology processing hardware offloads the calculation-intensive processes from the main cores, freeing them up to run other host applications and reduce development time.

The designer can configure and calibrate the metrology hardware by simply configuring the metrology control registers from the M3 core and initializing the metrology hardware. Following this, the metrology hardware samples the onboard 12-bit ADCs, filters and processes the voltage and current signals, and measures the RMS voltage, current, active, and reactive power and power factor. The advanced signal-processing algorithms run by the metrology hardware ensure an accuracy of 0.5% for a dynamic range of 6.66:1 even with a 12-bit ADC. The dynamic range is increased to 2000:1 using four analog gain stages. The metrology hardware has a built-in automatic gain stage selection, and the designer can calibrate each gain stage individually to achieve maximum accuracy.

The main processing core in this controller is a powerful ARM Cortex-M3, clocked at 75 MHz. This core is responsible for all communications, diagnostics, and for initializing and controlling the metrology hardware. With a wide variety of communications peripherals and 32 KB of dedicated RAM, the ARM core is capable of running any user-defined host application. With the metrology hardware taking care of the main signal processing, almost the entire bandwidth of the ARM core is available for a user application.

The secondary core is a 150-MHz C28 floating point DSP core. This core can be used to run additional signal processing and control algorithms. Future releases of this design will also have software support to run power-line communications from the C28 core, making this solution a single-chip metrology and PLC solution.

3 Block Diagrams

Figure 1 shows typical connections for a single phase electricity meter. The voltage sensor circuit is normally realized using a resistor divider that uses high-precision and low-drift resistors. The current sensor is either a shunt resistor (for low-cost, nonisolated applications) or a current transformer (for non-intrusive, isolated measurement). The outputs of these transducers is then fed to a pre-amplification stage that uses differential amplifiers by using TI's OPA4376 precision, low noise quad-op amp. The current from the op amps is fed to four separate gain stages to widen the dynamic range of the current and improve accuracy. This design can also use a TI PGA112 programmable gain amplifier instead of the op amps to realize variable gain is also provided.

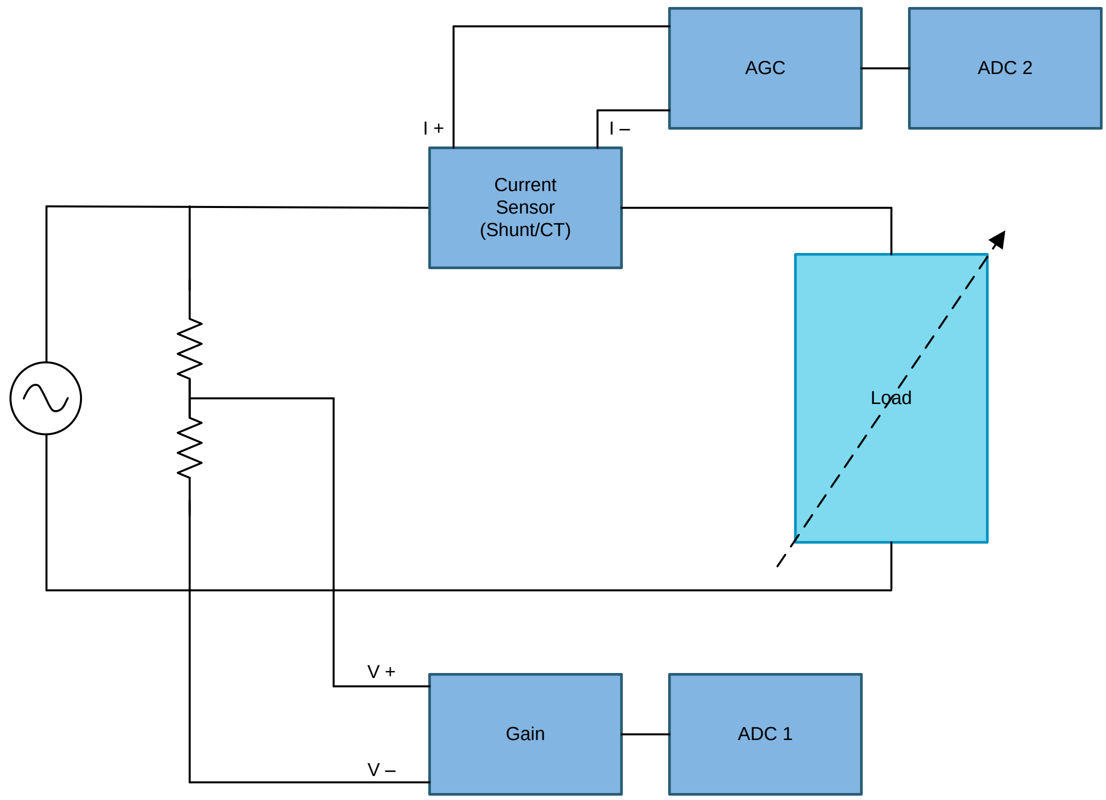

Figure 1. Typical Connections Inside an Electricity Meter

In the following sections, this reference will provide more information on the current and voltage sensors, ADCs, and so on.

Figure 2 shows a detailed block diagram of the high level interface used for a single-phase electricity meter. A current transformer (CT) connected to the live side measures the current drawn by the load. The CT has an associated burden resistor that has to be connected at all times to protect the measuring device. The choice of CT and burden resistor is done based on the manufacturer and the current range required for energy measurements. The CT can be easily replaced by a Rogowski coil with minimal changes to the front end. Voltage divider resistors for the voltage channel ensure the mains voltage divides down to adhere to normal input voltage range of the amplification circuit. The signal-conditioning circuits used for both current and voltage are discussed in detail in the following sections.

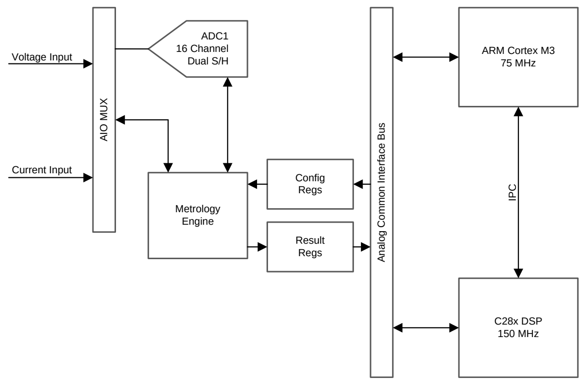

Figure 2. Block Diagram of Concerto-Based Electricity Meter

4 Circuit Design and Component Selection

This section describes various pieces that constitute the hardware for design of a working single-phase electricity meter that uses the F28M35 microcontroller.

4.1 Power Supply

The power supply for the main system derives from the mains using an isolated switching converter. This converter provides an output voltage of 15 V for the system. The microcontroller and amplification circuits run on a 3.3-V rail, which is derived from the 15-V rail using a TLV1117 adjustable low-dropout voltage (LDO) regulator set to give an output voltage of 3.3 V.

4.2 Analog Inputs

4.2.1 DC Bias Generation

Both the voltage and current sense blocks use a differential amplifier to increase the incoming signals and feed the conditioned signal to the ADC of the microcontroller. The output of these amplifiers centers on a DC bias equal to half the supply voltage. Therefore, for a 3.3-V MCU, the DC bias is set at 1.65 V. This voltage is generated using one of the op amps of the OPA4376 quad-op amp. Figure 3 illustrates the circuit used to generate the DC bias.

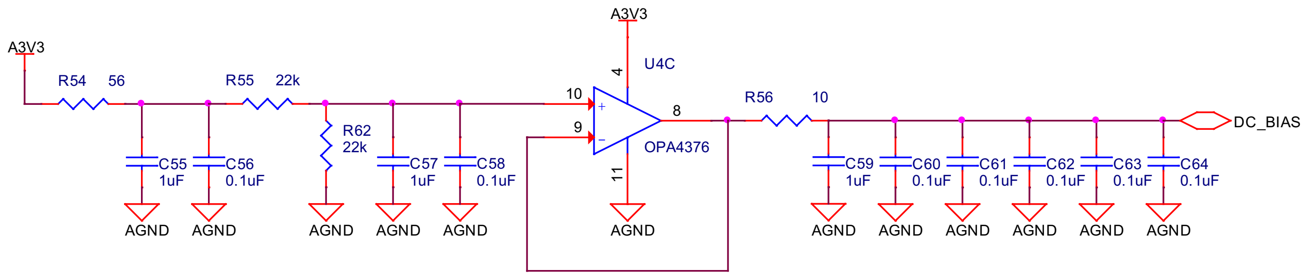

Figure 3. DC Bias Generation Circuit

4.2.2 Voltage Input

The voltage sense block should sense both positive and negative voltages since it is used to measure the line voltage. Therefore, a differential amplifier is used with an attenuation to scale the voltage down to the input voltage range acceptable by the ADC. The signal is also shifted by 1.65 V (the DC bias). Therefore, negative voltages appear between 0 and 1.65 V and positive voltages between 1.65 and 3.3 V.

The output of the amplifier is given by:

$$V_{OUT} = (V_+ - V_-) \times \frac{8.25\text{ k}}{(8.25\text{ k} + 5 \times 340\text{ k})} + 1.65\text{ V} \tag{1}$$

Thus, a voltage input of 0 V gives an output of 1.65 V, and the maximum deflection is ±340 V. The output for –340 V is 0 V and 340 V is 3.3 V.

4.2.3 Current Input

The target accuracy for active power measurement is ±0.5% over a current dynamic range of 2000:1 (0.05 to 100 A). Quantization error analysis was applied to determine the number of bits required to achieve ±0.5% active power accuracy, and nonlinearity of the 12-bit ADC was also taken into consideration.

The required dynamic range is 2000:1, or approximately 66 dB. Therefore, the total number of bits required is approximately 11 bits. However, the design requires even more bits to achieve an accuracy of ±0.5% over the entire dynamic range. Figure 4 shows the quantization error analysis used to determine the number of bits required for achieving this accuracy.

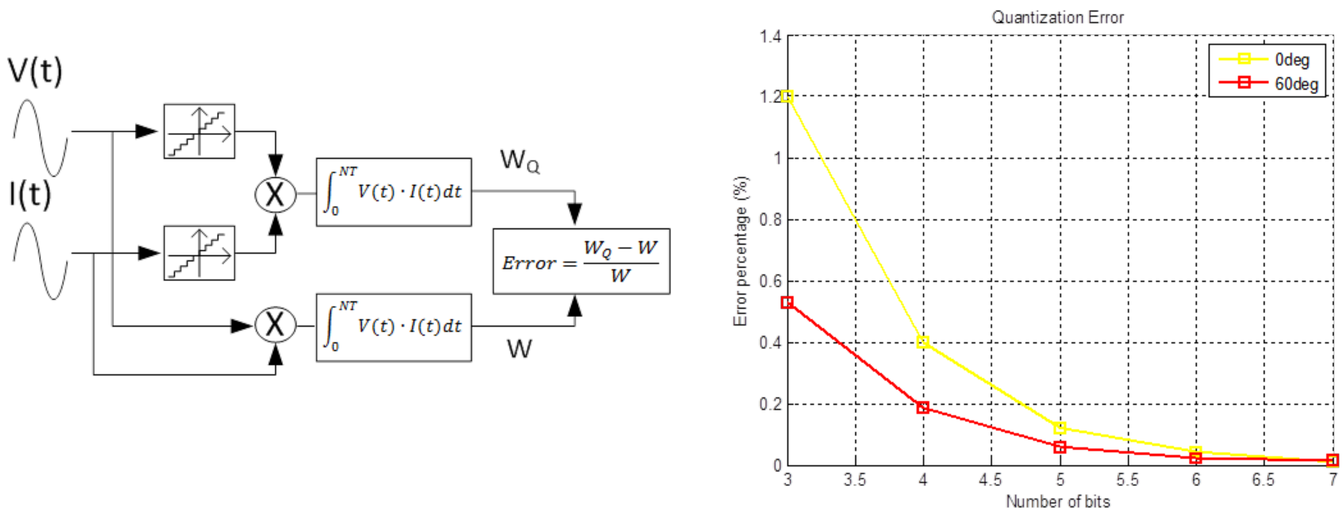

Figure 4. Quantization Error Analysis

From the output graph, an error of less than 0.5% needs at least four extra bits. This outcome brings the total number to 16 bits.

The ADC on the F28M35 MCU is a 12-bit ADC. However, the lower three bits are nonlinear and cannot be calibrated. Therefore, we are left with only nine effective bits. To overcome the shortage of bits, multiple gain stages have been implemented to reduce the effective dynamic range seen by the ADC while still maintaining the required accuracy and dynamic range of current to be measured. Ideally, three gain stages are sufficient with the last gain stage having a gain of x64. This design implemented four gain stages with the following gains:

- First gain stage (x2.2): 15 to 100 A
- Second gain stage (x6.8): 2 to 15 A
- Third gain stage (x51): 0.3 to 2 A
- Fourth gain stage (x330): 0.05 to 0.3 A

The first gain stage is used to feed the second, third, and fourth gain stages. Therefore, the gains of the last three gain stages listed above are additional gains over the existing x2.2 gain provided by the first stage.

Figure 5 shows the current sense circuit used in this design.

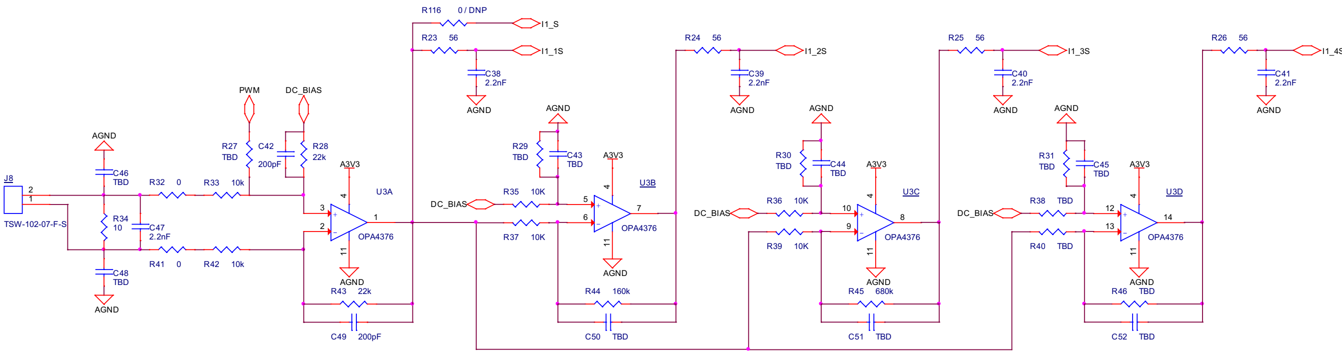

Figure 5. Current Sense Circuitry

5 Software Description

This section discusses the software for the implementation of single phase metrology using the Concerto device. The first subsection discusses the initialization of the metrology hardware. The next subsection describes the calibration and usage of this metrology hardware. The design guide then covers the configuration registers and result registers as well as their respective address.

5.1 Initializing the Metrology Library

The metrology library can be used to access the metrology hardware. The library consists of structures and functions used to initialize, calibrate, and store results. The library's initialization function needs to be called in the beginning to initialize the hardware. The initialization also takes care of initializing the relevant ADC channels, setting up the ADC trigger, and sampling the ADC. The function also initializes the GPIOs connected to the pulse LEDs of the meter as outputs. The pulses from these GPIOs can measure the power as well as calibrate the meter using a metering test setup.

The metrology library also contains an interrupt service register (ISR) that is triggered when the metrology hardware measures the passage of one second. This ISR is used to read the result registers of the metrology block and store the active, reactive, and apparent powers and the RMS voltage and current in a structure that can be read by the M3. The basic software flow is described in the flowcharts in Figure 6. This chart presents a basic dummy application, and the designer can modify the "infinite loop" shown in the main program flow to perform the function of a host application.

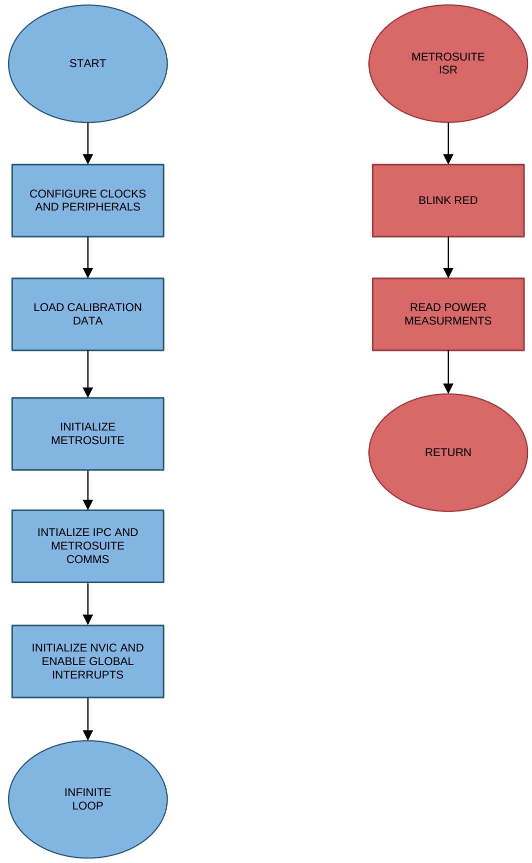

Figure 6. Metrology Software Flowchart

5.1.1 Metrology Library Functions and Data Structures

This section describes the functions and data structures that are used to communicate with the metrology block from the M3 core. The calibration data is stored in the structure "Calibration_Const" and is loaded into the metrology block using the function "LoadCalData()".

The function and structure prototypes are defined in the header file "metroSUITE.h", which should be included when using the library. Additionally, the library file "metroSUITE.lib" should be added to the Code Composer Studio™ (CCS) project and listed as a library under the Linker File Search Path settings of the CCS project as shown in Figure 7.

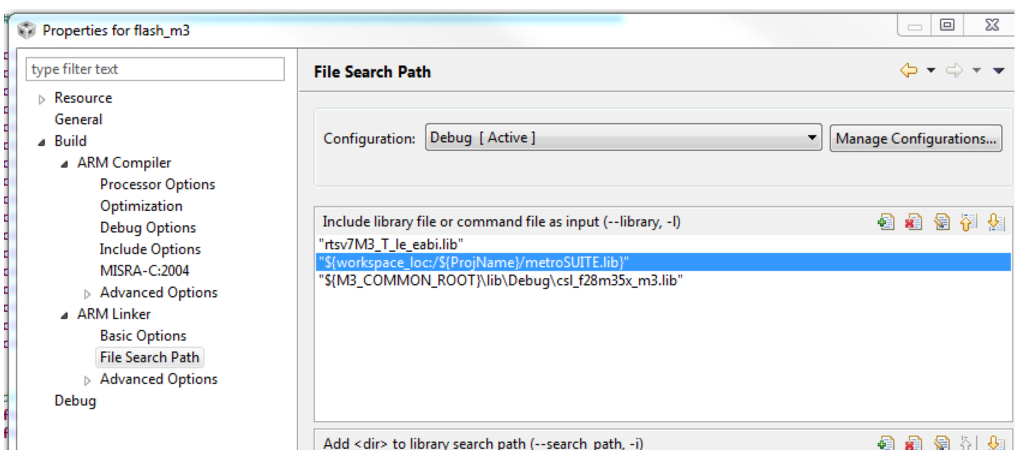

Figure 7. Adding the metroSUITE.lib File as a Library

Calibration_Const and LoadCalData()

Calibration_Const is a structure that contains the calibration data. The designer can load this structure into the metrology block at any time using the LoadCalData() function. The metrology block reads the values to perform calculations on current, voltage, and power. The structure members are described in Figure 8:

```
typedef struct
{
    //Current gain calibration
    volatile long Gain_S1;      //Current gain calibration for stages 1-4
    volatile long Gain_S2;
    volatile long Gain_S3;
    volatile long Gain_S4;

    //Power gain calibration
    volatile long PGain_S1;     //Power calibration for stages 1-4
    volatile long PGain_S2;
    volatile long PGain_S3;
    volatile long PGain_S4;

    //One Tick thresholds
    volatile long Tick_S1;      //One tick energy threshold for stages 1-4
    volatile long Tick_S2;
    volatile long Tick_S3;
    volatile long Tick_S4;

    //Fractional phase delay
    volatile long FracD1;       //Voltage fractional phase delay for stages 1-4
    volatile long FracD2;
    volatile long FracD3;
    volatile long FracD4;

   }Calibration_Const;
```

Figure 8. Calibration_Const Structure Definition

The structure calibrates the current gain first to reduce the error introduced by the CT and the gain stages. The structure calibrates the power gain to eliminate the error due to the fixed point calculations performed in the metrology hardware. The structure calibrates the fractional phase to compensate for the phase shift of the CT. This compensation is important when calibrating the meter at 60º and –60º.

The energy threshold for one pulse is different for each gain stage. This information is stored in the one-tick threshold variables, Tick_Sx.

The function used to load the calibration values into the metrology block is LoadCalData(Calibration_Const Kx). This function takes a structure of type Calibration_Const as an argument and copies the values stored in Calibration_Const to the memory locations that the metrology block reads from.

Metrology Lib Initialization Functions

Metrology Lib can be initialized by simply calling three initialization functions during the initialization phase of the main code. The functions are listed here:

- void metroSUITE_Init(void);
  - This function initializes the metrology block and the associated peripherals, such as the ADC and GPIOs used for metrology.
- void metroSUITE_INT1_EN();
  - This function enables the M3 core's metrology interrupt to service interrupts generated by the metrology block and read the output result data. The designer should call this function after the NVIC and NVIC vector table have been initialized.
- void metroSUITE_Comms_Init();
  - This function initializes the common interface bus, which is used to communicate with the metrology block. The designer should call this function once the metrology interrupt and global interrupts are enabled.

Calling these three functions in this order will initialize the metrology block and periodically generate interrupts that feed the power measurement results into the M3.

Metrology Result Register

The M3 reads the results generated by the metrology block during the metroSUITE ISR by the M3 and stores these results in the structure “metroSUITE_ResultRegs”. “metroSUITE_Results” is a variable of data type “metroSUITE_ResultRegs” that stores the results of the metrology measurements. Table 1 describes the members of this structure.

Table 1. metroSUITE_ResultRegs Structure Member Descriptions

STRUCTURE MEMBER	DATA TYPE	DESCRIPTION (FORMAT)
freq	Unsigned long int	Period of line frequency (IQ 1.15)
voltRMS	Signed long	RMS voltage (IQ 22)
currRMS	Signed long	RMS current (IQ 22)
actPwr	Signed long	Active power
reactPwr	Signed long	Reactive power
appPwr	Signed long	Apparent power
pwrFactor	Signed long	Power factor (IQ 1.8)

6 Meter Demo

The energy meter evaluation module (EVM) associated with this reference design has the F28M35 and demonstrates energy measurements. The complete demonstration platform consists of the EVM that can be easily hooked to any test system and the metrology software that can be calibrated using the JTAG debug interface and CCS.

6.1 EVM Overview

The following figures of the EVM describe the hardware. Figure 9 is the top view of the energy meter. Figure 10 illustrates the location of various circuit blocks of the EVM based on functionality.

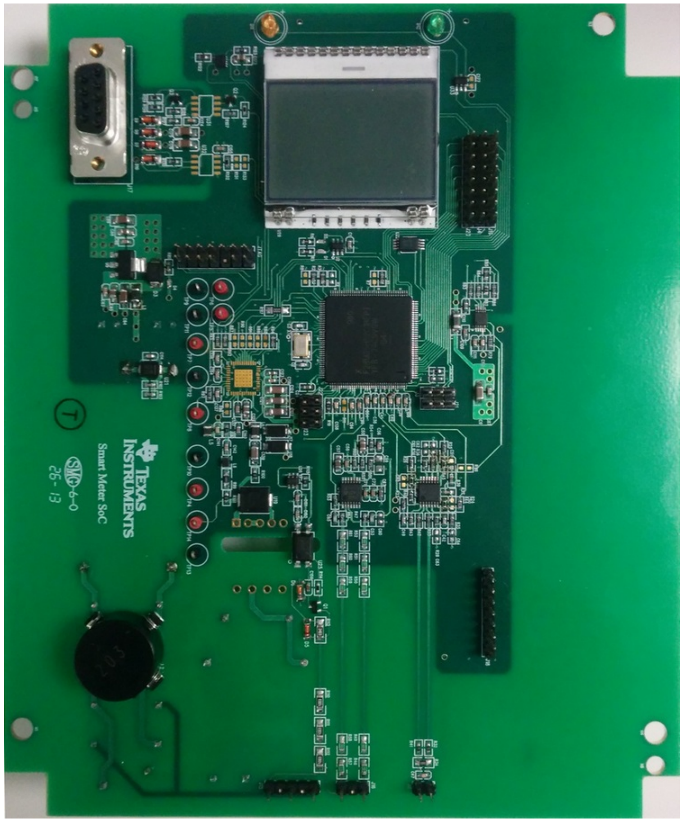

Figure 9. Top View of the Single-Phase Energy Meter EVM

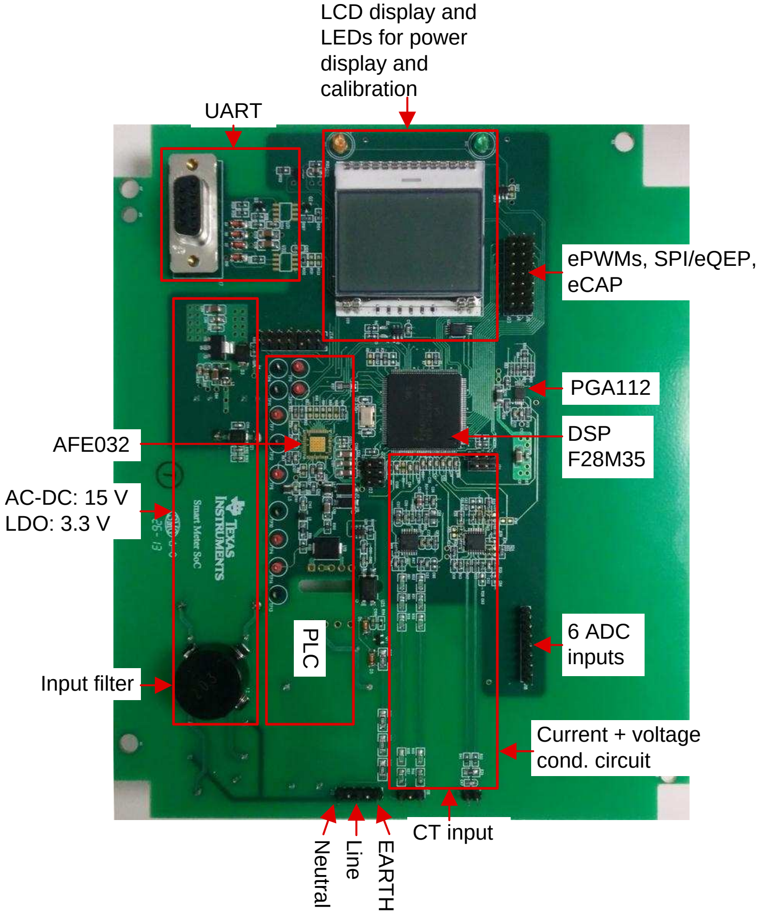

Figure 10. Top View of the EVM with Components Highlighted

6.1.1 Connections to Test Setup or AC Voltages

AC voltage or currents can be applied to the board for testing purposes at these points:

- LINE corresponds to the line connection.
- NEUTRAL corresponds to the connection to the neutral wire.
- EARTH corresponds to the earth connection.
- CT Input is the point where the inputs from the current transformer are fed into the system.

Figure 11 shows a front view of the EVM with connections for current inputs.

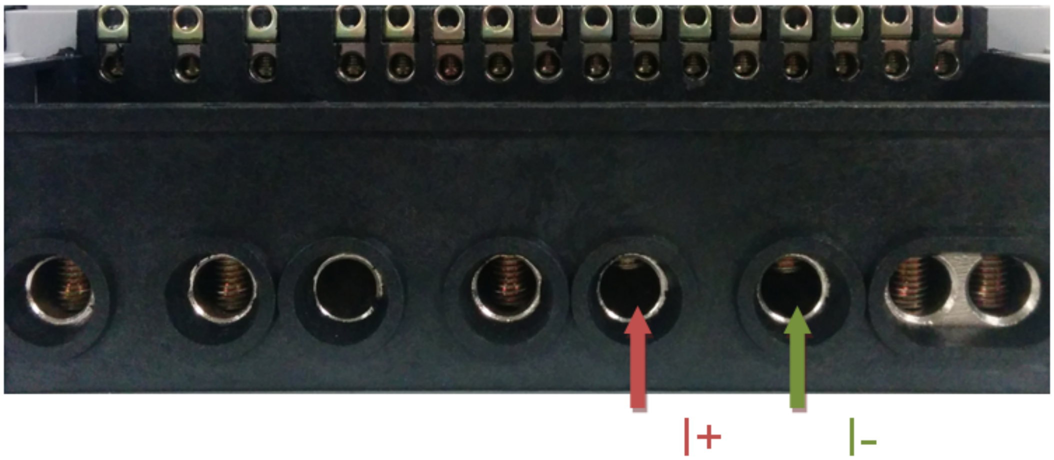

Figure 11. Front View of the EVM with Test Setup Connections

6.1.2 Loading the Example Code

The source code was developed in CCS v5.5. Older versions of CCS may not open this project.

Opening the Project

The folder “m3” contains the source codes, header files, and the metrology library. The library is stored in the folder labeled “metroSUITE”. For first time use, both projects should be completely rebuilt by performing the following steps:

1. Open CCS.
2. Click on Project, then Import Existing CCS Eclipse Project.
3. Browse to the “m3” folder.
   (a) Find two projects under the folder “csl_f28m35x_m3”, which is the chip support library and “flash_m3”, the metrology project.
   (b) Open “flash_m3”.
4. Once the project is open, right click on the project and select Build. The project should build with zero errors.

Flashing the EVM and Calibrating from CCS

Once the project has been built and the board is safely connected to a test setup, the code must be flashed into the microcontroller before testing. Once the board is powered up, connect a JTAG emulator to the board and the PC. The designer should follow these steps while calibrating from CCS:

1. Click on the Debug button on the CCS window to launch the debug session.
2. Once the code has been loaded onto the board, add "_defaults", "metroSUITE_Results", and "CalUpdateFlag" to the watch window.
3. Disconnect the emulator from the M3 core by clicking Disconnect Target from the Debug tab (see Figure 12).

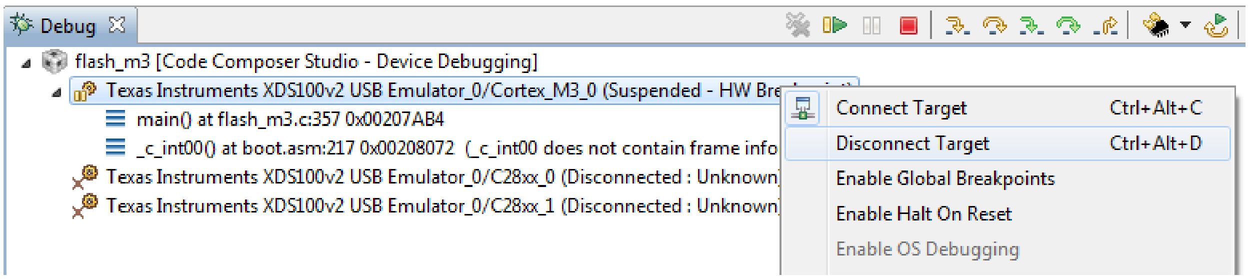

Figure 12. Connecting and Disconnecting the Target from CCS

4. Power cycle the board. The red LED should blink every second, indicating that the metrology code is now running.
5. Connect the target by clicking on Connect Target. This command will pause program execution, and the meter is now ready to calibrate.
6. Enter the initial calibration data in the watch window under "_defaults".
7. Set CalUpdateFlag to "1". This input will make the M3 call the LoadCalData() function and update the calibration constants.
8. Click on the Run button to begin code execution.
9. Turn on Continuous Refresh in the watch window to view the output results and to change the calibration values in real time (see Figure 13).

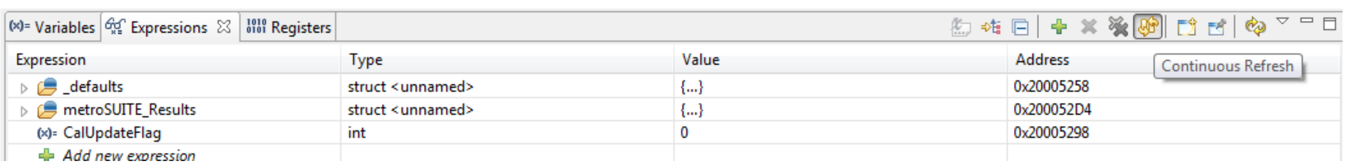

Figure 13. Activating Continuous Refresh

10. To calibrate the system on the fly, change the desired calibration constant under "_defaults" and toggle CalUpdateFlag to "1".

7 Test Results and Calibration

7.1 Metrology Results

The meter was tested using a metering test setup and calibrated to meet the accuracy requirement (±0.5%). Figure 14 shows the test setup used, and Figure 15 shows the accuracy test results, tested at 230-V, 50-Hz AC.

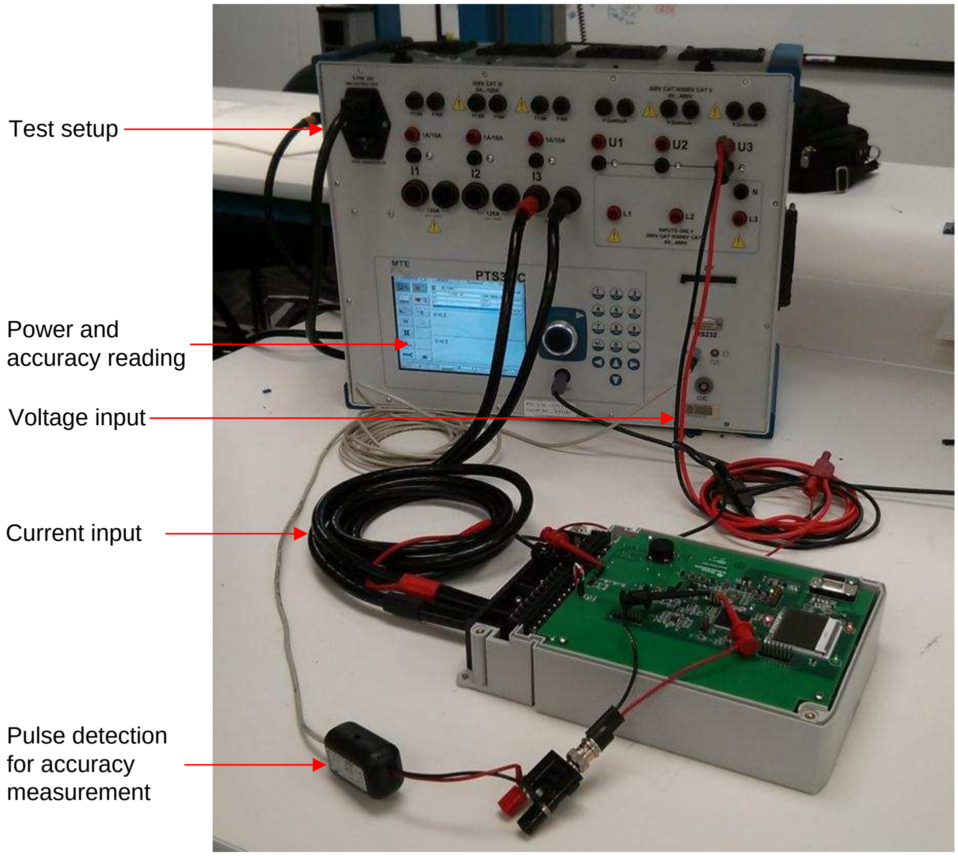

Figure 14. Test Setup Connections

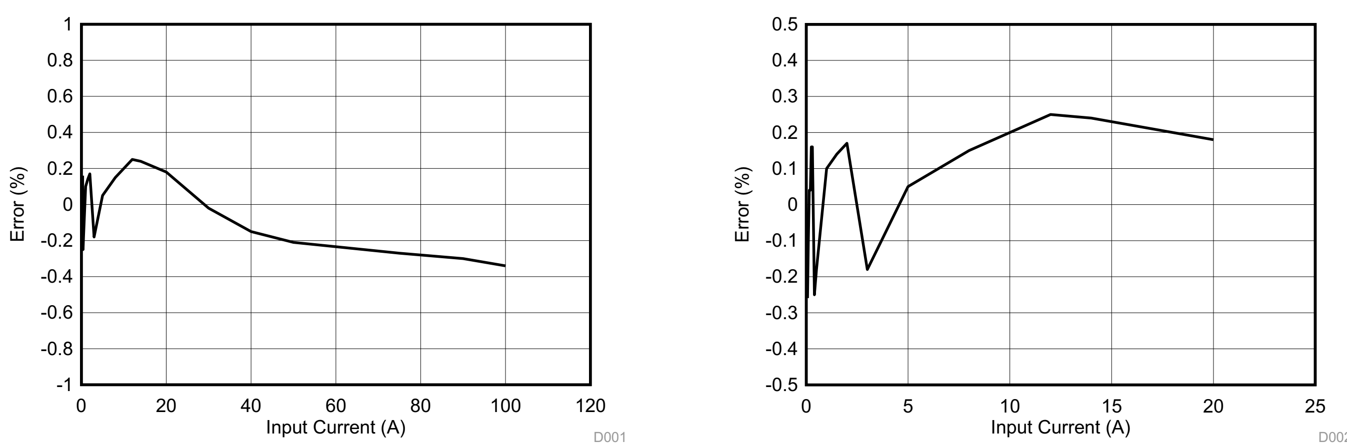

Figure 15. Left: Test Results (0.05 to 100 A); Right: Test Results (0.05 to 20 A)

The meter was calibrated using the JTAG debugger and CCS Debug mode. The calibration constants were adjusted, and current and power measurements were observed in real time. The voltage and current are stored in Q22 format. Therefore, the calculated power is also in Q22 format. The value of the one-tick energy can be calculated using the following formula:

$$1 \text{ tick} = \frac{1}{N_{Pulses}} \times \left(\frac{3600 \times f_s \times 2^{11} \times 2^{11} \times 1000}{I_{Base} \times V_{Base}} \right) \text{kWh/pulse}$$

where

- V_{Base} = 340 V
- I_{Base} = (150 A/Gain of the stage). (2)

The gains of the different stages are calculated relative to the first gain stage. Therefore, the I_{Base} for the first stage is 150 A.

The gains for the subsequent stages are given below:

- Stage 2: Gain = x6.8; I_{Base} = 22.05 A
- Stage 3: Gain = x51; I_{Base} = 2.941 A
- Stage 4: Gain = x330; I_{Base} = 0.454 A

Substituting the above values in the one-tick energy equation, the focus shifts to the one-tick energy constants for the different gain stages. The required pulse rate was set at N_{Pulses} = 600000 imp/kWh.

The calculated one-tick energies for each stage are given below:

- Stage 1: 1 tick = 4934475
- Stage 2: 1 tick = 33554432
- Stage 3: 1 tick = 251658240
- Stage 4: 1 tick = 1628376847

The calibration procedure followed for calibrating the board is as follows:

1. Calibrate current and voltage AC gains based on RMS for each gain stage.
2. Calibrate active power gain at 0°.
3. Calibrate the fractional delay, θ requirement at 60°.
4. Check accuracy at 0° again.

8 Design Files

8.1 Schematics

To download the schematics, see the design files at TIDM-EMETER-CORTEXM3.

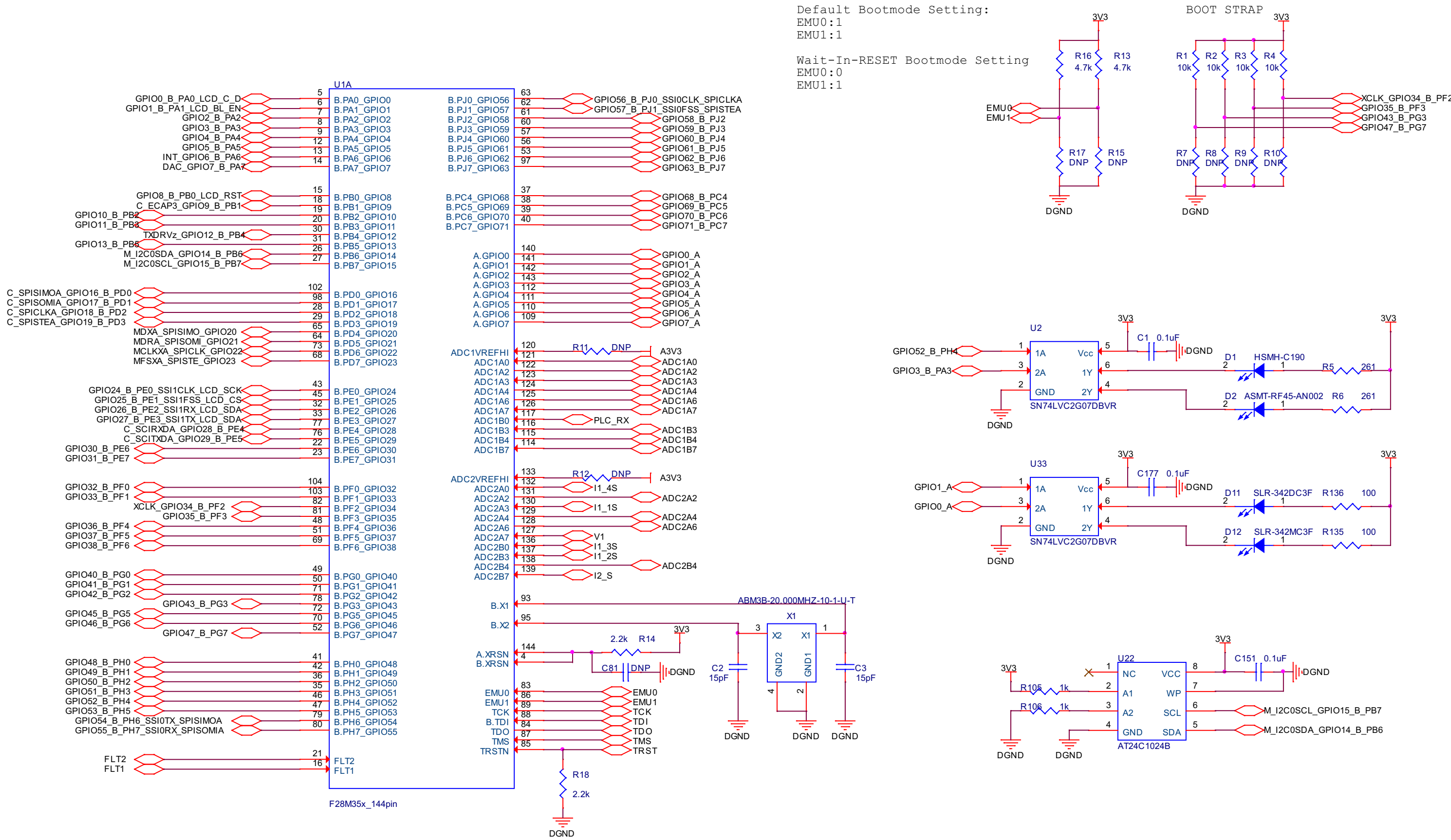

Figure 16. F28M35

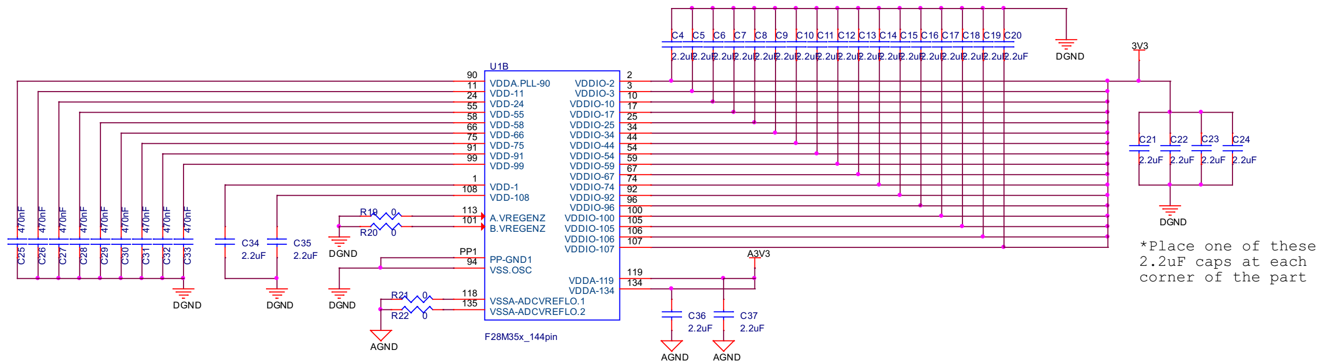

Figure 17. F28M35 Power

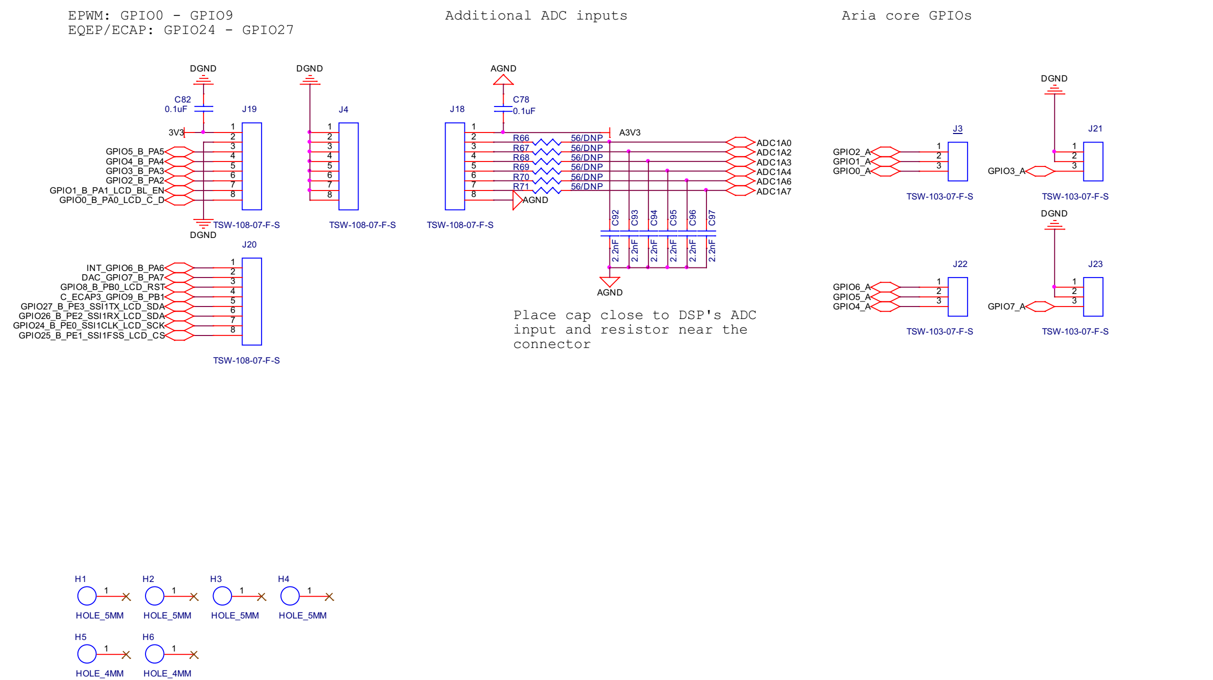

Figure 18. Connector

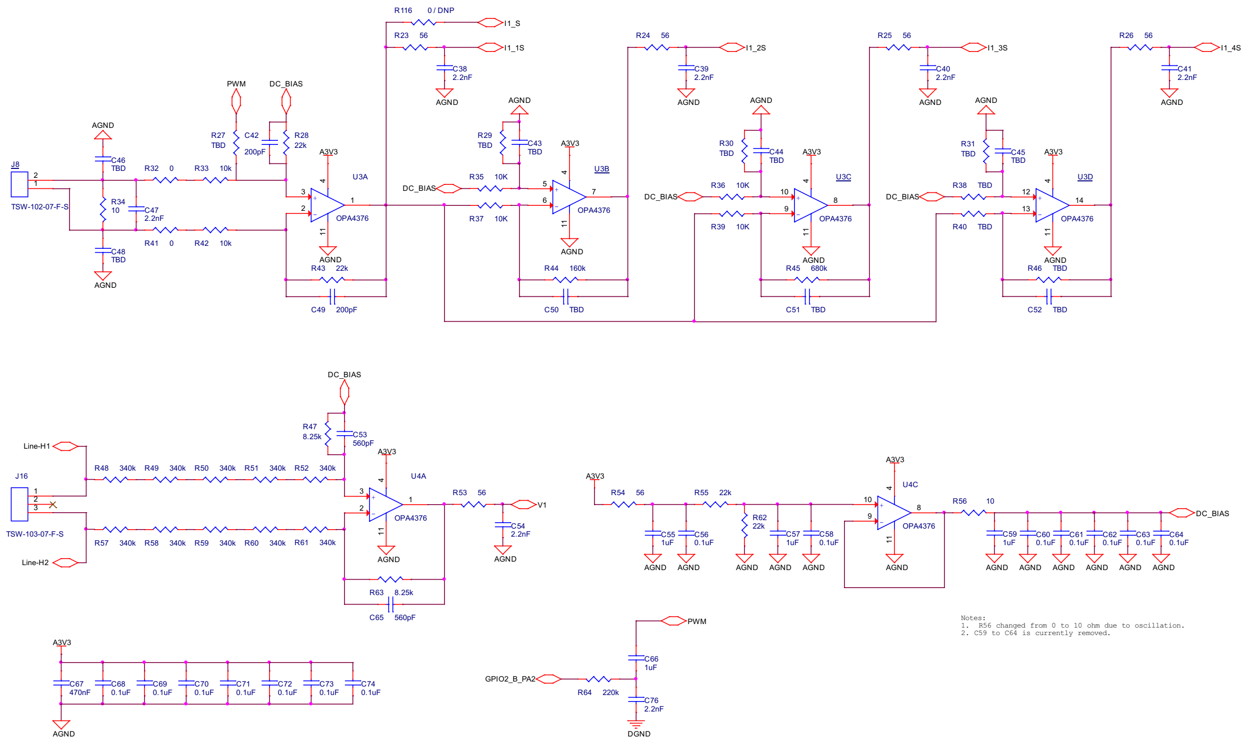

Figure 19. Metrology Front End

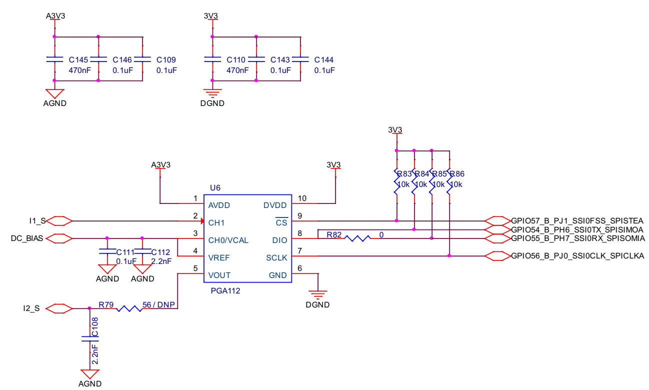

Figure 20. Metrology Front End 2

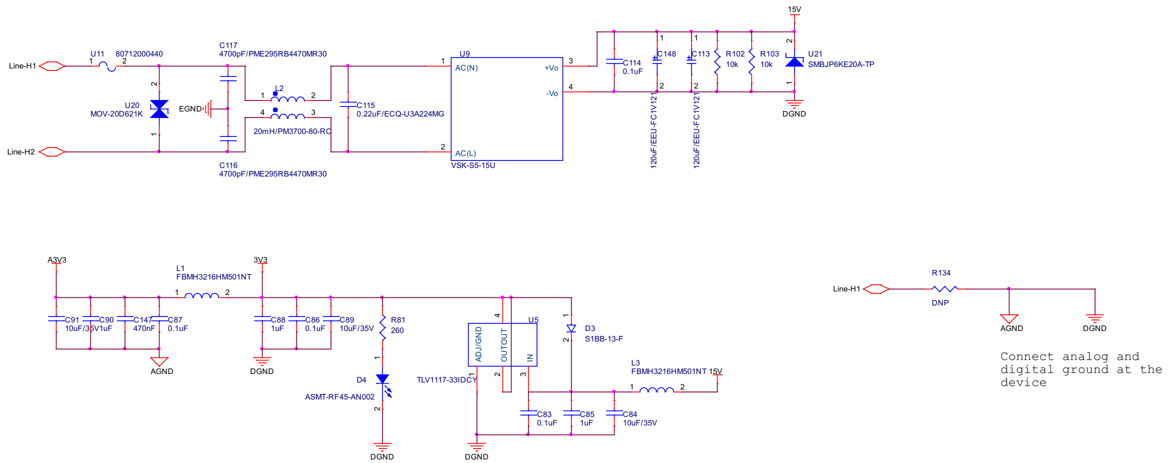

Figure 21. System Power

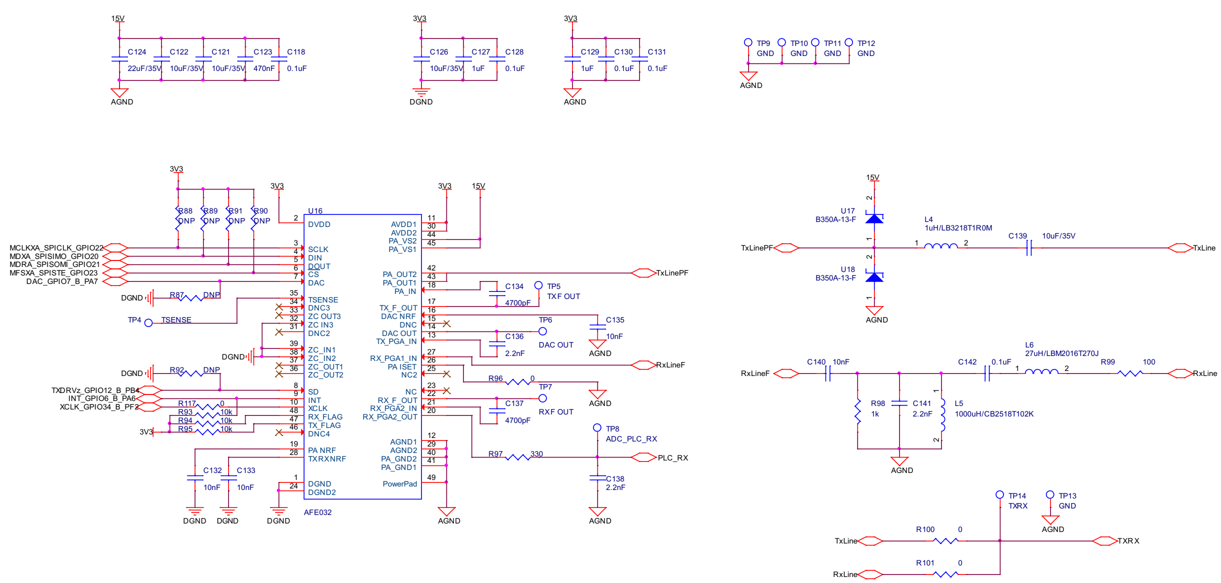

Figure 22. AFE032

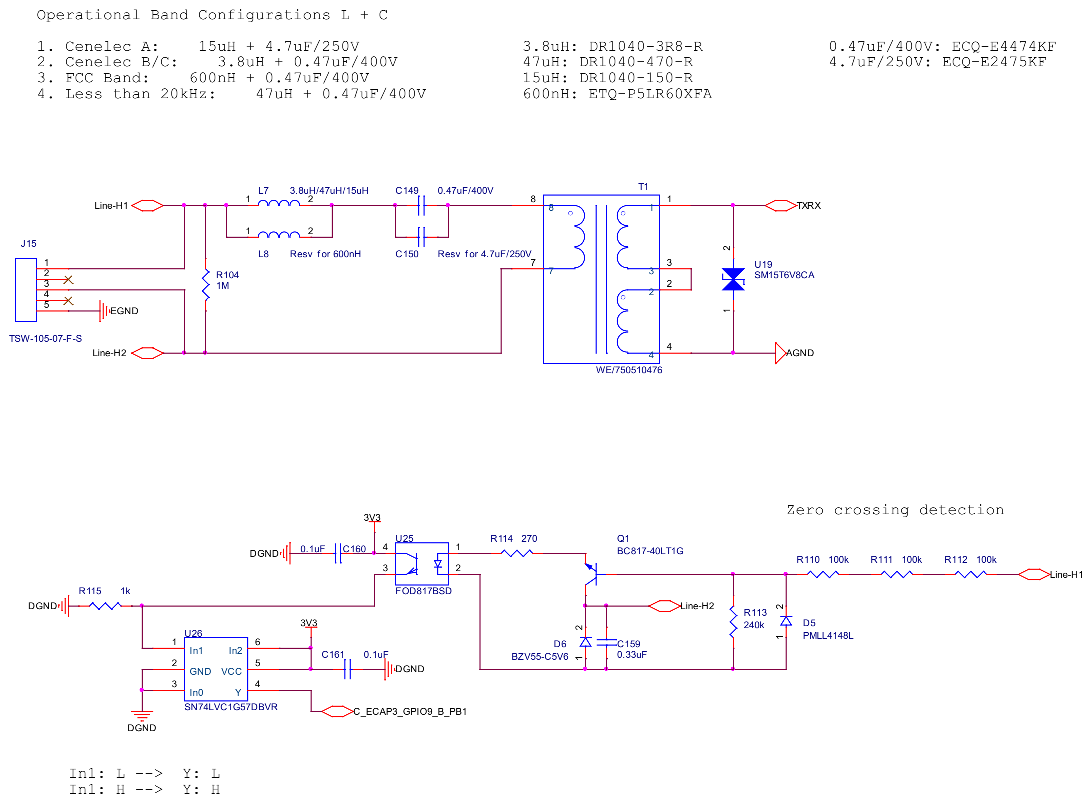

Figure 23. Coupling Circuit

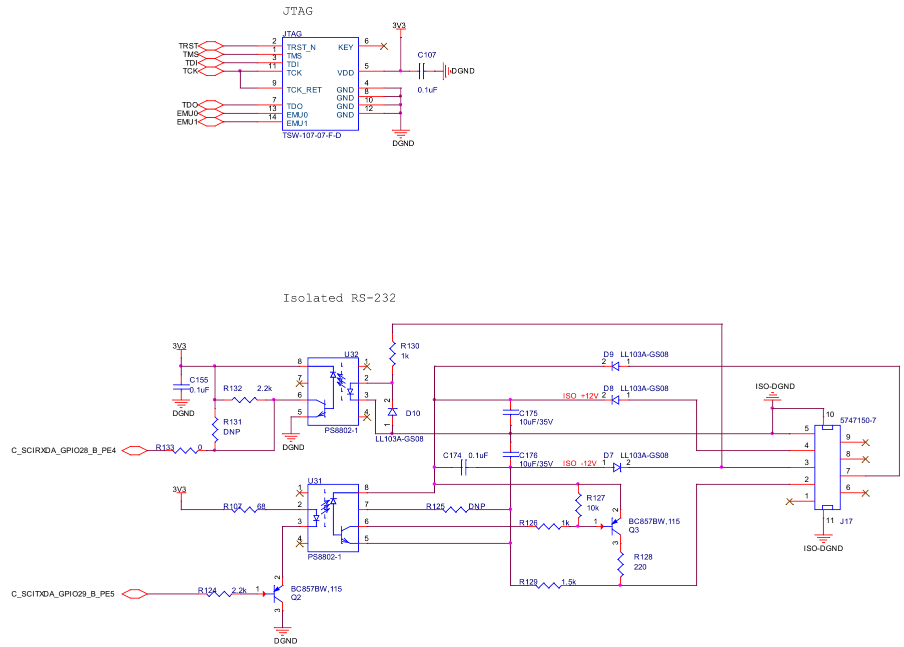

Figure 24. Communication Circuit

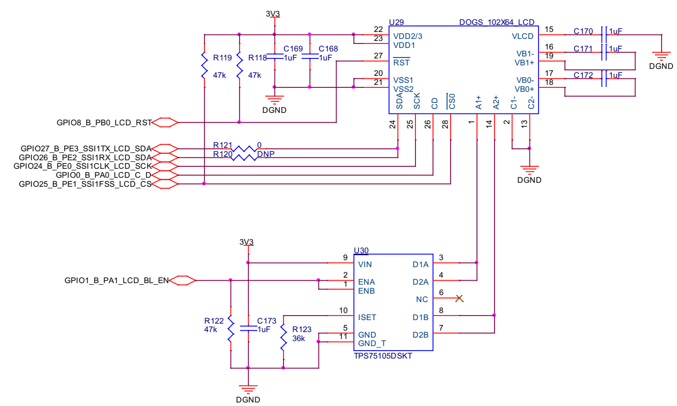

Figure 25. Display

8.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDM-EMETER-CORTEXM3.

Table 2. BOM

QTY	VALUE	DEVICE	PARTS
1	F28M35H52C1RFPT	CONCERTO DUAL-CORE MCU	U1
2	SN74LVC2G07DBVR	IC BUFF/DVR DL NON-INV SOT23-6	U2, U33
2	OPA4376AIPWR	IC OPAMP GP 5.5-MHZ QUAD 14TSSOP	U3,U4
1	TLV1117-33IDCY	IC REG LDO 3.3-V 0.8-A SOT223-4	U5
1	PGA112AIDGST	IC OPAMP PROG GAIN R-R 10MSOP	U6
1	VSKM-S5-15U	POWER SUPPLY SWITCHING 5 W 15 V	U9
1	80712000440	FUSE 250-V IEC TL TE7 SHORT 2 A	U11
1	AFE032	PLC ANALOG FRONTEND	U16
46	C1608X7R1H104K080AA	CAP CER 0.1-µF 50-V 10% X7R 0603	C1, C56, C58, C60, C61, C62, C63, C64, C68, C69, C70, C71, C72,C73, C74, C78, C82, C83, C86, C87, C107, C109, C111, C114, C118, C128, C130, C131, C142, C143, C144, C146, C151, C152, C153, C154, C155, C156, C157, C158, C160, C161, C162, C164, C166, C174
2	C1608C0G1H150J080AA	CAP CER 15-PF 50-V 5% NP0 0603	C2, C3
25	CGA3E1X7R0J225K080AC	CAP CER 2.2-µF 6.3-V 10% X7R 0603	C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, C15, C16, C17, C18,C19, C20, C21, C22, C23, C24, C34, C35, C36, C37
14	C1608X7R1C474K080AC	CAP CER 0.47-µF 16-V 10% X7R 0603	C25, C26, C27, C28, C29, C30, C31, C32, C33, C67, C110, C123, C145,C147
19	C1608C0G1H222J080AA	CAP CER 2200-PF 50-V 5% NP0 0603	C38, C39, C40, C41, C47, C54, C76, C81, C92, C93, C94, C95, C96, C97, C108, C112, C136, C138, C141
2	06035A201FAT2A	CAP CER 200-PF 50-V 1% NP0 0603	C42, C49
2	C1608C0G1H561J080AA	CAP CER 560-PF 50-V 5% NP0 0603	C53, C65
17	C2012X7R1H105K125AB	CAP CER 1-µF 50-V 10% X7R 0805	C55, C57, C59, C66, C85, C88, C90, C127, C129, C163, C165, C168, C169, C170, C171, C172, C173
9	C3216X7R1V106M160AC	CAP CER 10-µF 35-V 20% X7R 1206	C84, C89, C91, C121, C122, C126, C139, C176, C175
2	EEU-FC1V121	CAP ALUM 120-µF 35-V 20% RADIAL	C113, C148
1	ECQ-U3A224MG	CAP FILM 0.22-µF 300-V-AC RADIAL	C115
2	PME295RB4470MR30	CAP FILM 4700-PF 1.5 K-V-DC RADIAL	C116, C117
1	C3216X5R1V226M160AC	CAP CER 22-µF 35-V 20% X5R 1206	C124
4	C1608C0G1H103J080AA	CAP CER 10000-PF 50-V 5% NP0 0603	C132, C133, C135, C140
2	CGJ3E2C0G1H472J080AA	CAP CER 4700-PF 50-V 5% NP0 0603	C134, C137
1	ECQ-E4474KF	CAP FILM 0.47-µF 400-V-DC RADIAL	C149
1	ECQ-E2475KF	CAP FILM 4.7-µF 250-V-DC RADIAL	C150
1	C1608X7R1H334K080AC	CAP CER 0.33-µF 50-V 10% X7R 0603	C159
1	HSMH-C190	LED 660-NM RED DIFF 0603 SMD	D1
2	ASMT-RF45-AN002	LED CHIPLED 0.45-MM YLW/GRN 0603	D2, D4

Table 2. BOM (continued)

QTY	VALUE	DEVICE	PARTS
1	S1BB-13-F	DIODE GEN PURPOSE 100-V 1-A SMB	D3
1	PMLL4148L	DIODE SWITCHING 75-V 0.2-A LLDS	D5
1	BZV55-C5V6	DIODE ZENER 5.6-V 500-MW LLDS	D6
3	FBMH3216HM501NT	FERRITE BEAD 500 OHM 1206	L1, L3, L9
1	PM3700-80-RC	CHOKE COMMON MODE 20 MH SMD	L2
1	LB3218T1R0M	INDUCTOR 1.0 UH 1.075 A 20% SMD	L4
1	CB2518T102K	INDUCTOR POWER 1000 UH 1007	L5
1	LBM2016T270J	INDUCTOR WOUND 27 UH 5% 0806	L6
1	DR1040-3R8-R	INDUCTOR POWER SHIELD 3.8 UH SMD	L7
1	DR1040-470-R	INDUCTOR POWER SHIELD 47 UH SMD	L7
1	DR1040-150-R	INDUCTOR POWER SHIELD 15 UH SMD	L7
1	ETQ-P5LR60XFA	COIL POWER CHOKE .60 UH SMD	L8
1	BC817-40LT1G	TRANS NPN GP 500-MA 45-V SOT23	Q1
21	ERA-3AEB103V	RES 10 K-OHM 1/10 W .1% 0603 SMD	R1, R2, R3, R4, R33, R35, R36, R37, R39, R42, R83, R84, R85, R86, R92, R93, R94, R95, R102, R103, R127
3	ERJ-3EKF2610V	RES 261 OHM 1/10 W 1% 0603 SMD	R5, R6, R81
2	1622960-1	RES 4.70 K-OHM 1/10 W 1% 0603	R13, R16
4	ERJ-3EKF2201V	RES 2.2 K-OHM 1/10 W 1% 0603 SMD	R14, R18, R124, R132
12	ERJ-3GEY0R00V	RES 0.0 OHM 1/10 W JUMP 0603 SMD	R19, R20, R21, R22, R32, R41, R56, R82, R100, R101, R121
7	ERA-3AEB560V	RES 56 OHM 1/10 W .1% 0603 SMD	R23, R24, R25, R26, R53, R54, R79
1	ERJ-3EKF68R0V	RES 68 OHM 1/10 W 1% 0603 SMD	R107
2	ERJ-3EKF1000V	RES 100 OHM 1/10 W 1% 0603 SMD	R135, R136
4	ERA-3AEB223V	RES 22 K-OHM 1/10 W .1% 0603 SMD	R28, R43, R55, R62
1	1-1614884-7	RES 10.0 OHM 1/10 W 0.1% 0805	R34
1	ERA-3AEB164V	RES 160 K-OHM 1/10 W .1% 0603 SMD	R44
1	1-1879417-5	RES 680 K-OHM 1/16 W 0.1% 0603	R45
2	RNCS0603BKE8K25	RES 8.25 K-OHM 1/16 W 0.1% 0603	R47, R63
10	ERA-6AEB3403V	RES 340 K-OHM 1/8 W .1% 0805 SMD	R48, R49, R50, R51, R52, R57, R58, R59, R60, R61
1	ERJ-3EKF2203V	RES 220 K-OHM 1/10 W 1% 0603 SMD	R64
1	ERA-3AEB331V	RES 330 OHM 1/10 W .1% 0603 SMD	R97
6	1622866-1	RES 1.00 K-OHM 1/10 W 1% 0603	R98, R105, R106, R115, R126, R130
1	ERJ-3EKF2200V	RES 220 OHM 1/10 W 1% 0603 SMD	R128
1	ERJ-3EKF1501V	RES 1.5 K-OHM 1/10 W 1% 0603 SMD	R129
1	ERJ-6ENF1000V	RES 100 OHM 1/8 W 1% 0805 SMD	R99

Table 2. BOM (continued)

QTY	VALUE	DEVICE	PARTS
1	MCR25JZHF1004	RES 1 M-OHM 1/4 W 1% 1210 SMD	R104
3	ERJ-8ENF1003V	RES 100 K-OHM 1/4 W 1% 1206 SMD	R110, R111, R112
1	ERJ-8ENF2403V	RES 240 K-OHM 1/4 W 1% 1206 SMD	R113
1	ERJ-3EKF2700V	RES 270 OHM 1/10 W 1% 0603 SMD	R114
1	ERJ-8GEY0R00V	RES 0.0 OHM 1/4 W JUMP 1206 SMD	R117
3	ERJ-3EKF4702V	RES 47 K-OHM 1/10 W 1% 0603 SMD	R118, R119, R122
1	ERJ-3EKF3602V	RES 36 K-OHM 1/10 W 1% 0603 SMD	R123
6	5000	TEST POINT PC MINI .040"D RED	TP4, TP5, TP6, TP7, TP8, TP14
5	5001	TEST POINT PC MINI .040"D BLACK	TP9, TP10, TP11, TP12, TP13
1	750510476		T1
2	B350A-13-F	DIODE SCHOTTKY 50-V 3-A SMA	U17, U18
1	SM15T6V8CA	TRANSIL 1500-W 6.8-V BIDIR SMC	U19
1	MOV-20D621K	VARISTOR 620-V 6.5-KA DISC 20MM	U20
1	SMBJP6KE20A-TP	TVS 600-W 20-V UNIDIRECT SMBJ	U21
1	AT24C1024B	IC EEPROM 1-MBIT 1-MHZ 8TSSOP	U22
2	PS8802-1-F3-AX	OPTOISOLATOR ANALOG HS OUT 8SSOP	U23
1	MAX3221ECPWR	IC RS232 3 to 5.5-V DRVR 16-TSSOP	U24
1	FOD817BSD	OPTOCOUPLER PHOTOTRANS OUT 4-SMD	U25
1	SN74LVC1G57DBVR	IC MULT-FUNCTION GATE SOT23-6	U26
2	BC857BW, 115	TRANSISTOR PNP 45-V 100-MA SOT323	Q2,Q3
4	LL103A-GS08	DIODE SCHOTTKY 40-V 0.2-A SOD80	D7, D8, D9, D10
1	136	LED 3.1-MM 610-NM ORANGE TRANSP	D11
1	SLR-342MC3F	LED 3.1-MM 563-NM GREEN TRANSP	D12
1	ABM3B-20.000MHZ-10-1-U-T	CRYSTAL 20.0000-MHZ 10-PF SMD	X1
1	5747150-7	CONN D-SUB RECPT STR 9POS PCB AU	J17
1	TSW-107-07-F-D	100-mil space	JTAG
3	TSW-103-07-F-S	100-mil space	J3, J16, J21
4	TSW-108-07-F-S	100-mil space	J4, J18, J19, J20
1	TSW-102-07-F-S	100-mil space	J8
1	TSW-105-07-F-S	100-mil space	J15
1	TPS75105DSKT	LDO current source	U30
1	EA LED39x41-W	White LED Backlight For DOG-S Series	U29
1	EA DOGS102W-6	FSTN (+) Transflect White Background	U29
1	EA DOGS102N-6	FSTN (+) Reflective Superwhite Backround	U29

8.3 PCB Layer Plots

To download the layer plots, see the design files at TIDM-EMETER-CORTEXM3.

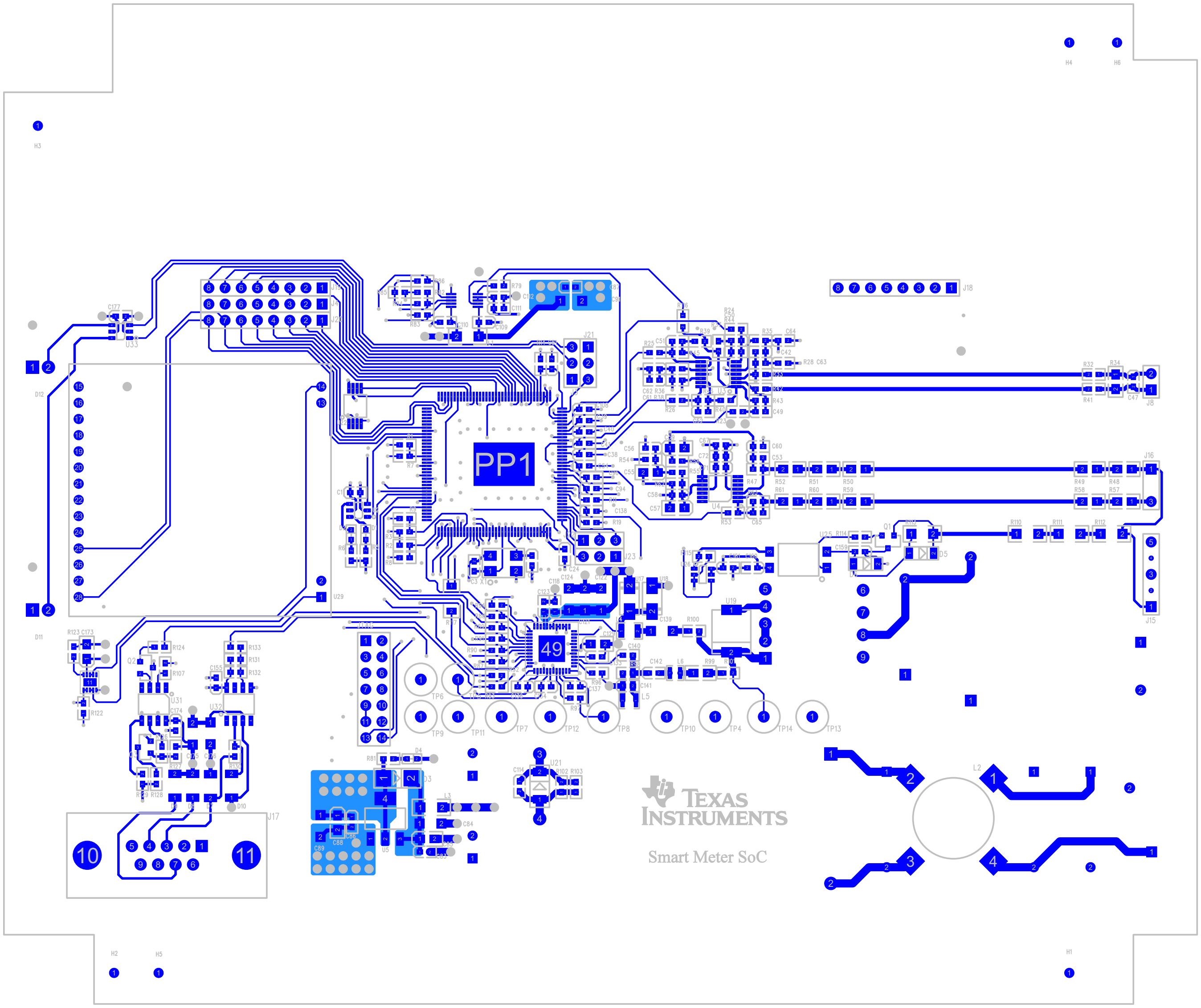

Figure 26. Top Layer

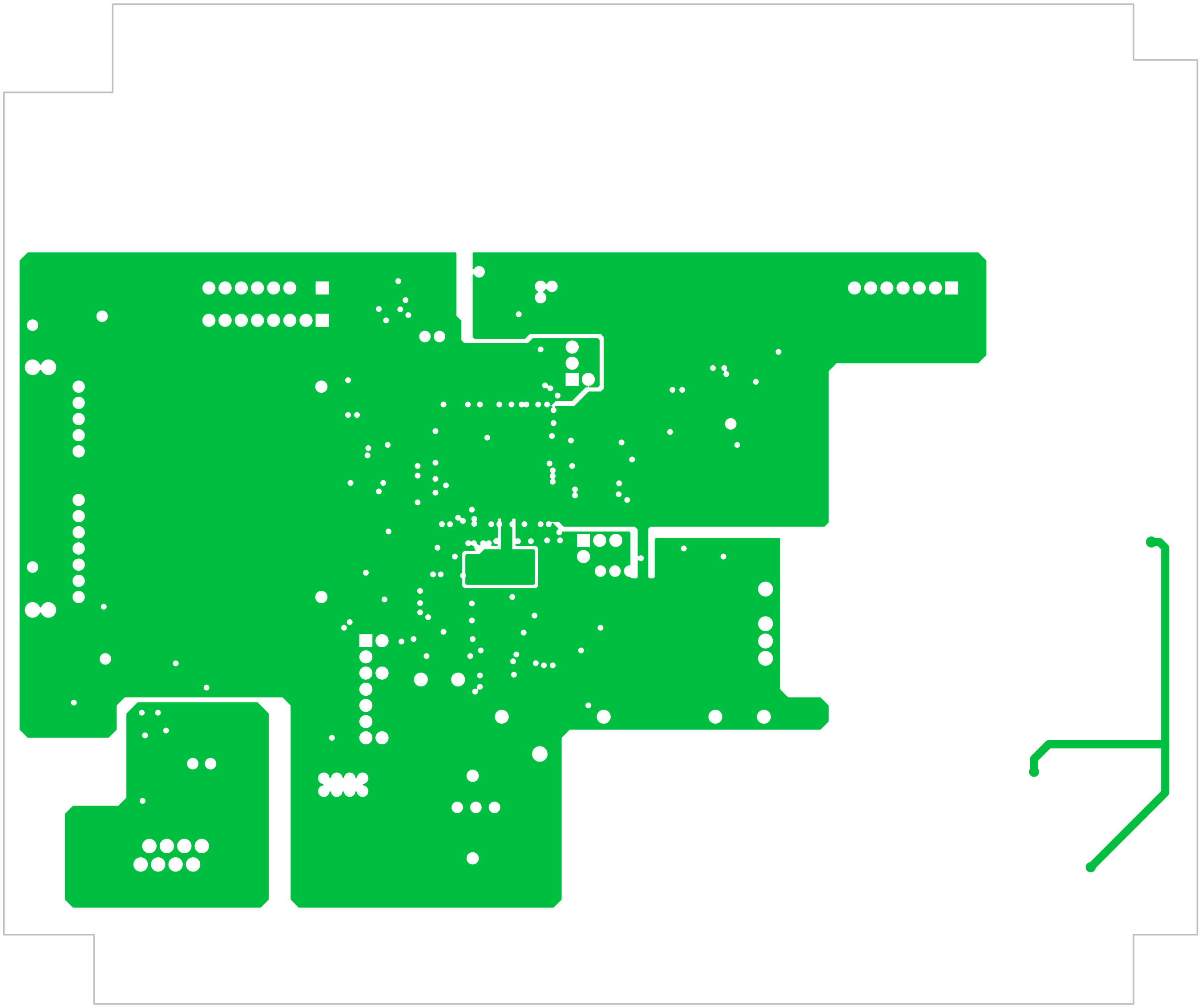

Figure 27. Ground Plane (Layer 2)

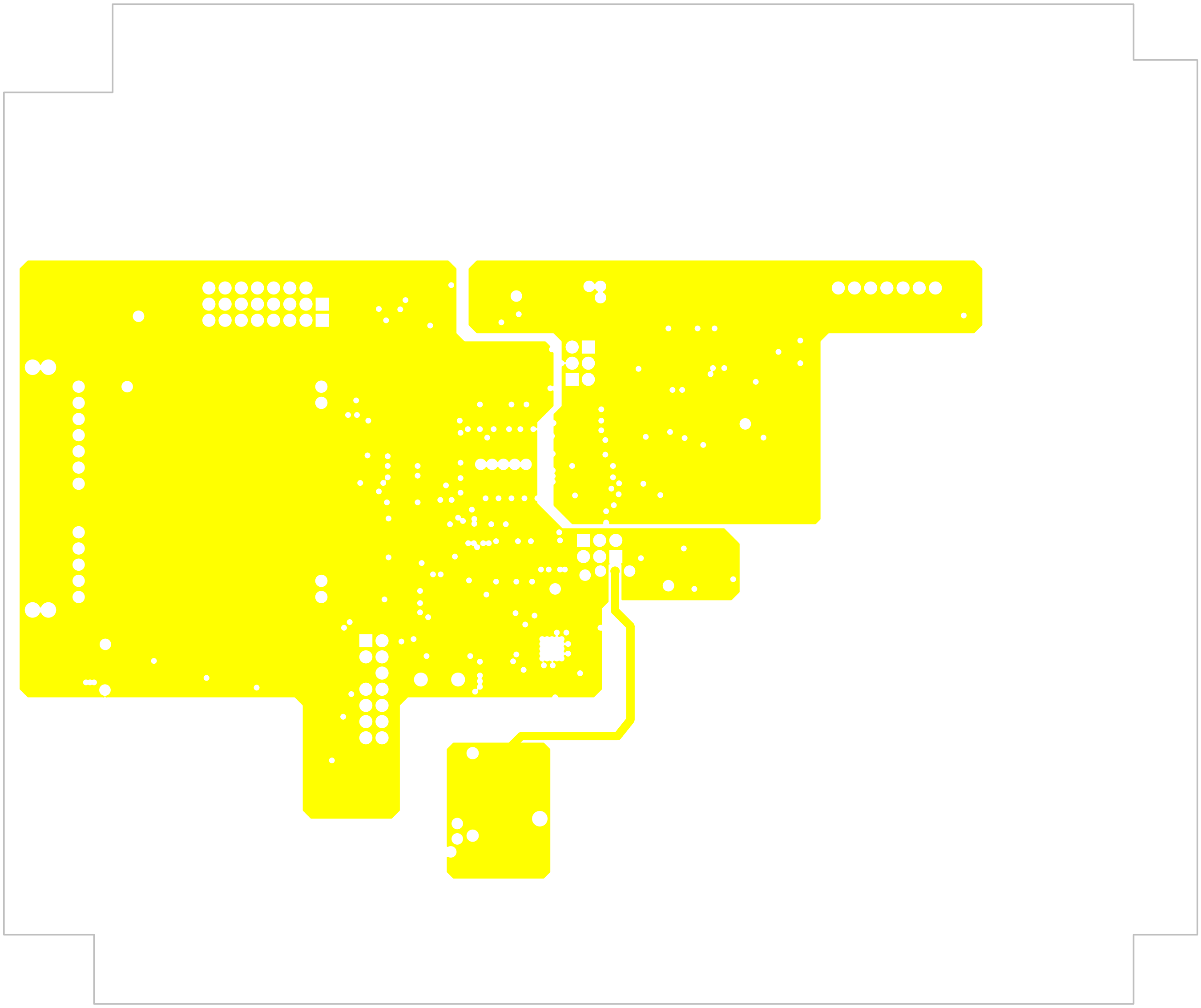

Figure 28. Power Plane (Layer 3)

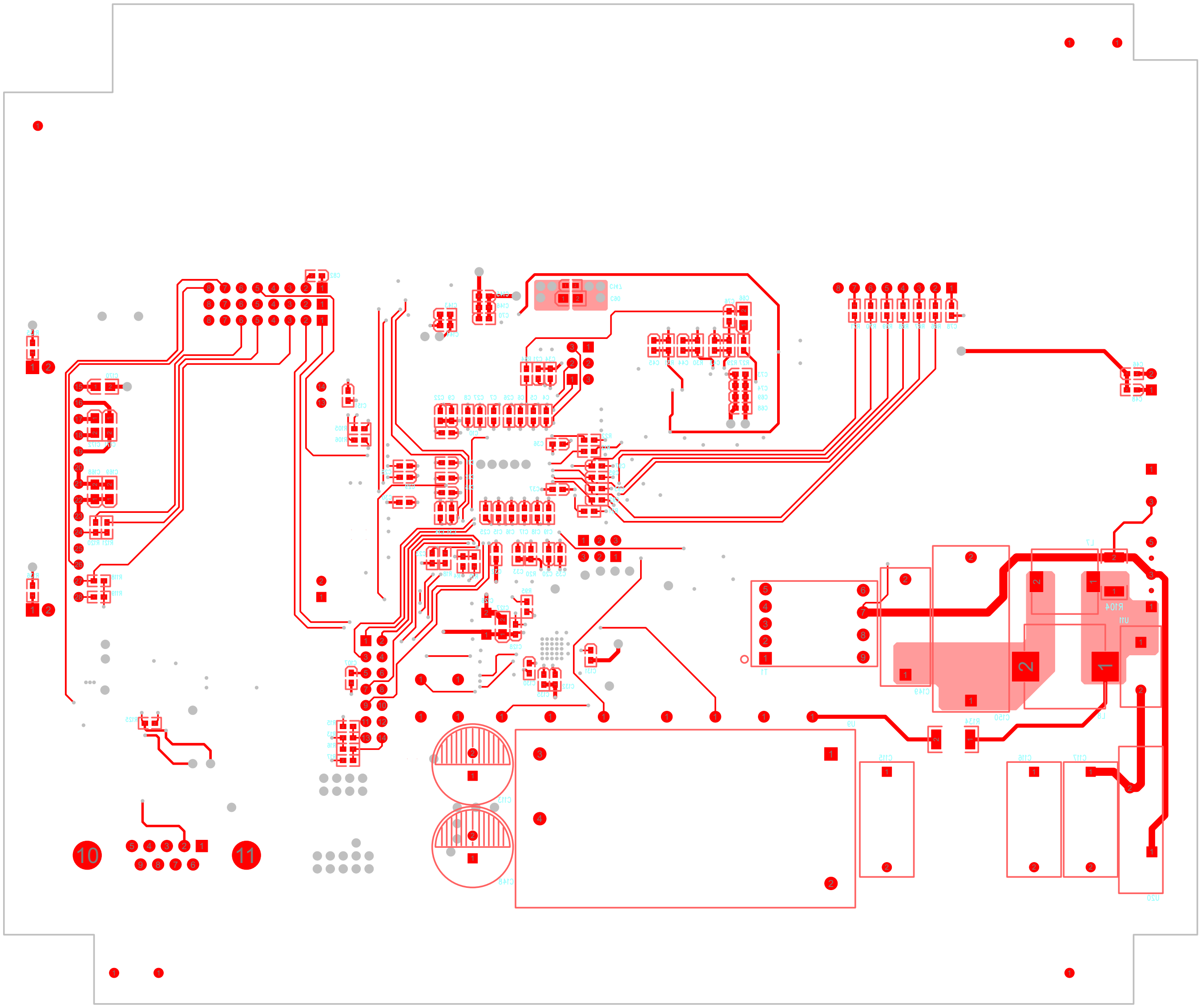

Figure 29. Bottom Layer

8.4 CAD Project

To download the CAD project files, see the design files at TIDM-EMETER-CORTEXM3.

8.5 Gerber Files

To download the Gerber files, see the design files at TIDM-EMETER-CORTEXM3.

9 Software Files

To download the software files, please see the link at TIDM-EMETER-CORTEXM3.

10 About the Author

ANIRBAN GHOSH works at TI as an Applications Engineer in the Smart Grid Business Unit for electricity metering and metrology related projects.

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