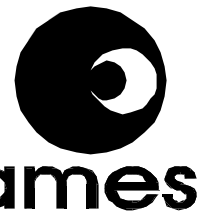# Application Note:
Energy Meter Evaluation Module

PM2002DP

INTRODUCTION

This application note describes the functionality of the SA2002D metering integrated circuit using the PM2002DP evaluation module.

The SA2002 enables the meter manufacturer to build a meter that measures the energy consumption, and records it t o a mechanical counter. Energy flow direction as well as energy metering activity is indicated by means of LEDs. This application note will focus on the practical use of the SA2002D, more detailed information specific to the SA2002D can be found in the applicable datasheet.

THE SA2002D PIN PROGRAMMABLE MONOCHIP METER

Setting	Calibrated LEDimp/kWh	PinStatus
6A/220V	6400	R 0 = 0 , R 1 = 0 , R 2 = 1
10A/220V	6400	R 0 = 0 , R 1 = 0 , R 2 = 0
20A/220V	3200	R 0 = 1 , R 1 = 0 , R 2 = 0
30A/220V	3200	R 0 = 1 , R 1 = 0 , R 2 = 1
40A/220V	1600	R 0 = 0 , R 1 = 1 , R 2 = 0
60A/220V	1600	R 0 = 0 , R 1 = 1 , R 2 = 1
80A/220V	800	R 0 = 1 , R 1 = 1 , R 2 = 0

Table1: A summary of the pin settings possible with the SA2002D. Pin status 0 indicates connection to VSS and 1 indicates connection to VDD.

CONNECTORS ON MODULE

The PM2002DP module connects directly to live and neutral on SCK1. The module is referenced to live and should be kept in mind when connecting test equipment to the module. The current is measured by the shunt on the top of the PCB. The left terminal of the shunt is connected to live. The live out will be connected to the right terminal of the shunt.

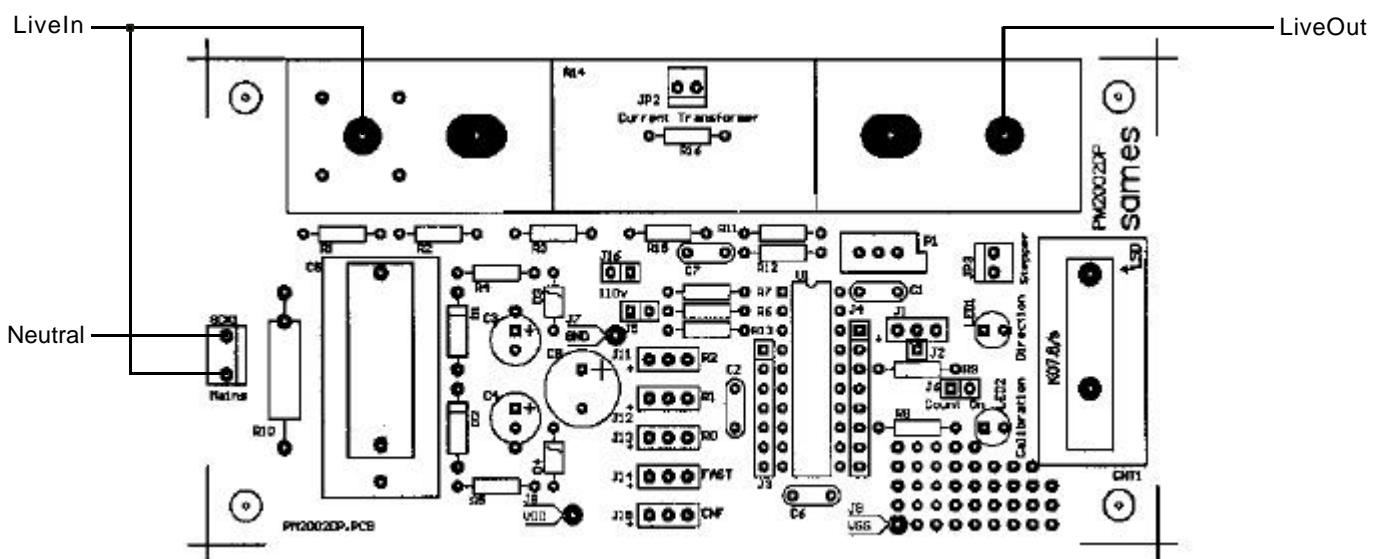| Name	FunctionDescription
SCK1	Mains connector for module power and voltage sense
JP2	Optional current transformer connector. (Underneath shunt resistor)
JP3	Optional Stepper motor connector. (Remove jumper J6 to disconnect impulse counter)

Table2: Connector descriptions

Figure1: Connection and jumper settings for 80A/220V bi-directional meter module

MODULESETUP

ThePM2002DPmoduleissetupforusewiththeSA2002Dintegratedcircuit.Resistorvaluesusedonthemodulearecalculatedfor ratedconditionsof80A/220V.

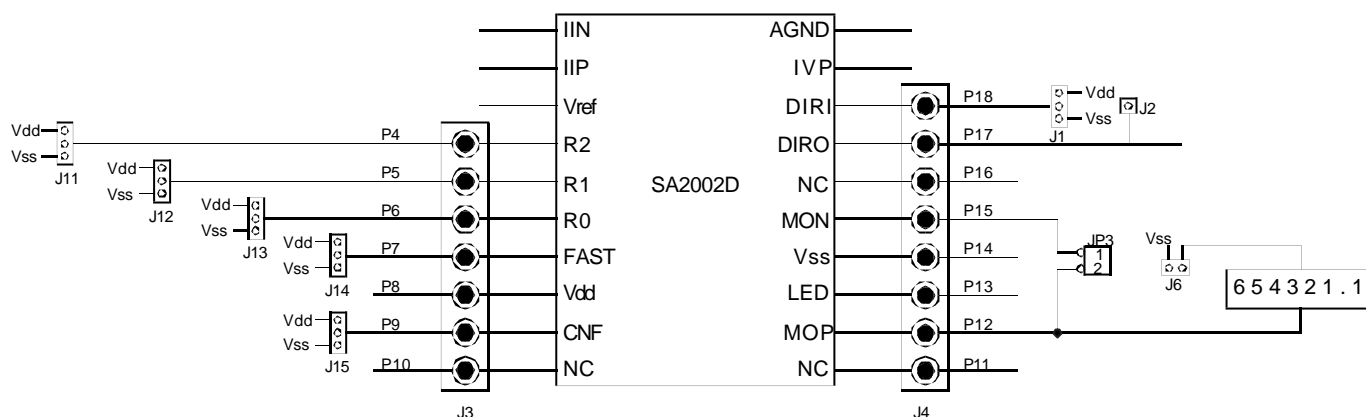*Figure 2:Jumperschematic,digitalIO's*

Name	FunctionDescription
J1	J1isusedtoselecttheenergydirection(DIRIpin).Thethreeoptionsavailableare: P18connectedtoVdd-Negativeenergymeasurement P18connectedtoVss-Positiveenergymeasurement P18connectedtoJ2(P17)-Bi-directionalenergymeasurement P18shouldnotbeleftfloatingandmustbeconnectedtooneoftheoptionsdescribedabove.
J2	J2isonlyused toselectbi-directionalenergymeasurementwhenconnectedtoP18
J3andJ4	ThesearetestpointsplacednexttothedigitalpinsoftheSA2002D
J5	Notfitted Thisisthecurrentsenseinputground.Ifacurrenttransformerisusedforcurrentsensingthetwo pinsofJ5 mustbeconnected.
J6	ConnectstheimpulsetoVSS. IfasteppermotorisconnectedtoJP3thenJ6shouldbeleftopen.
J7	Analoggroundtestpoint(seefigure1)
J8	Positivesupply testpoint(Vdd)(seefigure1)
J9	Negativesupply testpoint(Vss)(seefigure1)
J11,J12 andJ13	UsedtoselecttheR2,R1andR0 pins oftheSA2002Dforthevariousratedconditions.Refertotable1forthe possiblesettings
J14	Usedtoselectfastcalibrationmode.ConnectingP7toVddselectsfastcalibrationmode.Fornormaloperation P7mustbeconnectedtoVss
J15	Usedtoselectbetweennormalandconfigure/testmodes.FornormaloperationconnectP9toVss.
J16	Usedtoselectbetween220Vand110Vmainssystems(Seefigure3).Leaveopenfor220Vmains.

Table3:Jumpersettingsforvariousdeviceoptions

ANALOG SECTION

The analog (metering) interface described in this section is designed for measuring 220V/80A with precision better than Class1.

The most important external components for the SA2002D integrated circuit are the current sense resistors, the voltage sense resistors and the bias setting resistor. The resistors used in the metering section should be of the same type so temperature effects are minimized.

Voltage Input IVP

The voltage input of the SA2002D (IVP) is driven with a current of 14µA at nominal mains voltage. This voltage input saturates at approximately 17µA. At a nominal voltage current of 14µA allows for 20% overdriving. The mains voltage is divided with a voltage divider to 14V that is fed to the voltage input pins via a 1MΩ resistor

Voltage Divider

The voltage divider is (Figure3) calculated for a voltage drop of 14V. Treat C7 as a short circuit and ignore J16. Equations for the voltage divider in figure3 are:

$$RA = R1 + R2 + R3 + R15 + R10$$
$$RB = R12 || (R11 + P1/2)$$

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

Values for resistors R10=47Ω, R11=22kΩ, P1=10kΩ and R12=1MΩ are chosen.

Substituting the values result in:
$$RB = 26.29k\Omega$$
$$RA = RB \times (220V/14V - 1)$$
$$RA = 386.84k\Omega$$

Standard resistor values of R1, R2, R3 and R15 are chosen to be 47kΩ, 150kΩ, 47kΩ and 150kΩ. The resistor RA is divided so that the voltage drop across one resistor is within the specified limits of the resistor type that is used, usually 200VDC. The resistor value ratios are chosen so that shorting J16 the module could be used on a 110VAC mains system.

CURRENT SENSOR INPUT RESISTORS FIGURE4 (USING A SHUNT RESISTOR)

The resistors R6, R7 define the current level into the current sense inputs of the device. The voltage drop across the shunt should be at least 20mV at rated conditions. A shunt resistor with a value of 50mV @ 80A was chosen for the application module for its ease of use. The resistor values are calculated for an input current of 16µA on the current inputs at rated conditions. For a 80A meter the resistor values are calculated as follows:

$$R6 = R7 = (I_L/16\mu A) \times R_{SH}/2$$
$$= 80A/16\mu A \times 625u\Omega/2$$
$$= 1.5625k\Omega$$

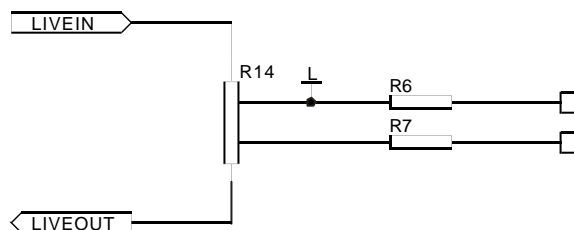$I_{L=}$ Line current

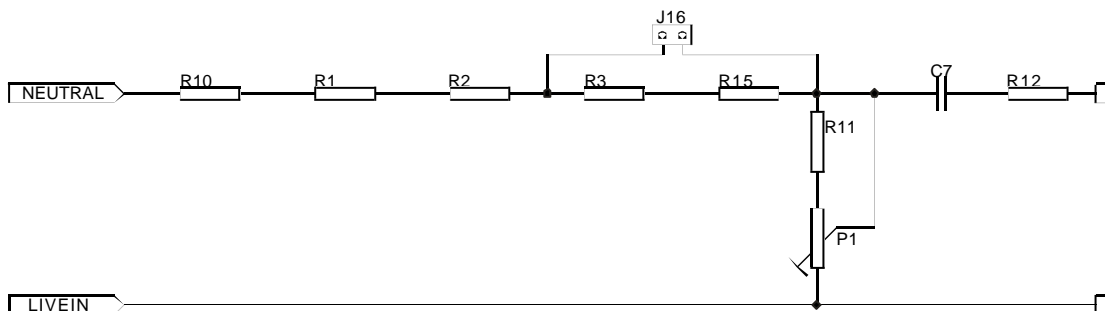A standard value of 1.6kΩ is chosen.

Figure4: Current input configuration

Figure3: Mains voltage divider

CT TERMINATION RESISTOR

Provision is made for the use of a current transformer on the module. The existing shunt needs to be removed and the current sense resistors will have to be recalculated for the specific current transformer. The voltage drop across the CT termination resistor at rated currents should be at least 20mV. The CT's used should have a low phase shift and a ratio of 1:2500. The CT is terminated with a 2.7Ω resistor giving a voltage drop of 864mV across the termination resistor at rated conditions

CURRENT SENSOR INPUT RESISTORS FIGURE 5 (USING A CURRENT TRANSFORMER)

The resistors R6, R7 define the current level into the current sense inputs the device. The resistor values are selected for an input current of 16µA on the current inputs at rated conditions. For an 80A-rated meter the resistor values are calculated as follows:

$$R6 = R7 = (I_L / 16µA) \times R_{SH} / 2$$
$$= 80A / 16µA \times 2.7Ω / 2$$
$$= 2.7kΩ$$

I_L = Line current
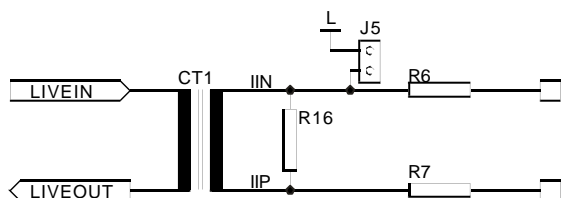RSH = CT Termination resistor
2500 = CT ratio

Figure 5: Current input configuration

Phase Compensation (When using a current transformer)

Phase shift caused by the current transformer may be corrected by inserting a capacitor in the voltage divider circuit. See Figure 6, Capacitor C7. To compensate for a phase shift of 0.18 degrees the capacitor value is calculated as follows:

$$C = 1 / (2 \times \pi \times Mains frequency \times R5 \times tan(Phase shift angle))$$
$$C = 1 / (2 \times \pi \times 50 \times 1M \times tan(0.18 degrees))$$
$$C = 1.013µF$$

Reference Voltage VREF

The VREF pin of the SA2002D is connected to a resistor that determines the on chip bias current.

Ground GND

The GND pin of the SA2002D is to the live phase, which is halfway between VDD and VSS. Note that supply bypass capacitors C1 and C2 are positioned as close as possible to the supply pins of the device, and connected to a solid ground plane.

COMPONENTLISTS

The following component list covers all components fitted on the PM2002DP module as shipped

Symbol	Description	Detail
U1	SA2002D	PDIP20
D1,D2	Diode,Silicon,1N4007	
D3,D4	Diode,Zener,2.4V	
R1,R3	Resistor,47k,1/4W,1%,metal	
R2,R15	Resistor,150k,1/4W,1%,metal	
R4,R5	Resistor,100R,1/4W,1%,metal	
R6,R7	Resistor,1.6k,1/4W,1%,metal	Note1
R8,R9	Resistor,2.4k,1/4W,1%,metal	
R10	Resistor,47R,2W,5%,wirewound	
R11	Resistor,22k,1/4W,1%,metal	
R12	Resistor,1M,1/4W,1%,metal	
R13	Resistor,24k,1/4W,1%,metal	
R14	Shuntresistor,80A/50mV	
R16	Resistor,1/4W,1%,metal	Note1
P1	Trimpot,10k,Multiturn	
C1,C2	Capacitor,220nF	
C3,C4	Capacitor,220µF,16V,electrolytic	
C5	Capacitor,470nF,275VAC	
C6	Capacitor,820nF	
C7	Capacitor	Note2
C8	Capacitor,2200uF,16V,electrolytic	
LED1,LED2	3mmLightemittingdiode	
CNT1	Impulsecounter,Kuebler,K07.80	
SCK1	Molex3pinconnector,200milpinspacing	
JP3	Molex2pinconnector,100milpinspacing	
J1,J2,J3,J4,J5,J6,J7,J8, J9,J11,J12,J13,J14,J15, J16	Jumpers	

Note1: In case a current transformer is used on the board R16 is the termination resistor. Resistors R6 and R7 values may need to be changed to match the CT used.

Note2: Capacitor values may be selected to compensate for phase errors caused by current transformers.

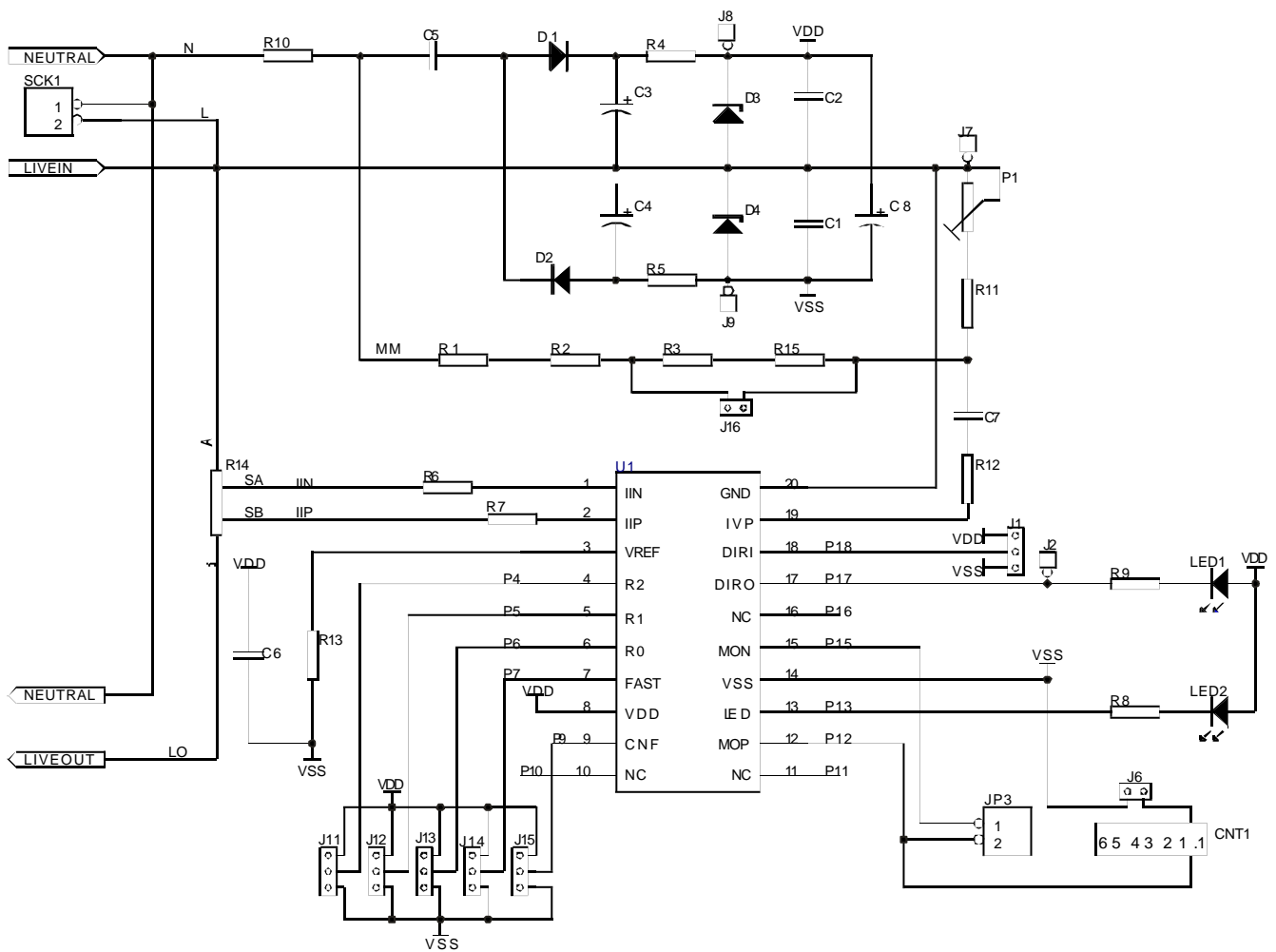*Table4: Components for PM2002DP module setup for 220V/80A*

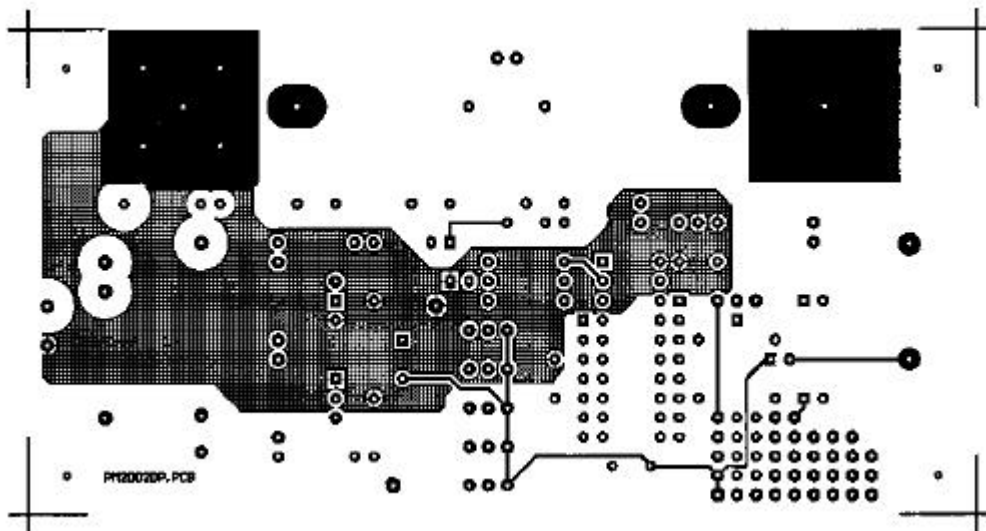*Figure6:SchematicdiagramofthecompletePM2002DPmodule*

PCB LAYOUT

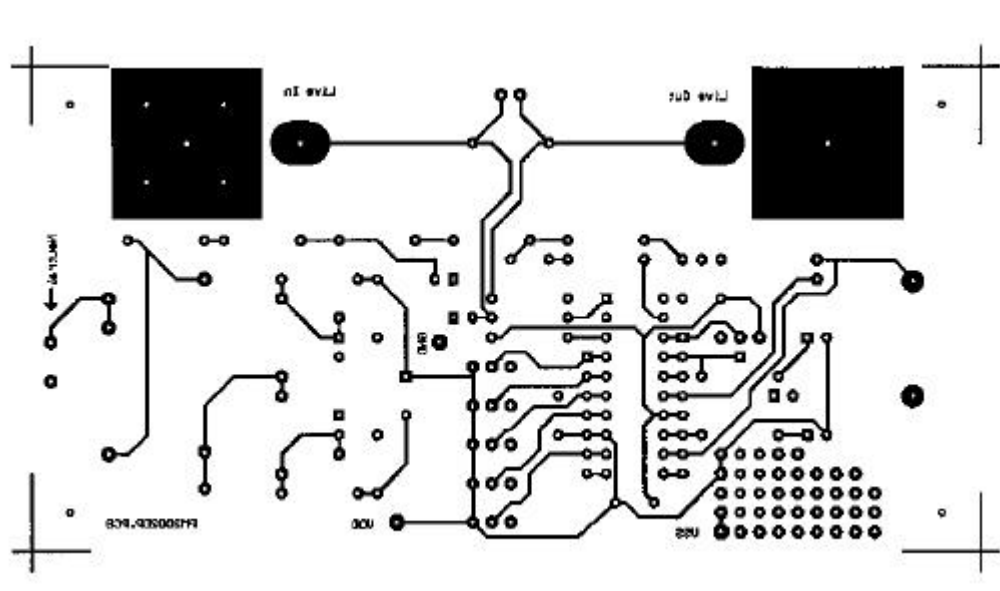*Figure 7: Top layer layout of the PM2002D module*

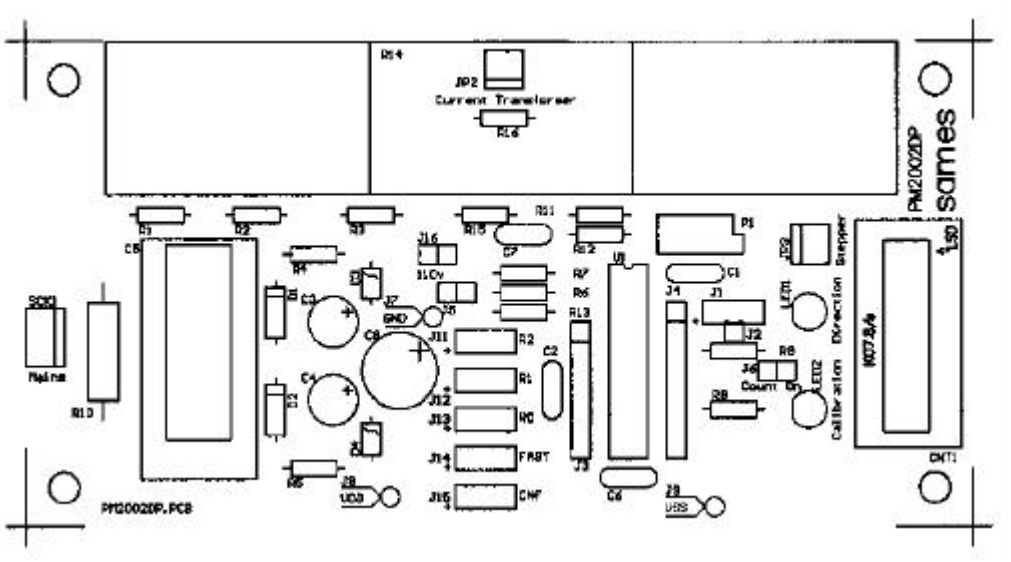*Figure 8: Bottom layer layout of the PM2002D module*

Figure 9: Silkscreen of the PM2002D module

NOTE:

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