Evaluation Board for the SA2005F Energy Metering IC

PM2005FPD

FEATURES

- Designed to be used as a fully functional Watt-Hour meter.
- Better than Class 1 operation
- On-board power supply
- 3 Phase 4 Wire configuration
- On-board current transformers
- Can be used with external micro controller for calibration and different pulse rates

DESCRIPTION

The SA2005F IC is an enhancement of the SA9105F.

The PM2005FPD evaluation board provides energy data via an isolated pulse output for three-phase four-wire applications using the SA2005F. The mains voltages easily connect to the module by way of a Molex connector (SK1). The 3 on-board current transformers measure the current in each phase. A simple capacitive power supply supplies the energy metering IC with power. The LM431 regulators are used to generate 5V supply voltage for the IC on the board.

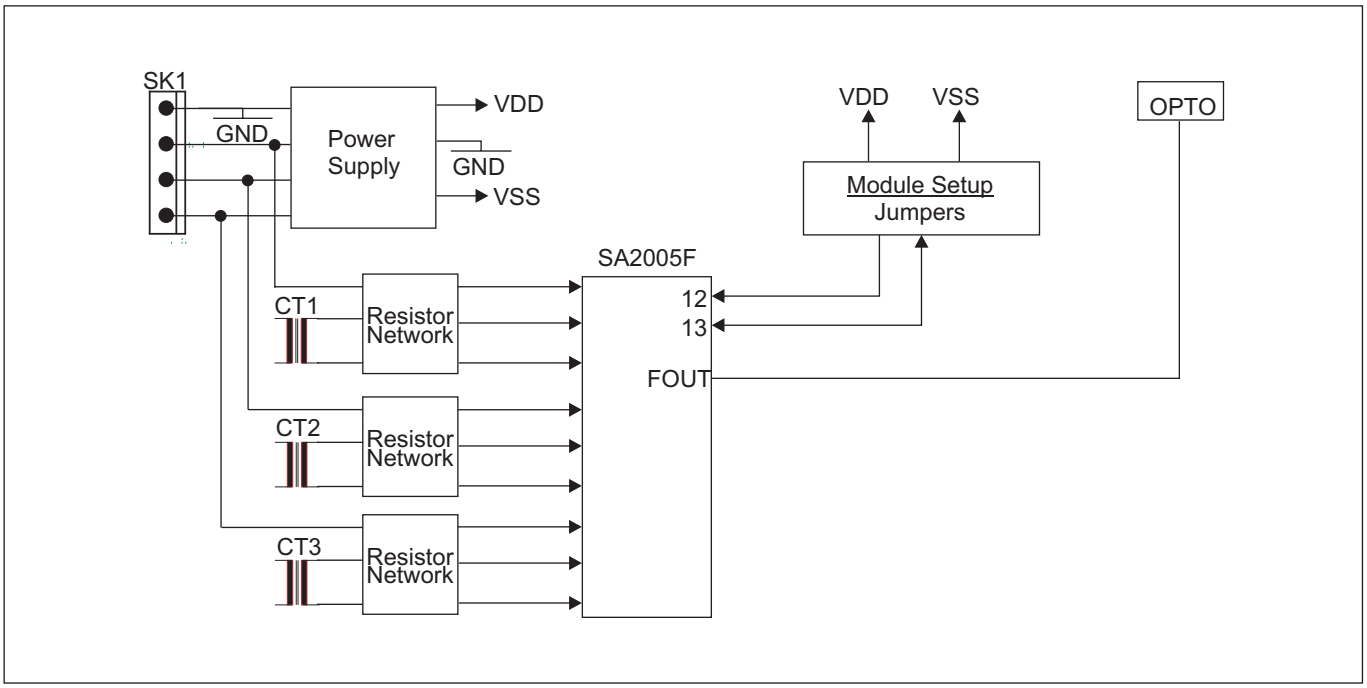


Figure 1: Block diagram

SETTING UP THE PM2005F MODULE

JUMPER DESCRIPTION

Power Supply Jumpers

The power supply jumpers are used to disconnect the on-board power supply, allowing the metering section of the circuit to be powered from an external power supply if required.

Jumper	Description
J4	Connects VDD to the metering circuitry.
J5	Connects VSS to the metering circuitry.
J6	GND connection point.
J7	Connection point between the power supply GND (N) and the SA2005 GND

Voltage Selection Jumpers

These jumpers are used to select between 115V and 230V operation. When closed the jumpers will half the series resistance in the voltage divider to the voltage sense inputs.

Jumper	230V	115V
J1	Open	Closed
J2	Open	Closed
J3	Open	Closed

Module Setup Jumpers

The following jumpers (J8 and J9) are used to switch between the different dividing ratios.

Mode	PGM1	PGM0	Frequency at Rated Conditions
0	V_{SS}	V_{SS}	64Hz
1	V_{SS}	V_{DD}	64Hz
2	V_{DD}	V_{SS}	64Hz
3	V_{DD}	V_{DD}	1160Hz

CONNECTOR DESCRIPTION

SK1

Connects the three phase 4 wire supply to the module.

J11

Interface for external µ Processor.

Number	Signal Name	SA2005F (U1)
1	V_{DD}	Pin 6
2	Fout	Pin 8
3	V_{SS}	Pin 14

J10 is used to take the output either to the opto couple or to J11, to be used with a micro.

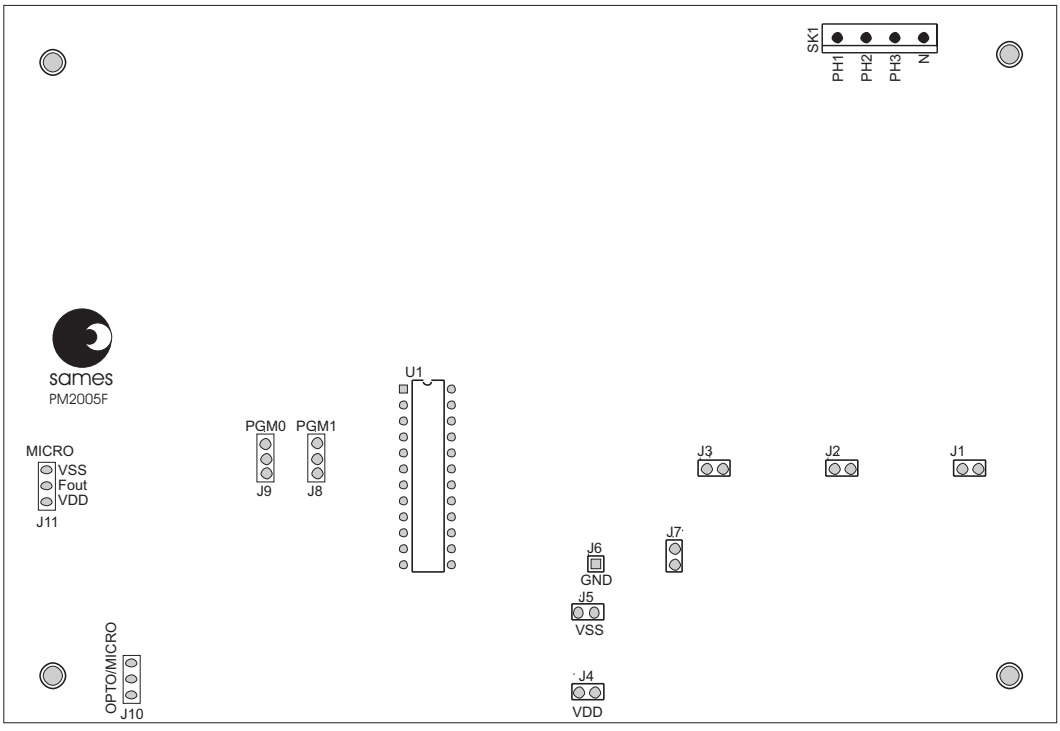


Figure 2: Jumper positions

SETTING UP THE MODULE FOR ENERGY MEASUREMENT

Figure 3 below shows a typical setup for the PM2005F evaluation module. The three phase voltages are connected directly to SK1 and each corresponding phase current is wired through the on-board CT's.

Figure 3 also shows the default jumper settings. The PM2005F evaluation module is setup by default for 3x230V/60A operation. For 3x 115V operation jumpers J1, J2 and J3 need to be closed and capacitors C12, C13 and C14 values must be changed to 1µF / 150VAC.

A single red LED indicates when all three phases measures reverse energy. Individual direction information is available on the Fout pin.

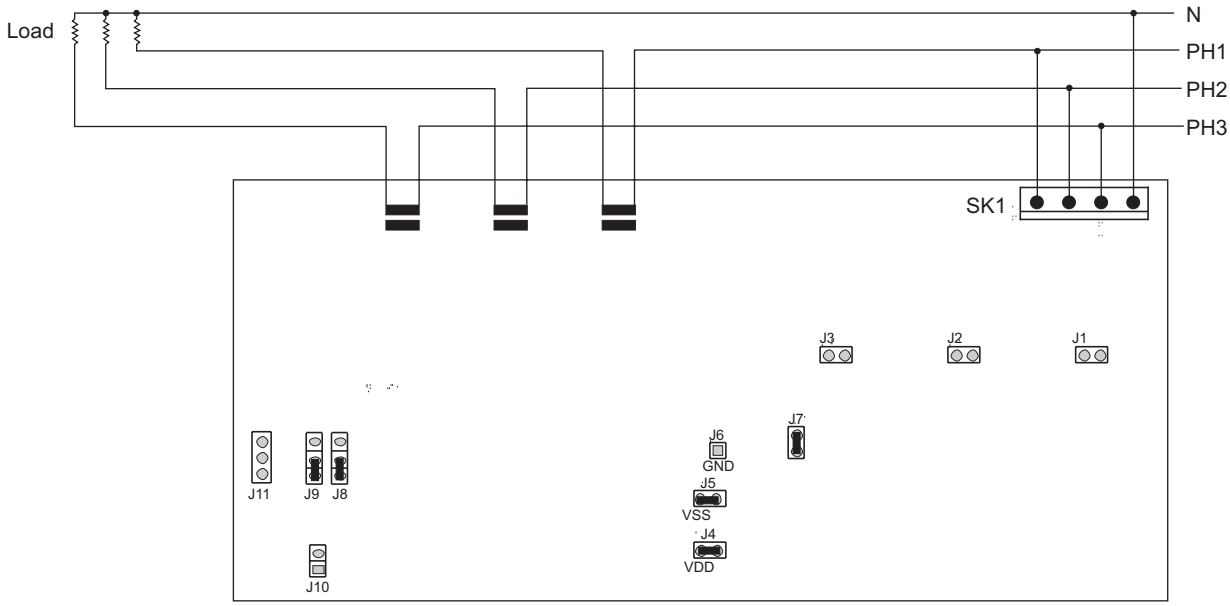


Figure 3: PM2005FPD setup and connection

CIRCUIT DESCRIPTION

ANALOG SECTION

The analog (metering) interface described in this section is designed for measuring 3x 230V/60A with precision better than Class 1.

The most important external components for the SA2005F 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.

BIAS RESISTOR

Pin VREF (SA2005F pin 15) is connected to VSS via R7 which determines the on chip bias current. With R7 = 24kΩ optimum conditions are set. VREF does not require any additional circuitry.

CT TERMINATION RESISTOR

The voltage drop across the CT termination resistor at rated current should be at least 16mV. The CT's used have low phase shift and a ratio of 1:2500. The CT is terminated with a 3.6Ω resistor giving a voltage drop across the termination resistor of 86.4mV at rated conditions (Imax for the meter).

CURRENT SENSOR INPUT RESISTORS

Referring to figure 4 the resistors R1 and R2 define the current levels into the SA2005's current sense inputs (phase on IIP1 and IIN1). The resistor values are selected for an input current of 16µA into the current inputs at rated conditions. According to the equation described in the Current Sense inputs section of the datasheet:

$R1 = R2 = (I / 16\mu A) \times R_{SH} / 2$
$= 60A / 2500 / 16\mu A \times 3.6\Omega / 2$
$= 2.7k\Omega$
I_{-} Line current / CT Ratio
The three current channels are identical so R1=R2=R3=R4=R5=R6.

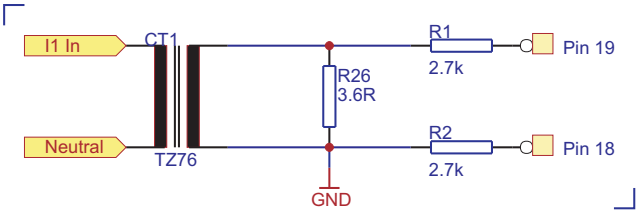


Figure 4: Current Input Configuration

VOLTAGE DIVIDER

Referring to figure 5 the connections for the voltage sense input for one phase is shown. The current into the A/D converter (IVP) is set 14µA$_{RMS}$ at nominal mains voltage. This voltage sense input saturates at approximately 17µA$_{RMS}$. A nominal voltage current of 14µA allows for 20% over driving. Each 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.

The following equation is used to calculate the 14V voltage drop:
RA = R22 + R23 + R24 + R25
RB = R8 || (R13 + P1)

Combining the two equations gives:
(RA + RB) / 230V = RB / 14V
A 24kΩ resistor is chosen for R13 and P1 combined. A 1MΩ resistor is used for R8.

Substituting the values result in:
RB = 23.44kΩ
RA = RB x (230V / 14V - 1)
RA = 361.6kΩ

Resistor values of R22, R24 are chosen to be 82kΩ and resistors R23 and R25 is chosen to be 100kΩ each.

The three voltage channels are identical so
R14 = R16 = R18 = R20 = R22 = R24 = 82k and R15 = R17 = R19 = R21 = R23 = R25 = 100kΩ

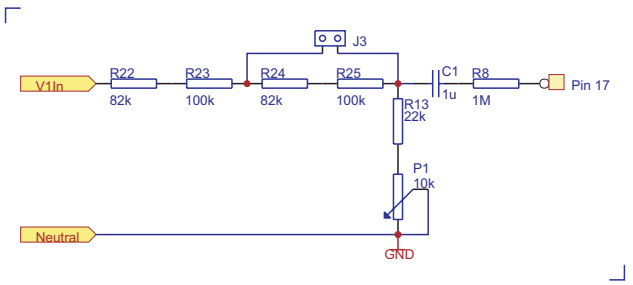


Figure 5: Mains Voltage Divider

The capacitors C1, C2 and C3 is used to compensate for phase shifts between the SA2005 voltage sense inputs and current sense inputs. The on-board Ct's were characterized and found to have a constant phase shift of 0.18 degrees. The value of the phase shift compensation capacitors were calculated as follows:

C = 1 / (2 x π x Mains frequency x R5 x tan (Phase shift angle))
C = 1 / (2 x π x 50 x 1MΩ x tan (0.18 degrees))
C = 1.013µF

POWER SUPPLY

Referring to figure 10, capacitor C10 is charged through D2 during the positive half of the sine wave from the R29, C12 mains voltage dropper. Identical charging circuitry exists for the other two phases. During the negative sine wave, C11 is charged through diode D1. The unregulated voltage charged on C10 and C11 is limited to 47 V by means of zener diode D7. Resistors R32 and R33 act as current limiting resistors that feed the unregulated voltage to the positive and negative voltage regulators U3 and U4. The voltage regulators need a load capacitance of around 10µF (C8 and C9) to be in a stable operating region. C15 acts as a supply voltage storage capacitor.

Jumpers J4, J5 and J7 allow the power supply to be completely disconnected form the metering section from the device.

PCB DESIGN

The module represents a Class 1 meter that is designed to demonstrate the functionality and performance of the SA2005F metering circuits. The SA2005F is a single chip solution for a three-phase meter with both fast and slow output. When the meter PCB is designed, it should be taken into account that the SA2005 is a mixed signal integrated circuit and special care should to be taken with the power supply and signal routing to the device.

Protection

The SA2005 should be protected from its measuring environment. This is achieved by using resistor dividers to scale all the SA2005 input signals. MOV's Z1, Z2, Z3 together with resistors R29, R30, R31 protects the power supply capacitors. The current setting resistors on the current sense inputs of the device attenuates common mode and asymmetrical transients.

Component placement

All the resistors connecting to the SA2005's current sense inputs should be placed as close as possible to the SA2005. This eliminates the possibility of any stray signal coupling into the divided input signal.

Ground Plane

The GND pin of the SA2005 is connected to the neutral phase, which is halfway between V_{DD} and V_{SS}. Note that supply bypass capacitors C4 and C5 are positioned as close as possible to the supply pins of the SA2005, and connected to a solid ground plane. Capacitor C6 is positioned as close as possible to the supply pins of the device for proper supply bypassing.

Power Supply routing and de coupling

The 5V supply is de-coupled and routed directly to the power pins of the IC by means of capacitor C5. Care is taken not to have current flowing in the node that connects the voltage reference resistor to V_{SS} as it may introduce power supply noise on the voltage reference circuit.

Signal Routing

Most of the signal routing is done in such a manner that any signal coupling in to the measured signal will be a common mode noise signal and is rejected subsequently. Care should be taken that the signals to the SA2005 is not influenced by other sources such as transformers with electric fields coupling in to the signals.

CALIBRATION

Calibration can be done by adjusting the trimpots (P_1, P_2, P_3) connected tot he three voltage inputs.

COMPONENT LIST

Part Type	Designator	Description
1µ / 100v / No Polarity	C1, C2, C3	Capacitor Electrolytic Radial
220n / 63v	C4, C5	Capacitor Monolithic Ceramic
1µ / 63v	C6	Capacitor Monolithic Ceramic
10µ / 16v	C8, C9	Capacitor Tantalum
470µ / 25V	C11, C15	Capacitor Electrolytic Radial
470n / 250VAC	C12, C13, C14	Capacitor Polyester
470µ / 25V	C10	Capacitor Electrolytic Radial
1N4007	D1, D2, D3, D4, D5, D6	Rectifier Diode
47V	D7	47V Zener Diode
LED	L2	LED 3mm Diameter, Red
2.7k	R1, R2, R3, R4, R5, R6	¼ Watt, 1% Metal Film Resistor
24k	R7	¼ Watt, 1% Metal Film Resistor
1M	R8, R9, R10	¼ Watt, 1% Metal Film Resistor
22k	R11, R12, R13	¼ Watt, 1% Metal Film Resistor
82k	R14, R16, R18, R20, R22, R24	¼ Watt, 1% Metal Film Resistor
100k	R15, R17, R19, R21, R23, R25	¼ Watt, 1% Metal Film Resistor
3R6	R26, R27, R28	¼ Watt, 1% Metal Film Resistor
47R / 2 Watt	R29, R30, R31	2 Watt, 1% Wire Wound Resistor
470R / 1 Watt	R32, R33	1 Watt, 1% Wire Wound Resistor
680R	R34, R37	¼ Watt, 5%, Carbon Resistor
Pot 10k	P1, P2, P3	Multi turn trim pot, Top adjust
MAINS	SK1	7 Pin Molex, Canter square pin, Friction Lock
PGM1	J8	3 Pin Header
S10 / 275	Z1, Z2, Z3	Metal Oxide Varistor
SA2005F	U1	24 Pin IC Socket, Tulip Type
TL431	U3, U4	TO -92 Package
TZ76	CT1, CT2, CT3	1:2500, Current Transformer
Micro	J11	3 Pin, Molex, Canter square pin, Friction Lock
Opto/Micro	J10	3 Pin, Molex, Canter square pin, Friction Lock
PGM0	J9	3 Pin Header

PCB LAYOUT

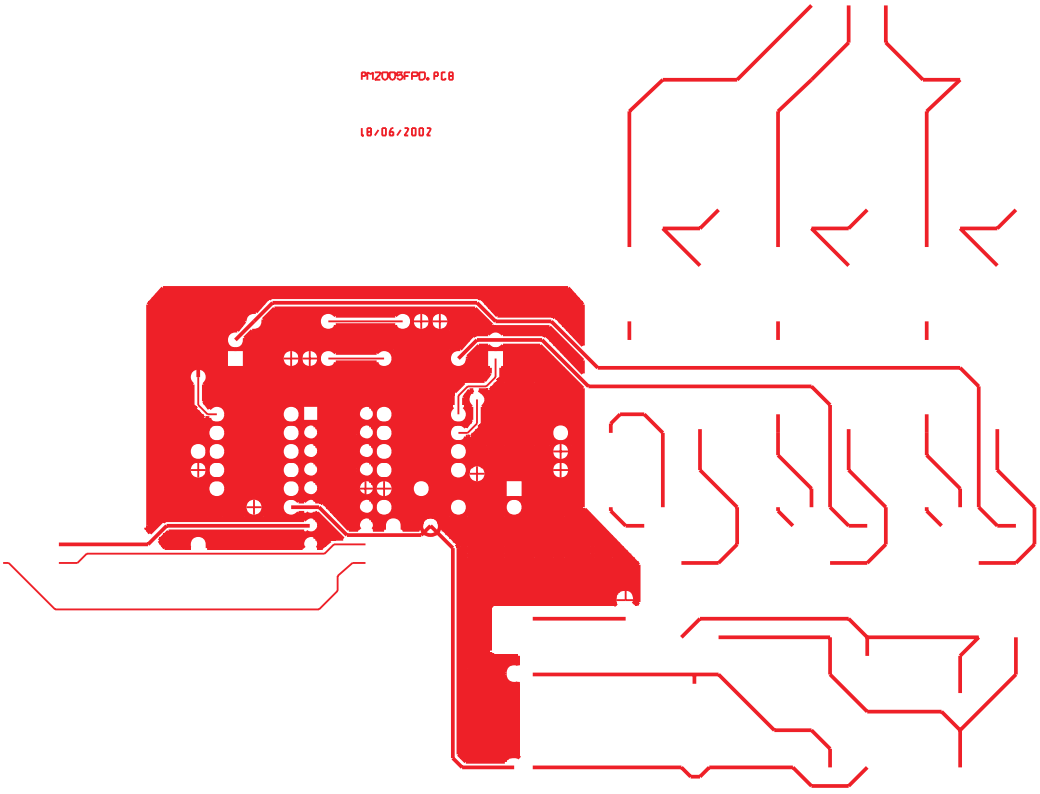


Figure 6: PM2005F Top PCB layout

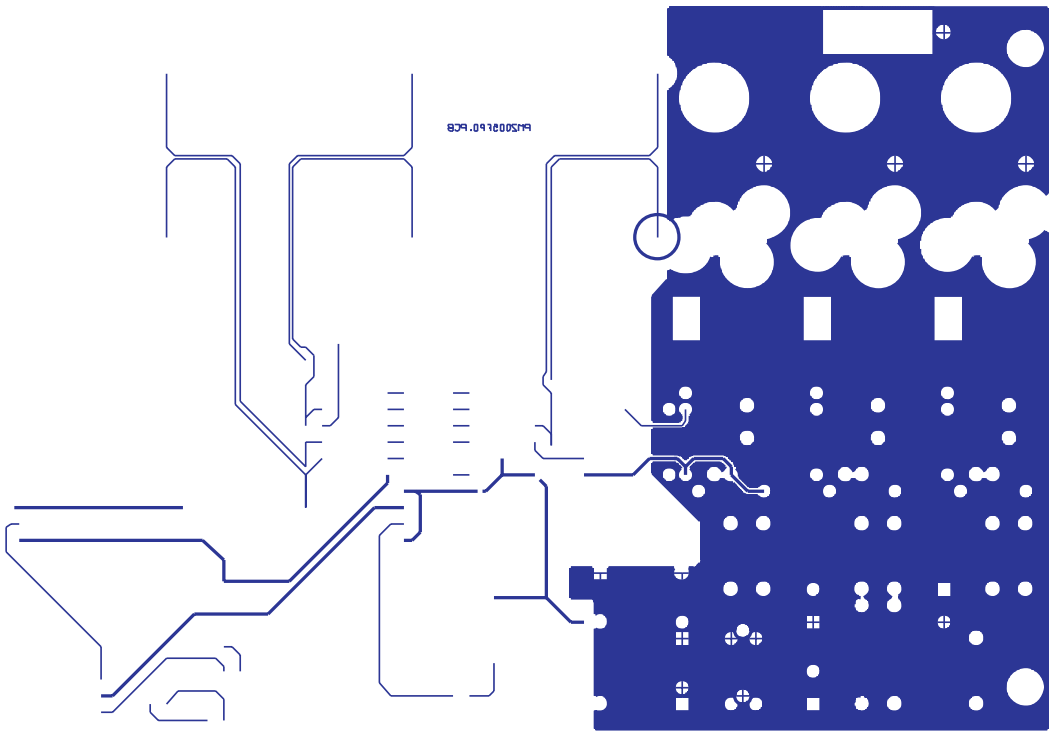


Figure 7: PM2005F Bottom PCB layout

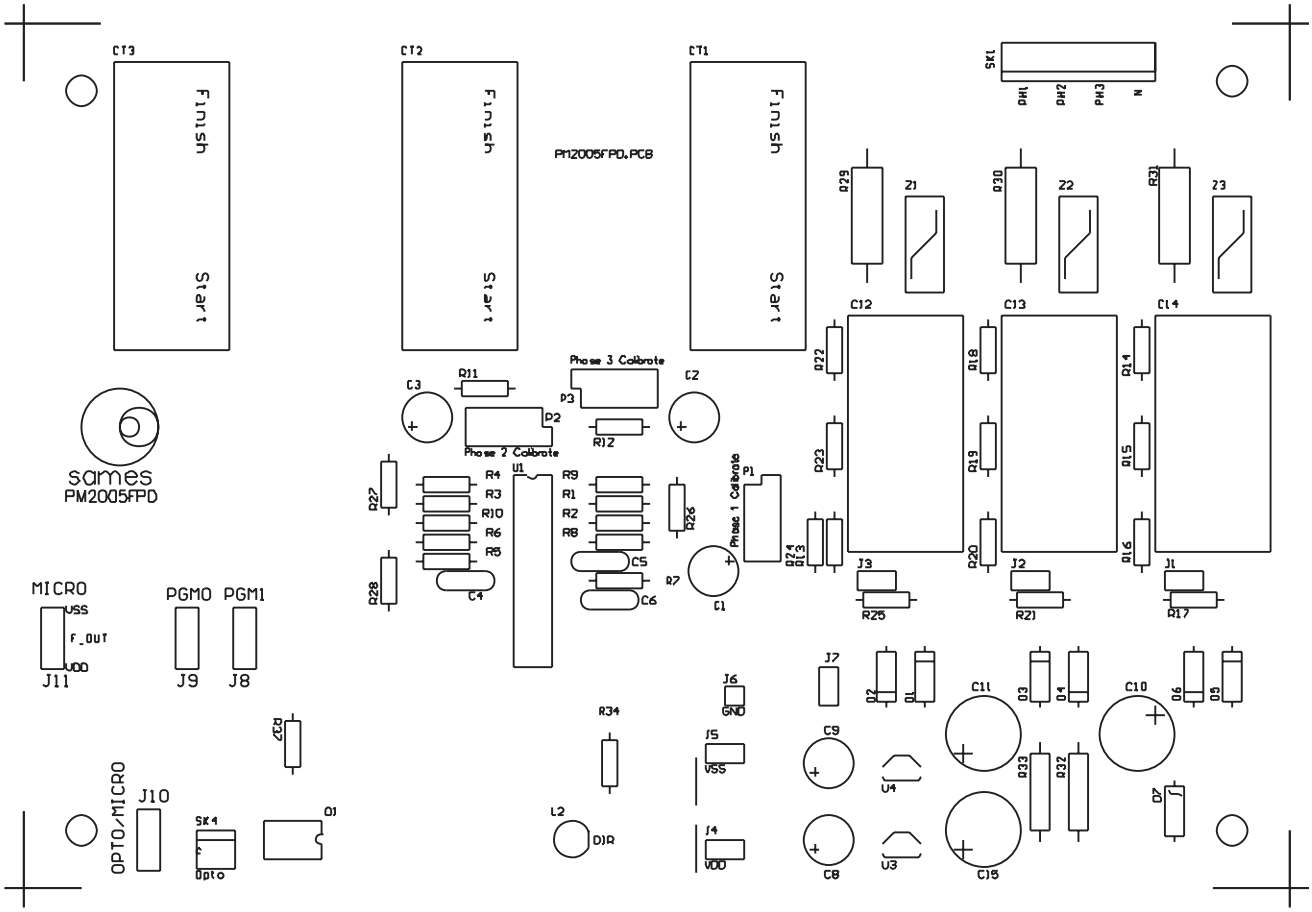


Figure 8: PM2005F Silkscreen PCB layout

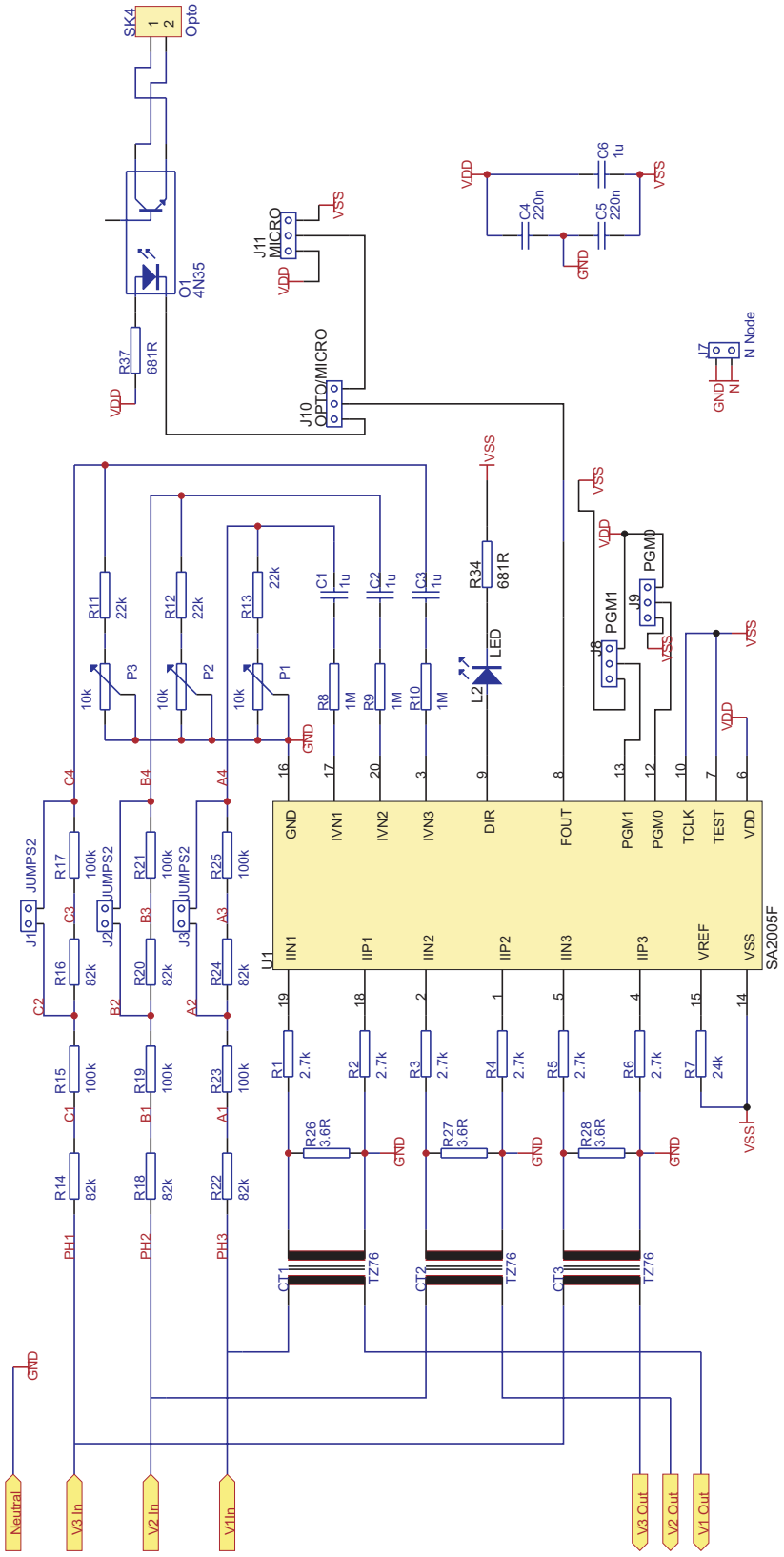


Figure 9: Schematic Diagram for Metering Section

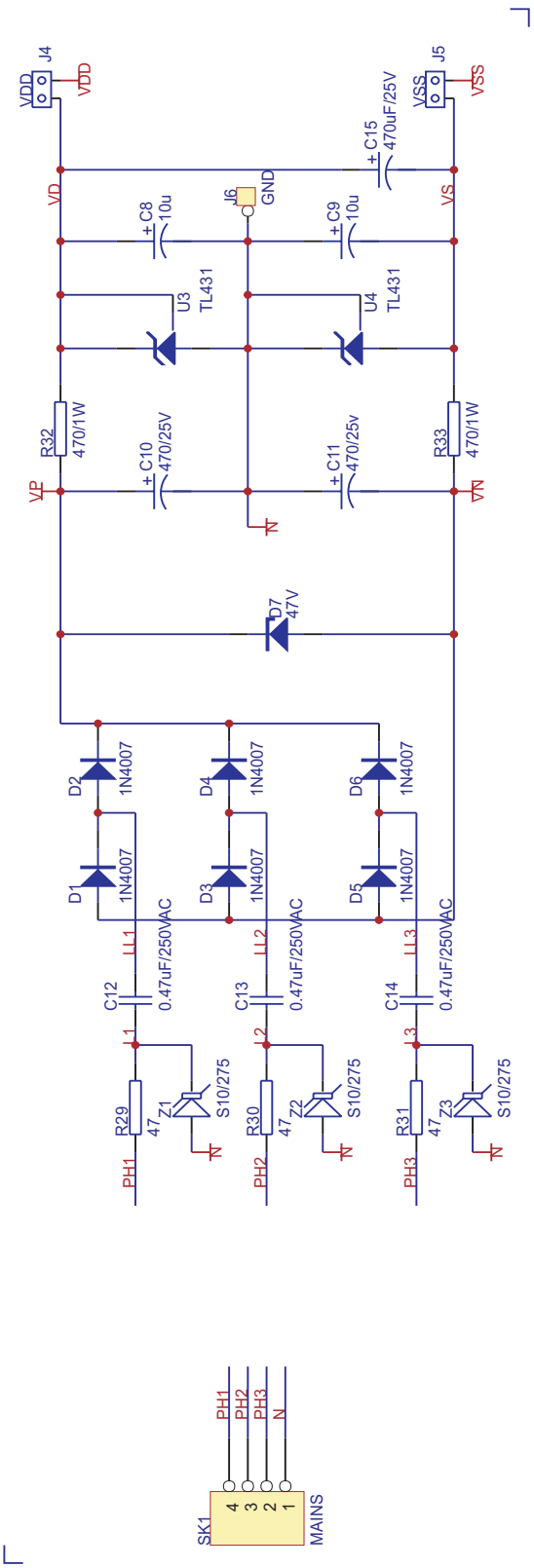


Figure 10: Schematic Diagram of Power Supply

NOTES:

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