PM2102DPD Application Note: Energy Meter Evaluation Module

PM2102DPD

FEATURES

- Meets the IEC 61036 / 60687 accuracy requirements for class 0.5 active energy measurement
- Uni-directional and Bi-directional power and energy measurement
- Current sensing via on-board shunt or CT.
- Selectable rated conditions, LED pulse rates and counter resolutions
- On-board precision calibration
- On-board impulse counter or drive facility for stepper-driven counters
- Energy flow indicator
- On-board capacitive supply
- Easy accessible test pins

INTRODUCTION

This application note describes the SAMES PM2102DPD application module to demonstrate the use of the SA2102D as a low cost, accurate watt-hour meter.

The PM2102DPD module surpasses the accuracy requirements as quoted in IEC 60687 class 0.5 specification for both unity and ±0.5 power factor over a dynamic range of 800.

The measured energy consumption is displayed by means of an on-board counter. Provision has been made for a stepper motor counter to be connected. The Pulse LED is used for calibration purposes, its pulse rate can be selected for either normal or fast operation. When in normal operation, the pulse rate is a low frequency and is proportional to the average power consumption. In fast mode the LED pulse output is set at a high frequency and is proportional to the instantaneous power consumption. This mode is useful for faster calibration times. The Direction LED is used to indicate the energy direction.

The metering module can easily be configured for a broad range of pulse constants at different meter ratings. Various examples and standard tables are presented in this application note.

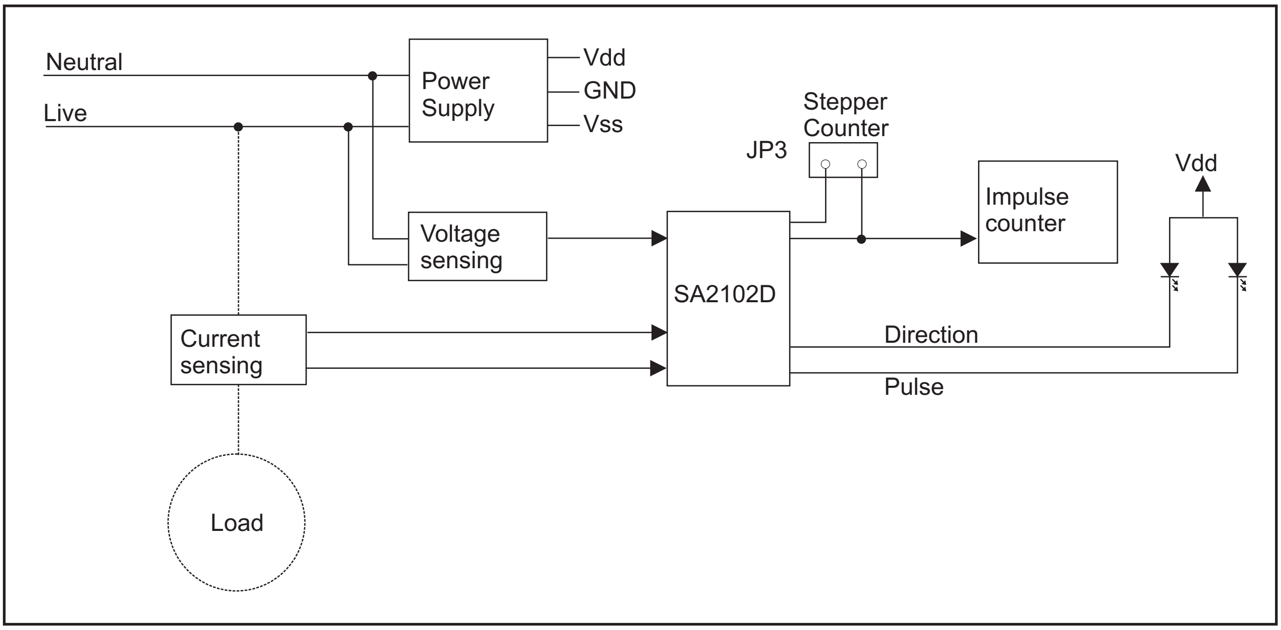

Figure 1: Block Diagram

ANALOG INPUT

The PM2102DPD module connects directly to Live and Neutral supply lines by means of a Molex connector (SCK1), and the current is measured by using a shunt on the module. The live is connected to the left terminal of the shunt and live out to the right (as seen in Fig 2 below). The module is setup for a 80A, 220V shunt sensing application using a 625µΩ shunt.

Please take note that the module is referenced to live, and care must be taken when connecting non-isolated test equipment to the module.

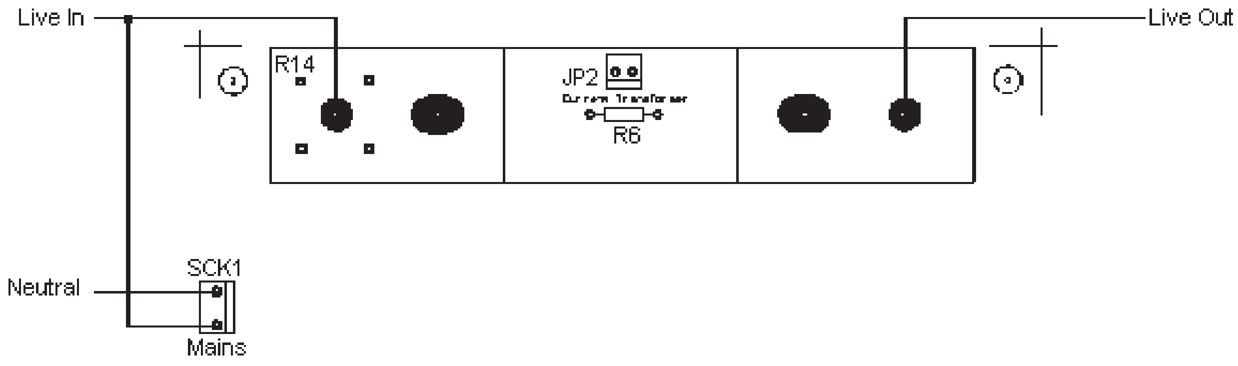

Figure 2: Current and mains voltage connection diagram

As an option a stepper motor counter can be directly connected to JP3 and JP2 is used to connect a CT as current sensing element.

Name	Function Description
SCK1	Mains connector for module power and voltage sense
JP2	Optional current transformer connector. (Underneath shunt resistor)
JP3	Optional Stepper motor connector. (Remove jumper J6 to disconnect impulse counter)

Table 1: External connector descriptions

The selection and positioning of the current and voltage sense resistors as well as the biasing resistor is very important to ensure the correct operation of the SA2102D. These resistors must be of the same type as specified in the parts list to ensure that temperature effects and noise susceptibility is minimized.

VOLTAGE INPUT IVP

The voltage input of the SA2102D is driven with a current of 14µA_{RMS} at the nominal rated main voltage. Please note that this input will saturate with currents bigger than approximately 17µA_{RMS} or 25µA_{peak}, which translates into a 20% overdrive capability. This also ensures that the device will not saturate with a 10% variance in mains voltage. The mains voltage is divided down via a resistor network (see Figure 3) to 14V. This voltage is fed to a 1MΩ resistor (R12) to realize the 14µA_{RMS}

The resistor values are chosen in such a way that shorting jumper J16 halfs the voltage on the voltage divider output. This feature makes the module compatible for both 220V and 110V supply networks.

Ignoring jumper J16 the values of RA and RB can be calculated as follows:

RA = R1 + R2 + R3 + R15
RB = R12 || (R11 + 0.5P1)

The center position of P1 is used in the equation to ensure that calibration can be done by adjusting P1 to a higher or lower value.

Combining the two equations gives:
(RA + RB) / 220V = RB / 14V

Values for resistors were selected as R10 = 47Ω, R11 = 22kΩ, P1 = 10kΩ and R12 = 1MΩ.
Substituting the values result in:

RB = 26.29kΩ
RA = RB x (220V / 14V -1)
RA = 386.84kΩ

Choosing standard resistor values for R1, R2, R3, R15 and keeping in mind that J16 must half the output voltage lead to the following values:

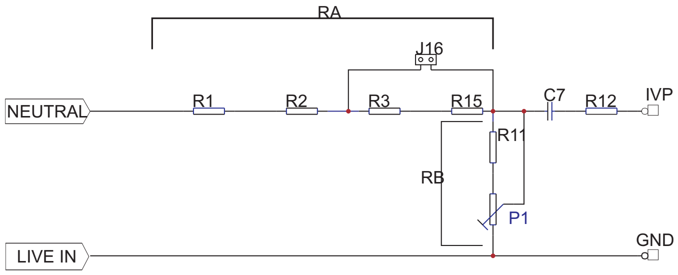

Figure 3: Voltage divider circuit

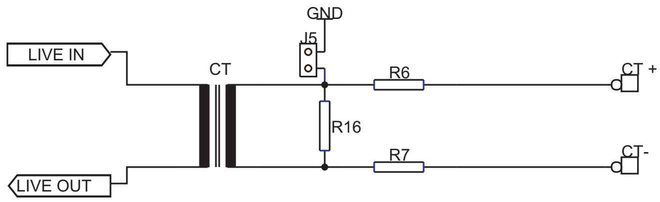

Figure 4: Current sensing using a CT

R1 = R3 = 82kΩ and
R2 = R15 = 100 kΩ.

Current Sense Input

Resistors R6 and R7 (figure 4 and figure 5) define the current at the current sense inputs of the SA2102D. The PM2102DPD module uses a 625μΩ shunt. At I_{max} (80A) the voltage drop across the shunt will be 50mV. To ensure proper current sensing it is advisable to use a shunt that will give a voltage drop of at least 20mV at I_{max}. The resistor values are calculated for an input of 16μA_{RMS} on the current sense inputs at I_{max} (see Figure 5). The design equation is as follows:

$R6 = R7 = (I_L / 16\mu A) \times R_{SH} / 2$

I_L = Line current
R_{SH} = Shunt value

Also see the section on **SETUP EXAMPLES**.

Sensing Method (CT or SHUNT)

Provision is made for the use of either a Current Transformer (CT) or a Shunt on the application module. The module is by default setup for a shunt, which must be removed if a CT is chosen as the sensing device. When using a CT, the terminating resistor (R16), phase compensation capacitor (C7) and jumper (J5) must be inserted. The jumper references one side of the CT to ground for sensing. The current sensing resistors (R6 and R7) must be changed according to the equation stated below (see Figure 4):

$R6 = R7 = (I_L / 2500 / 16\mu A) \times R_{terminating} / 2$

I_L = Line current
CT ratio = 1:2500

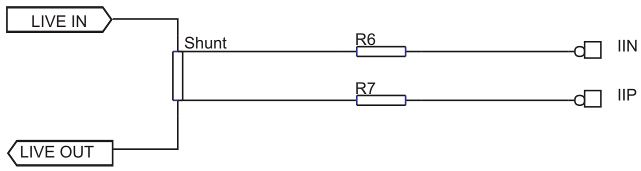

Figure 5: Current sensing using a shunt

The capacitor C7 is inserted to correct or compensate for the phase shift caused by the current transformer. The following equationshows how to calculate the capacitor value for a phase shift of 0.18 degrees.

$C = 1 / (2 \times \pi \times \text{Mains frequency} \times R12 \times \tan(\text{Phase shift angle}))$
$C = 1 / (2 \times \pi \times 50 \times 1M \times \tan(0.18 \text{ degrees}))$
$C = 1.013\mu F$

Also see the section on **SETUP EXAMPLES**.

A CT with a low phase shift and a ratio of 1:2500 is recommended for optimum module performance.

Name	Option	Description
J1	VSS (-)	Connecting to VSS will allow only negative energy to be measured.
	VDD (+)	Connecting to VDD will allow only positive energy to be measured.
	J2	Connecting to jumper J2 will allow bi-directional energy measurement.
J2	J1	Connected to J1 allows for bi-directional energy measurement.
J3	N/A	These are digital test pins placed immediately next to the device for convenient testing.
J4	N/A	These are digital test pins placed immediately next to the device for convenient testing.
J5	Closed	This jumper must be closed when measurement is done via a CT. The jumper connects one side of the current sense resistor to ground.
	Open	Leave this jumper open when a shunt is used.
J6	Closed	Closing this jumper enables the onboard mechanical counter.
	Open	Leave unconnected if the onboard mechanical counter is not to be used, or if a stepper motor counter is used.
J7 (Used in conjunction with J8)	Open	This jumper connects the VDD rail of the onboard power supply to the rest of the circuit. Leave open if an external source is to be used.
	Closed	This jumper must be closed to connect the onboard power supply VDD rail to the circuit.
J8 (Used in conjunction with J7)	Open	This jumper connects the VSS rail of the onboard power supply to the rest of the circuit. Leave open if an external source is to be used.
	Closed	This jumper must be closed to connect the onboard power supply VDD rail to the circuit.
J11	VDD (+) VSS	Used to select the required rated conditions. See table 3 and figure 6 for further detail on the various settings possible.
J12	VDD (+) VSS	Used to select the required rated conditions. See table 3 and figure 6 for further detail on the various settings possible.
J13	VDD (+) VSS	Used to select the required rated conditions. See table 3 and figure 6 for further detail on the various settings possible.
J14	VSS	Used to select between fast and normal pulse output mode. When connected to VSS the normal pulse output mode is selected.
	VDD (+)	Connection to VDD selects the fast output pulse mode.
J15	VSS	This selects the IC manufacturers test mode for normal metering. Connect to VSS.
J16	Open	This jumper selects between 220V and 110V supply networks. Leaving this jumper open (default) selects a 220V network.
	Closed	Closing this jumper selects a 110V network. **See power supply design when opting for the 110V setting.**
J17	N/A	This is a test pin connected to the VDD power supply. If opting for an external supply, the VDD rail can be connected here after J7 is removed.
J18	N/A	Ground connection pin. Use this pin to connect the external supply mid-rail point.
J19	N/A	This is a test pin connected to the VSS power supply. If opting for an external supply, the VSS rail can be connected here after J8 is removed.
SO	VSS (-)	When fast mode is selected this input can be used to enable or disable the internal pulse stability circuitry for the LED output pulses. Connecting to VSS disables this circuitry.
	VDD (+)	Connecting to VDD enables this circuitry.

Table 2: Jumper options

Analog Ground (GND)
The GND pin of the SA2102D is connected to the live phase, which is halfway between V_{DD} and V_{SS}.

The PM2102DPD evaluation module comes with several jumper selections, which allows the user to evaluate all of the SA2102D's functionality. Tables 1 and 2 describe the various jumper options. These tables should be used in conjunction with figure 6, which will make it easier to locate the appropriate jumper.

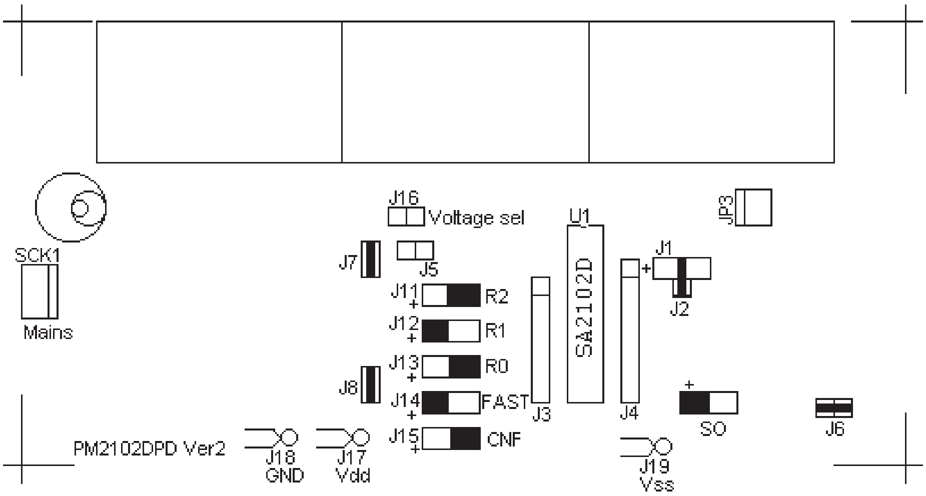

Figure 6: Jumper positions
For selection as indicated: Pulse stability enabled, fast mode with power supply enabled

Selection of R1, R2 and R0 for different rated conditions
The following equations and table state the basic pulse constants and motor constants obtainable with the PM2102DPD meter.

The Output pulse equation is:

LED p/kWh = 1160p/sec x (1/DF_LED) x [3600/((Vnom x Imax) / 1000)]

The equation for the motor constant is:
MOTOR p/kWh = LED p/kWh / DF_MO

where dividing factors **DF_LED** and **DF_MO** are described in Table 3 (R2, R1 and R0 are input pins for SA2102D).

R2	R1	R0	DF_LED	DF_MO
0	0	0	322	64
0	0	1	322	32
0	1	0	322	16
0	1	1	322	8
1	0	0	536	64
1	0	1	214	16
1	1	0	214	8

Table 3: DF_LED and DF_MO factors for SA2102D

In the above table a “1” implies that the selector is connected to VDD.

SETUP EXAMPLES

The following examples can be used for the setup conditions indicated.

Example 1

Rated voltage: 220V
Rated current: 80A
Sensing element: SHUNT (80A, 50mV, 625µΩ)
Pulse constant: 800 imp/kWh
Motor constant: 100 imp/kWh

Calculate R6 and R7:

R6 = R7 = (IL / 16µA) x RSH / 2
= 80A / 16µA x 625µΩ / 2.
= 1.5625 kΩ

A standard value of 1K6Ω is chosen.

The pulse constant is derived from the equation below:

LED p/kWh = 1160 p/sec x 1 / DF_LED) x [3600 / ((Vnom x Imax) / 1000)]
= 1160 p/sec x 1 / DF_LED) x [3600 / (220 x 80) / 1000]
800 = 1160 p/sec x (1 / DF_LED) x 204.54
1 / DF_LED = 0.0033717
DF_LED = 296

MOTOR p/kWh = LED p/kWh / DF_MO
100 = 800 / DF_MO
DF_MO = 8

Thus using table 3, we see that R0 = 1, R1 = 1, and R2 = 0.

Example 2

Rated voltage: 220V
Rated current: 20A
Sensing element: SHUNT (80A, 50mV, 625µΩ)
Pulse constant: 3200 imp/kWh
Motor constant: 100 imp/kWh

Calculate R6 and R7:

R6 = R7 = (IL / 16µA) x RSH / 2
= 20A / 16µA x 625µΩ / 2.
= 390.625 Ω

A standard value of 390Ω is chosen.

The pulse constant is derived from the equation below:

LED p/kWh = 60p/sec x (1 / DF_LED) x [3600/((Vnom x Imax)/1000)]
= 1160 p/sec x (1 / DF_LED) x [3600 / (220 x 20) / 1000]
3200 = 1160 p/sec x (1 / DF_LED) x 818.18
1 / DF_LED = 0.003371
DF_LED = 296

MOTOR p/kWh = LED p/kWh / DF_MO
100 = 320 / DF_MO
DF_MO = 32

Thus using table 3, we see that R0 = 1, R1 = 0, and R2 = 0.

Example 3

Rated voltage: 220V
Rated current: 40A
Sensing element: CT (80A max rated, 1:2500 low phase shift internal impedance of 50Ω)
Pulse constant: 1600 imp/kWh
Motor constant: 100 imp/kWh

When a CT is to be used as the sensing element, the terminating or burden resistor (R16) must also be calculated and inserted.

R16 is dependent on the type of CT used and can normally be found on a CT datasheet specified as "burden resistor, Rb".

The terminating or burden resistor for the TZ76V CT is 5.4Ω yielding 86.4mV at 40A rated.

Please note that there should ideally be a voltage drop of 86.4mV but not less than a minimum of 20mV across the burden resistor at I_{max}

Calculate R6 and R7:

R6 = R7 = (IL / 2500 / 16µA) x Rterminating / 2
= 40 / 2500 / 16µA x 5.4 / 2
= 2700Ω

IL= Line current
CT ratio = 2500

A standard value of 2K7Ω is chosen.

The compensating capacitor C7 is calculated next for a phase shift of 0.18 degrees.

C = 1/ (2 x π x mains frequency x R12 x tan (Phase shift angle))
C = 1/ (2 x π x 50 x 1M x tan (0.18 degrees))
C = 1.013µF

Use a standard value 1µF non-polar electrolytic capacitor with a working voltage of at least 16V.

The pulse constant is derived from the equation below:

LED p/kWh = 1160p/sec x (1 / DF_LED) x [3600/((Vnom x Imax)/1000)]
= 1160 p/sec x (1 / DF_LED) x[3600 / (220 x 40) / 1000]
1600 = 1160 p/sec x (1 / DF_LED) x 409.0
1 / DF_LED = 0.003372
DF_LED = 296

MOTOR p/kWh = LED p/kWh / DF_MO
100 = 1600 / DF_MO
DF_MO= 16

Therefore from table 3, R0 = 0, R1 = 1, and R2 = 0.

Standard meter constants for various rated conditions
The following table list the most common and frequently used pulse and motor constants for different rated conditions. This is an easy reference for meter manufacturers, and the constants not listed can be calculated from the equations provided in the previous examples.

R2	R1	R0	Rated Condition (V / I)	LED Output (p/kWh)	MON, MOP (p/kWh)
0	0	0	220/10A	6400	100
0	0	1	220/20A	3200	100
0	1	0	220/40A	1600	100
0	1	1	220/80A	800	100
1	0	0	220/6A	6400	100
1	0	1	220/30A	3200	100
1	1	0	220/60A	1600	100

Table 4: Different meter constants

Module Calibration
The output frequency can be adjusted and calibrated by means of the variable resistor P1 connected in the voltage divider as shown in figure 3 on page 3.

PCB Design considerations
These are a number of aspects to consider when designing a PCB for a power/energy meter application. Only a few of the more critical aspects are discussed here.

The sense resistors on the current input, R6 and R7 must be located as close to the SA2102D-input pins as possible. This also holds true for the 1MΩ resistor (R12), and the biasing resistor R13. Also note that the supply bypass capacitors C1, C2 and C6 must be positioned as close as possible to the supply pins of the SA2102D, and connected to a solid ground plane.

It is advisable to keep the ground plane surrounding the device clear of noise that may influence the sensing signals.

The module is protected from high transients on the mains voltage input by means of a Metal Oxide Varistor. The MOV will clamp high transients with a sufficiently long rise time, hence protecting the PCB.

Power supply
The onboard power supply consists of a simple capacitive divider to deliver the output voltage that is rectified by a diode pair, and held constant by means of two TL431 regulators.

The maximum current available from the power supply is approximately 20mA.

Please take note that the module is fitted with a 470nF/250VAC X3 type capacitor for 220VAC mains supply. This capacitor must be changed to 1µF/150VAC X3 type when the mains supply voltage is changed to a 110VAC network.

TYPICAL PERFORMANCE CURVES

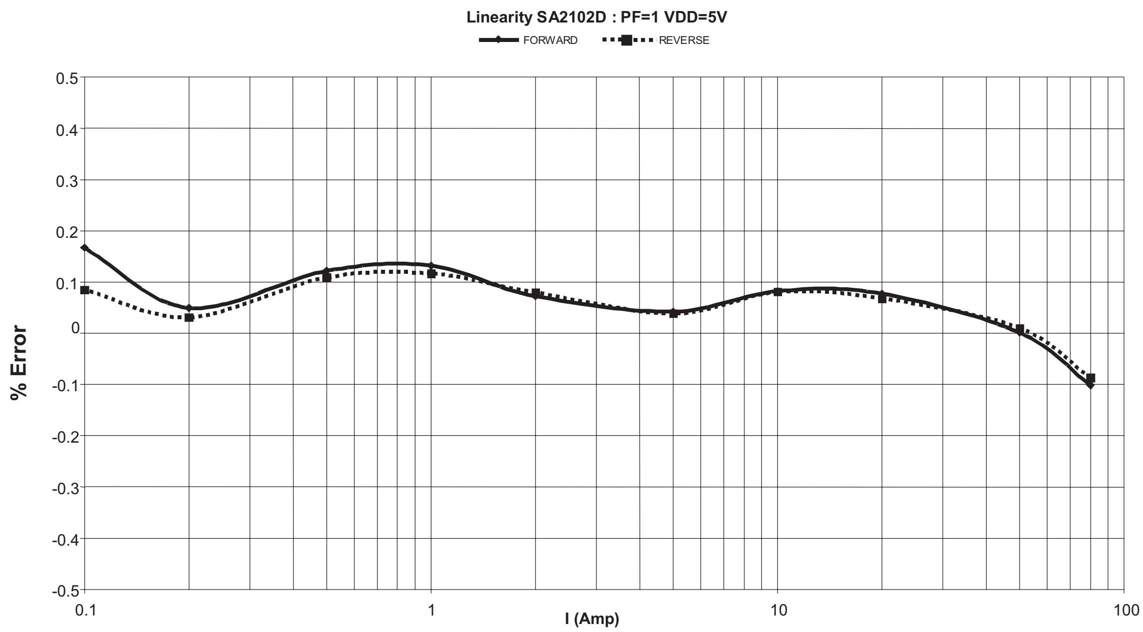

Figure 6: Linearity over a dynamic range of 800 for PF = 1

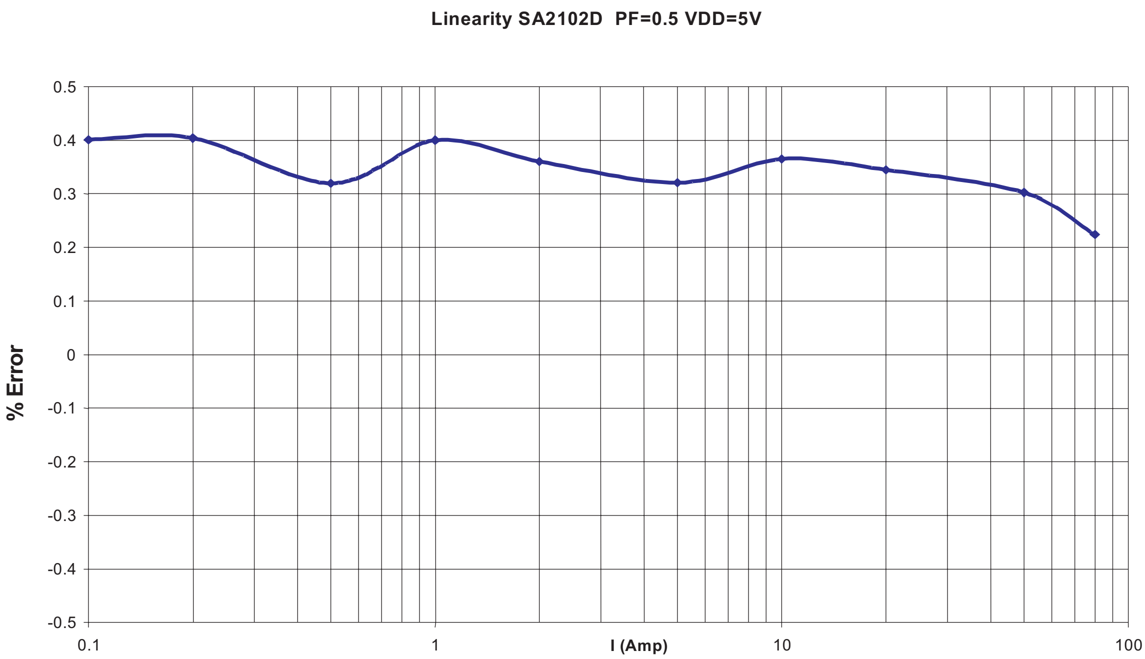

Figure 7: Linearity at PF = +0.5

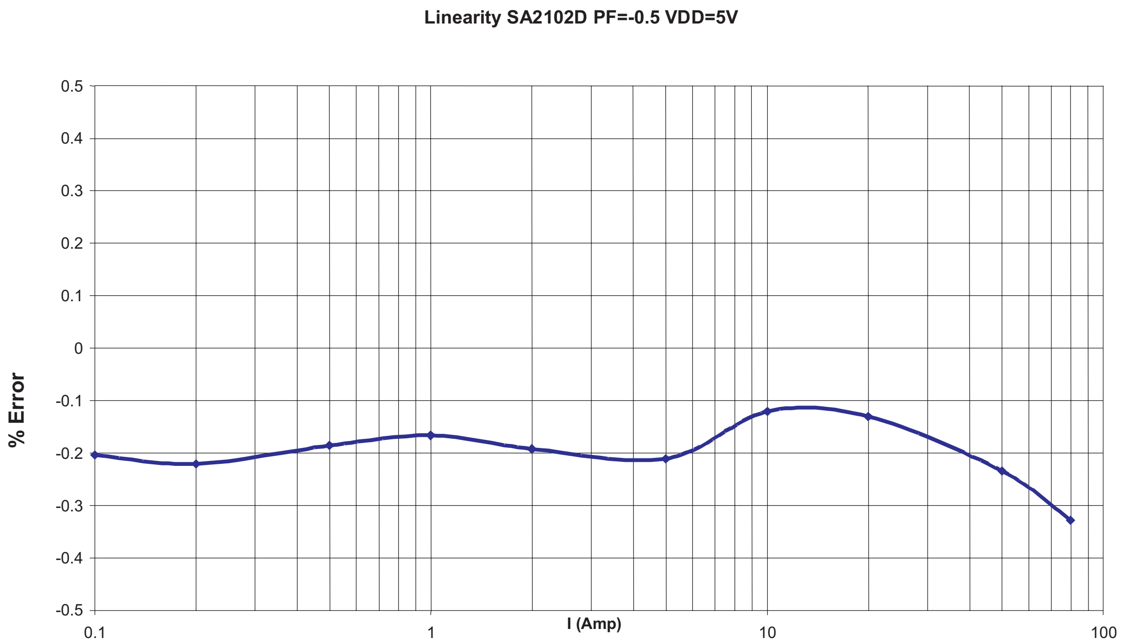

Figure 8: Linearity at PF = -0.5

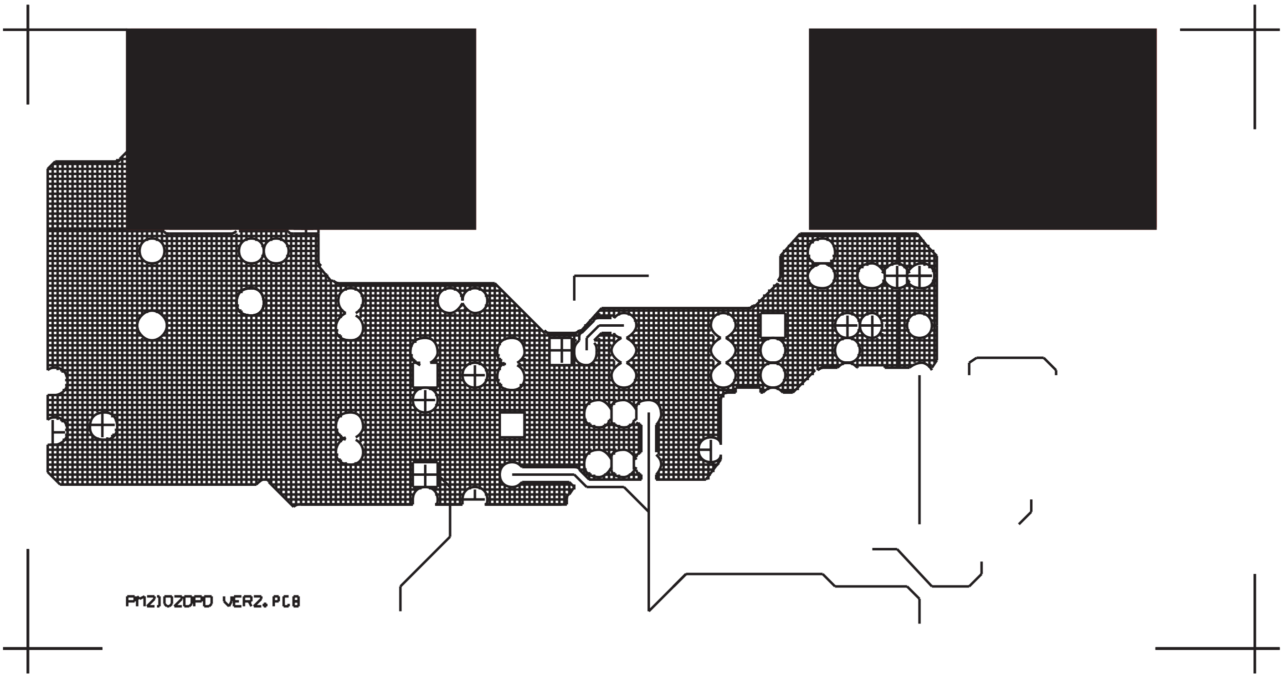

Figure 9: Top PCB Layout

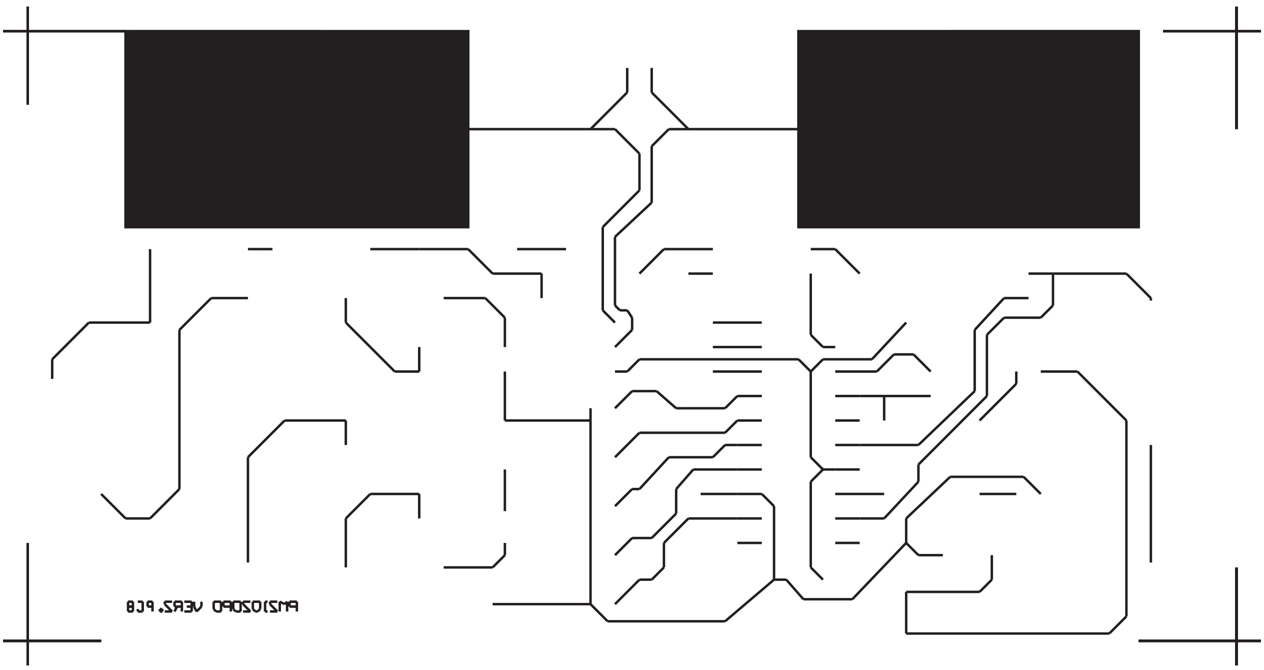

Figure 10: Bottom PCB Layout

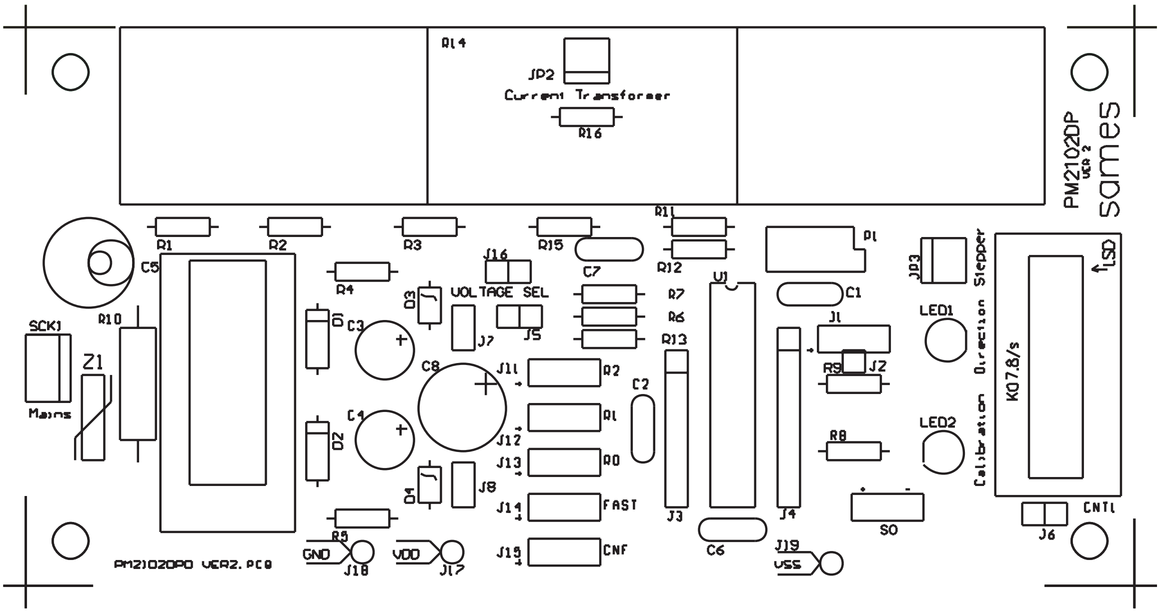

Figure 11 : Slikscreen PCB Layout

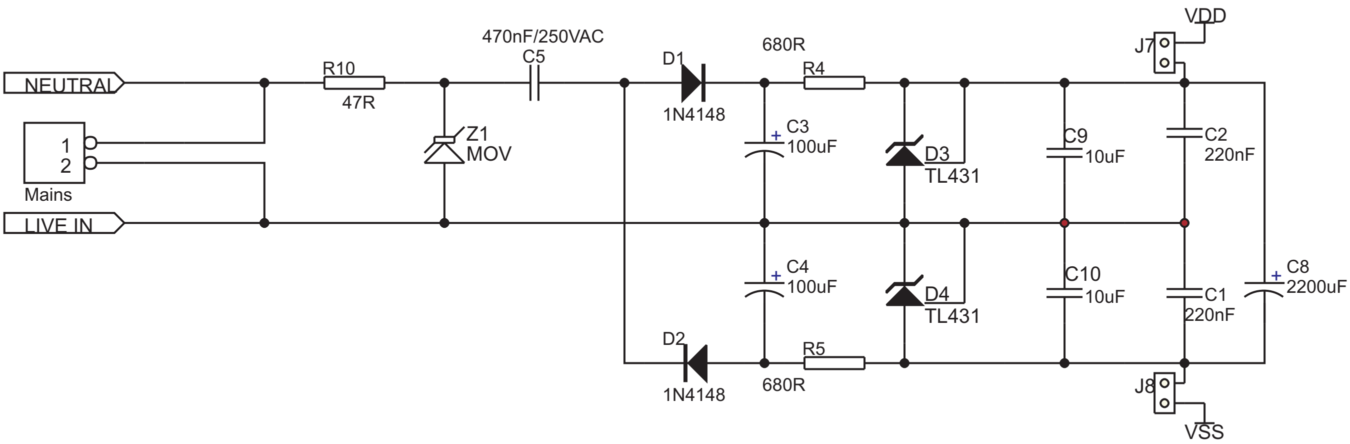

Figure 12 : Schematic diagram of Power Supply

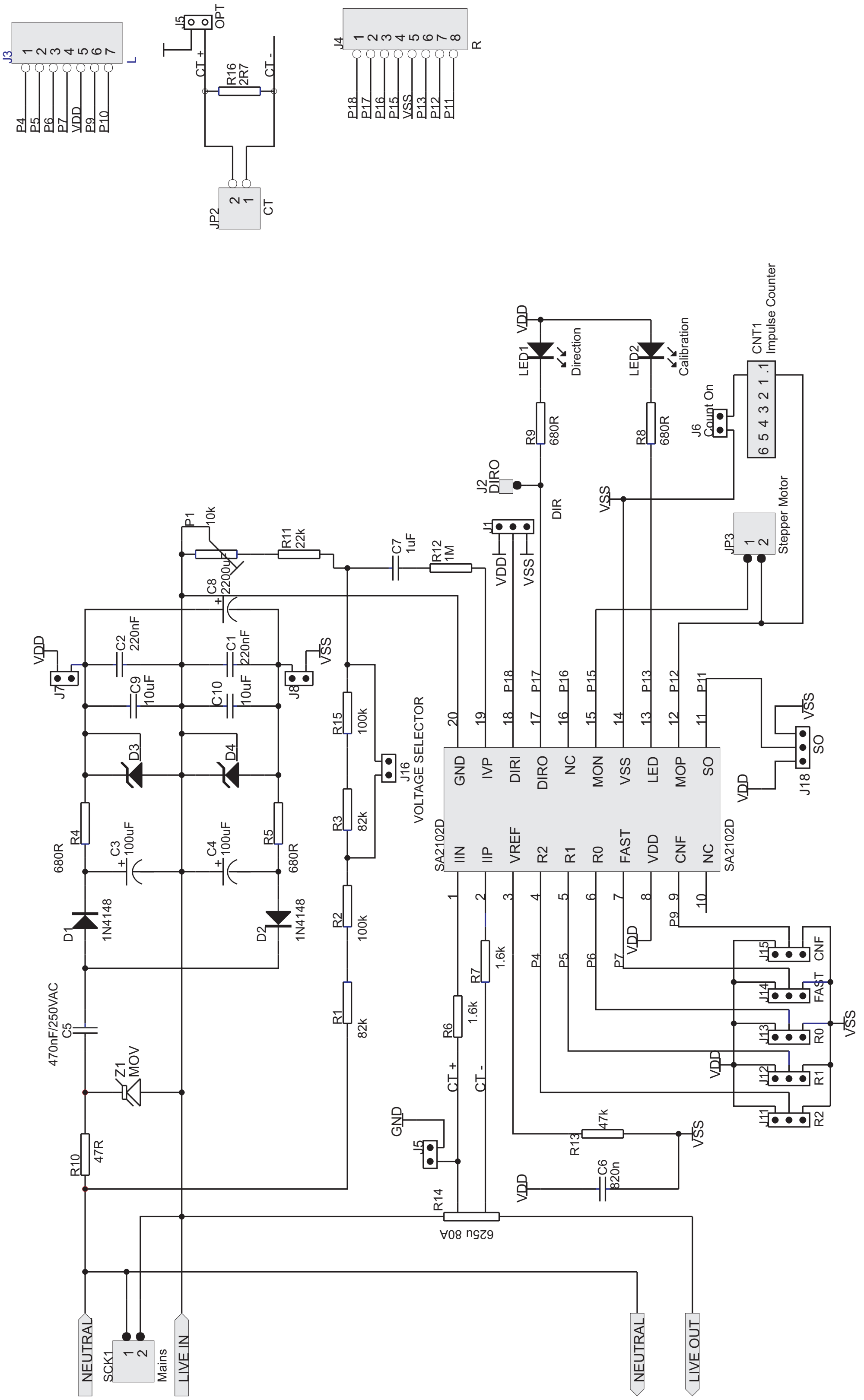

Figure 13 : Schematic diagram of Metering Section

EVALUATION BOARD COMPONENT LIST

Designator	Value	Description	Detail
C1, C2	220nF	Capacitor Monolithic Ceramic	
C3, C4	100µF/16V	Capacitor Electrolytic Radial	
C5	470nF/250VAC	Capacitor Polyester, X2 or X3	Note 1
C6	820nF	Capacitor Monolithic Ceramic	
C7	1µF / 100V	Capacitor Electrolytic Radial, Non-Polarised	Note 3
C8	2200µF/25V	Capacitor Electrolytic Radial	
C9, C10	10µF/16V	Capacitor Tantalum	
CNT1	Kuebler, K07.80.240	Impulse counter	
CT	TZ76V	TAEHWATRANS optional CT not fitted	
D1, D2	1N4148	Silicon Diode	
D3, D4	TL431	Precision Shunt Regulator, TO-92 Package.	
J1	DIR	3 Pin SIP	Note 2
J2	DIRO	Single pin	
J3	L	7 Pin SIP	
J4	R	8 Pin SIP	
J5	GND Enable	2 Pin SIP	Note 3
J6	Count On	2 Pin SIP	
J7	VDD Enable	2 Pin SIP	
J8	VSS Enable	2 Pin SIP	
J11	R2	3 Pin SIP	
J12	R1	3 Pin SIP	
J13	R0	3 Pin SIP	
J14	Fast	3 Pin SIP	
J15	CNF	3 Pin SIP	
J16	Voltage	2 Pin SIP	
J17	VDD	Single pin	
J18	GND	Single pin	
J19	VSS	Single pin	

Designator	Value	Description	Detail
JP2	CT	Not fitted	Note 3
JP3	Stepper	2 Pin Molex, Center square pin, Friction Lock	
LED1, LED2	3mm LED	Red, Green	
P1	Trimpot, 10k	Multi turn, Top Adjust	
R1, R3	82k	1/4W, 1% Metal Film Resistor	
R2, R15	100k	1/4W, 1% Metal Film Resistor	
R4, R5	680R	1/4W, 1% Metal Film Resistor	
R6, R7	1k6	1/4W, 1% Metal Film Resistor	
R8, R9	680R	1/4W, 1% Metal Film Resistor	
R10	47R	2W, 5% Wire Wound Resistor	
R11	22k	1/4W, 1% Metal Film Resistor	
R12	1M	1/4W, 1% Metal Film Resistor	
R13	47k	1/4W, 1% Metal Film Resistor	
R14	80A, 50mV (625µΩ)	Shunt Resistor	
R16	To be calculated	1/4W, 1% Metal Film Resistor	Note 3
SCK1	Mains	2 Pin Molex, Center square pin, Friction Lock <200mil pitch>	Note 4
SO	Pulse Stability	3 Pin SIP	
Z1	S10/275	Metal Oxide Varistor	

Notes
1. Use 1µF/150V_{AC} for 115V mains supply
2. Single Inline Pins
3. Only required if a CT is used.
4. Standard 3-pin Molex with centre pin removed.

NOTES:

DISCLAIMER:

Any sales or technical questions may be posted to our e-mail address below:
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For the latest updates on datasheets, please visit our web site:
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