

PM4301APDA Application Note: Evaluation Module for SA4301A and SA9105G



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PM4301APDA

FEATURES

- Compatible with SA4301A and SA9105G
- Operation from either a single 5V supply or a dual 2.5V supply
- Connection of various current transformers, mains voltage and power supply by means of screw terminals
- On-board LED indicators for pulse output and tamper conditions
- On-board optically isolated pulse output for direct connection to test equipment
- On-board precision calibration networks by means of analog trimpots
- Connection of stepper motor counter or impulse counter by means of screw terminals
- Easily accessible jumpers for setting up all possible device options

DESCRIPTION

The PM4301APDA evaluation module is designed to demonstrate the functionality and performance of the SA4301A and SA9105G energy metering devices. A complete three phase energy meter can be built up and evaluated using this module, thereby allowing the performance of the SA4301A/SA9105G to be evaluated in an end user application. The required current sensing elements, a power supply as well as a stepper motor counter or an impulse counter can be connected by means of screw terminals.

The on-board calibration networks are based on trimpots and allow accurate calibration of the energy meter. The various device options can be selected by means of on-board jumpers, while all device outputs have been equipped with LED indicators for easy evaluation. An opto-isolated pulse output is available for direct connection to any energy meter test equipment.

This application note should be used in conjunction with the datasheet for the specific device that is being evaluated.

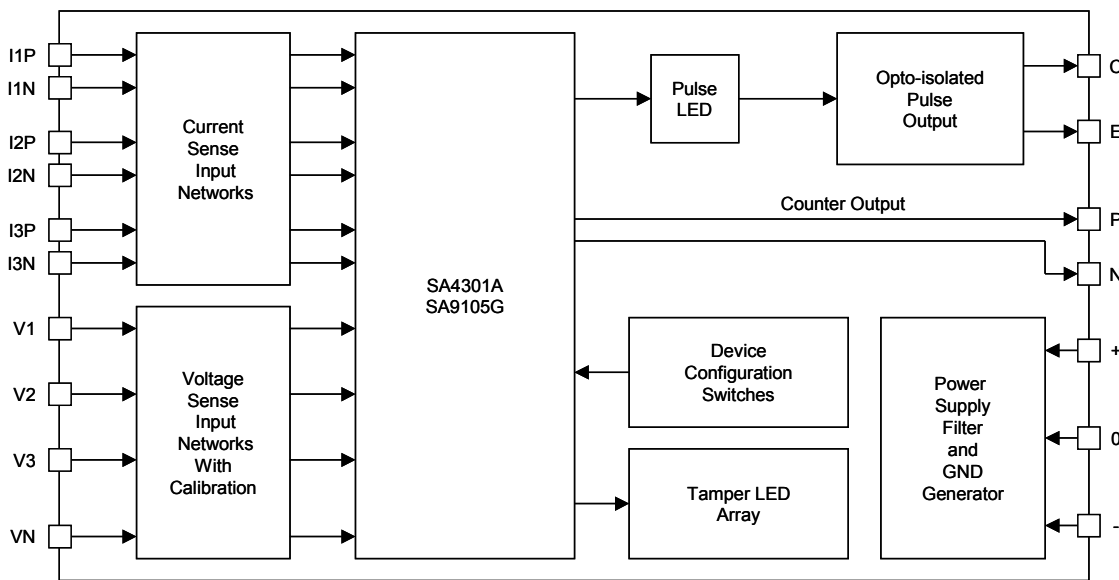


Figure 1: Functional block diagram



ANALOG INPUTS

The most important external circuitry required for the SA4301A/SA9105G are the voltage sense input and current sense input networks. These circuits translate the mains voltages and load currents into signals that can be sensed by the energy metering device. These networks should be constructed using good quality resistors and capacitors to ensure adequate immunity to temperature and noise.

The functions of the current and voltage input networks are the following:

- to sense the load currents and mains voltages and convert them to signals that are appropriate for the SA4301A/SA9105G,
- to allow calibration of the meter,
- to compensate for any phase shift present in the current transformers and
- to filter all high frequency noise and other disturbances in the current and voltage signals in order to maintain adequate accuracy when electromagnetic disturbances are applied to the energy meter.

Current Sense Input Networks

A typical three phase energy metering system has to use current transformers (CTs) as current sensing elements in order to provide the required isolation between the three line voltages. The PM4301APDA has therefore been designed to be used with current transformers as current sensing elements. Three identical current input networks are provided on the evaluation module, one for each phase of a three phase system. All three current input networks should be identical.

The PM4301APDA evaluation module has been set up for a meter with an I_{MAX} of 60A when using a current transformer with a turns ratio of 1:2500. The current input networks can easily be reconfigured for any other I_{MAX} or current transformer turns ratio by simply changing the current transformer burden resistors (R1 and R2) as illustrated in Table 1.

Figure 2 shows the circuit diagram of one current input network as implemented on the PM4301APDA evaluation module (Phase 1) with an external current transformer connected. The circuit is repeated for the other two current input networks.

At maximum rated mains current (I_{MAX}) the current input network should be designed to supply an input current of 16µA_{RMS} to the current sense inputs (IIP1/IIN1, IIP2/IIN2 and IIP3/IIN3) of the SA4301A/SA9105G. The current sense inputs saturate at an input current of ±17.6µA_{RMS} (±25µA_{PEAK}), so this allows about 10% headroom until saturation occurs. Referring to Figure 2, the resistors R1 and R2 form the current transformers termination resistor. The reference level is connected in the centre of the termination resistor to achieve purely differential input currents. The voltage drop across the current transformer termination resistors at maximum rated mains current should be in the order of 100mV_{RMS}. Assuming current transformers with a low phase shift and a turns ratio of 1:2500, the value of the termination resistors R1 and R2 is therefore

$$R1 = R2 = 100mV \times \frac{N_{CT}}{I_{MAX}} \times \frac{1}{2} \approx 2\Omega = R_B$$

where N_{CT} is the current transformer ratio (2500) and I_{MAX} is the maximum rated mains current (60A).

The resistors R3 to R6 define the current flowing into the energy metering device. The optimum input network is achieved by setting the input resistors equal, i.e. setting R3 = R4 = R5 = R6. Noting that the energy metering device creates a virtual short circuit between the differential current sense inputs (IIP and IIN) the values can be calculated as follows:

$$R3 = R4 = R5 = R6 = \frac{I_{MAX}}{N_{CT}} \times \frac{R_B}{2 \times 16\mu A} = 1.5k\Omega = R_C$$

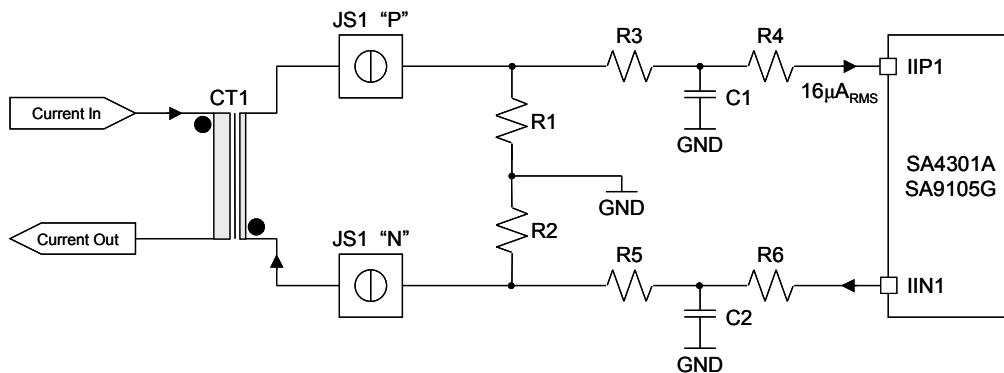


Figure 2: Current channel 1 input network on the PM4301APDA



PM4301APDA

For best immunity to electromagnetic disturbances the SA4301A/SA9105G requires low-pass filters on the current sense inputs. Referring to Figure 2, these filters are realized by means of the capacitors C1 and C2. The typical cut-off frequency of these filters should be between 10kHz and 20kHz. The equivalent resistance associated with each capacitor is $R_C/2$ so the capacitor value should be in the order of

$$C1 = C2 = \frac{1}{\pi f_{Cl} R_C} = \frac{1}{\pi \times 10\text{kHz} \times 1.5\text{k}\Omega} \approx 22\text{nF} = C_C$$

where f_{Cl} is the required cut-off frequency of the low-pass filters of the current input networks.

To reconfigure the PM4301APDA for a different I_{MAX} or a different CT turns ratio typically only the current transformer burden resistors need to be changed. This will then not affect any other characteristics of the current input networks. The new value for the burden resistors can be calculated using

$$R1 = R2 = 2 \times 16\mu\text{A} \times R_C \times \frac{N_{CT}}{I_{MAX}}$$

The values of the burden resistors for some typical values of I_{MAX} when using current transformers with a turns ratio of 1:2500 ($N_{CT} = 2500$) and assuming $R_C = 1.5\text{k}\Omega$ are shown in Table 1, rounded to the nearest available resistor value.

Table 1: Current transformer burden resistors required for some common values of I_{MAX} when using current transformers with a turns ratio of 1:2500 and $R_C = 1.5\text{k}\Omega$

I_{MAX} (A)	Value of Burden Resistors (Ω)
6	20
10	12
20	6.2
25	4.7
30	3.9
40	3
50	2.4
60	2
80	1.5
100	1.2
120	1

Voltage Sense Input Networks

The voltage input networks on the PM4301APDA have been designed for operation at both 220V and 110V mains voltage. The mains voltage is selected by means of jumpers (J1, J2 and J3). The voltage input networks attenuate the mains voltage signals to lower voltages by means of voltage dividers. Trimpots are used to tap these voltage dividers at different levels to effect calibration.

Figure 3 shows the voltage sense input network for channel 1 on the PM4301APDA. The circuit is identical for the other two channels. The voltage sense input saturates at an input current of $\pm 17.6\mu\text{A}_{RMS}$ ($\pm 25\mu\text{A}_{PEAK}$). The current into the voltage sense input should therefore be set between $11\mu\text{A}_{RMS}$ and $12\mu\text{A}_{RMS}$ at nominal mains voltage (V_{NOM}) to allow for a mains voltage variation of up to +30% and -50% without saturating the voltage sense input.

The input resistor R24 sets the current input into the device. This resistor should not be too large else the capacitor for the low-pass filter will be quite small. This could cause inaccurate phase shift due to parasitic capacitances and affect the performance of the module at low power factor. Therefore $R24 = 100\text{k}\Omega$ is chosen. For the purpose of the evaluation module a very large tuning range on the trimpot is selected, so let R23 and P1 be $1\text{k}\Omega$ each and the voltage over the combination of R23 and P1 be 1.76V. This allows the input currents on the voltage sense inputs of the device to be scaled from $17.6\mu\text{A}_{RMS}$ down to $8.8\mu\text{A}_{RMS}$.

The following equations can be used to obtain the remaining resistor values:

$$1.76\text{V} = 220\text{V} \frac{2\text{k}\Omega}{R19 + R20 + R21 + R22 + 2\text{k}\Omega}$$

and

$$1.76\text{V} = 110\text{V} \frac{2\text{k}\Omega}{R19 + R20 + 2\text{k}\Omega}$$

This results in $R19 + R20 = 123\text{k}\Omega$ and $R21 + R22 = 125\text{k}\Omega$ and the values are chosen as $R19 = 75\text{k}\Omega$, $R20 = 47\text{k}\Omega$, $R21 = R22 = 62\text{k}\Omega$. The effect of R24 can be ignored in the above equations, given the fact that R24 is significantly larger than the combination of P1 and R23.

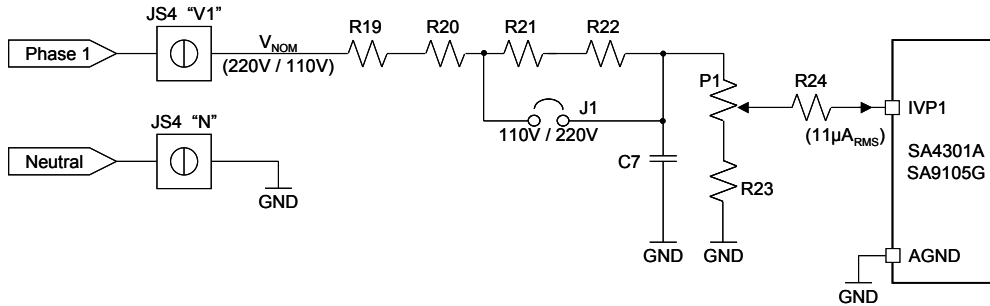


Figure 3: Voltage channel 1 input network on the PM4301APDA

Low-pass filters are required on the voltage sense inputs to remove any high frequency signals that could affect the performance of the SA4301A/SA9105G. The phase shift of the current transformers is compensated by means of these low-pass filters as well, by purposefully increasing the cut-off frequency.

Referring to Figure 3, the capacitor C7 is used to both implement the high frequency filtering as well as compensating for any phase shift caused by the current transformer. The cut-off frequency of the filter is adjusted so that the phase shift of the voltage input network is identical to the sum of the phase shifts of the current transformer and the current input network. The PM4301APDA module has been set up to compensate for a phase shift of 0.09 degrees at 50Hz. This can be changed by changing the capacitors on the voltage input networks (C7, C8, C9). The new capacitor value can be calculated by adapting the following calculation as required.

The phase shift of the current input network is

$$\phi_{II} = -\arctan(\pi R_C C_C \times 50\text{Hz}) \approx -0.297 \text{ degrees}$$

The phase shift required on the voltage input networks is therefore

$$\phi_{IV} = \phi_{II} + \phi_{CT} = -0.297 + 0.09 = -0.207$$

where ϕ_{CT} is the phase shift of the current transformer which is typically between about 0.05 degrees and 0.5 degrees for a good quality current transformer. Neglecting R19, R20, R21, R22 and R24 because all these resistors are significantly larger than P1 and R23, the capacitance required to achieve the -0.207 degree phase shift is

$$C7 = \frac{|\tan \phi_{IV}|}{2\pi(P1 + R23) \times 50\text{Hz}} \approx 5.6\text{nF}$$

resulting in a cut-off frequency of

$$f_{CV} = \frac{1}{2\pi(P1 + R23) \times C7} \approx 13.7\text{kHz}$$

The value of the cut-off frequency of the voltage input network is less critical than that of the current input networks because the dynamic range of the voltage input is small. A cut-off frequency between 10kHz and 25kHz is acceptable.

POWER SUPPLY

The PM4301APDA has an on-board filtered voltage divider to allow the evaluation board to be used with a single 5V supply. The ground level GND which represents the reference level of the meter (connected to NEUTRAL of the mains voltage) can be generated by the on-board voltage divider. This level is also connected to the AGND pin of the energy metering device. If the module is used in conjunction with a dual 2.5V supply then the on-board voltage divider is simply overdriven by the external supply. The centre point of the split supply is the reference level of the energy meter.

REFERENCE VOLTAGE

The on-chip reference currents of the SA4301A/SA9105G are determined by the bias resistor R37. This resistor must be 47kΩ to set optimum bias conditions for the analog circuits of the energy metering device.

LED OUTPUTS

The PM4301APDA is equipped with LEDs to display the various outputs of the SA4301A/SA9105G. These are the pulse output and the per phase mains voltage and direction indicators. The LEDs can be disconnected if not required.

TESTPOINTS

Test points for several signals are located on the PM4301APDA evaluation board. These test points allow certain critical signals on the current and voltage input networks to be measured. Test points for the meter reference level (GND) and the power supplies are also present.



SETTING UP THE PM4301APDA

The PM4301APDA evaluation board can be set up for the various functionality of the SA4301A/SA9105G through jumpers. The function of each jumper is described in Table 2. The connection of the jumpers corresponds to the markings on the evaluation board.

Table 2: Jumper functionality for the PM4301APDA

Jumper	Description
J1, J2, J3	Mains Voltage Selection: These jumpers are used to select the mains voltage of the system. They are left open when the mains voltage is 220V and should be closed when 110V mains voltage is used.
J4, J5, J6	RA Selection: These three jumpers are used to set the value of the RA input pin to select the various pulse output dividers for the SA4301A/SA9105G and to select the enabled channel when the device is placed in single phase calibration mode. Closing J4 sets RA to V _{DD} , closing J5 sets RA to V _{SS} and closing J6 sets RA to PH/DIR. Leaving all three jumpers open sets RA to a floating condition. Only one of these jumpers should be closed at a time.
J7, J8, J9	RB Selection: These three jumpers are used to set the value of the RB input pin to select the various pulse output dividers. Closing J7 sets RB to V _{DD} , closing J8 sets RB to V _{SS} and closing J9 sets RB to PH/DIR. Leaving all three jumpers open sets RB to a floating condition. Only one of these jumpers should be closed at a time.
J10, J11, J12	MS Selection: These three jumpers are used to set the value of the MS input pin to select the mode of the programmable adder. Closing J10 sets MS to V _{DD} to enable absolute sum mode, closing J11 sets MS to V _{SS} to enable total sum mode and closing J12 sets MS to PH/DIR to enable import energy only summing mode. Leaving all three jumpers open sets MS to a floating condition and single phase calibration mode is enabled. Only one of these jumpers should be closed at a time.
J13	FMS Selection: This jumper is used to set the value of the FMS pin and can be set to "0" to set FMS to V _{SS} or "1" to set FMS to V _{DD} . This jumper can be left open to set FMS to a floating condition to enable FAST mode on the SA4301A/SA9105G.
J15, J16, J17, J18	Tamper Enable: These jumpers allow the LED tamper indicator array to be disconnected from the SA4301A/SA9105G. If all four jumpers are closed the LED array is fully functional.
J20	LED Enable: This jumper can be used to disable the pulse output of the evaluation board. Leaving this jumper open will disable the PULSE LED as well as the PULSE opto-isolated output (JS6).
J22, J23	Counter Enable: These jumpers can be used to disable and configure the external energy counter that is connected to the COUNTER output (JS7). Leaving both jumpers open disconnects the counter from the energy metering device. Closing J22 and setting J23 to "A" configures the COUNTER output to accommodate a stepper motor counter by connecting the COUNTER terminal to MON and MOP of the energy metering device. Closing J22 and setting J23 to "B" configures the COUNTER output to accommodate an impulse counter by connecting the COUNTER terminal to MON of the energy metering device and V _{SS} .

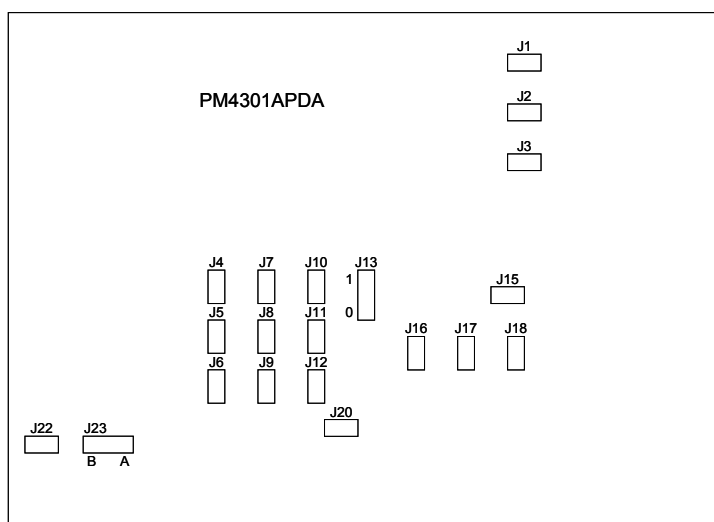


Figure 4: Layout of jumpers on the PM4301APDA



EXTERNAL CONNECTIONS TO THE PM4301APDA

The PM4301APDA evaluation board has external connectors to connect the various equipment required to evaluate the SA4301A/SA9105G in an end user application. The external connectors are described in the Table 3. The connection points correspond to the markings on the evaluation board. Figure 5 illustrates the connection of the PM4301APDA to test equipment.

Table 3: External connectors on the PM4301APDA

Connector	Description
JS1, JS2, JS3	Connection Points for Current Transformers: Connect the current transformers for the three phases to these connectors. The current transformers should be connected in such a way that a positive current flows "in" on terminal "P" and "out" on terminal "N".
JS4	Connection Point for Mains Voltage: The three phase mains voltage must be connected on this connector. The NEUTRAL line should be connected to terminal "N" and the three LIVE voltages should be connected to "V1", "V2" and "V3" for the three phases respectively.
JS5	Connection Point for Power Supply: The power supply to the PM4301APDA should be connected at this connector. A single 5V supply can be connected between the "+" and "-" terminals or a dual 2.5V supply can be connected to the "+", "0" and "-" terminals.
JS6	Connection Point for Pulse Output: This connector is used to access the opto-isolated pulse output. The emitter and collector output terminals of the opto-coupler are marked "E" and "C" respectively. No pull-up resistor is present on the PM4301APDA. The pulse output is primarily used for performance evaluation and calibration of the SA4301A/SA9105G.
JS7	Connection Point of Energy Counter: A stepper motor counter or impulse counter can be connected to this connection point to register the energy measured by the SA4301A/SA9105G. When an impulse counter is used the positive and negative terminals of the counter should be connected to the "P" and "N" terminals respectively.
J14	Tamper Output: This connector contains the signals PH3 ("3"), PH2 ("2"), PH1 ("1") and PH/DIR ("PD") and is useful for interfacing the mains fail and direction indicators to a separate system, i.e. a micro-controller.
J19	LED Output: This connector contains the LED output of the device (centre terminal) as well as the V _{DD} and V _{SS} power supply voltages of the PM4301APDA. This terminal is useful when interfacing the pulse output to external circuitry such as an alternative opto-coupler or a micro-controller.
J21	Motor Output: This connector contains the MON ("N") and MOP ("P") outputs of the device as well as the V _{DD} ("1") and V _{SS} ("0") power supply voltages of the PM4301APDA. This terminal is useful when interfacing the counter outputs to external energy registration circuitry or a micro-controller.

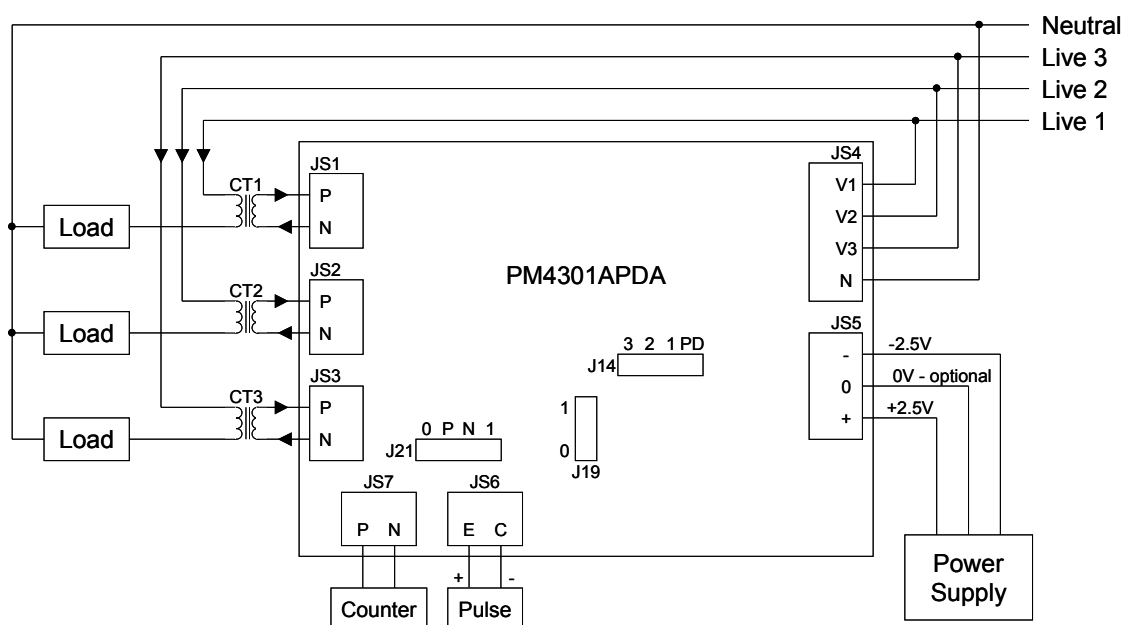


Figure 5: Connecting the PM4301APDA to test equipment



CALIBRATING THE PM4301APDA

The PM4301APDA is best calibrated by making use of the single phase calibration mode of the SA4301A/SA9105G. The module has to be calibrated phase by phase by means of the respective trimpots P1, P2 and P3. The following procedure should be used.

1. Connect the module to the test system and set up the rated conditions and programmable adder mode as required using the jumpers for RA, RB, FMS and MS. Selecting the required meter constant and programmable adder mode is fully described in the datasheets of the SA4301A or SA9105G.
2. Power up the module.
3. Set the energy metering device to single phase calibration mode (J10, J11 and J12 open) and select channel 1 (J5 closed, J4 and J6 open).
4. Set the mains voltage and load current on channels 2 and 3 to zero and apply the mains voltage and required load current to channel 1.
5. Channel 1 can now be calibrated by means of P1 until the error is zero.
6. Select channel 2 in single phase calibration mode (J4 closed, J5 and J6 open).
7. Set the mains voltage and load current on channels 1 and 3 to zero and apply the mains voltage and required load current to channel 2.
8. Channel 2 can now be calibrated by means of P2 until the error is zero.
9. Select channel 3 in single phase calibration mode (J4, J5 and J6 open).
10. Set the mains voltage and load current on channels 1 and 2 to zero and apply the mains voltage and required load current to channel 3.
11. Channel 3 can now be calibrated by means of P3 until the error is zero.
12. Set RA and MS back to the values required for meter operation. The module is now calibrated.



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PM4301APDA CIRCUIT SCHEMATIC

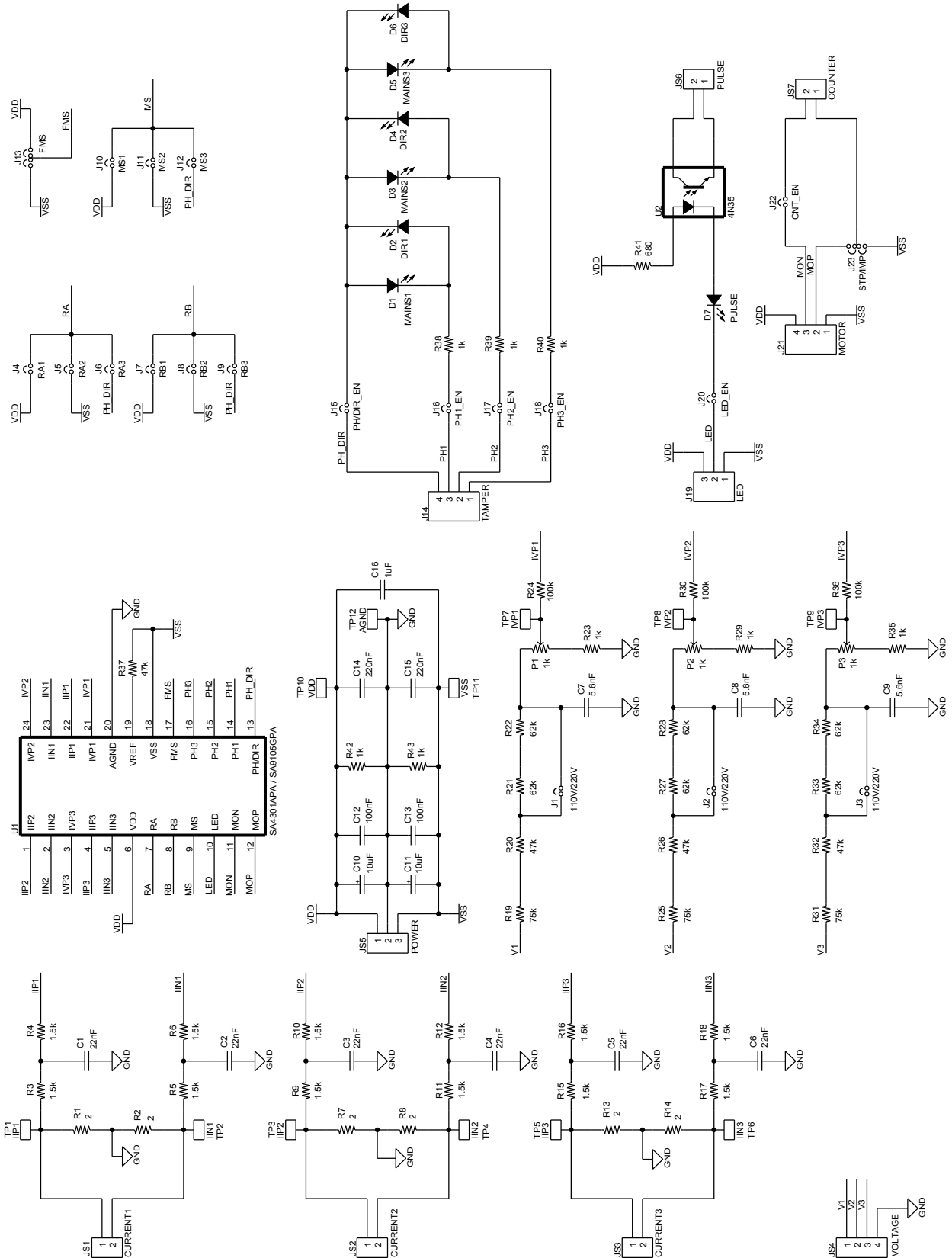


Figure 6: Circuit schematic for the PM4301APDA



PM4301APDA COMPONENT LIST

Table 4: Component list for the PM4301APDA

Symbol	Description
U1	24-pin DIP IC socket, tulip type
U1	Energy metering device from SAMES, SA4301APA or SA9106GPA
U2	6-pin DIP IC socket, tulip type
U2	Opto-coupler, 1N35
R1 ¹ , R2 ¹	Resistor, 2Ω, 1%, 1/4W, metal film
R3, R4, R5, R6	Resistor, 1.5kΩ, 1%, 1/4W, metal film
R7 ¹ , R8 ¹	Resistor, 2Ω, 1%, 1/4W, metal film
R9, R10, R11, R12	Resistor, 1.5kΩ, 1%, 1/4W, metal film
R13 ¹ , R14 ¹	Resistor, 2Ω, 1%, 1/4W, metal film
R15, R16, R17, R18	Resistor, 1.5kΩ, 1%, 1/4W, metal film
R19, R25, R31	Resistor, 75kΩ, 1%, 1/4W, metal film
R20, R26, R32	Resistor, 47kΩ, 1%, 1/4W, metal film
R21, R22, R27, R28, R33, R34	Resistor, 62kΩ, 1%, 1/4W, metal film
R23, R29, R35	Resistor, 1kΩ, 1%, 1/4W, metal film
R24, R30, R36	Resistor, 100kΩ, 1%, 1/4W, metal film
R37	Resistor, 47kΩ, 1%, 1/4W, metal film
R38, R39, R40	Resistor, 1kΩ, 1%, 1/4W, metal film
R41	Resistor, 680Ω, 1%, 1/4W, metal film
R42, R43	Resistor, 1kΩ, 1%, 1/4W, metal film
P1, P2, P3	Trim-pot, 25 turns, top adjust, 1kΩ
C1, C2, C3, C4, C5, C6	Capacitor, 22nF, ceramic
C7 ² , C8 ² , C9 ²	Capacitor, 5.6nF, ceramic
C10, C11	Capacitor, 10μF, electrolytic
C12, C13	Capacitor, 100nF, ceramic
C14, C15	Capacitor, 220nF, ceramic
C16	Capacitor, 1μF, ceramic
D1, D2	3mm light emitting diode, red
D3, D4	3mm light emitting diode, yellow
D5, D6	3mm light emitting diode, green
D7	3mm light emitting diode, red
JS1, JS2, JS3	2-way screw terminal
JS4	4-way screw terminal
JS5	3-way screw terminal
JS6, JS7	2-way screw terminal

Note 1: Resistors R1, R2, R7, R8, R13 and R14 must be changed when redesigning the PM4301APDA for an I_{MAX} other than 60A or when using current transformers with a winding ratio other than 1:2500.

Note 2: Capacitors C7, C8, C9 must be changed when the phase shift of the current transformers is changed from 0.09 degrees.

*Table 4: Component list for the PM4301APDA (continued)*

Symbol	Description
J1, J2, J3	2 single inline pins
J4, J5, J6	2 single inline pins
J7, J8, J9	2 single inline pins
J10, J11, J12	2 single inline pins
J13	3 single inline pins
J14	4 single inline pins
J15, J16, J17, J18	2 single inline pins
J19	3 single inline pins
J20	2 single inline pins
J21	4 single inline pins
J22	2 single inline pins
J23	3 single inline pins
TP1, TP2, TP3, TP4, TP5, TP6	1 single inline pin
TP7, TP8, TP9	1 single inline pin
TP10, TP11, TP12	1 single inline pin



PCB LAYOUT

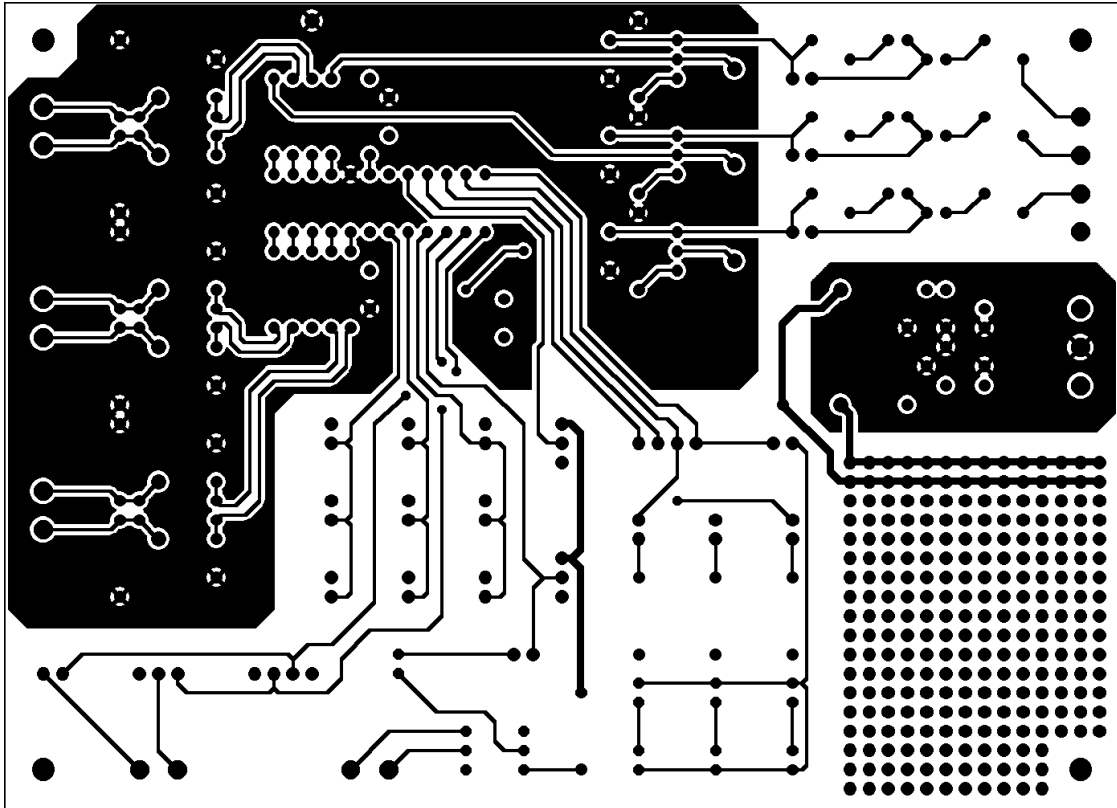


Figure 7: Top layer of PCB (scale 1:1)

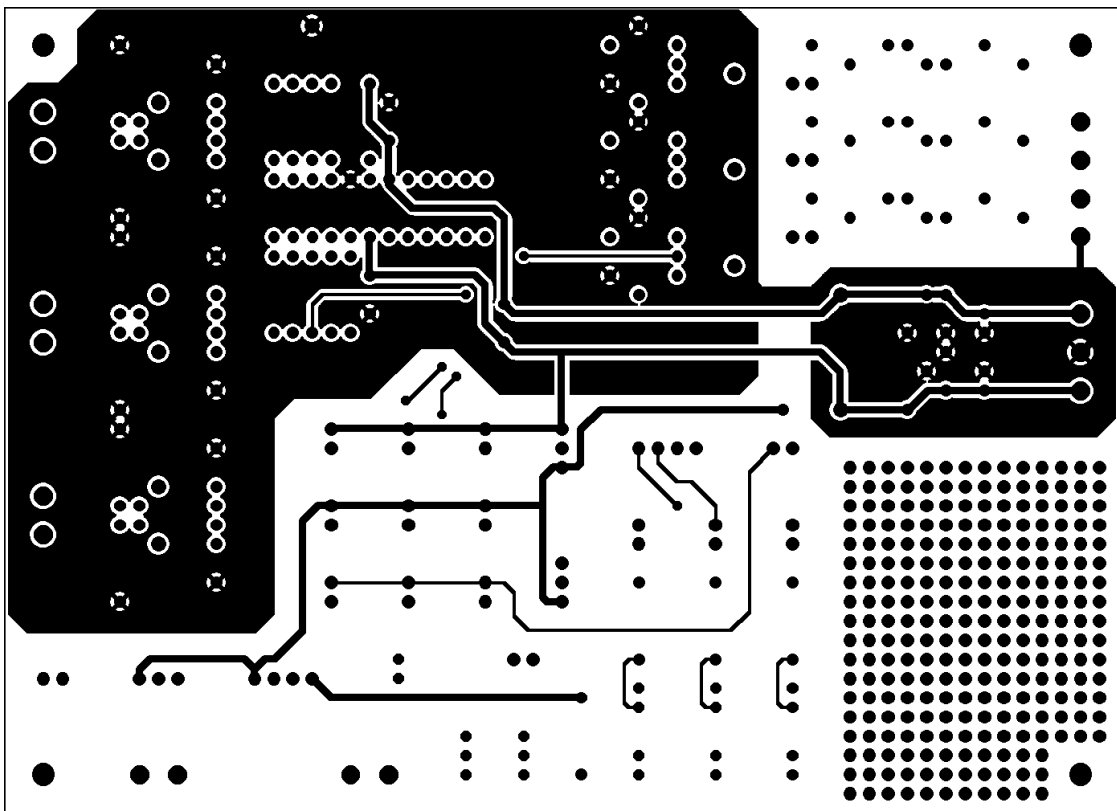


Figure 8: Bottom layer of PCB (scale 1:1)

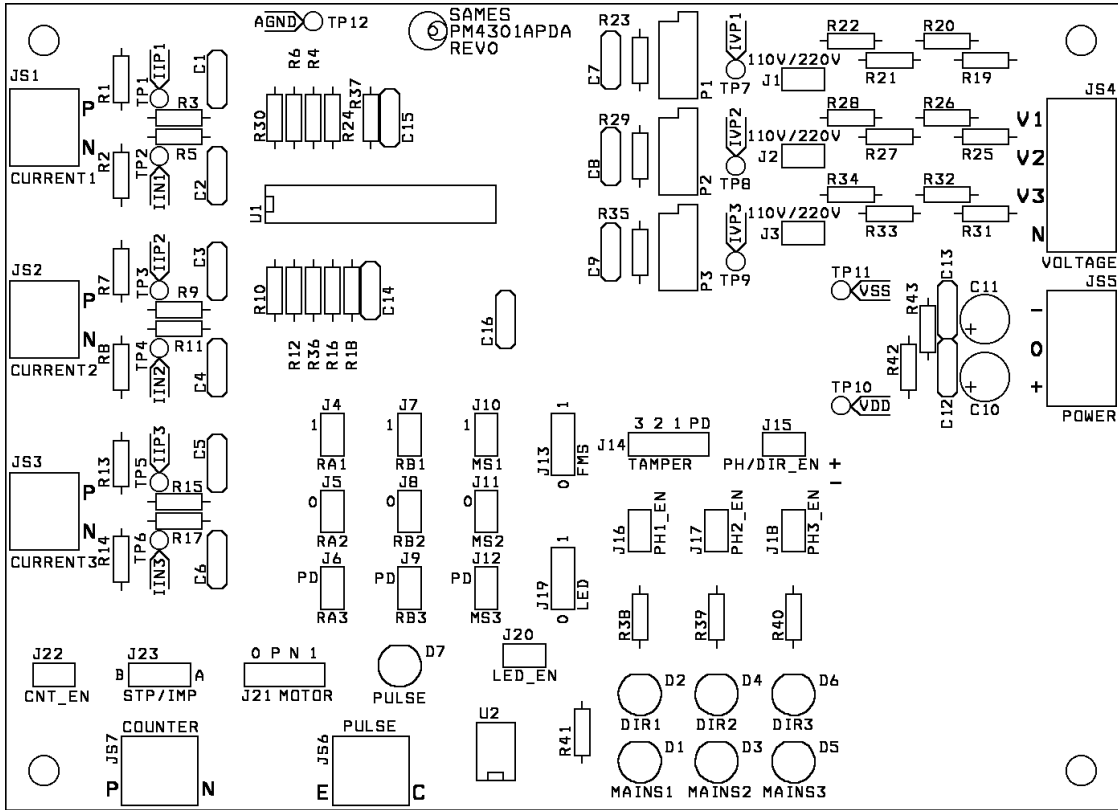


Figure 9: Top silkscreen layer of PCB (scale 1:1)

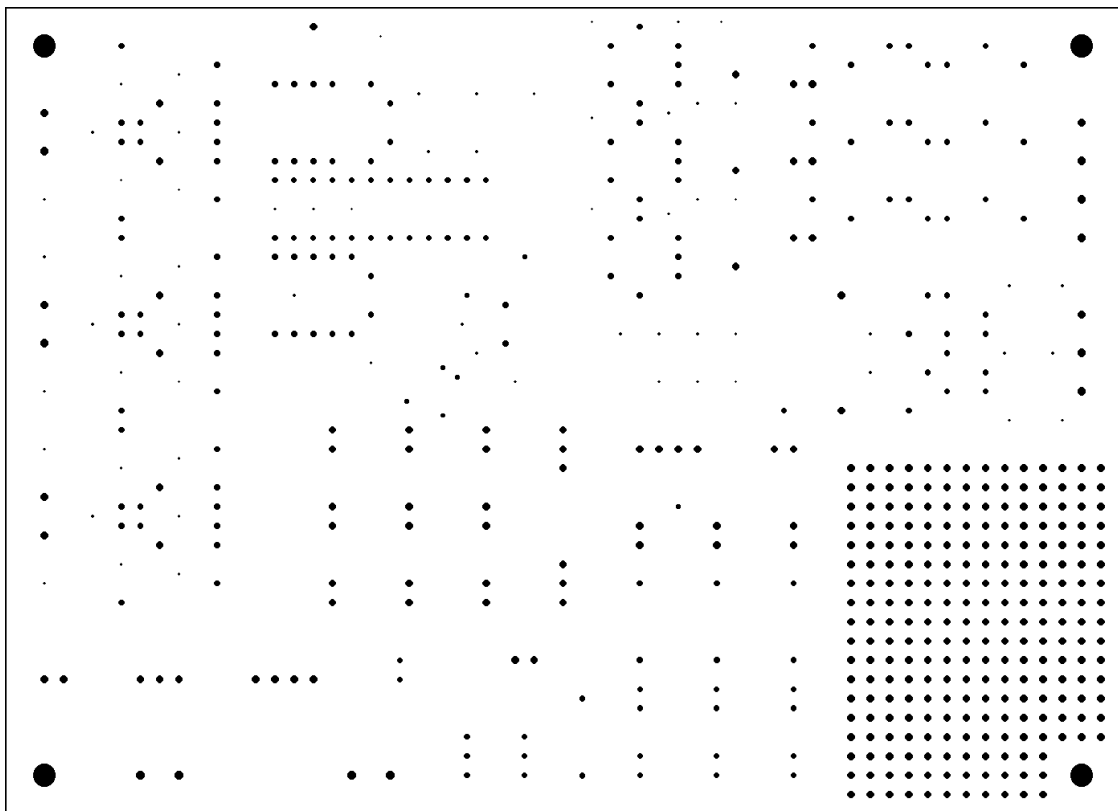


Figure 10: Drill layer of PCB (scale 1:1)



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