Application Note:
Energy Meter Evaluation Module

PM2007M/PPE

INTRODUCTION

This Application Note describes the functionality of the SA2007M and the SA2007P metering integrated circuits using the PM2007M/PPE evaluation module. The SA2007 family is a low cost solution specifically designed to meet the needs of markets that require both live and neutral energy measurement to detect any meter tampering. Using the SA2007 family the meter manufacturer is able to build a meter that measures the energy consumption, even during a tamper condition, and record it to a mechanical counter.

This application note will focus on the practical use of the SA2007 family. More detailed information specific to the SA2007M or SA2007P can be found in the applicable datasheet.

THE SA2007 SERIES ENERGY METER ICS

The SA2007 family is characterized by its ability to measure live and neutral power consumption simultaneously. A correctly installed meter should measure equal amounts of power consumption in the live and neutral phases. During meter tampering the two measurements are no longer equal. The SA2007 will use the larger of the two currents for the energy measurement. Differences of more than 12% between the live and neutral power measurements are indicated on the SA2007's ELT output which can drive a LED directly. However the SA2007 will use the larger of the two currents even if the difference is less than a percent.

The SA2007 is designed to drive mechanical counters directly. The module is fitted with an impulse type counter that increments with a single 71ms pulse. The SA2007 can also drive low cost mechanical counters (stepper motors) that use two consecutive pulses with opposing voltages to advance the counter one position. The SA2007 outputs these two opposing pulses in close succession, minimizing the chance of the stepper motor being in the wrong phase after a power failure and possibly losing a count.

Calibration pulses, reverse power, earth loop tamper and active channel information is displayed via four LEDs fitted on the module.

THE SA2007M PIN PROGRAMMABLE MONOCHIP METER

Using the SA2007M, the rated conditions of the meter as well as the LED pulse rate and counter resolution can be selected for a particular meter design. The meter manufacture is thus able to produce a range of meters utilizing the same counter and the same metering constant with a single integrated circuit. Calibration of the meter is done with trim-pots or resistor ladders. Table 1 gives a short list of all the possible meter configurations possible with the SA2007M using the PM2007M/PPE module. Note that the values of the current transformer's termination resistor will change to make some of the rated conditions possible. This will be covered in the Analog Section.

Setting	Pin Status
20A / 230V	RATED = 0
40A / 230V	RATED = Open
60A / 230V	RATED = 1
1 pulse / kWh	MP1 = 0, MP0 = 0
10 pulse / kWh	MP1 = 0, MP0 = 1
100 pulse / kWh	MP1 = 1, MP0 = 0

Table 1: A summary of the pin settings possible with the SA2007M. Pin status 0 indicates connects to VSS and 1 indicates connection to VDD

THE SA2007P MONOCHIP METER WITH EEPROM CALIBRATION

The SA2007P uses an external EEPROM to store calibration data as well as meter specific settings. A major advantage of the SA2007P is that no external trim-pots or resistor ladders are required to calibrate the meter. This greatly enhances the meter reliability and can improve meter production times if used in an automatic meter calibration system.

The SA2007P integrated circuit together with an external EEPROM provides more meter setup features than the SA2007M. Additional information regarding the meter (serial numbers, client, and manufacture date) can also be stored in the unused sections of the EEPROM memory. An IIC bus based EEPROM is used to store configuration and meter setup data for the SA2007P. The SA2007P will load this data from the EEPROM during power up. During normal meter operation it periodically reloads the data from the EEPROM. The SA2007P never writes to the EEPROM. For more specific configuration information please refer to the SA2007P datasheet.

MAINS CONNECTION TO MODULE

The PM2007M/PPE module connects directly to live and neutral on CON1. The module is referenced to neutral and this should be kept in mind when connecting test equipment to the module.

CON2 is used for in circuit programming of the EEPROM (U3) when the SA2007P is used. The connector does not have any significance when a SA2007M device is used in the module.

Name	Function Description	SA2007M	SA2007P
Con1	Connector for the 220VAC power for the module	1 Live 2 Neutral	1 Live 2 Neutral
Con2	Connector for the opto isolator module	Not used	VDD RLOAD SCL SDA FOUT DIRO VSS

Table 2: Connector Descriptions

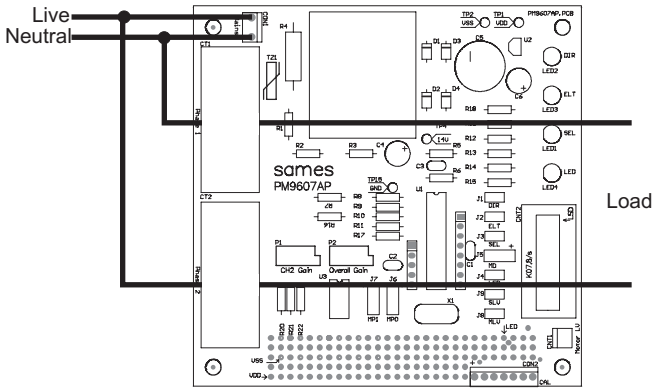

Figure 1: Connection diagram for normal metering application

MODULE SETUP

The PM2007M/PPE module is setup for use with the SA2007M integrated circuit. Resistor values used on the module is calculated for rated conditions of 60A/230V and the counter resolution pin programming is set for 100 pulses/kWh.

Name	Function Description	SA2007M setting	SA2007P setting
J1	Connect pin 18 to DIR LED		
J2	Connect pin 17 to ELT LED		
J3	Connect pin 16 to SEL LED		
J4	Connect pin 13 to Calibration LED		
J5	Rated condition select jumper, pin 15		
J6	Motor pulse rate select jumper, pin 7		
J7	Motor pulse rate select jumper, pin 6		
J8	Connect one terminal of a Low Voltage stepper to pin 12, the terminal of the stepper is always connected to pin 9.		
J9	Connect impulse counter to pin 12		
J10 and J11	Test pins are placed next to the digital pins of the SA2007	J10: 1 IIN1, 2 IIP1, 3 IIN2, 4 IIP2, 5 VREF, 6 MP1/SCL, 7 MP0/SDA, 8 VDD, 9 MON, 10 TCLK/Test J11: 20 GND, 19 IVP, 18 DIRO, 17 ELT, 16 SEL1, 15 Rated/Rload, 14 VSS, 13 LED, 12 MOP, 11 TCLK	

Table 3: Jumper settings for various device options

USING THE SA2007P IC

The EEPROM on the SA2007AP module may be programmed in circuit with the use of a PC and the IIC interface module. The interface module includes a IIC interface, a 7 way connector cable as well as all the components needed to convert the module to a trim pot less meter. Figure 2 show how to connect the module, and the interface module to a PC.

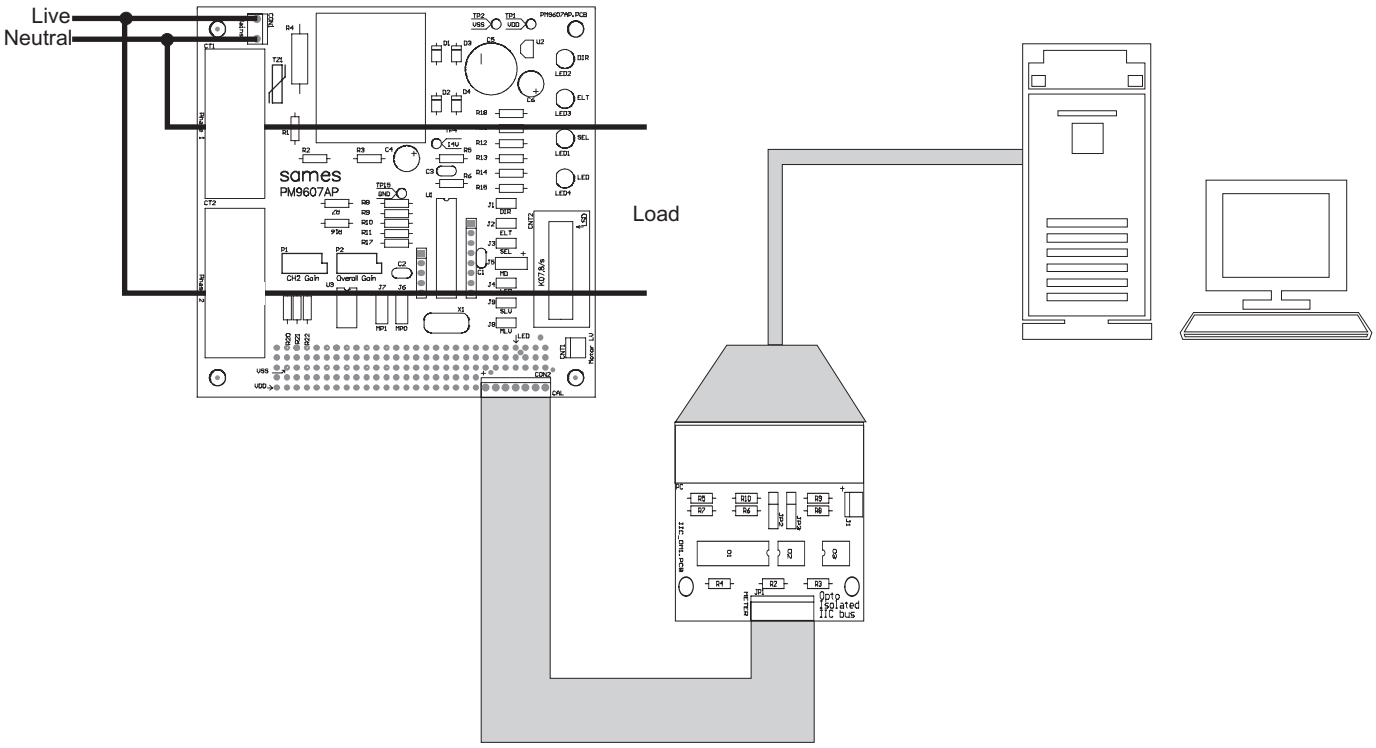

Figure 2: PM2007M/PPE mains connections as well as PC programming setup

To use the PM2007M/PPE module with a SA2007P integrated circuit the following components need to be changed:

- Replace termination resistor R16 with 3.6Ω resistor.*
- Remove Channel 2 trim-pot P1.*
- Remove jumpers J5, J6 and J7.

* Component change is only require if the module should not contain any trim-pots.

MODULE OVERVIEW

ANALOG SECTION

The analog (metering) interface described in this section is designed for measuring 230V/60A with precision better than Class 1.

The most important external components for the SA2007 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.

Current Input IIN1, IIP1, IIN2, IIP2

Two current transformers are used to measure the current in the live and neutral phases. The output of the current transformer is terminated with a low impedance resistor. The voltage drop across the termination resistor is converted to a current that is fed to the differential current inputs of the SA2007.

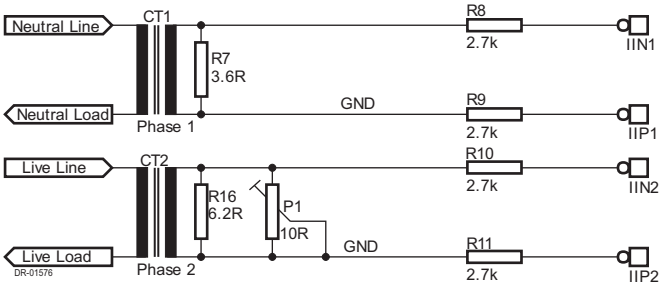

Figure 3: Current input configuration

CT Termination Resistor

The voltage drop across the CT termination resistor at rated current should be at least 20mV. The CTs have low phase shift and a ratio of 1:2500. The CT is terminated with a 3.6Ω resistor giving a voltage drop of 86.4mV across the termination resistor at rated conditions (I_{max} for the meter).

The termination resistor on the second current channel is adjustable by means of P1 to facilitate channel equalization calibration. The termination resistor is chosen so that a 10Ω trimpot in parallel will provide a sufficient channel range. If the SA2007P is being used, P1 can be removed and R16 replaced with a 3.6Ω resistor, as channel equalization data can be read from the external EEPROM, requiring no trim-pots.

Current Sensor Input Resistors

The resistors R8, R9 and R10, R11 define the current level into the current sense inputs of the SA2007. The resistor values are selected for an input current of 16µA on the current inputs. For a 60A meter at 2500:1 CT the resistor values are calculated as follows:

$R8 = R9 = (I_L / 16\mu A) \times R_{SH} / 2$

$= 60A / 2500 / 16\mu A \times 3.6\Omega / 2$

$= 2.7k\Omega$

I_L = Line current

RSH = CT Termination resistor

2500 = CT ratio

The two current channels are identical so R8 = R9 = R10 = R11.

Voltage Input Ivp

The voltage input of the SA2007 (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 calculated for a voltage drop of 14V. Equations for the voltage divider in figure 4 are:

RA = R1 + R2 + R3 + R4

RB = R6 || (R5 + P1)

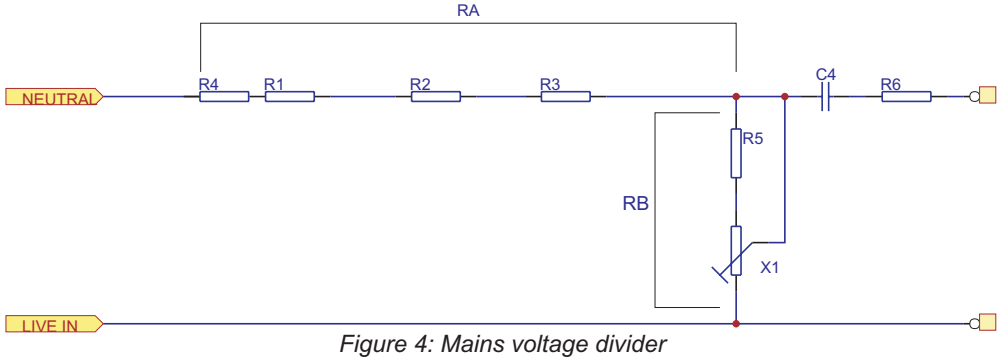

Figure 4: Mains voltage divider

A 10K trimpot (P2) is used in the voltage channel for meter calibration (for the SA2007M). The center position on the pot is used in the formulae, so P2 = 10K.

Combining the two equations gives:

(RA + RB) / 230V = RB / 14V

Values for resistors R4 = 10Ω, R5 = 22kΩ and R6 = 1MΩ is chosen.

Substituting the values result in:

RB = 23.437kΩ

RA = RB x (230V / 14V – 1)

RA = 361.607kΩ.

Standard resistor values of R1, R2, R3 and R4 are chosen to be 120kΩ, 120kΩ, 120kΩ and 10Ω.

Device calibration is done on the voltage input of the SA2007M. P2 can be varied for precise meter calibration.

Calibration using P2 is not necessary when using the SA2007P as device calibration data is read from the external EEPROM. P2 can be removed, the footprint short circuited and R5 replaced by a 24K resistor.

The capacitor C4 is used to compensate for phase shift between the voltage sense inputs and the current sense inputs of the device, in cases where CTs with phase errors are used. The phase shift caused by the CT may be corrected by inserting a capacitor in the voltage divider circuit. To compensate for a phase shift of 0.18 degrees the capacitor value is calculated as follows:

C = 1 / (2 x π x Mains frequency x R6 x tan (Phase shift angle))

C = 1 / (2 x π x 50 x 1MΩ tan (0.18 degrees))

C = 1.013µF

Reference Voltage VREF

The VREF pin of the SA2007 is connected to a resistor (R17) that determines the on chip bias current. With R17 = 24K optimum conditions are set.

Ground GND

The GND pin of the SA2007 is connected to the neutral 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.

Protection

A MOV together with R4 protects the transformer and the voltage divider circuit against voltage transients.

Common mode and asymmetrical transients are attenuated by the current setting resistors R8, R9 R10 and R11.

POWER SUPPLY

The PM2007M/PPE module uses a transformer based power supply to ensure flexibility for different counter drive configurations. The current indicated in table 4 is worst-case peak pulse current. The normal operating current of the module is closer to 15mA. A 78LC05-voltage regulator is used to regulate the voltage from the transformer. Two resistors R18 and R19 generate the analog ground voltage for the SA2007. The SA2007 operates between 5 Volt and 0 Volt with its GND pin connected to mid-rail.

Source	Max current	Unit
SA2007M/P IC	5	mA
DIR LED	5	mA
SEL1 LED	5	mA
ELT LED	5	mA
Pulse LED	5	mA
Counter	11	mA
GND ref	3	mA
EEPROM	2	mA
Total	41	mA

Table 4: Maximum peak current drawn by components on the module

IN CIRCUIT EEPROM CONFIGURATION

The EEPROM remains on the PCB and is reprogrammed via the IIC bus.

No	Name	Function
1	VDD	Positive supply
2	Rload	A positive edge on Rload with DIRO high will trigger a configuration reload
3	SDA	Serial data pin
4	SCK	Serial clock pin
5	FOUT	LED pin of device
6	DIRO	DIRO need to be high before Rload is pulsed to trigger a reload
7	VSS	Negative supply voltage

Table 5: Pin description of the CAL connector

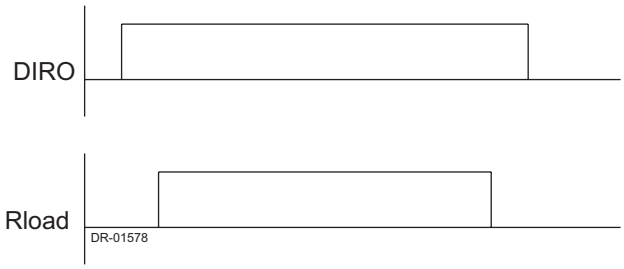

Figure 5: Wave forms describing the configuration trigger

ISOLATED PC INTERFACE MODULE

OPERATION

The isolator module connects to a standard PC printer port by means of an extender cable on the one side and to the PM2007M/PPE on the other side. The PC is completely isolated form the evaluation module and can be used to program the EEPROM on the PM2007M/PPE module safely.

The SA2007P is designed to be the bus master and does not support multi master mode. Resistor R22 is used to overdrive the clock signal of the SA2007P during programming.

Connect an external power supply to the programming module if your PC is unable to supply the module.

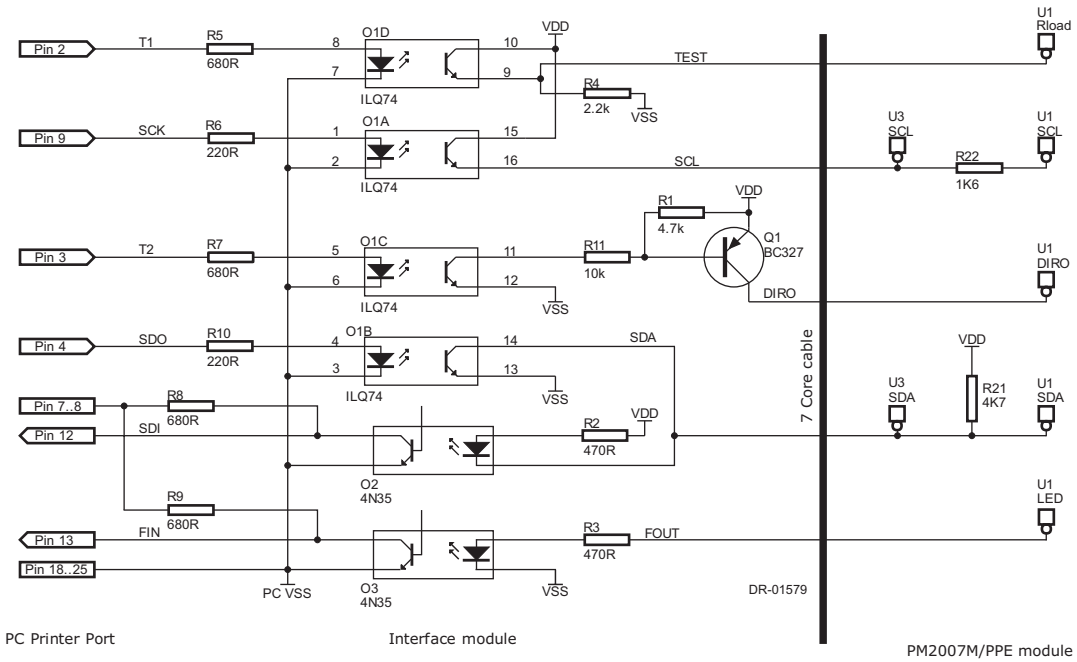

Figure 6: Schematic diagram of the IIC opto-isolator module as well as relevant components on the PM2007M/PPE module

CALIBRATION AND SETUP

Software is available to setup and calibrate the SA2007P device and is supplied with this module.

The software was written with Borland C++ Ver 3 and should run on any PC with DOS operating system. The program was written as clear as possible so that it can easily be modified for specific needs.

Start the program from the DOS prompt with:
A:\Dos\sa2007p 1 1000

NAVIGATING

Use the cursor keys to move up and down between the parameters listed under the "SA9607P Meter Parameters" section. Press Enter on the parameter that needs to be changed. The options available will be displayed. Type in the correct option or value and press Enter again. The new setting will be displayed.

A detailed description of the parameters listed on the screen are described in the SA2007P datasheet. The following is a description of the functionality of the SA2007P Meter Parameters, displayed on the PC's screen, figure 7.

V_{nom} and I_{max}

V_{nom} and I_{max} make up the rated conditions of the module (SA2007P's Kr parameter). V_{nom} is the module's rated voltage and Imax the module's rated current. The PM2007M/PPE module is designed for rated conditions of 230V/60A. The software defaults to Vnom = 230V and Imax = 60A.

LED Constant

LED Constant selects the module's LED pulse rate (calibration LED), which is the SA2007P's CLED parameter. The options available are 6400 p/kWh or 3200 p/kWh. Entering a '0' will enable the 1252 pulses/second (at rated conditions) mode for fast calibration.

Counter Resolut.

Counter resolution sets the modules counter resolution (SA2007P's CRES parameter). The options are 1,10 or 100p/kWh.

Counter PW

Counter PW set up the mechanical counter's pulse width (SA2007P's CPW parameter). The available options are 71ms and 142 ms. The PM2007M/PPE module uses an impulse counter with a pulse width of 71ms.

Channel1 Err / Channel2 Err

The module may be calibrated by entering the percentage error in relation to a calibrated meter or Wh-Standard. The percentage error is calculated as follows:

Error=(Energy from module – Real energy)/Real energy x 100

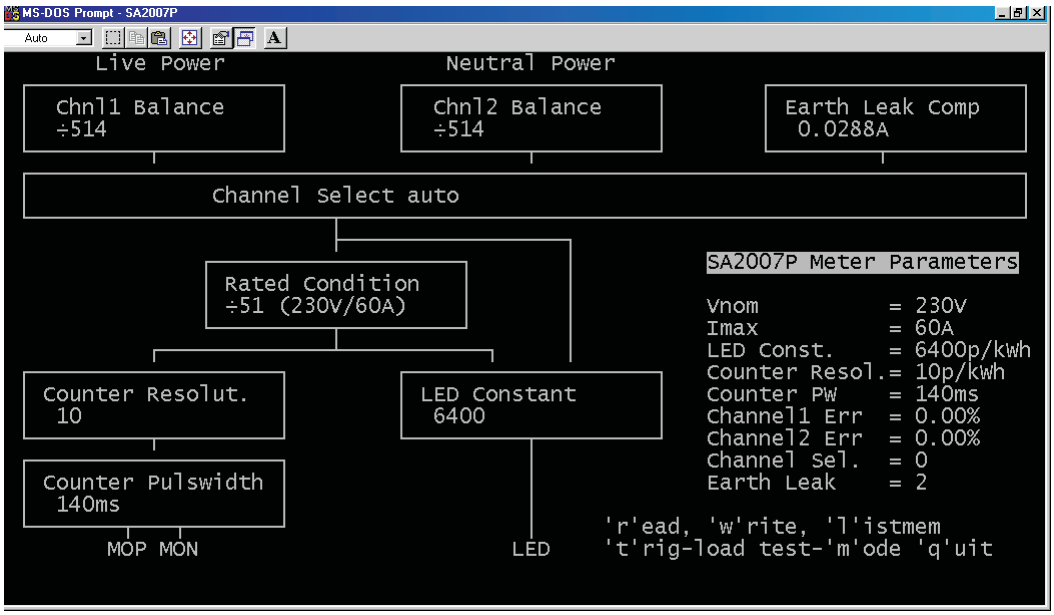

Figure 7: Screen capture of the SA2007P setup program

For module calibration use Channel Sel. (below) to switch to one of the two channel permanently. Calibrate the channel and switch to the next channel. Calibrate the channel and set Channel Sel to automatic for normal meter operation. This is equal to the SA2007P's Kc parameter, which is used for channel balance.

Channel Sel.
The channel select parameter selects the source for energy metering. (SA2007P's CS parameter). The options are '0' for automatic, '1' for channel 1 and '2' for channel 2.

Earth Leak
The modules earth leakage compensation value is set up with this parameter. (SA2007P's Ne parameter). The options are '0' for a factor of 0.15, '1' for a factor of 0.076 and '2' for a factor of 0.032.

LIST MEMORY
The memory map, as calculated from the settings in the program, is listed by pressing "l". It does not show the content of the EEPROM.

WRITE TO EEPROM
Pressing "w" writes to the EEPROM. The EEPROM on the PM2007M/PPE module will be updated with settings specified by the program.

DEVICE RELOAD TRIGGER
Pressing "t" triggers a reload. The SA2007P is triggered and reloads the parameters from the EEPROM. The SA2007P will reload the parameters every 1132 seconds. Reload also happens with power-up.

READ FROM EEPROM
The contents of the EEPROM is displayed by pressing "r".

QUIT THE PROGRAM
The program is exited by pressing "q".

PCB DESIGN
The module represents a Class 1 meter and is designed to demonstrate the functionality and performance of both the SA2007M and the SA2007P single phase metering circuits. The SA2007M requires external settings and gain adjustment. The SA2007P allows for complete digital calibration without any external adjustments. The board can be configured for either of the two ICs by means of jumper settings.

The module is a demonstration unit as well as a reference point for the meter manufacturer. All the digital pins of the device have at least one test point. Jumpers isolate LED's and counters from the device

GROUND PLANE
The ground plane, which is connected to neutral, protects the device from external noise and is used to connect the power supply bypass capacitors C1 and C2. On the current input resistors and the CT termination resistor loops are introduced to cancel out the signal induced by the transformer's magnetic field.

The 5V supply is de-coupled and routed directly to the power pins of the IC.

COMPONENT LISTS

The following component list covers all components fitted on the PM2007M/PPE module as shipped and configured for the SA2007M device.

Designator	Value	Description	Detail
C1, C2	220n	Capacitor Monolithic Ceramic	
C3	820n	Capacitor Monolithic Ceramic	
C4	1u / 100V	Capacitor Electrolytic Radial, Non-Polarised	
C5	2200u / 16V	Capacitor Electrolytic Radial	
C6	220u / 16V	Capacitor Electrolytic Radial	
CT1, CT2	TZ76V	TAEHWATRANS	
CNT2	Kuebler, K07.80.240	Impulse counter	
CNT1	2 Pin Molex	7 Pin Molex, Centre square pin, Friction Lock	
CON2	CAL	2 Pin Molex, Centre square pin, Friction Lock	
CON1	Mains	Silicon Diode	
D1, D2, D3, D4	1N4148	2 Pin SIP	Note 1
J1	DIR	2 Pin SIP	
J2	ELT	2 Pin SIP	
J3	SEL	2 Pin SIP	
J4	LED	2 Pin SIP	
J5	RATED	3 Pin SIP	
J6	MP0	2 Pin SIP	
J7	MP1	2 Pin SIP	
J8	MLV	2 Pin SIP	
J9	SLV	2 Pin SIP	
J10	R	8 Pin SIP	
J11	L	5 Pin SIP	
LED1, LED2, LED3, LED4	SEL, DIR, ELT, LED	3mm LED: green, yellow, red, green	
P1	Trimpot, 10R	Multi turn, Top Adjust	
R1, R2, R3	120k	1/4 Watt, 1%, Metal Film Resistor	
R4	10R	2 Watt, 5%, Wire Wound Resistor	
R5	22k	1/4 Watt, 1%, Metal Film Resistor	
R6	1M	1/4 Watt, 1%, Metal Film Resistor	
R7	3R6	1/4 Watt, 1%, Metal Film Resistor	
R8, R9, R10, R11	2k7	1/4 Watt, 1%, Metal Film Resistor	
R12, R13, R14, R15	680R	1/4 Watt, 1%, Metal Film Resistor	
R16	6R2	1/4 Watt, 1%, Metal Film Resistor	
R17	24k	1/4 Watt, 1%, Metal Film Resistor	
R18, R19	1k	1/4 Watt, 1%, Metal Film Resistor	
R21	4k7	1/4 Watt, 10%, Metal Film Resistor	
R22	1k6	1/4 Watt, 1%, Metal Film Resistor	
T1	Transformer	230 / 9V 1.5VA	
TP1, TP2, TP4, TP15	VDD, VSS, 14V, GND	Test-pin	
TZ1	S10 / 275	Metal Oxide Varistor	
U1	SA2007M	20 Pin IC socket, Tulip type	
U2	78L05	TO-92 Package	
U3	24C01	8 Pin IC socket, Tulip type	
X1	Trimpot, 10k	Multi turn, Top Adjust	

Note 1: Single Inline Pins

Table 6: Components for SA2007M functionality, 60A rated setup

The following component list covers components that need to be changed to use the module with the SA2007P device.

Designator	Description	Detail
U1	SA2007P	Insert
U3	24C01A, IIC bus interfaced EEPROM	Insert
R16	Resistor, 3.6R, 1/4W, 1%, metal	Insert
P1	Multi-turn trim pot, 10R	Remove

Table 7: Components for SA2007P functionality, 60A rated setup

Designator	Description	Detail
O1	ILQ74	PDIP16
O2, O3	4N35	PDIP16
R1	Resistor, 4.7k, 1/4W, 1%, metal	
R2, R3	Resistor, 470R, 1/4W, 1%, metal	
R5, R7, R8, R9	Resistor, 680R, 1/4W, 1%, metal	
R6, R10	Resistor, 220R, 1/4W, 1%, metal	
R11	Resistor, 10K, 1/4W, 1%, metal	
Q1	Transistor, BC327	T0, 92, PNP
JP1	Molex 7 pin connector, 100 mil pin spacing	
J1	Molex 2 pin connector, 100 mil pin spacing	External 5V supply
SK2	DB25 PCB Mount, Female connector	
6	Header pins	

Table 8: Interface Module components

PCB LAYOUT

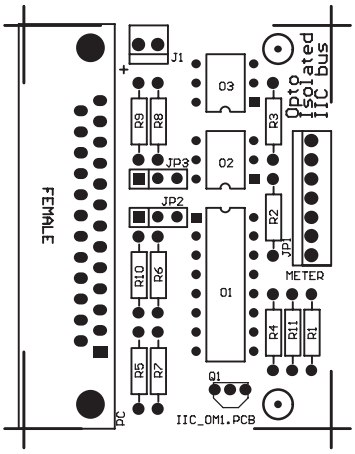

Figure 8: IIC Module Component layout

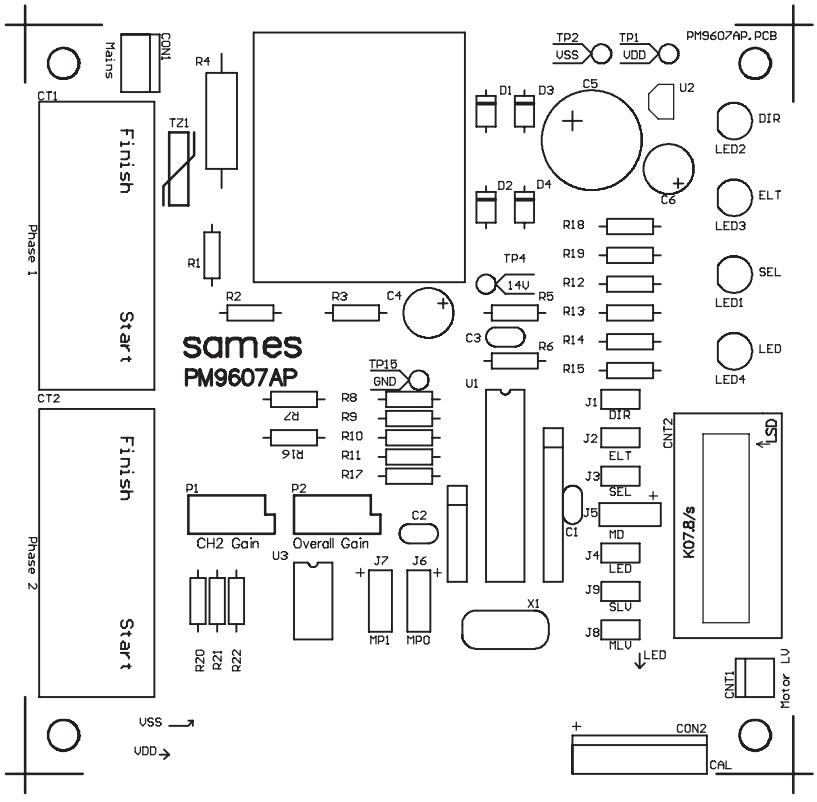

Figure 9: Component layout

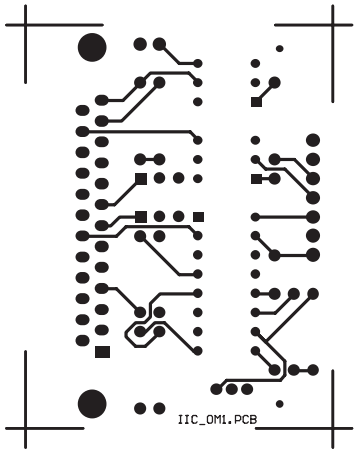

Figure 10: IIC Module Top Side

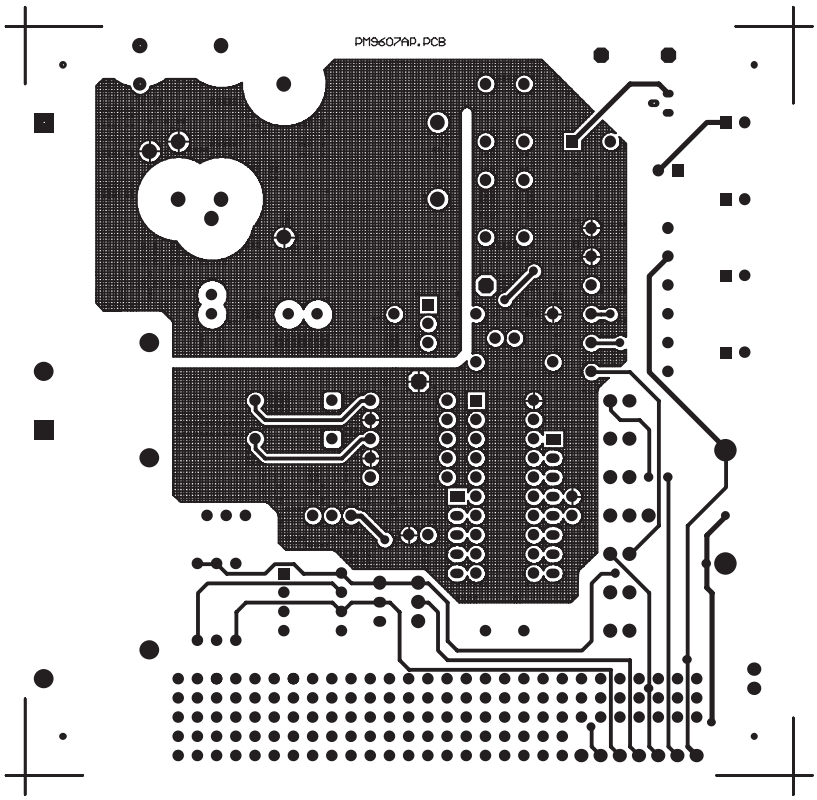

Figure 11: Top Side

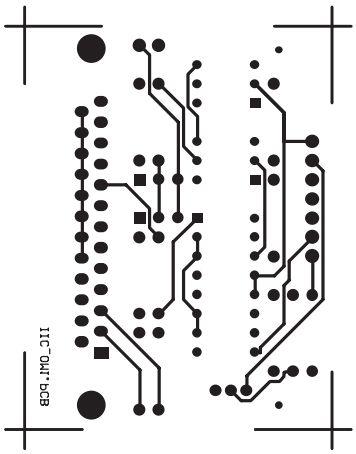

Figure 12: IIC Module Bottom Side

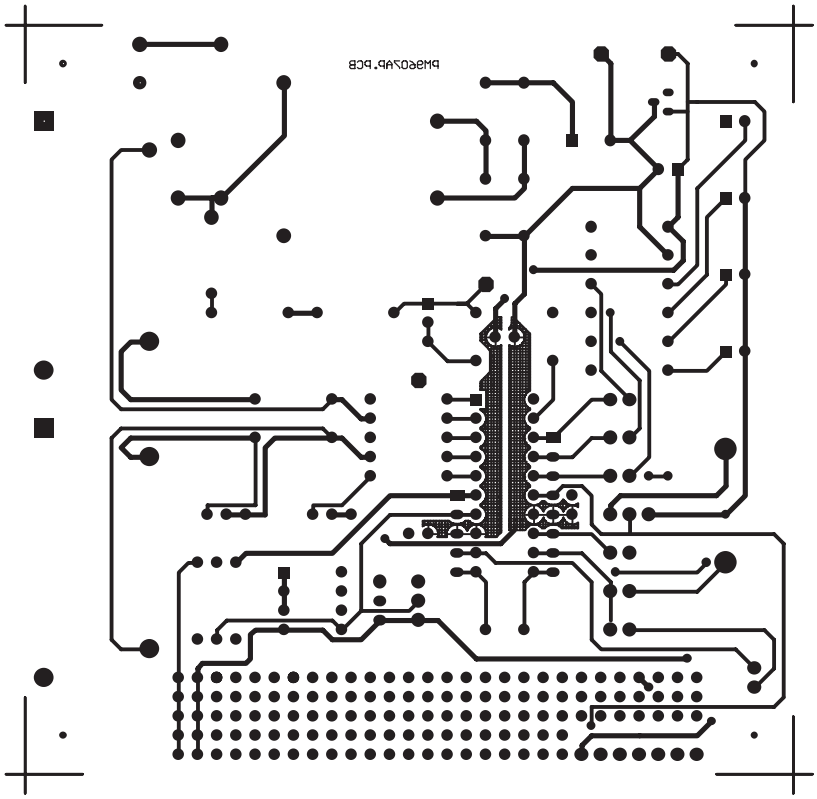

Figure 13: Bottom Side

SCHEMATIC

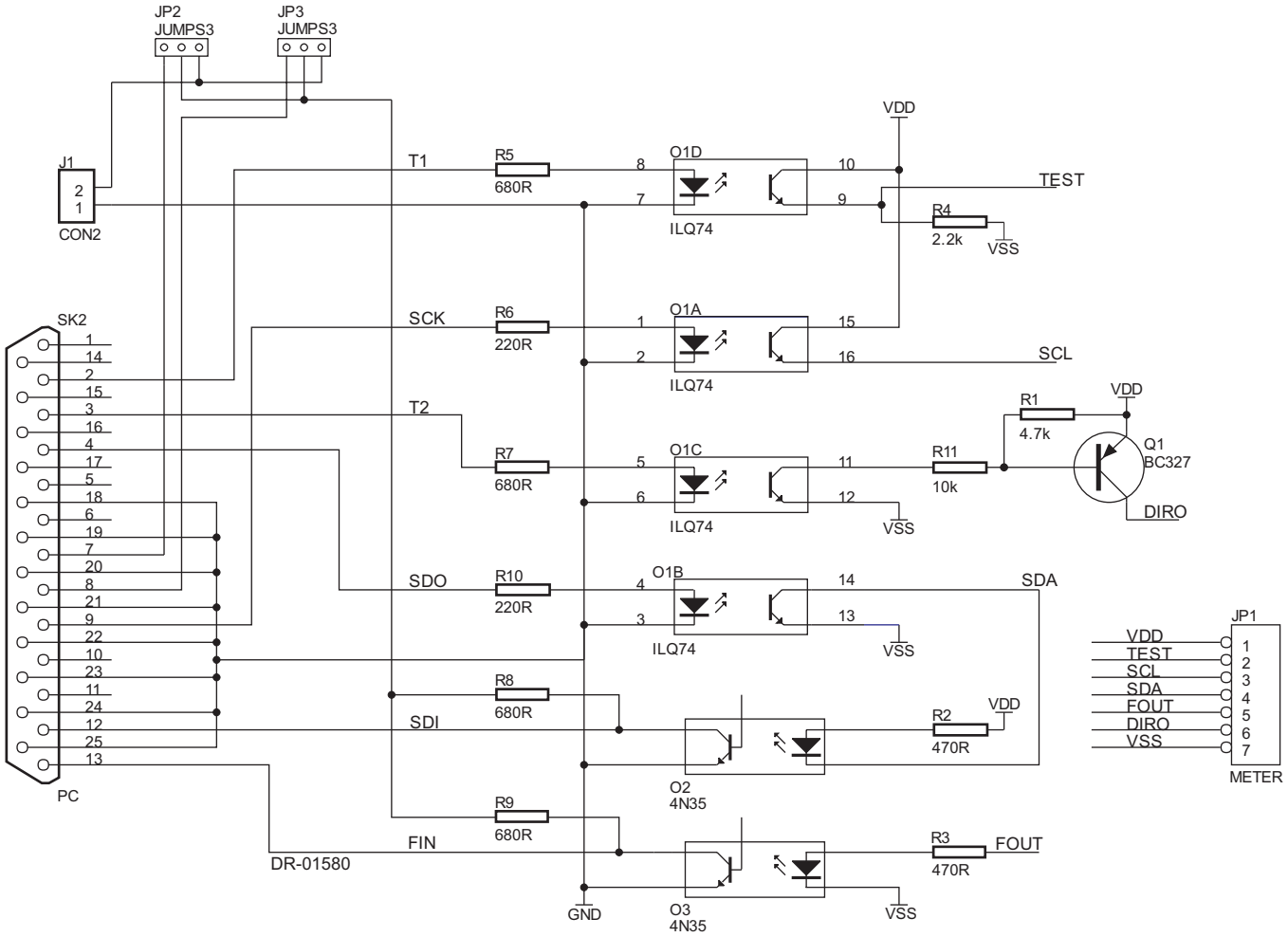

Figure 14: Schematic diagram of the IIC opto-isolator module

	PC Power select	Ext Power select
JP2	● ● ○	○ ● ●
JP3	● ● ○	○ ● ●

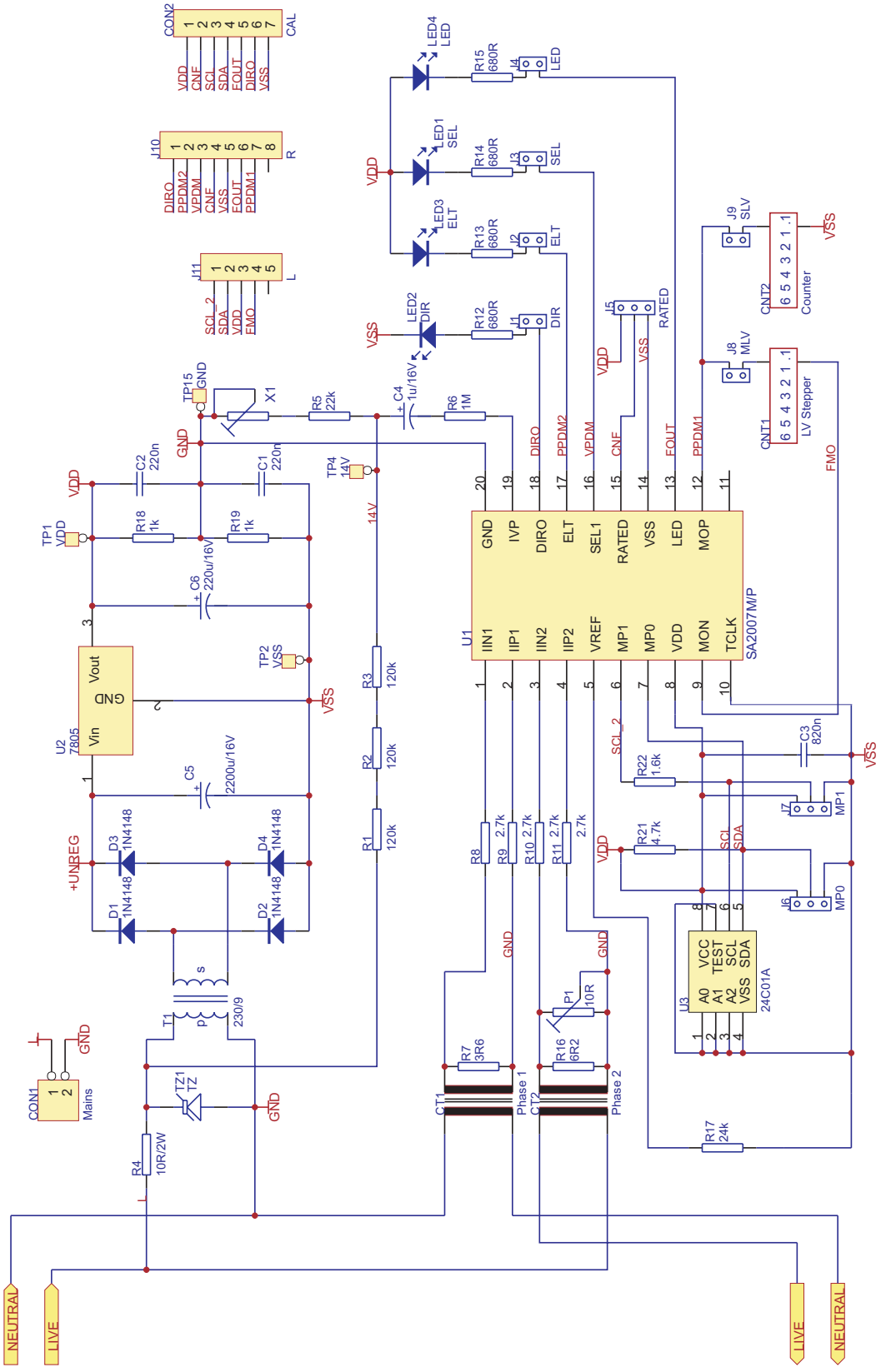

Figure 15: Schematic diagram of the complete PM2007M/PPE module

DISCLAIMER:

Any sales or technical questions may be posted to our e-mail address below:
energy@sames.co.za

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SOUTH AFRICAN MICRO-ELECTRONIC SYSTEMS (PTY) LTD

Tel: (012) 333-6021
Tel: Int +27 12 333-6021
Fax: (012) 333-8071
Fax: Int +27 12 333-8071

P O BOX 15888
LYNN EAST
0039
REPUBLIC OF SOUTH AFRICA

33 ELAND STREET
KOEDOESPOORT INDUSTRIAL AREA
PRETORIA
REPUBLIC OF SOUTH AFRICA