

Application Note: Energy Meter Evaluation Module



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PM9607AP

INTRODUCTION

This Application Note describes the functionality of the SA9607M and the SA9607P metering integrated circuits using the PM9607AP evaluation module. The SA9607 family is a low cost solution specifically designed to meet the needs of markets that require both live and neutral energy measurement, in order to detect possible meter tampering. Using the SA9607 family the meter manufacturer is able to build a meter that measures the energy consumption, even during a tamper condition, and records it to a mechanical counter.

This application note will focus on the practical use of the SA9607 family. More detailed information specific to the SA9607M or SA9607P can be found in the applicable datasheet.

THE SA9607 SERIES ENERGY METERS

The SA9607 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 SA9607 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 SA9607's ELT output which can drive a LED directly.

The SA9607 are designed to drive mechanical counters directly. The module is fitted with an impulse type counter that increments with a single 71ms pulse. The SA9607 can also drive low cost mechanical counters (stepper motors) that use two consecutive pulses with opposing voltages to advance the counter one position. The SA9607 outputs these two opposing pulses in close succession, minimizing the chance of the stepper motor being in the wrong phase after a power failure. Calibration pulses, reverse power, earth loop tamper and active channel are displayed with four LEDs fitted on the module.

THE SA9607M PIN PROGRAMMABLE MONOCHIP METER

Using the SA9607M, 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 manufacturer 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 SA9607M using the PM9607AP module. Note that the values of the current transformer's resistor values need to 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 SA9607M. Pin status 0 indicates connects to VSS and 1 indicates connection to VDD

THE SA9607P MONOCHIP METER WITH ON CHIP CALIBRATION

The SA9607P uses an external EEPROM to store calibration data as well as meter specific settings. A major advantage of the SA9607P 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 SA9607P integrated circuit together with an external EEPROM provides more meter setup features than the SA9607M. 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 SA9607P. The SA9607P will load this data from the EEPROM during power up. During normal meter operation it reloads periodically the data from the EEPROM. The SA9607P never writes to the EEPROM. For more specific configuration information please refer to the SA9607P datasheet.



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MAINS CONNECTION TO MODULE

The PM9607AP module connects directly to live and neutral on CON1. The module is referenced to neutral and 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 SA9607P is used. The connector does not have any significance when a SA9607M device is used in the module.

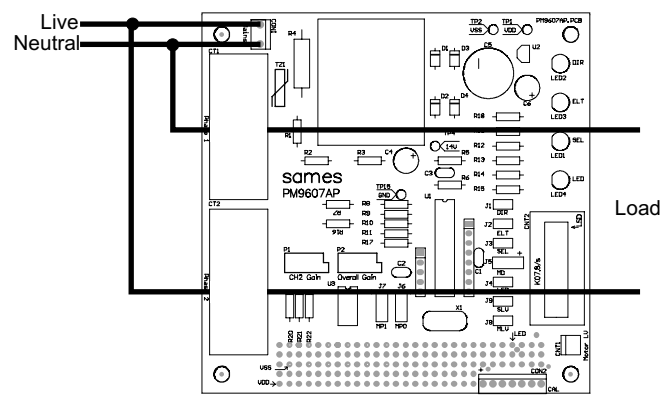


Figure 1: Connection diagram for normal metering application

Name	Function Description	SA9607M	SA9607P
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 CNF SCL SDA FOUT DIRO VSS

Table 2: Connector Descriptions

MODULE SETUP

The PM9607AP module is setup for use with the SA9607M 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	SA9607M setting	SA9607P 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 18, 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 SA9607		

Table 2: Jumper settings for various device options

USING THE SA9607P IC

The EEPROM on the SA9607AP module may be programmed in circuit with the use of a PC and a IIC interface module. The interface module is available from SAMES and 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 metering module, interface module as well as the PC.

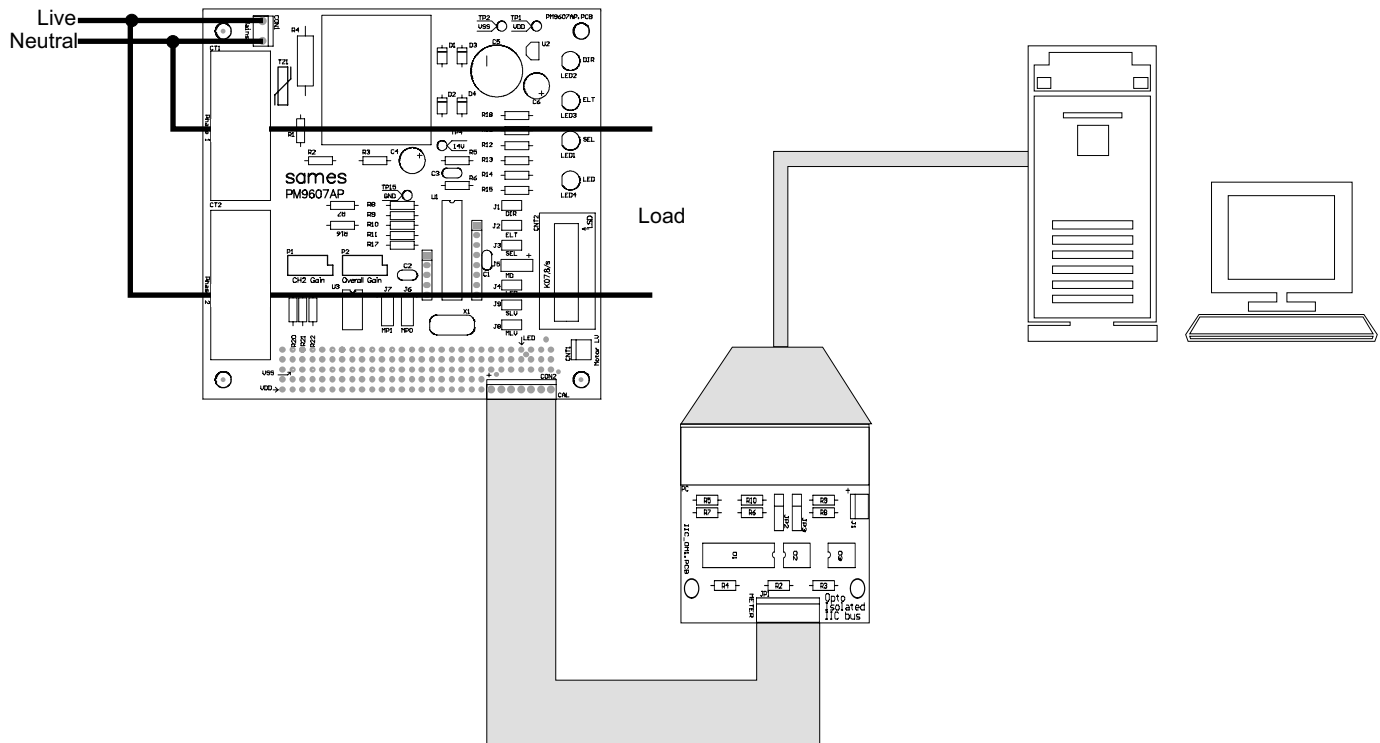


Figure 2: PM9607AP mains connections as well as PC programming setup

To use the PM9607AP module with a SA9607P integrated circuit the following components need to be changed:

- Insert the EEPROM from socket U3.
- Replace termination resistors R16 and R7 with 3.6 resistor.*
- Remove Channel 2 trim-pot P1.*
- Remove P2 trim-pot. Short-circuit the trim-pot footprint.*
- Replace resistor R17 with a 24K resistor.*
- Remove jumpers J5, J6 and J7.
- Resistor R22 must be fitted if EEPROM will be programmed in circuit.

* 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 SA9607 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 SA9607.

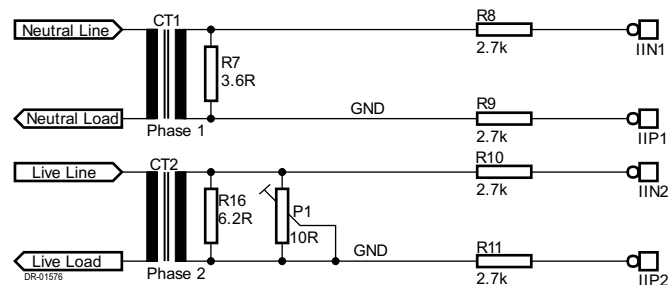


Figure 3: Current input configuration

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 3.6 resistor giving a voltage drop of 86.4mV across the termination resistor at rated conditions (Imax for the meter).

The termination resistor on the second current channel is adjustable by means of P2 to facilitate channel equalization calibration. The termination resistor is chosen so that a 10 trimpot in parallel will provide a sufficient channel range.

Current Sensor Input Resistors

The resistors R8, R9 and R10, R11 define the current level into the current sense inputs of the SA9607. The resistor values are selected for an input current of 16µA on the current inputs of the SA9607 at rated conditions. For a 60A meter at 2500:1 CT the resistor values are calculated as follows:

$$R8 = R9 = (I_L / 16\mu A) \times R_{SH} / 2$$
$$= 60A / 2500 / 16\mu A \times 3.6 / 2$$
$$= 2.7k$$

I_L = Line current
 R_{SH} = 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 SA9607 (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 1M resistor.

Voltage Divider

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

$$RB = R1 + R2 + R3 + R4$$
$$RB = R6 || R5$$

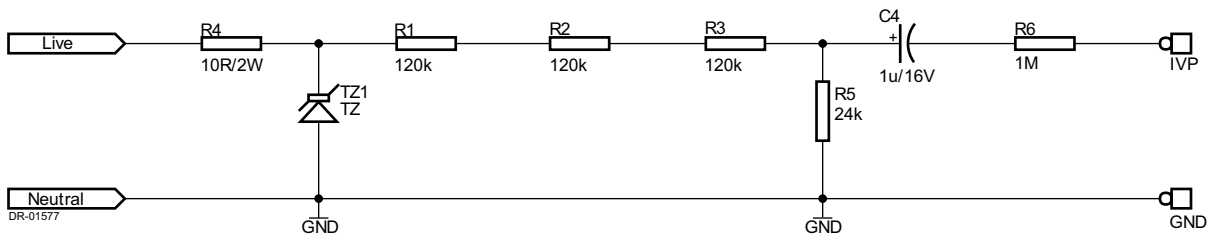


Figure 4: Mains voltage divider



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Combining the two equations gives:

$$(R_A + R_B) / 230V = R_B / 14V$$

Values for resistors R4 = 10 , R5 = 24k and R6 = 1M is chosen.

Substituting the values result in:

$$R_B = 23.437k$$

$$R_A = R_B \times (230V / 14V - 1)$$

$$R_A = 361.607k$$

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

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:

$$C = 1 / (2 \times \pi \times \text{Mains frequency} \times R_5 \times \tan(\text{Phase shift angle}))$$

$$C = 1 / (2 \times \pi \times 50 \times 1M \times \tan(0.18 \text{ degrees}))$$

$$C = 1.013\mu F$$

Reference Voltage VREF

The VREF pin of the SA9607 is connected to a resistor that determines the on chip bias current. The PM9607AP module is set up for the SA9607M, so the bias resistor is made up of resistor R17 and trimpot P1 in series. The multi turn trimpot P1 may be varied for precise calibration.

Calibration of the bias current is not necessary when using the SA9607P as device calibration is loaded from the external EEPROM.

Ground GND

The GND pin of the SA9607 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 PM9607AP module uses a transformer based power supply to ensure flexibility for different counter drive configurations. The maximum current that can be drawn by the circuit is as follows:

The average power consumption of the module is usually less. The current indicated in table 2 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 SA9607. The SA9607 operates between 5 Volt and 0 Volt with its GND pin connected to mid-rail.

Source	Max current	Unit
SA9607M/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



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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	CNF	A positive edge on CNF 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 CNF 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 PM9607AP on the other side. The PC is completely isolated from the evaluation module and can be used to program the EEPROM on the PM9607AP module safely.

The SA9607P 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 SA9607P during programming.

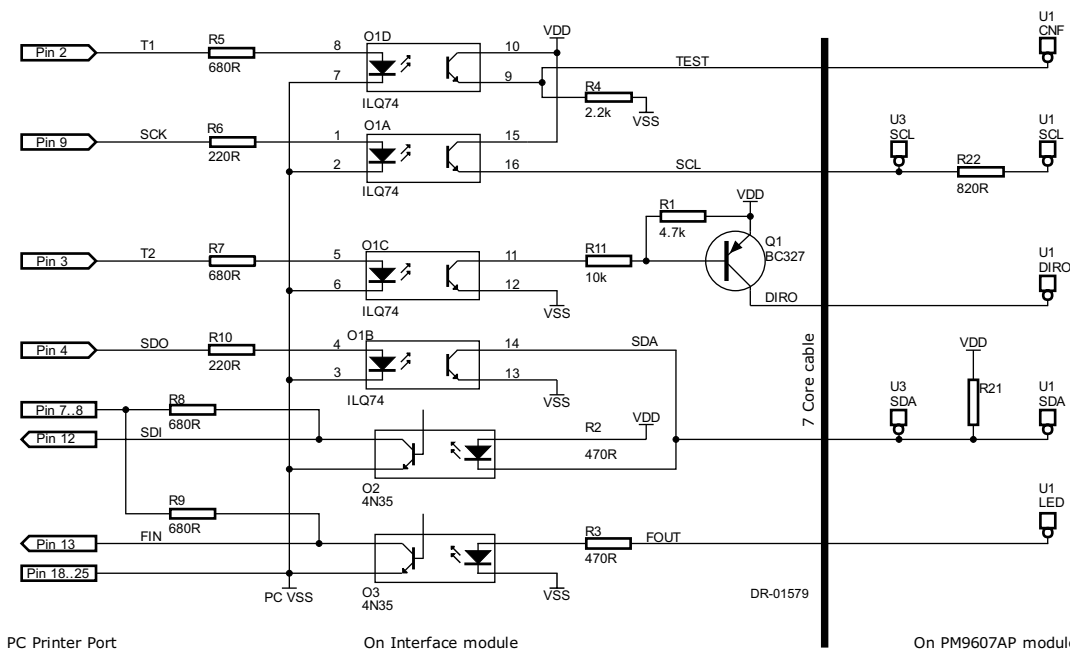


Figure 6: Schematic diagram of the IIC opto-isolator module as well as relevant components on the PM9607AP module



CALIBRATION AND SETUP

Software is available to setup and calibrate the SA9607P device. Download the SA9607P1.zip file from the SAMES web site. From the following URL:

<http://www.sames.co.za/emsoft/9607-1.zip>

The latest version of the evaluation software and source code is included in the zip file. 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:
c:\>sa9607p 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 SA9607P datasheet. The following is a description of the functionality of the SA9607P 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 (SA9607P's Kr parameter). V_{nom} is the module's rated voltage and I_{max} the module's rated current. The PM9607AP module is designed for rated conditions of 230V/60A. The software defaults to V_{nom} = 230V and I_{max} = 60A.

LED Constant

LED Constant selects the module's LED pulse rate (calibration LED), which is the SA9607P'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 Resol.

Counter resolution sets the modules counter resolution (SA9607P's CRES parameter). The options are 1,10 or 100p/kWh.

Counter PW

Counter PW set up the mechanical counter's pulse width (SA9607P's CPW parameter). The available options are 71ms and 142 ms. The PM9607AP 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:

$$\text{Error} = (\text{Energy from module} - \text{Real energy}) / \text{Real energy} \times 100$$

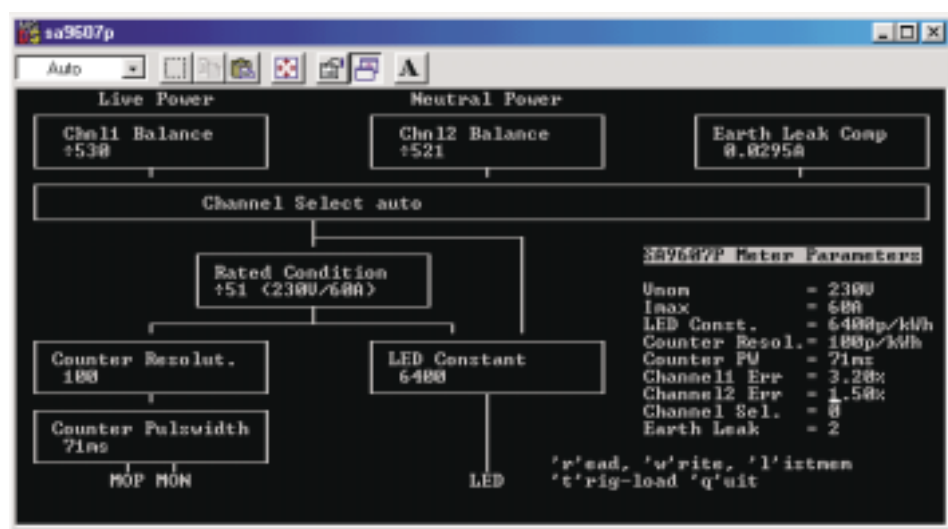


Figure 7: Screen capture of the SA9607P setup program



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 SA9607P's Kc parameter, which is used for channel balance.

Channel Sel.

The channel select parameter selects the source for energy metering. (SA9607P'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. (SA9607P'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 PM9607AP module will be updated with settings specified by the program.

DEVICE RELOAD TRIGGER

Pressing "t" triggers a reload. The SA9607P is triggered and reloads the parameters from the EEPROM. The SA9607P will reload the parameters every 1132 seconds.

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 SA9607M and the SA9607P single phase metering circuits. The SA9607M requires external settings and gain adjustment. The SA9607P 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 groundplane, 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 transformers magnetic field.

The 5V supply is de-coupled and routed directly to the power pins of the IC. P2 is connected with a separate track to the VSS pin of the SA9607.

**COMPONENT LISTS**

The following component list covers all components fitted on the PM9607AP module as shipped and configured for the SA9607M device.

Symbol	Description	Detail
U1	SA9607M	DIP-20
IC2	78C05, Voltage regulator	
D1, D2, D3, D4	Diode, Silicon, 1N4148	
R1, R2, R3	Resistor, 120k, 1/4W, 1%, metal	
R4	Resistor, 10R, 2W, Wire wound	
R5	Resistor, 24k, 1/4W, 1%, metal	
R6	Resistor, 1M, 1/4W, 1%, metal	
R7	Resistor, 3.6R, 1/4W, 1%, metal	
R16	Resistor, 6.2R, 1/4W, 1%, metal	
R17	Resistor, 22k, 1/4W, 1%, metal	
R8, R9, R10, R11	Resistor, 2.7k, 1/4W, 1%, metal	
R12, R13, R14, R15	Resistor, 22k, 1/4W, 1%, metal	
R18, R19	Resistor, 680R, 1/4W, 1%, metal	
R20, R21	Resistor, 1k, 1/4W, 1%, metal	
R22		0R for SA9607M
C1, C2	Capacitor, 220nF	
C3	Capacitor, 220nF	
C4	Capacitor, 1uF, 16V, electrolytic	
C5	Capacitor, 2200uF, 16V, electrolytic	
C6	Capacitor, 220uF, 16V, electrolytic	
LED1, LED2, LED3, LED4	3mm Light emitting diode	
T1	Transformer, 230V/9V, 1.5VA	
TZ1	S20K275	
CNT1	Impulse counter, Kuebler, K07.80	
Con1	Molex 3 pin connector, 200 mil pin spacing	
Con2	Molex 7 pin connector, 100 mil pin spacing	
CT1, CT2	Current Transformer, TZ-76, PCB Mount	
9	Jumpers	
25	Header pins	
X1	Crystal, 3.5795 Mhz	

Table 6: Components for SA9607M functionality, 60A rated setup

**PM9607AP**

The following component list covers components that need to be changed to use the module with the SA9607P device.

Symbol	Description	Detail
U1	SA9607P	DIP-20
IC3	24C01A, IIC bus interfaced EEPROM	Insert
R7, R16	Resistor, 3.6R, 1/4W, 1%, metal	Insert
R17	Resistor, 22k, 1/4W, 1%, metal	Remove
R17	Resistor, 24k, 1/4W, 1%, metal	Insert
R20, R21	Resistor, 4.7k, 1/4W, 1%, metal	Optional
R22	Resistor, 1.6k, 1/4W, 1%, metal	Insert
P1	Multi-turn trim pot, 10R	Remove
P2	Multi-turn trim pot, 5k	Link

Table 7: Components for SA9607P functionality, 60A rated setup

Symbol	Description	Detail
O1	ILQ74	DIP-16
O2, O3	4N35	DIP-16
R1	Resistor, 4.7k, 1/4W, 1%, metal	
R2, R3	Resistor, 470R, 1/4W, 1%, metal	
R5, R7	Resistor, 680R, 1/4W, 1%, metal	
R8, R9, 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

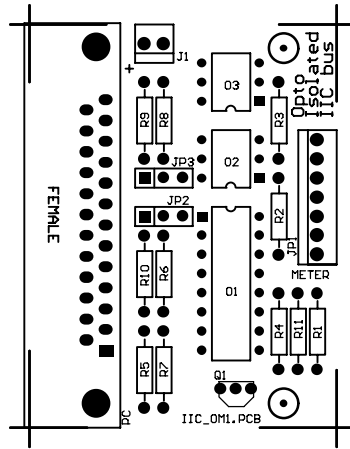


Figure 8A: IIC Module Component layout

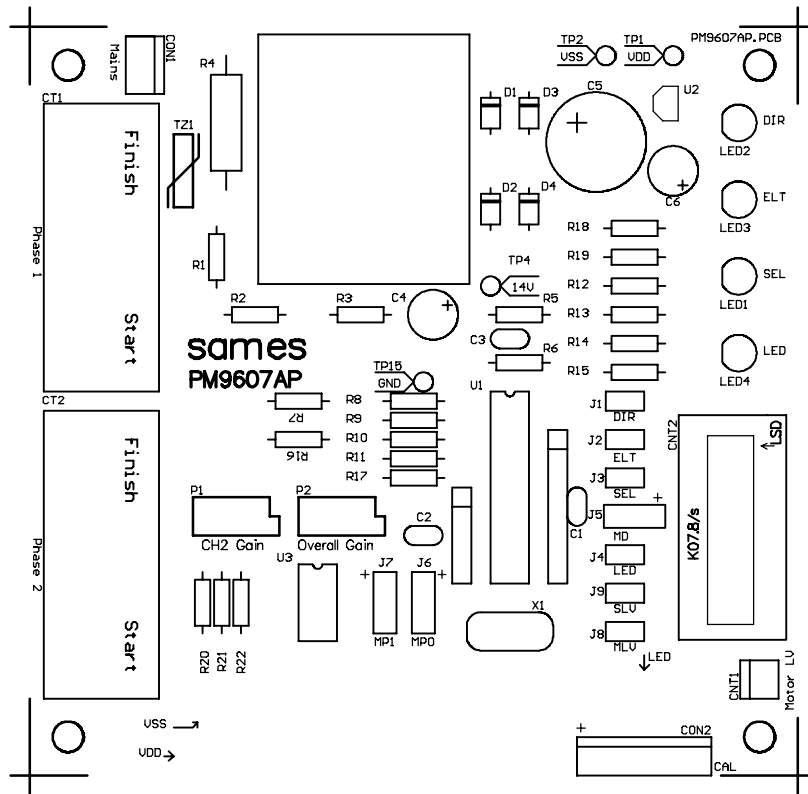


Figure 9A: PM9607AP Component layout

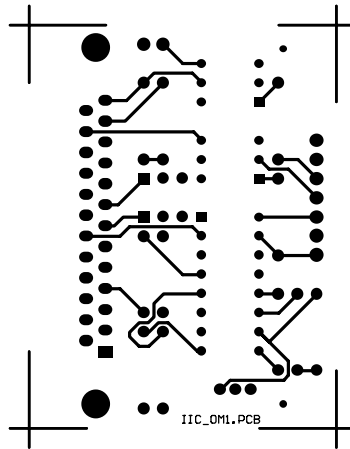


Figure 8B: IIC Module Top Side

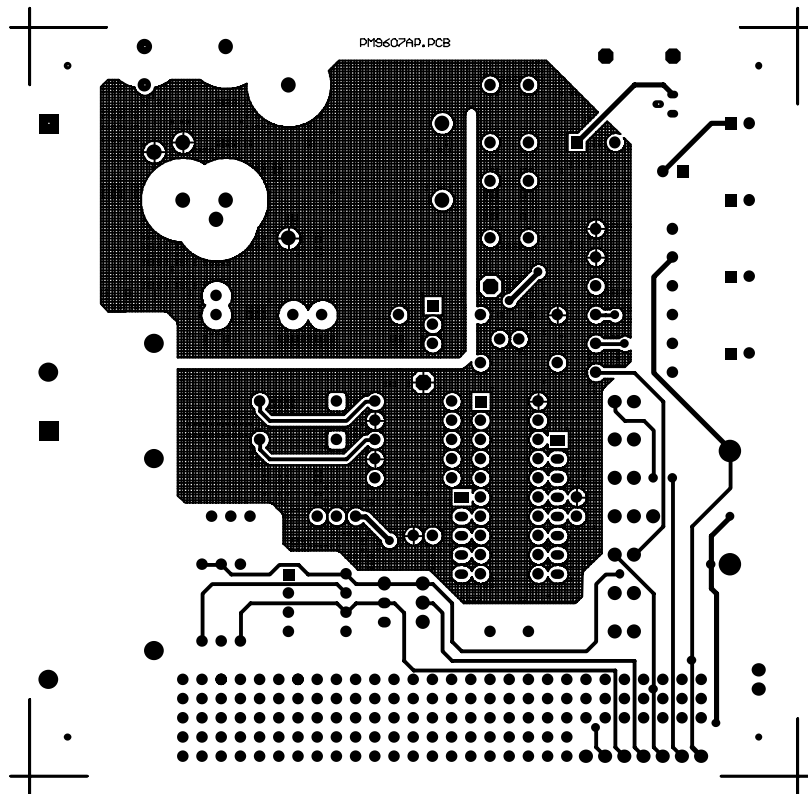


Figure 9B: PM9607AP Top Side

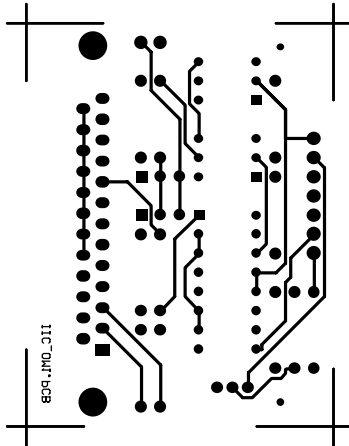


Figure 8C: IIC Module Bottom Side

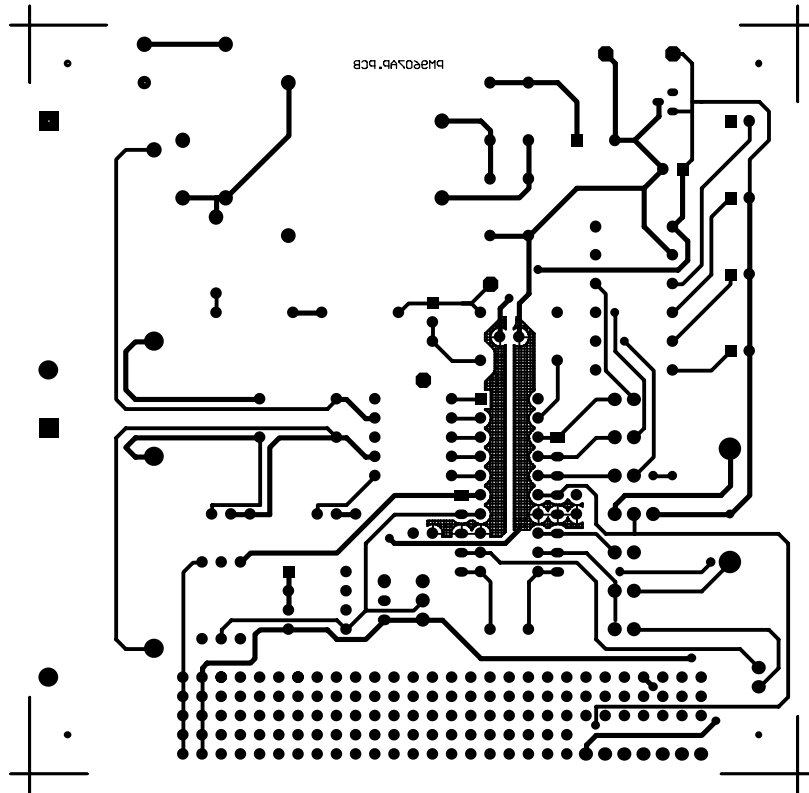


Figure 9C: PM9607AP Bottom Side

SCHEMATIC

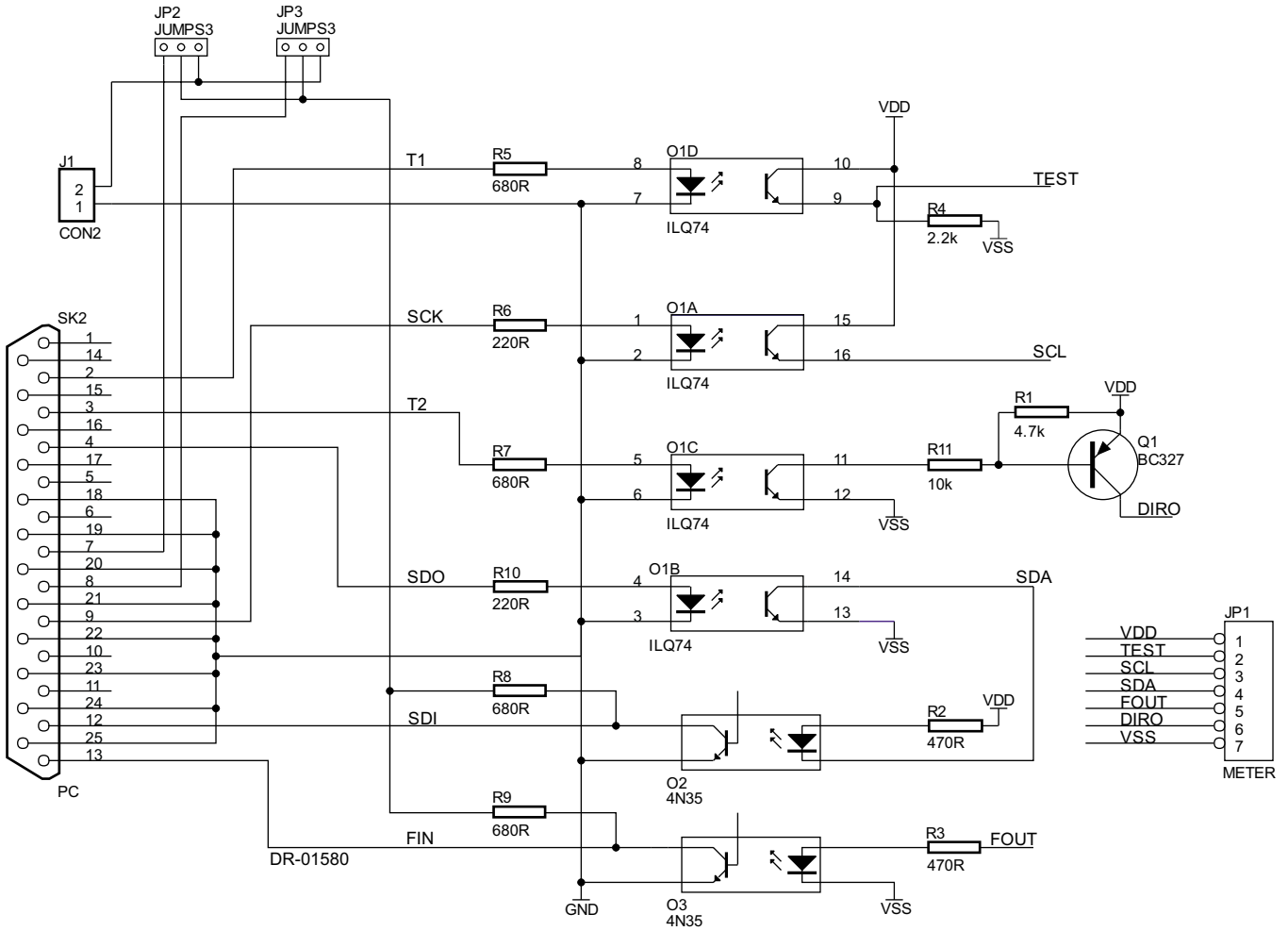


Figure 10: Schematic diagram of the IIC opto-isolator module

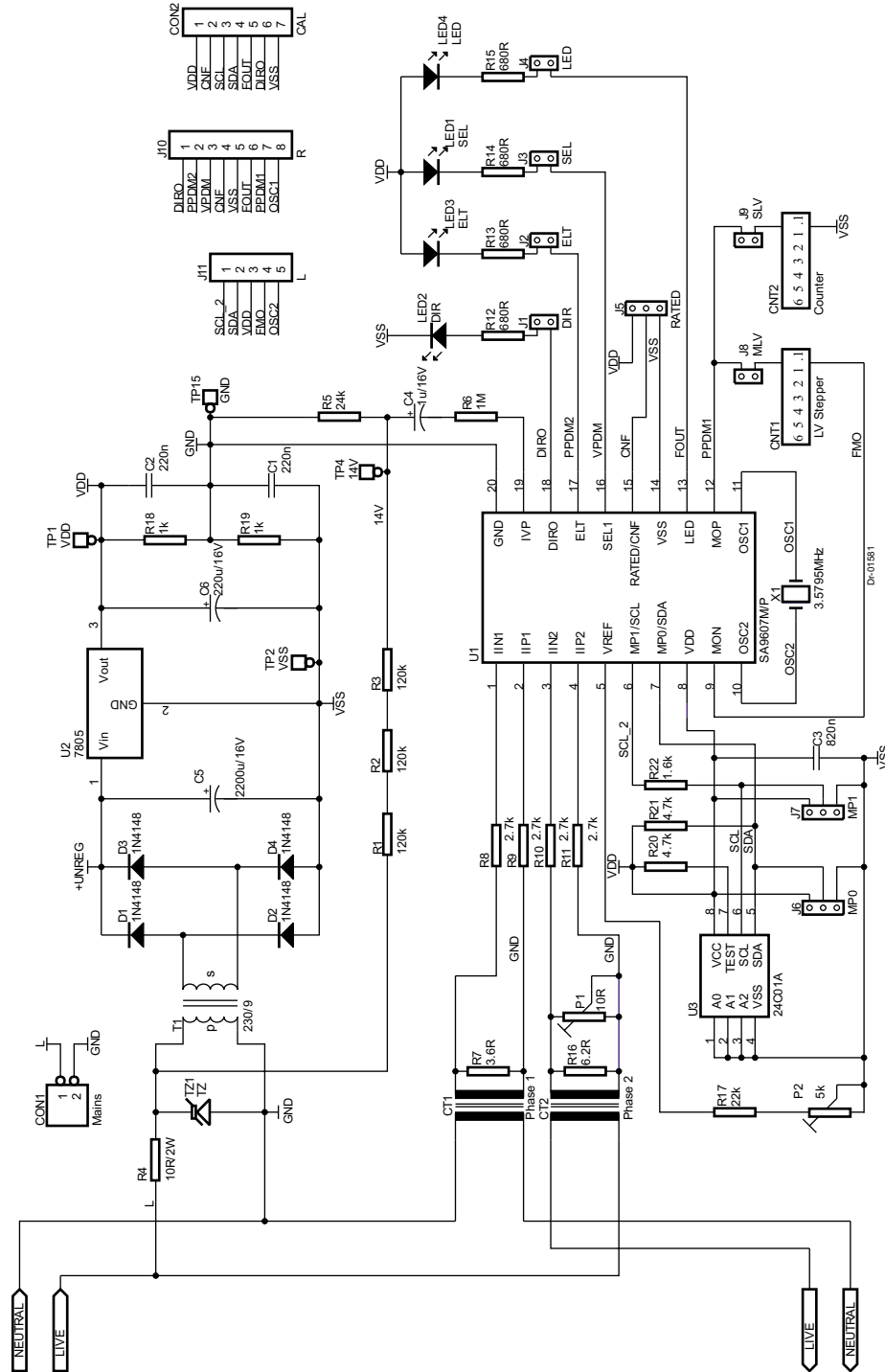


Figure 11: Schematic diagram of the complete PM9607AP module

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