Single Phase Power/Energy Metering IC with Tamper Detection

SA2007M

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 30mW
- Adaptable to different types of sensors
- Operates over a wide temperature range
- Precision voltage reference on-chip
- Precision oscillator on chip

DESCRIPTION

The SAMES SA2007M 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. A precision oscillator, that replaces an external crystal is integrated on chip.

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 SA2007M drives the calibration LED, the indicator LEDs and the electro-mechanical counter directly.

The SA2007M integrated circuit is available in 20 pin dual-in-line plastic (DIP-20) and small outline (SOIC-20) package types.
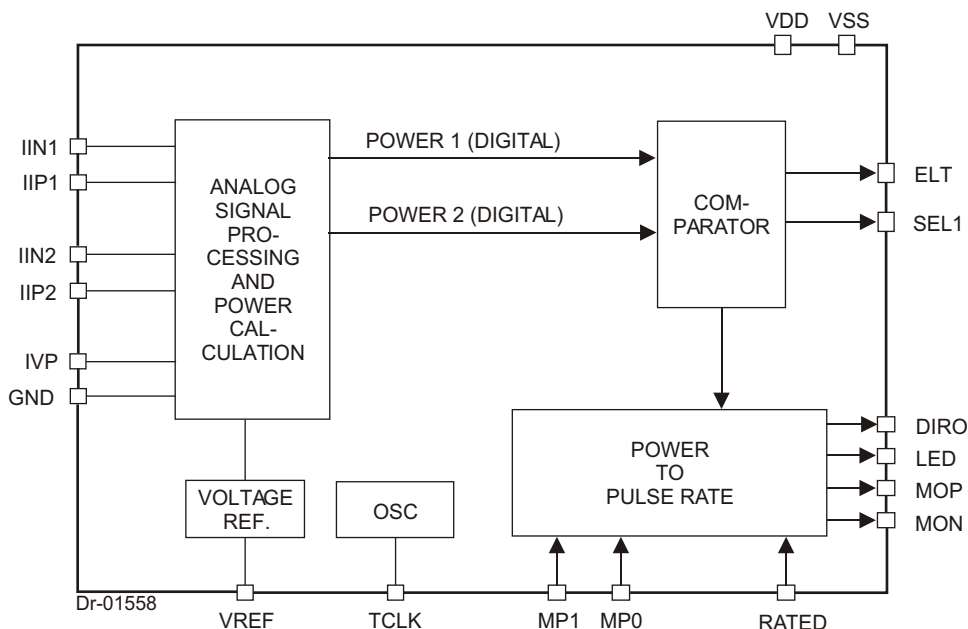

Figure 1: Block diagram

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}	4.1	5.8	8.2	mA	
Supply Current: Negative	I_{SS}	4.1	5.8	8.2	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 VREF Ref. Current Ref. Voltage	$-I_R$ V_R	45 1.1	50	55 1.3	µA V	With R = 24k connected to V_{SS} Reference to V_{SS}
Digital I/O						
Pins DIRO, LED, MON, MOP Output High Voltage Output Low Voltage	V_{OH} V_{OL}	V_{DD}-1		V_{SS}+1	V V	I_{OH} = -2mA I_{OL} = 5mA
Pins MP0, MP1, TCLK, RATED, SEL1, ELT Input High Voltage Input Low Voltage	V_{IH} V_{IL}	V_{DD}-1		V_{SS}+1	V V	
Pin RATED Pin scan current**	I_{IH} $-I_{IL}$	3.1 2		7 4.6	mA mA	V_I = V_{DD} V_I = V_{SS}
Pins MP0, MP1, TCLK Pull down current	I_{IH}	48		110	µA	V_I = V_{DD}

#Extended Operating Temperature Range available on request.
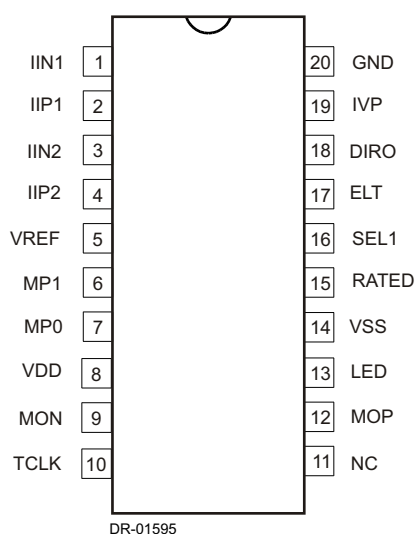** Switched to pin-scan mode every 1.1 seconds for 71µs.

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.

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 transformer 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 ±25µA 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 ±25µA peak.
5	VREF	This pin provides the connection for the reference current setting resistor. A 24k resistor connected to V_{SS} sets 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.
11	NC	No Connection.
10	TCLK	Test input. Connect to V_{SS} for normal operation.

DR-01595

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

ORDERING INFORMATION

Part Number	Package
SA2007MPA	DIP-20
SA2007MSA	SOIC-20

FUNCTIONAL DESCRIPTION

The SA2007M 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 SA2007M 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 SA2007M 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 Figure 6, the voltage drops across the current transformers terminating resistors are converted to currents for each current sense input, by means of resistors R_{10} and R_{11} (channel 1) as well as R_{12} and R_{13} (channel 2). The current sense input saturates at an input current of ±25μA peak.

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_7 (1M .

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 SA2007M integrated circuit's input's/outputs are protected against ESD.

POWER CONSUMPTION

The power consumption rating of the SA2007M integrated circuit is less than 30mW.
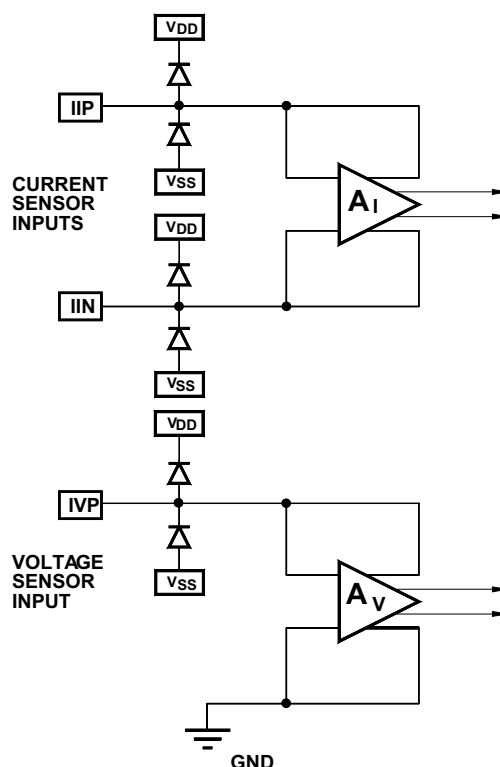
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Figure 3: Analog input internal configuration

INPUT SIGNALS
VREF
A bias resistor of 24k sets optimum bias and reference conditions on chip. Calibration of the SA2007M should be done on the voltage input as described in Typical Application.

Motor pulse rate select (MP1 and MP0)
The pulse rate of the motor driver output of the SA2007M is selected by the inputs MP1 and MP0. Three pulses 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 for the rated meter current. 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 230V40A. With the rated condition select the SA2007M allow for the development of different rated meters requiring minimal changes. The following table below lists the option available (assuming the rated condition to be 230V/60A).
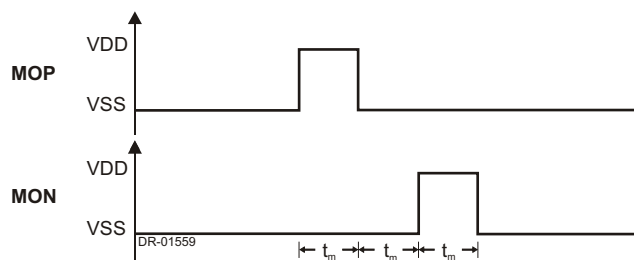
Rated condition select (RATED)

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:

t_m = 142ms

Figure 4: Motor drive on MON and MOP pins

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:
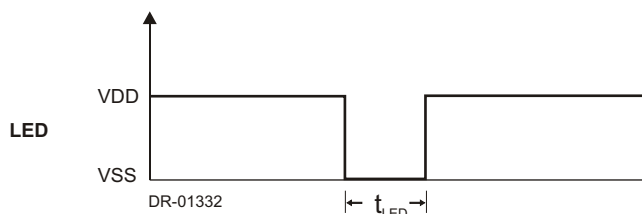

Figure 5: LED pulse output

An integrated anti-creep function prevents any output pulses if the measured power is less than 0.02% of the meters rated current.

Selected input indicator (SEL1)
The SA2007M 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
SEL 1	0	Channel 1 selected (IIN1/IIP1)
	1	Channel 2 selected (IIN2/IIP2)

Switching between channels will not be faster than once per second when both channels are balanced.

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 SA2007M 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 SA2007M provides information about the energy flow direction of both current channels on pin DIRO .

A logic 1 on pin DIRO indicates reverse energy flow of both current channels. 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 both current sense input are in phase, is indicated on pin DIRO as a logic 0.

The DIRO output will toggle between 1 and 0 a rate of 1Hz when one of the current channels measure positive energy and the other negative energy. This condition may occur with a improper installed or tampered meter.

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
	1Hz	Out of phase current channels

TYPICAL APPLICATION

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 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 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 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 (I_{max} 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 R10, R11 and R12, R13 define the current level into the current sense inputs of the SA2007M. The resistor values are selected for an input current of 16µA on the current inputs of the SA2007M at rated conditions. For a 60A meter at 2500:1 CT the resistor values are calculated as follows:

$R10 = R11 = (I_L / 16µA) \times R_{SH} / 2$
$= 60A / 2500 / 16µA \times 3.6 / 2$
$= 2.7k$
I_L = Line current
RSH = CT Termination resistor
2500 = CT ratio

The two current channels are identical so R10 = R11 = R12 = R13.

Voltage Input IVP

The voltage input of the SA2007M (IVP) is driven with a current of 14µA at nominal mains voltage. The 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 are:

$RA = R1 + R2 + R3$
$RB = R7 \| (R5 + P1)$

A 5k trimpot will be used in the voltage channel for meter calibration. The center position on the pot is used in the calibration P1 = 2.5k.

Combining the two equations gives:

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

Values for resistors R5 = 22k, P1 = 2.5k and R7 = 1M is chosen.

Substituting the values result in:

$RB = 23.9k$
$RA = RB \times (230V / 14V – 1)$
$RA = 369k.$

Standard resistor values of R1, R2 and R3 are chosen to be 120k, 120k and 130k.

The capacitor C1 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:

$C = 1 / (2 \times \times Mains frequency \times R5 \times tan (Phase shift angle))$
$C = 1 / (2 \times \times 50 \times 1M \times tan (0.18 degrees))$
$C = 1.013µF$

Reference Voltage Bias resistor

R6 defines all on chip and reference currents. With R6 = 24k optimum conditions are set. Device calibration is done on the voltage input of the device.
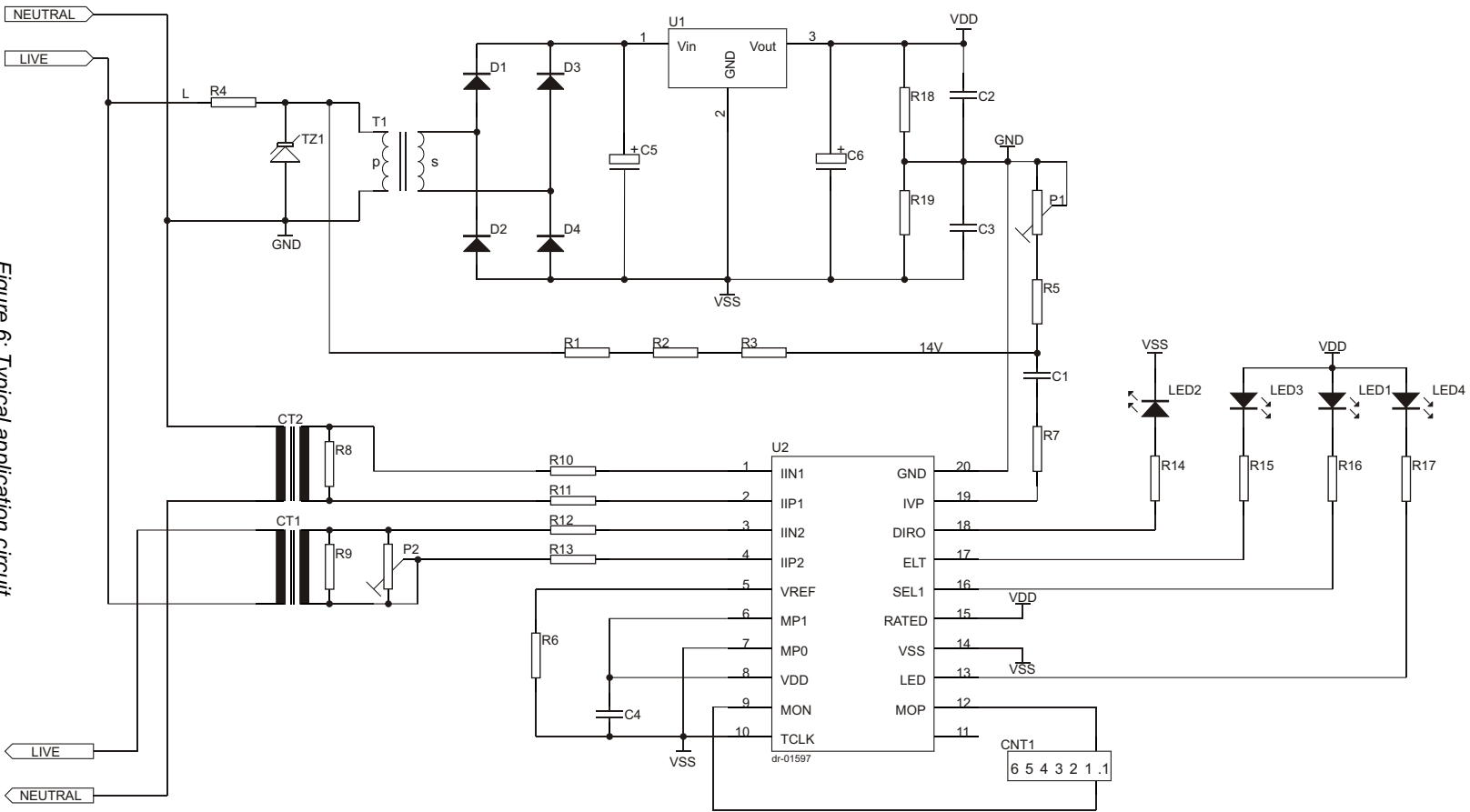
Figure 6: Typical application circuit

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Parts List for Application Circuit: Figure 6

Item	Symbol	Description	Detail
1	U2	SA2007M	DIP-20/SOIC-20
2	D1	Diode, Silicon 1N4148	or Similar
3	D2	Diode, Silicon 1N4148	or Similar
4	D3	Diode, Silicon 1N4148	or Similar
5	D4	Diode, Silicon 1N4148	or Similar
6	LED1	Light emitting diode, Amber	
7	LED2	Light emitting diode, Green	
8	LED3	Light emitting diode, Red	
9	LED4	Light emitting diode, Green	
10	R1	Resistor, 120k, 1/4W, 1%, metal	
11	R2	Resistor, 120k, 1/4W, 1%, metal	
12	R3	Resistor, 130k, 1/4W, 1%, metal	
13	R4	Resistor, 10 , 2W, Wire wound	
14	R5	Resistor, 24k, 1/4W, 1%, metal	
15	R6	Resistor, 22k, 1/4W, 1%, metal	
16	R7	Resistor, 1M, 1/4W, 1%, metal	
17	R8	Resistor, 1/4W, 1%, metal	Note 2
18	R9	Resistor, 1/4W, 1%, metal	Note 2
19	R10	Resistor, 1/4W, 1%, metal	Note 1
20	R11	Resistor, 1/4W, 1%, metal	Note 1
21	R12	Resistor, 1/4W, 1%, metal	Note 1
22	R13	Resistor, 1/4W, 1%, metal	Note 1
23	R14	Resistor, 1k, 1/4W, 5%	
24	R15	Resistor, 1k, 1/4W, 5%	
25	R16	Resistor, 1k, 1/4W, 5%	
26	R17	Resistor, 1k, 1/4W, 5%	
27	R18	Resistor, 1k, 1/4W, 5%, metal	
28	R19	Resistor, 1k, 1/4W, 5%, metal	
29	P1	Multi-turn, Trim pot, 10k	Note 2
30	P2	Multi-turn, Trim pot, 10	
31	C1	Capacitor	Note 4
32	C2	Capacitor, 220nF	
33	C3	Capacitor, 220nF	
34	C4	Capacitor, 820nF	Note 3
35	C5	Capacitor, 2200µF, 25V, electrolytic	
36	C6	Capacitor, 100µF, 16V, electrolytic	
37	CT1	Current Transformer	
38	CT2	Current Transformer	
39	T1	Transformer, 230V/9V	
40	U1	78LC05, Voltage regulator	
41	CNT1	Bipolar step motor	
42	TZ1	400V, Metal oxide varistor	

Note 1: Resistor (R10, R11, R12 and R13) values are dependent upon the selected value of R8 and R9
Note 2: See TYPICAL APPLICATION when selected the value of R8 and R9.
Note 3: Capacitor (C4) to be positioned as closed to Supply Pins (V_{DD} & V_{ss}) of U-1, as possible.
Note 4: Capacitor (C1) selected to minimize phase error introduced by current transformer (typically 1.5µF for normal CTs)

DISCLAIMER:

Any sales or technical questions may be posted to our e-mail address below:
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For the latest updates on datasheets, please visit our web site:
http://www.sames.co.za.

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