

Single Phase Power/Energy Metering IC with Tamper Detection



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SA9607M

FEATURES

- Provides direct interface to mechanical counters
- Monitors Live and Neutral for tamper detection
- Performs bidirectional energy measurement
- Various setup modes selectable
- Meets the IEC 521/1036 Specification for Class 1 AC Watt hour meters

- Total power consumption rating below 25mW
- Adaptable to different types of sensors
- Operates over a wide temperature range
- Precision voltage reference on chip.

DESCRIPTION

The SAMES SA9607M is a single-phase bidirectional energy metering integrated circuit. It provides a mono-chip solution for energy meters with electro-mechanical displays, such as stepper motors and impulse counters.

Two current sensor inputs allow the measurement of energy consumption on both the live and neutral.

Direction detection of energy flow as well as other common tamper conditions are flagged.

The power consumption on both the live and neutral are continuously measured and the larger of the two is selected for energy metering.

The SA9607M drives the calibration LED and the electro-mechanical counter directly.

The SA9607M integrated circuit is available in 20 pin dual-in-line plastic (DIP-20) and small outline (SOIC-20) package types.

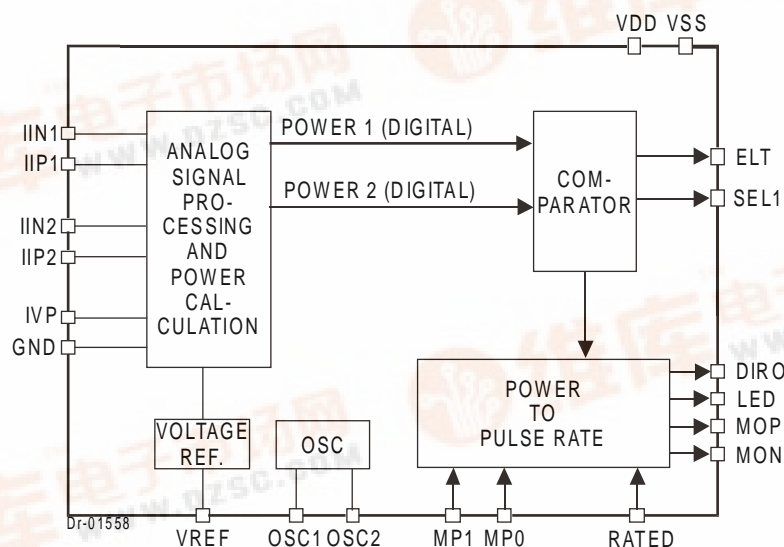


Figure 1: Block Diagram

**SA9607M****sames****ELECTRICAL CHARACTERISTICS**(V_{DD} = 2.5V, V_{SS} = -2.5V, over the temperature range -10°C to +70°C#, unless otherwise specified.)

| Parameter | Symbol | Min | Typ | Max | Unit | Condition |
|---|--|--------------------|-----|--------------------|---------|--|
| Operating temp. range | T _o | -25 | | +85 | °C | |
| Supply Voltage: Positive | V _{DD} | 2.25 | | 2.75 | V | |
| Supply Voltage: Negative | V _{SS} | -2.75 | | -2.25 | V | |
| Supply Current: Positive | I _{DD} | | 5 | 6 | mA | |
| Supply Current: Negative | I _{SS} | | 5 | 6 | mA | |
| Current Sensor Inputs (Differential) | | | | | | |
| Input Current Range | I _{II} | -25 | | +25 | µA | Peak value |
| Voltage Sensor Input (Asymmetrical) | | | | | | |
| Input Current Range | I _{IV} | -25 | | +25 | µA | Peak value |
| Pin DIRO, LED Output High Voltage Output Low Voltage | V _{OH} V _{OL} | V _{DD} -1 | | V _{SS} +1 | V V | I _{OH} = -2mA I _{OL} = 5mA |
| Pin MP0, MP1 Input High Voltage Input Low Voltage | V _{IH} V _{IL} | V _{DD} -1 | | V _{SS} +1 | V V | Pull down |
| Pin MOP, MON Output High Voltage Output Low Voltage | V _{OH} V _{OL} | V _{DD} -1 | | V _{SS} +1 | V V | I _{OH} = -2mA I _{OL} = 5mA |
| Pin RATED, SEL1, ELT Input High Voltage Input Low voltage | V _{IH} V _{IL} | V _{DD} -1 | | V _{SS} +1 | V V | Bi-direct** |
| Pin VREF Ref. Current Ref. Voltage | -I _R V _R | 45 1.1 | 50 | 55 1.3 | µA V | With R = 24kΩ connected to V _{SS} Referred to V _{SS} |
| Oscillator | Recommended crystal: TV colour burst crystal f = 3.5795 MHz | | | | | |

Extended Operating Temperature Range available on request.

** Switched to output mode every 1.1 seconds for 140 µS.

ABSOLUTE MAXIMUM RATINGS*

| Parameter | Symbol | Min | Max | Unit |
|-----------------------|----------------------------------|------|------|------|
| Supply Voltage | V _{DD} -V _{SS} | -0.3 | 6.0 | V |
| Current on any pin | I _{PIN} | -150 | +150 | mA |
| Storage Temperature | T _{STG} | -40 | +125 | °C |
| Operating Temperature | T _O | -25 | +85 | °C |

*Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only. Functional operation of the device at these or any other condition above those indicated in the operational sections of this specification, is not implied. Exposure to Absolute Maximum Ratings for extended periods may affect device reliability.



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PIN DESCRIPTION

| PIN | Designation | Description |
|--------------|--------------------------|--|
| 20 | GND | Analog Ground. The voltage to this pin should be mid-way between V_{DD} and V_{SS} . |
| 8 | V_{DD} | Positive supply voltage. The voltage to this pin is typically +2.5V if a shunt resistor is used for current sensing or in the case of a current transformer a +5V supply can be applied. |
| 14 | V_{SS} | Negative Supply Voltage. The voltage to this pin is typically -2.5V if a shunt resistor is used for current sensing or in the case of a current transofer a 0V supply can be applied. |
| 19 | IVP | The current into the A/D converter should be set at $14\mu A_{RMS}$ at nominal mains voltage. The voltage sense input saturates at an input current of $\pm 25\mu A$ peak. |
| 1, 2 3, 4 | IIN1, IIP1 IIN2, IIP2 | Inputs for current sensor - channel 1 and Channel 2. The shunt resistor voltage from each channel is converted to a current of $16\mu A_{RMS}$ at rated conditions. The current sense input saturates at an input current of $\pm 25\mu A$ peak. |
| 5 | VREF | This pin provides the connection for the reference current setting resistor. A $24k\Omega$ resistor connected to V_{SS} set the optimum operating condition. |
| 6, 7 | MP0, MP1 | Motor pulse rate select inputs. Described under Input Signals. |
| 9, 12 | MON, MOP | Motor pulse outputs. These outputs can be used to drive an impulse counter or stepper motor directly. |
| 13 | LED | Calibration LED output. Refer to section Led Output (LED) for the pulse rate output options. |
| 15 | RATED | Rated condition select input. Described under Input Signals. |
| 16 | SEL1 | Current channel select output. This output indicates which channel is been used for kWh metering. |
| 17 | ELT | Earth loop tamper output. This output indicates an earth loop tamper condition. |
| 18 | DIRO | Direction output. This output indicates the energy flow direction. |
| 10, 11 | OSC1, OSC2 | Connections for a crystal or ceramic resonator. (OSC1 = input; OSC2 = Output) |

ORDERING INFORMATION

| Part Number | Package |
|-------------|---------|
| SA9607MPA | DIP-20 |
| SA9607MSA | SOIC-20 |

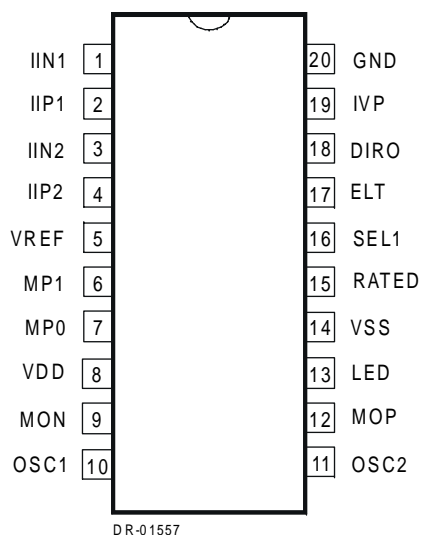


Figure 2: Pin connections: Package: Dip-20, SOIC-20

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FUNCTIONAL DESCRIPTION

The SA9607M is a CMOS mixed signal analog/digital integrated circuit, which performs power/energy calculations across a power range of 1000:1, to an overall accuracy of better than Class 1.

The integrated circuit includes all the required functions for 1-phase power and energy measurement such as oversampling A/D converters for the voltage and current sense inputs, power calculation and energy integration. Internal offsets are eliminated through the use of cancellation procedures. The SA9607M incorporates an anti-tamper scheme by continuously measuring the power consumption on both LIVE and NEUTRAL lines. A fault is indicated when these measurements differ by more than 12.5%. The SA9607M generates pulses with a frequency proportional to the larger of the two current measurements. The source (LIVE or NEUTRAL) for these pulses is indicated on the SEL1 pin.

Frequency outputs (MOP, MON and LED) are available. The pulse rate on these pins follows the instantaneous active power consumption measured.

A low voltage stepper may be driven directly from the device by connecting it between the MOP and MON pins, alternatively an impulse counter may be driven directly by connecting it between MOP and V_{SS} .

POWER CALCULATION

In the Application Circuit (Figure 7), the voltage drop across the shunt will be between 0 and $16mV_{RMS}$ (0 to 80A through a shunt resistor of $200\mu\Omega$). The voltage across the current transformers terminating resistor will also be between 0 and $16mV_{RMS}$. These voltages are converted to currents of between 0 and $16\mu A_{RMS}$ for each current sense inputs by means of resistors R_1 and R_2 (channel 1) as well as R_3 and R_4 (channel 2).

The current sense input saturates at an input current of $\pm 25\mu A$ peak.

For the voltage sensor input, the mains voltage (230VAC) is divided down through a divider to $14V_{RMS}$. The current into the A/D converter input is set at $14\mu A_{RMS}$ at nominal mains voltage, via resistor R_6 ($1M\Omega$).

Different pulse rates are available at the MOP and MON pins. The device may be programmed for a 1 pulse/kWh, 10 pulses/kWh or 100 pulses/kWh output, depending on the status of the motor pulse rate select pins MP0 and MP1.

The LED pulse rate is fixed at 6400 pulses per kWh. Rated

conditions such as 230V/20A, 230V/40A and 230V/60A may be chosen with the rated pin. This facility allows meter manufacturers to cater for a wide range of metering applications with minimal design changes.

ANALOG INPUT CONFIGURATION

The input circuitry of the current and voltage sensor inputs are illustrated below.

These inputs are protected against electrostatic discharge through clamping diodes.

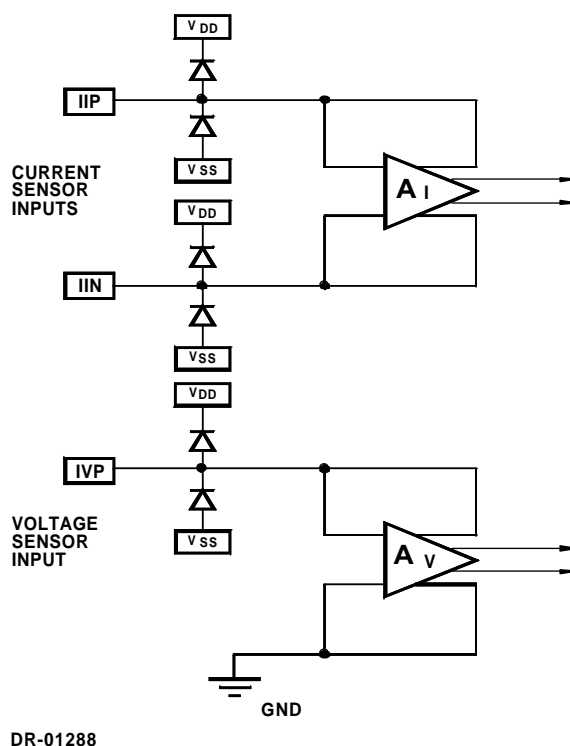
The feedback loops from the outputs of the amplifiers A_I and A_V generate virtual shorts on the signal inputs. Exact duplications of the input currents are generated for the analog signal processing circuitry.

ELECTROSTATIC DISCHARGE (ESD) PROTECTION

The SA9607M integrated circuit's input's/outputs are protected against ESD.

POWER CONSUMPTION

The power consumption rating of the SA9607M integrated circuit is less than 30mW.



DR-01288

Figure 3: Analog Input Internal Configuration



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INPUT SIGNALS

VREF

The VREF pin is the reference for the bias resistor and is the recommended point for calibration. With a bias resistor of 24k Ω optimum conditions are set. It may be varied within $\pm 10\%$ for calibration purposes. Any changes to the bias resistor will affect the output pulse rate quadratically (i.e. $\Delta R = +5\%, \Delta f = 10\%$).

Motor pulse rate select (MP1 and MP0)

The pulse rate of the motor driver output of the SA9607M is selected by the inputs MP1 and MP0. Three pulse rate options are available as shown in the following table:

Pulse rate selection

| Pulse Rate Selection Input | | Motor drive output selection | Unit |
|----------------------------|-----------------|------------------------------|------------|
| MP1 | MP0 | | |
| V _{SS} | V _{SS} | 1 | pulses/kWh |
| V _{SS} | V _{DD} | 10 | pulses/kWh |
| V _{DD} | V _{SS} | 100 | pulses/kWh |
| V _{DD} | V _{DD} | Device test mode | |

Please note that the device will not perform metering functions as described in this document while in test mode.

Rated condition select (RATED)

The rated condition select pin gives the option of having a 3:2:1 scaling ratio of the rated current easily available. This feature is particularly useful in circumstances where a manufacturer requires a meter for use in a system rated for two different conditions, for example 230V/60A and 230V/40A. With the rated condition select the SA9607M allows for the development of different rated meters requiring minimal changes. The following table below lists the options available (assuming the rated condition to be 230V/60A).

Rated condition select (RATED)

| Signal Input RATED | Rated Conditions |
|--------------------|------------------|
| V _{SS} | 230V / 20A |
| OPEN | 230V / 40A |
| V _{DD} | 230V / 60A |

OUTPUT SIGNALS

Motor output (MOP, MON)

The MON pulse will follow the MOP pulse within 142ms. This prevents that the motor armature is in the wrong position after a power failure. Both MOP and MON outputs are active high. The motor drive wave forms are shown below:

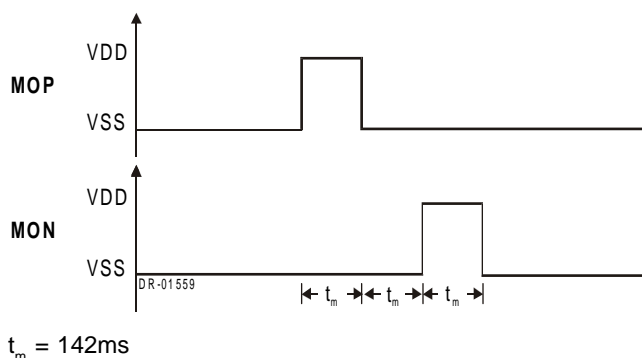


Figure 5: Motor drive waveform

LED output (LED)

The LED output pulse at a fixed rate of 6400 pulses per kWh. The LED output is active low. The LED waveform is shown below:

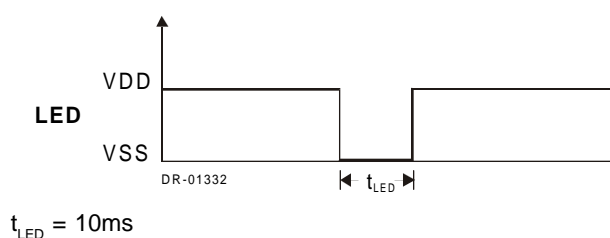


Figure 4: LED pulse output

Selected input indication (SEL1)

The SA9607M continuously compares the power consumptions on current channel 1 inputs and current channel 2 inputs. The larger of the two measurements are used for metering. The SEL1 output pin indicates which channel is currently being used for the pulse output.

| Signal Output | Value | Description |
|---------------|-------|--------------------------------|
| SEL1 | 0 | Channel 1 selected (IIN1/IIP1) |
| | 1 | Channel 2 selected (IIN2/IIP2) |

**SA9607M****Earth loop tamper indication (ELT)**

If the power measurements from both current channels differ by more than 12.5%, (indicating a earth loop tamper condition), the ELT output is set to zero. The SA9607M continues to generate output pulses from the larger of the two measured powers in this condition. The ELT output is active low.

Direction indication (DIRO)

The SA9607M provides information about the energy flow direction on pin DIRO.

A logic 1 on pin DIRO indicates reverse energy flow. Reverse energy flow is defined as the condition where the voltage sense input and current sense input are out of phase (greater than 90 degrees).

Positive energy flow, when voltage sense and current sense input are in phase, is indicated on pin DIRO a logic 0.

The DIRO pin may be used to drive a LED in order to indicate reverse energy.

| Signal Output | Value | Description |
|---------------|-------|---------------------|
| DIRO | 1 | Reverse energy flow |
| | 0 | Forward energy flow |



TYPICAL APPLICATION

In Figure 1, the components required for a stand-alone power metering application, is shown.

Current transformers are used for mains current sensing. The channel showing the highest power consumption will be selected by the SA9607M for energy metering.

The most important external components for the SA9607M integrated circuit are the current sense resistors, the voltage sense resistors as well as the bias setting resistor.

Current Sense Resistors

The resistors R1, R2, R3 and R4 define the current level into the current sense inputs of the device. The component should be selected for input currents of $16\mu\text{A}_{\text{RMS}}$ into the current channels of the SA9607M at I_{MAX} (rated current of the meter). The voltage drop of the resistors R_{10} and R_{17} should be at least 20mV.

Current Channel 1

$$R_1 = R_2 = (I_L / 16\mu\text{A}_{\text{RMS}}) \times R_{10} / 2$$

Current Channel 2

$$R_3 = R_4 = (I_L / 16\mu\text{A}_{\text{RMS}}) \times R_{11} / 2$$

Where:

I_L = Line current/CT-ratio

R10 = Termination resistor

R11 = Termination resistor

Voltage Sense Resistors

R9, R8, R6 and R5 set the current for the voltage sense input.

The values should be selected so that the input current into the voltage sense input (virtual ground) is set to $14\mu\text{A}_{\text{RMS}}$.

Bias Resistor

R_7 defines all on-chip bias and reference currents. With $R_7 = 24\text{k}\Omega$, optimum conditions are set.

R_7 may be varied within $\pm 10\%$ for calibration purposes. Any change to R_7 will affect the output quadratically (i.e.: $R_7 = +5\%$, $fP = +10\%$).

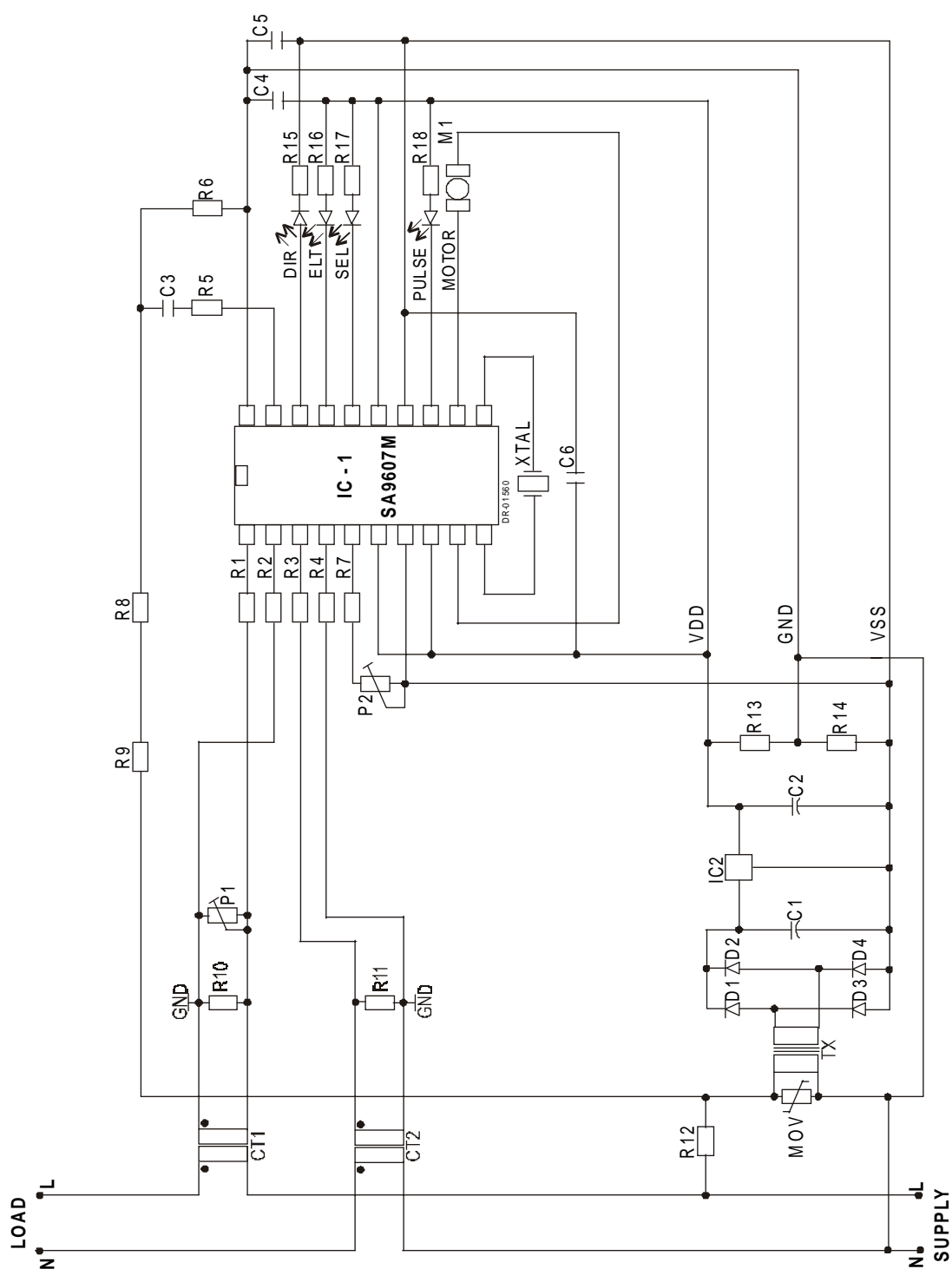


Figure 7: Application Circuit

**SA9607M****sames****Parts List for Application Circuit: Figure 7**

| Item | Symbol | Description | Detail |
|------|--------|---|----------------|
| 1 | IC1 | SA9607M | DIP-20/SOIC-20 |
| 2 | D1 | Diode, Silicon 1N4007 | |
| 3 | D2 | Diode, Silicon 1N4007 | |
| 4 | D3 | Diode, Silicon 1N4007 | |
| 5 | D4 | Diode, Silicon 1N4007 | |
| 6 | D5 | Light emitting diode, Red | |
| 7 | D6 | Light emitting diode, Green | |
| 8 | D7 | Light emitting diode, Amber | |
| 9 | D8 | Light emitting diode, Green | |
| 10 | XTAL | Crystal, 3.5759MHz | |
| 11 | R1 | Resistor, 1/4W, 1%, metal | Note 1 |
| 12 | R2 | Resistor, 1/4W, 1%, metal | Note 1 |
| 13 | R3 | Resistor, 1/4W, 1%, metal | Note 1 |
| 14 | R4 | Resistor, 1/4W, 1%, metal | Note 1 |
| 15 | R5 | Resistor, 1M, 1/4W, 1%, metal | |
| 16 | R6 | Resistor, 24k, 1/4W, 1%, metal | |
| 17 | R7 | Resistor, 22k, 1/4W, 1%, metal | |
| 18 | R8 | Resistor, 180k, 1/4W, 1%, metal | |
| 19 | R9 | Resistor, 200k, 1/4W, 1%, metal | |
| 20 | R10 | Resistor, 1/4W, 1%, metal | Note 2 |
| 21 | R11 | Resistor, 1/4W, 1%, metal | Note 2 |
| 22 | R12 | Resistor, 10 Ω , 2W, Wire wound | |
| 23 | R13 | Resistor, 1k, 1/4W, 1%, metal | |
| 24 | R14 | Resistor, 1k, 1/4W, 1%, metal | |
| 25 | R15 | Resistor, 1k, 1/4W, 5%, carbon | |
| 26 | R16 | Resistor, 1k, 1/4W, 5%, carbon | |
| 27 | R17 | Resistor, 1k, 1/4W, 5%, carbon | |
| 28 | R18 | Resistor, 1k, 1/4W, 5%, carbon | |
| 29 | P1 | Multi-turn, Trim Pot | |
| 30 | P2 | Multi-turn, Trim Pot, 5k | Note 2 |
| 31 | C1 | Capacitor, 100 μ F, 16V, electrolytic | |
| 32 | C2 | Capacitor, 100 μ F, 16V, electrolytic | |
| 33 | C3 | Capacitor | Note 4 |
| 34 | C4 | Capacitor, 220nF | |
| 35 | C5 | Capacitor, 220nF | |
| 36 | C6 | Capacitor, 820nF | Note 3 |
| 37 | CT1 | Current Transformer | |
| 38 | CT2 | Current Transformer | |
| 39 | TX | Transformer, 230V/9V | |
| 40 | IC2 | 78LC05, Voltage regulator | |
| 41 | M1 | Bipolar step motor | |
| 42 | M0V | 400V, Metal oxide varistor | |

Note 1: Resistor (R1, R2, R3 and R4) values are dependant upon the selected value of R10 and R11.

Note 2: See TYPICAL APPLICATION when selecting the value of R10 and R11.

Note 3: Capacitor (C6) to be positioned as closed to Supply Pins (V_{DD} & V_{SS}) of IC-1, as possible.

Note 4: Capacitor (C7) selected to minimize phase error introduced by current transformer (typically 1.5 μ F for normal CT5, approx. 100nF)

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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
33 Eland Street
Lynn East 0039
Republic of South Africa

33 Eland Street
Koedoespoort Industrial Area
Pretoria
Republic of South Africa