Evaluation Board for the SA2007M Energy Metering IC

PM2007MSE

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FEATURES

- Designed to be used as fully functional Watt-Hour meter.
- Continuously measures both Live and Neutral for tamper detection.
- Accurately measures the energy consumption even under partial tamper conditions of less than one percent.
- Four on-board LED's for calibration, reverse power indication, earth loop tamper indication and active channel indication.
- Easily connects to two current sensors.
- Easily connects to a low cost mechanical counter.
- On-board capacitive power supply.
- Selectable rated conditions, LED pulse rates and counter resolutions
- Calibration done via on-board resistor networks

DESCRIPTION

The SA2007 family is a low cost solution specifically designed for markets requiring both live and neutral energy measurement to detect meter tampering. The SA2007 family enables meter manufacturers to design meters that measure energy consumption accurately, even under **PARTIAL tamper conditions** of less than a percent.

The SA2007 family of devices consists of the SA2007H, the SA2007M and the SA2007P. The H device is used in conjunction with a micro- controller with pulse and energy direction outputs for each current channel. The M device is a single-chip solution with pin programmable features. The P device is also a single-chip solution and retrieves its configuration and calibration information from an external EEPROM. More detailed information specific to the SA2007H, SA2007M or SA2007P can be found in the applicable data sheets.

The PM2007MSE evaluation board has been designed with the SA2007M as a fully functional Watt-Hour meter. The evaluation board connects to a 240V source, current sensors (CT's) as well as a mechanical counter. No external power supply is required. Calibration is easily done via the on-board resistor networks.

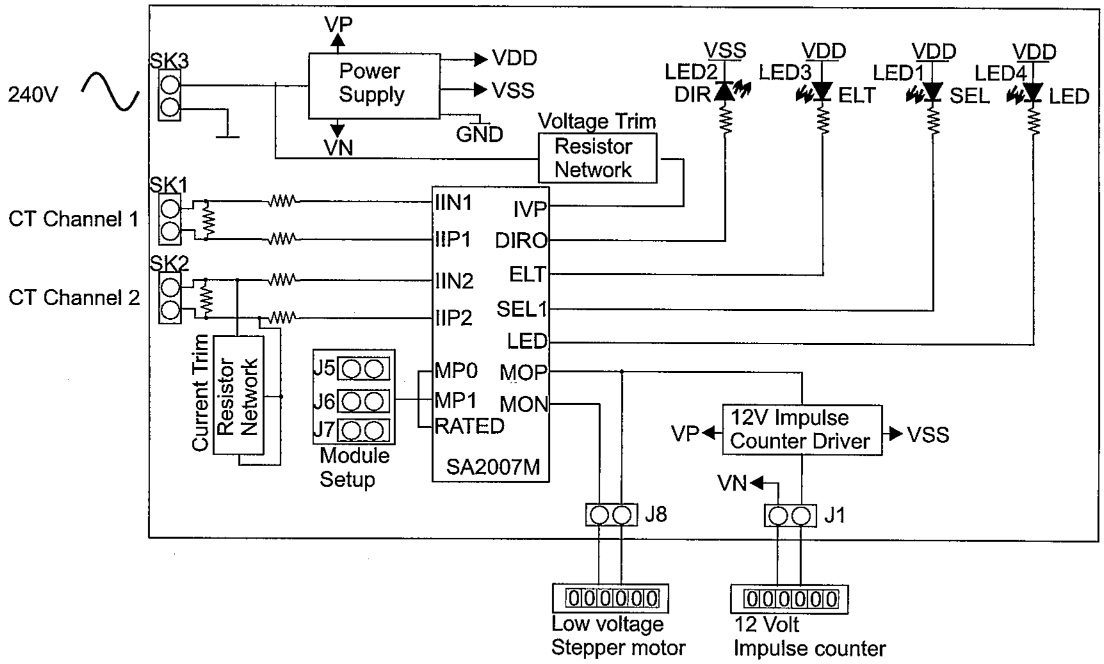


Figure 1: Block diagram

THE SA2007M ENERGY METER IC

A correctly installed meter should measure equal amounts of power consumption in the live and neutral phases. During meter tampering the two measurements are not equal and the energy measured should be from the channel with the larger value, no matter how minute the difference between the two channels are.

Referring to figure 2 a typical tampering condition is shown where the live and neutral lines are reversed and part of the load (10%) is returned to earth. A meter using the SA2007M will **immediately** use CT 2 for metering as this channel has the higher current (100%).

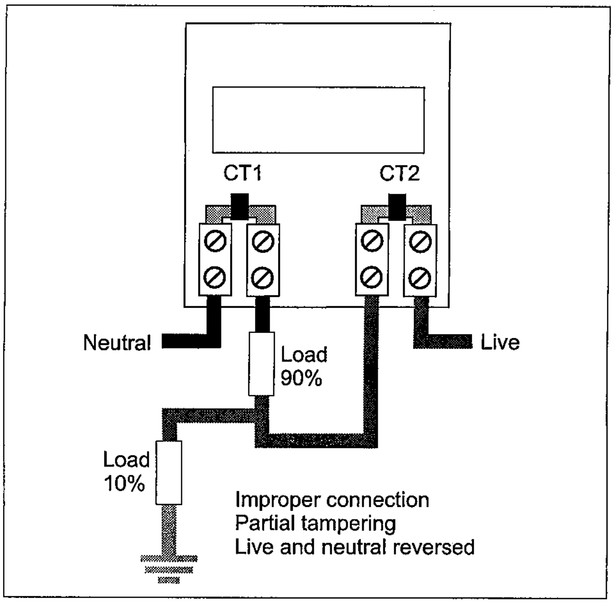


Figure 2: Typical partial meter tamper

A meter using the SAMES SA2007M will ensure class 1 accuracy for the tamper condition illustrated and will even take care of partial tampering of less than a percent.

The SA2007M can drive a low cost mechanical counter (stepper motor) that require two consecutive pulses with opposing voltages to advance the counter one position. These two opposing pulses are generated in close succession, minimizing the chance of the stepper motor being in the wrong phase after a power failure. The PM2007MS module also makes provision to drive a 12V impulse counter with 142 ms pulses.

The SA2007M directly drives the four LEDs installed on the module. These LED's give a visible indication of the calibration pulses, energy direction, earth loop tamper condition and indicates which channel is been used for the kWh metering. LED1 indicates channel select, LED2 direction, LED3 earth loop tamper, and LED4 the pulse output.

The reverse power and earth loop tamper LEDs come into operation from the starting current of 0.02% of Imax.

Tamper conditions are INDICATED when the power consumption of the two channels differ by more than 12%.

Using the SA2007M, the meter's rated conditions, the LED pulse rate and counter resolution can be selected for various meter design. The meter manufacturer is able to produce a range of meters utilizing the same counter and the same metering constants with a single integrated circuit. Table 1 below lists some of the possible meter configurations available on the PM2007MSE module. Note that the values of the current transformer's resistors need to be changed to make some of the rated conditions possible.

Setting	Jumper	Pin
20A / 240V	J5 = 0	RATED = 0
40A / 240V	J5 = Open	RATED = OPEN
60A / 240V	J5 = 1	RATED = 1
1 pulse/ kWh	J7 = 0, J6 = 0	MP1 = 0, MP0 = 0
10 pulses / kWh	J7 = 0, J6 = 1	MP1 = 0, MP0 = 1
100 pulses / kWh	J7 = 1, J6 = 0	MP1 = 1, MP0 = 0

Table 1: A summary of possible meter configurations and corresponding pin and jumper settings on the PM2007MSE module. Pin status 0 indicates connection to 0V and 1 indicates connection to 5V.

Setting up the PM2007MSE module

The PM2007MSE module is setup for use with the SA2007M integrated circuit. Resistor values used on the module are calculated for rated conditions of 60A/240V. The counter resolution is set at 100 pulses/kWh and the LED pulse rate at 6400 pulses / kWh.

JUMPER DESCRIPTION

Table 2 describes the PM2007MSE various jumpers.

Jumper	Description
J2-J4, J9-J13	Mains voltage divider jumpers
J5	Rated conditions select jumper, pin 15
J6	Motor pulse rate select jumper, pin 7
J7	Motor pulse rate select jumper, pin 6
J14 - J21	Channel 2 current divider jumpers

Table 2: Jumper descriptions

These jumpers can be closed by placing a drop of solder across the pads on the PCB's jumper footprint. Meter calibration is done via the resistor networks (J2-J4, J9-21).

CONNECTOR DESCRIPTION

Table 3 describes the PM2007MSE various connectors.

Connector	Description
SK3	Module power and voltage sense input.
SK1	Channel 1 current transformer
SK2	Channel 2 current transformer
J1	12V Impulse counter
J8	Low voltage stepper motor

Table 3: Connector descriptions

The PM2007MSE module connects directly to live and neutral on SK3. The module is referenced to neutral and this should be kept in mind when connecting test equipment to the module.

SK1 and SK2 are provided for direct connection of the live and neutral current transformers. By connecting mains to the module as well as a load the polarity of the current transformers should be checked. A flashing Direction LED (LED2) will indicate that the current measured in both channels are of opposite direction. To correct this swap the terminals of one of the current transformers.

A 200:1 stepper counter can be connected to J8, the polarity of MOP and MON does not matter.

A transistor driver circuit is used to drive a 12V counter connected to J1.

CIRCUIT DESCRIPTION

ANALOG SECTION

The analog (metering) interface described in this section is designed for measuring 240V/60A with precision better than Class 1.

The most important external components for the SA2007M 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 that 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 SA2007M.

CT TERMINATION RESISTOR

The voltage drop across the CT termination resistor at rated current should be at least 20mV. The CT's used with the PM2007MSE module should have low phase shift and a ratio of 1:2500. The CT is terminated with a 3.6Ω resistor to give 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 selecting up to 8 resistors in parallel to facilitate channel equalization calibration. The resistors in the resistor ladder are chosen to cover a ±20% range.

CURRENT SENSOR INPUT RESISTORS

Referring to figure 3 the resistors R8, R9, R10 and R11 define the current levels into the SA2007M current sense inputs. The resistor values are selected for an input current of 16µA at rated conditions. For a Imax of 60A and using CT's with a ratio of 2500:1 the resistor values are calculated as follows:

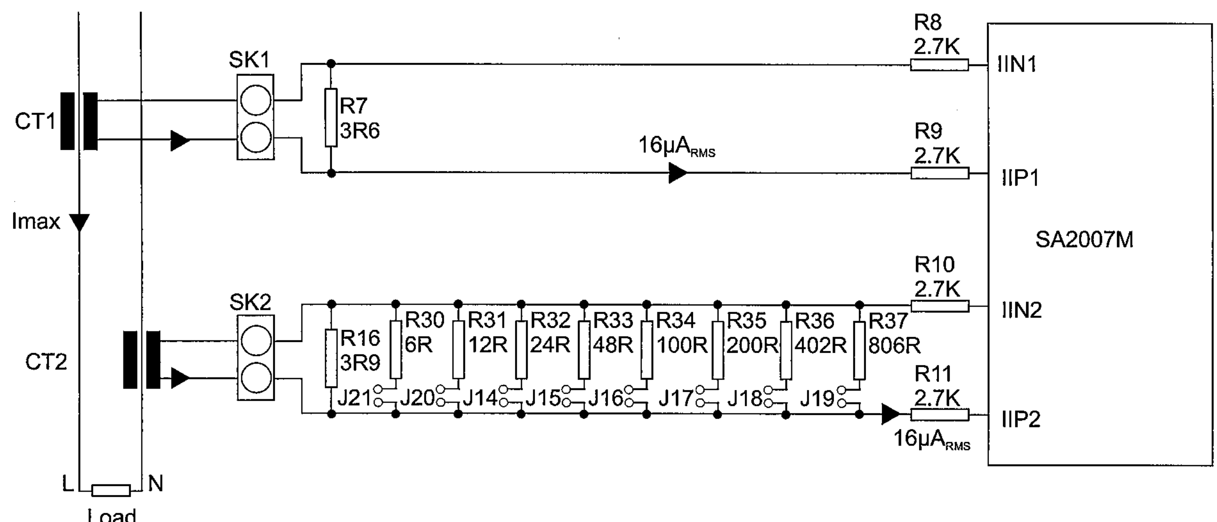


Figure 3: Current input configuration example as setup for a 60A meter.

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

where
I_L = Line current (Imax)
R_{SH} = CT Termination resistor
2500 = CT ratio
The two current channels are identical so R8=R9=R10=R11.

VOLTAGE INPUT IVP

Referring to figure 4 the connections for the voltage sense input is shown. The current into the A/D converter (IVP) is set 14µARMS at nominal mains voltage. This voltage sense input saturates at approximately 17µARMS. A nominal voltage current of 14µA allows for 20% over driving. The mains voltage is divided down by a voltage divider to 14V. The current into the voltage sense input is set at 14µA via a 1MΩ resistor (R6). The voltage sense input is also used to calibrate the meter by means of the 256 selectable resistor combinations (J2-J4, J9-J13).

The following equation is used to calculate the resistor values for 14V voltage drop:

$RA = R1 + R2 + Rtrim$
$RB = R6 \,||\, R5$

Combining the two equations gives:

$(RA + RB) / 240V = RB / 14V$

Values for resistors R5 = 24kΩ and R6 = 1MΩ is chosen.
Substituting the values result in:

$RB = 23.437k\Omega$
$RA = RB \times (240V / 14V - 1)$
$RA = 378.34k\Omega$

Standard resistor values of 100KΩ are chosen for R1 and 180K for R2. Note that R1 can be changed to 180K when normal calibration cannot be achieved. This will only be required for some modules that have a larger offset. The value of the Rtrim is chosen to cover ±20% of RA. The values in the resistor ladder are used so that the resistor value halves with the next value. This resulted in using only two E96 range of resistors.

The capacitors C10 and C11 are used to compensate for any phase shift between the voltage sense inputs and the current sense inputs where CT's which generate phase errors are used. Two footprints are placed in parallel on the PCB to provide the most flexibility with various current transformers. To compensate for a phase shift of, for example 0.18 degrees, the capacitor value is calculated as follows:

$C = 1 / (2 \times \pi \times \text{Mains frequency} \times R6 \times \tan(\text{Phase shift angle}))$
$C = 1 / (2 \times \pi \times 50Hz \times 1M\Omega \times \tan(0.18 \text{ degrees}))$
$C = 1.013\mu F$

REFERENCE VOLTAGE VREF

Pin VREF (SA2007M pin 5) is connected to Vss via R17 which determines the on chip bias current. With R17=24KΩ optimum conditions are set.

GROUND GND

The GND pin of the SA2007M is connected to the neutral phase, which is midway between VDD and VSS. Note that the supply bypass capacitors C1 and C2 are physically positioned close to the SA2007M. This is to provide a proper bypassed supply to the SA2007M. The ground plane is split in two parts, one part is associated with the power supply and the other part is associated with the signals to the SA2007M.

IMPULSE COUNTER DRIVER

The SA2007M is able to directly drive a low voltage stepper motor counter via the MOP and MON outputs. These outputs are available on connector J8.

Additional circuitry for driving a 12V impulse counter is also provided on the module see figure 5. The impulse driver is triggered from the SA2007M's MOP output. The impulse counter is switched using the unregulated supply voltage VP and VN. The impulse counter can be connected to J1.

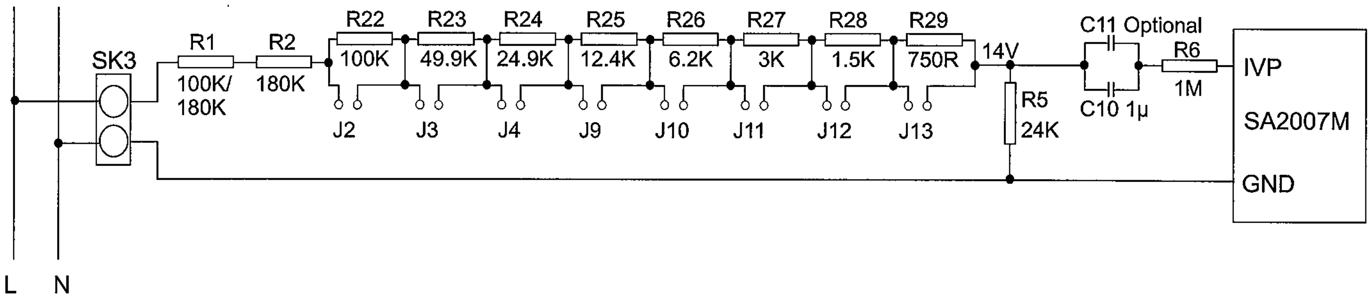


Figure 4: Mains voltage divider

PROTECTION

A MOV (D3) together with resistor R4 protects the rest of the circuit against voltage transients.

The current setting resistors R8, R9, R10 and R11 attenuates common mode and asymmetrical transients.

POWER SUPPLY

The PM2007MSE module uses a capacitive power supply. The burden on the mains is less than 10VA. Two TL431 voltage regulators are used to generate the ±2.5V needed to power the SA2007M. The SA2007M operates between ±2.5V with its GND pin connected to mid-rail. The maximum current the power supply can deliver is approximately 15 mA, so it is important to store as much energy as possible in storage capacitors to enable the SA2007M's output pulse to advance the counter. The current drawn by the LED's is kept to a minimum by having the series resistors values as high as possible.

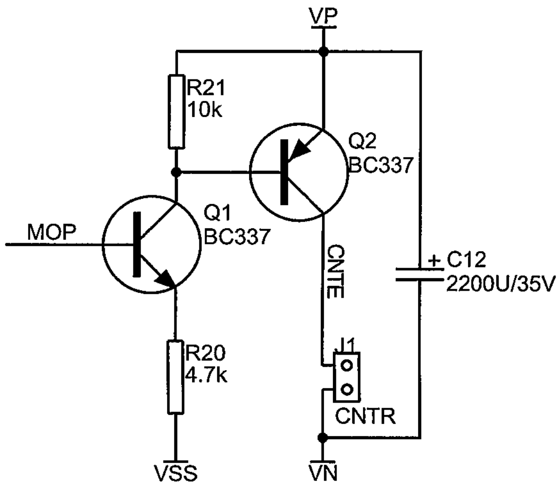


Figure 5: 12 Volt impulse counter driver

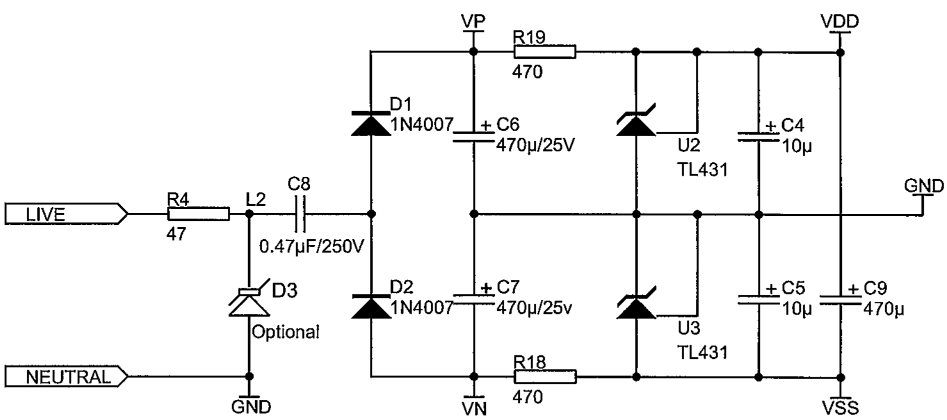
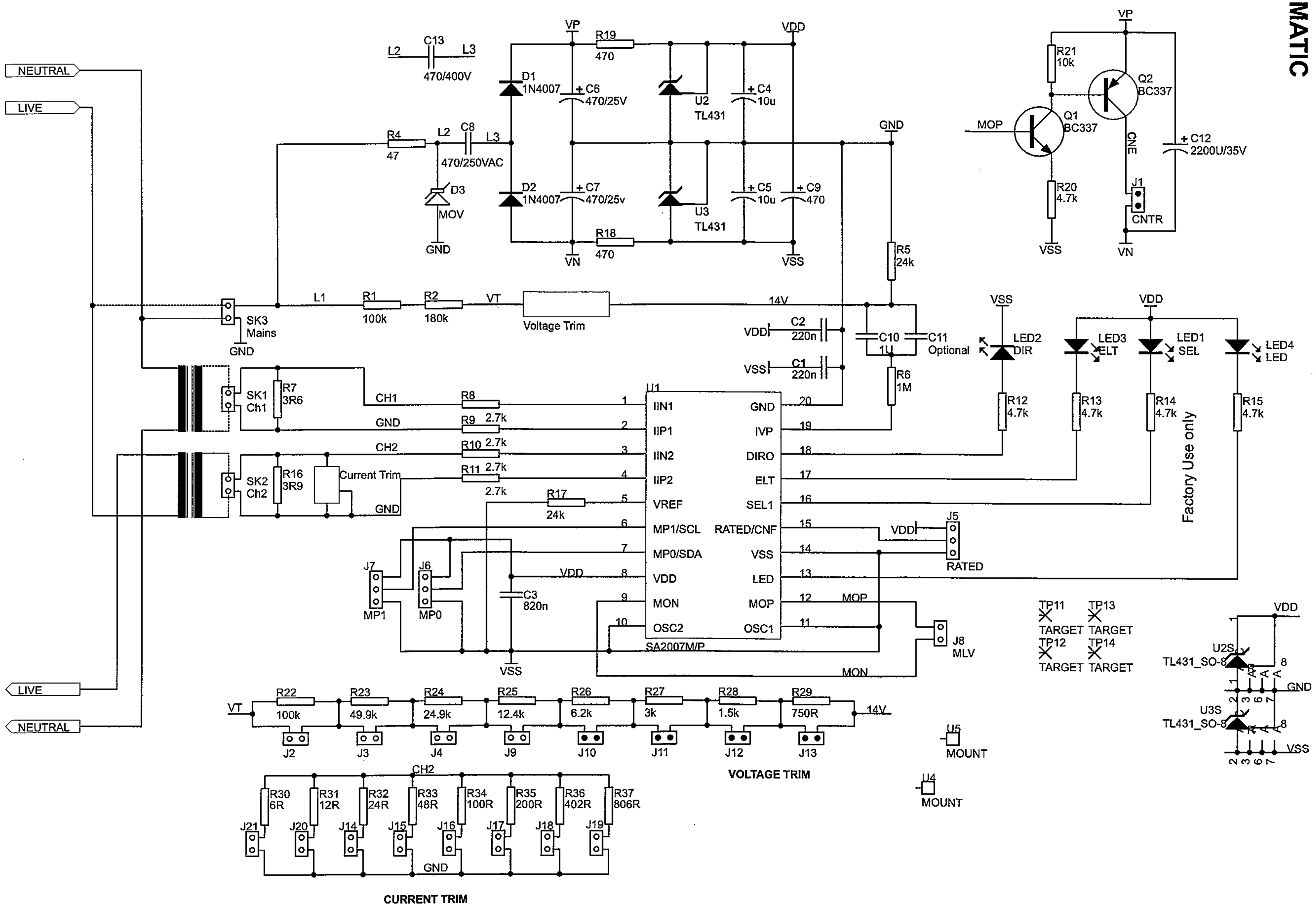


Figure 6: Capacitive power supply

SCHEMATIC



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PCB LAYOUT

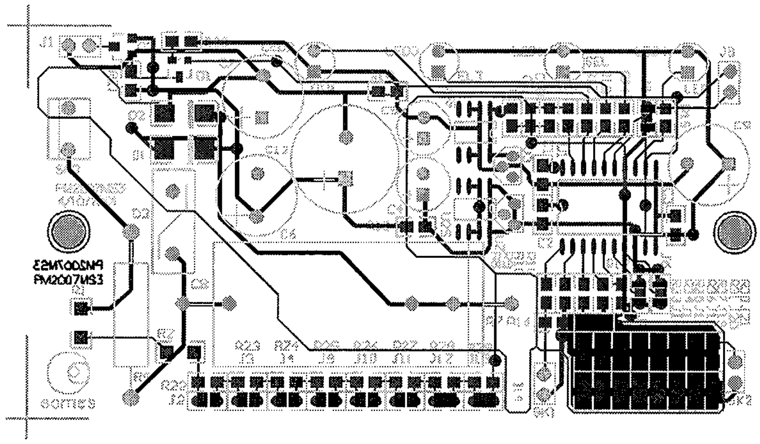

Figure 7: PM2007MSE PCB silkscreen

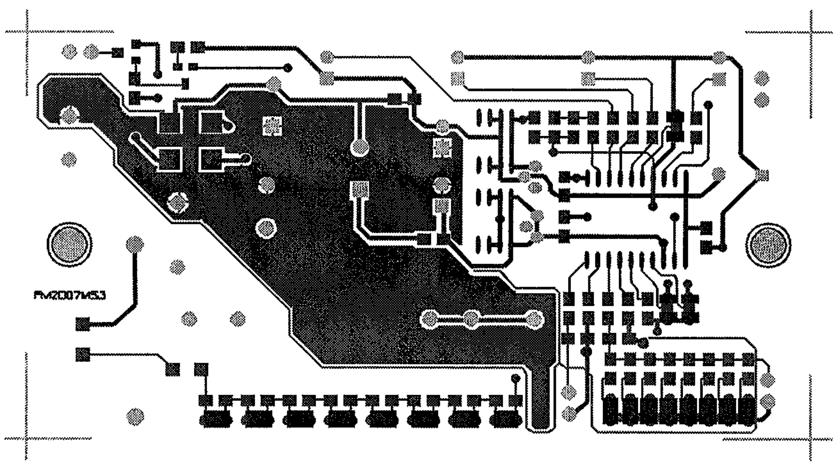

Figure 8: PM2007MSE PCB top

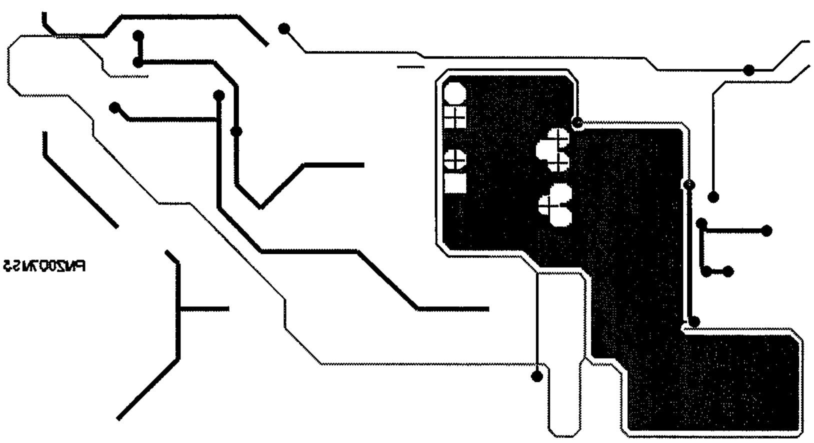

Figure 9: PM2007MSE PCB buttom

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COMPONENT LIST

The following lists all the components fitted on the PM2007MSE evaluation module.

Symbol	Description	Detail
U1	SA2007M	SOIC-20 300mil wide
U2, U3	TL431, Voltage regulator	SOIC-8, 150 mil wide
D1, D2	Diode, Silicon, Sm4007	Melf
R1	Resistor, 100k, E24, 1% or 180K	0805
R2	Resistor, 180k, E24, 1%	0805
R4	Resistor, 47R, 2W, 5%, Wire wound	
R5	Resistor, 24k, E24, 1%	0805
R6	Resistor, 1M, E24, 1%	0805
R7	Resistor, 3R6, E24, 1%	0805
R8, R9, R10, R11	Resistor, 2.7k, E24, 1%	0805
R12, R13, R14, R15, R20	Resistor, 4.7k, E24, 1%	0805
R16	Resistor, 3R9, E24, 1%	0805
R17	Resistor, 24k, E24, 1%	0805
R18, R19	Resistor, 470R, E24, 1%	0805
R21	Resistor, 10k, E24, 1%	0805
R22	Resistor, 100k, E24, 1%	0805
R23	Resistor, 49.9k, E96, 1%	0805
R24	Resistor, 24.9k, E96, 1%	0805
R25	Resistor, 12.4k, E96, 1%	0805
R26	Resistor, 6.2k, E24, 1%	0805
R27	Resistor, 3k, E24, 1%	0805
R28	Resistor, 1.5k, E24, 1%	0805
R29	Resistor, 750R, E24, 1%	0805
R30	Resistor, 6R, E24, 1%	0805
R31	Resistor, 12R, E24, 1%	0805
R32	Resistor, 24R, E24, 1%	0805
R33	Resistor, 48R, E24, 1%	0805
R34	Resistor, 100R, E24, 1%	0805
R35	Resistor, 200R, E24, 1%	0805
R36	Resistor, 402R, E96, 1%	0805
R37	Resistor, 806R, E96, 1%	0805
C1, C2	Capacitor, 220nF	0805
C3	Capacitor, 820nF	0805
C4, C5	Capacitor, 10uF, 16V, tantalum	
C6, C7	Capacitor, 470uF, 25V, electrolytic	
C8	Capacitor, 470nF, 250VAC	
C9	Capacitor, 470uF, 16V, electrolytic	
C10	Capacitor, 1uF	0805
C11	Capacitor	Not fitted
C12	Capacitor, 2200uF, 35V, electrolytic	
C13	C13 can be used in place of C8 to provide 27.5 mm pitch	
Q1	BC337, Silicon NPN transistor	SOT-23
Q2	BC337, Silicon PNP transistor	
LED1, LED2, LED3, LED4	3mm Light emitting diode	Fitted
D3	S10K275	

NOTE:

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