

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 40mW
- 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.

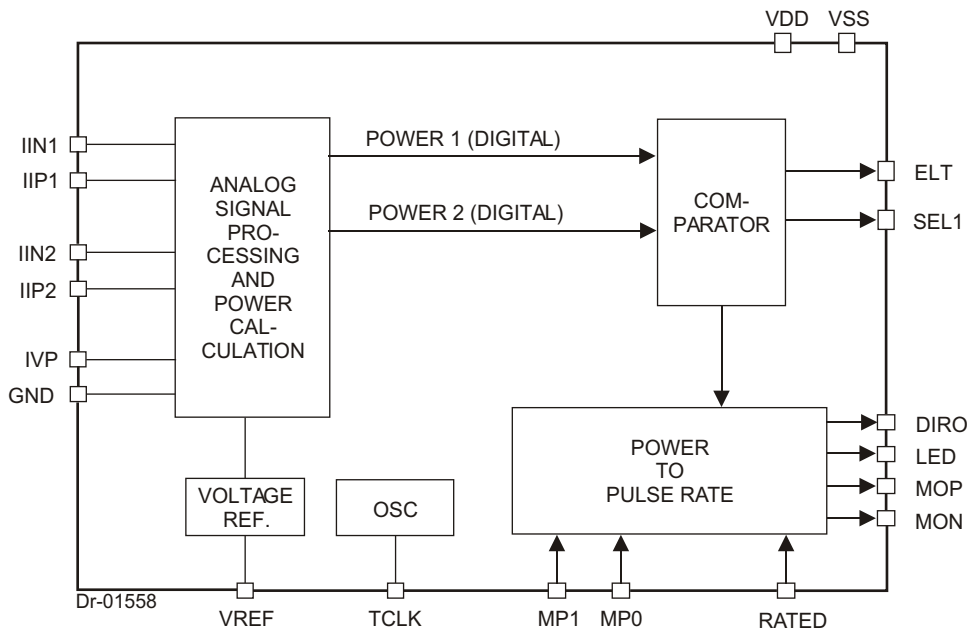


Figure 1: Block diagram

**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						
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**

#Extended Operating Temperature Range available on request.

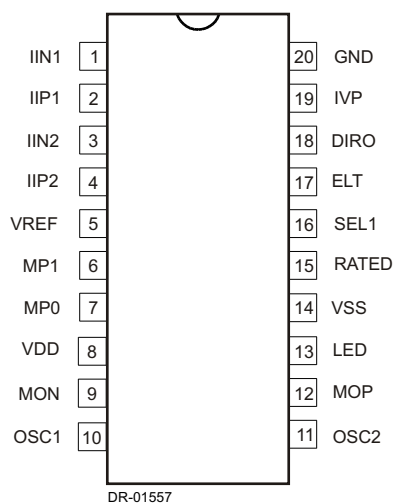
ABSOLUTE MAXIMUM RATINGS*

Parameter	Symbol	Min	Max	Unit
Supply Voltage	V _{DD} -V _{SS}	3.6	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 $\pm 25\mu A$ 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 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.
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



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 drops across the shunt will be between 0 and 16mV_{RMS} (0 to 80A through a shunt resistor of 200μ). The voltage across the current transformers terminating resistor will also be between 0 and 16mV_{RMS}. These voltage are converted to currents of between 0 and 16μA_{RMS} for each current sense inputs by means of resistors R₁ and R₂ (channel 1) as well as R₃ and R₄ (channel 2).

The current sense input saturates at an input current of ±25μA 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 14μA_{RMS} at nominal mains voltage, via resistor R₆(1M .

Different pulse rates are available at the MOP and MON pins. The device can be programmed for a 1, 10 or 100 dividing ratio for this output (counter resolution), depending on the status of the motor pulse rate select pins MP0 and MP1.

The rated condition select pin allows the metering constants (LED output and Motor Drive output) to remain unchanged for different rated conditions having a 1:2:3 scaling ratio, for example 230V/20A, 230V/40A and 230V/60A. The 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.

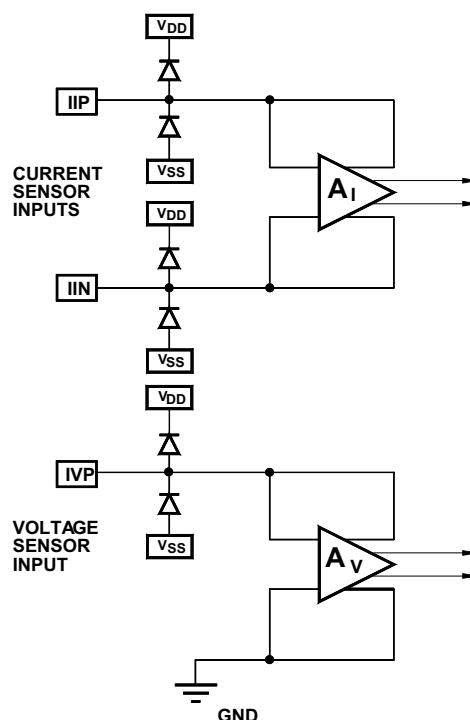
The feedback loops from the outputs of the amplifiers A_I and A_V generate virtual shorts on the signal inputs. Exact duplications of the input currents are generated for the analog signal processing circuitry.

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 40mW.



DR-01288

Figure 3: Analog input internal configuration



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 optimum conditions are set. It may be varied within ±10% for calibration purposes. Any changes to the bias resistor will affect the output pulse rate quadratically (i.e. $R = +5\%$, $f = 10\%$).

Rated condition select (RATED)

The rated condition select pin allows the metering constants (LED output and Motor Drive output) to remain unchanged for different rated conditions having a 1:2:3 scaling ratio, for example 230V/20A, 230V/40A and 230V/60A. This option allows for the development of different rated meters requiring minimal changes. The only changes to be implemented is the selection of the current sense resistors for the expected rated load currents and the selection of pins RATED, MP1 and MP0.

RATED pin	Rated Conditions Multiplying Ratio
V _{SS}	1/3
OPEN	2/3
V _{DD}	3/3

At a rated condition of 230V/60A (13800W), setting the RATED pin to VDD (ratio set to 3/3) the LED pulse rate will be 6400 pulses/KWh. With a combination of RATED, MP0 and MP1 settings, various rated condition can easily be met. Refer to the section "Using the RATED, MP0 and MP1 inputs" for further information.

Motor pulse rate select (MP1 and MP0)

The MP1 and MP2 inputs select between 1, 10 and 100

dividing ratio for the motor drive outputs (counter resolution). Please note that the device will not perform metering functions while in test mode.

Pulse Rate Selection Input		Counter resolution
MP1	MP0	
V _{DD}	V _{SS}	100
V _{SS}	V _{DD}	10
V _{SS}	V _{SS}	1
V _{DD}	V _{DD}	Test Mode

Using the RATED, MP1 and MP0 inputs

The following formulas can be used to calculate the LED output and motor pulse rates. **Note that for the motor pulse rates shown in the datasheet a MOP pulse followed by a MON pulse is treated as two energy pulses.**

1. LED pulse rate

LED pulses/kWh = (13800/VA) x 6400 x (RATED Pin)

Where:

VA = Meters I_{max} x V_{max} (in watts)

RATED Pin = 1/3, 2/3 or 3/3 (see rated condition select pin section)

2. MOTOR pulse rate

MOTOR pulses/kWh = (13800/VA) x 200 x (RATED Pin) x (1/RESOLUTION)

Where:

VA = Meters I_{max} x V_{max} (in watts)

RATED Pin = 1/3, 2/3 or 3/3 (see rated condition select pin section)

RESOLUTION = 1, 10 or 100 (see motor pulse select rate section)

The following table shows the combinations for some the common rated conditions:

RATED Pin	Rated Condition	LED output (Pulses / kWh)	Motor Pulse Rate		
			MP1 pin	MP0 pin	Pulse / kWh
Vss	230V / 10A (2300 watts)	12800	Vss	Vss	4
			Vss	Vdd	40
			Vdd	Vss	400
Vss	230V / 20A (4600 watts)	6400	Vss	Vss	2
			Vss	Vdd	20
			Vdd	Vss	200
Open	230V / 40A (9200 watts)	6400	Vss	Vss	2
			Vss	Vdd	20
			Vdd	Vss	200
Vdd	230V / 60A (13800 watts)	6400	Vss	Vss	2
			Vss	Vdd	20
			Vdd	Vss	200
Open	230V / 80A (18400 watts)	3200	Vss	Vss	1
			Vss	Vdd	10
			Vdd	Vss	100



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The LED pulse is not restricted to the rates mentioned in the above table. Using the formulae's on page 5, different combinations can be achieved as shown in the following table.

I _{max} (at 230V)	RATED PIN		
	V _{ss}	OPEN	V _{dd}
10	12800	25600	38400
20	6400	12800	19200
30	4566	8533	12800
40	3200	6400	9600
60	2133	4266	6400
80	1600	3200	4800
100	1066	2133	3200

A suitable motor pulse rate can be selected from the following table:

LED Pulse rate	Motor pulse rate (as per MP0 and MP1 settings)		
3200	1	10	100
6400	2	20	200
12800	4	40	400
25600	8	80	800

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. 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}. Both MOP and MON outputs are active high. The motor drive wave forms are shown below:

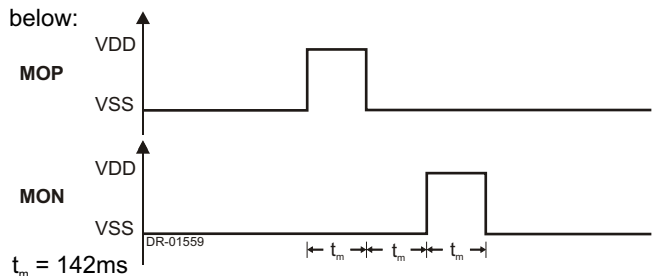


Figure 4: Motor drive waveform

LED output (LED)

The LED output is active low. Refer to the section "Using the RATED MP1 and MP0 inputs" to calculate the LED pulse rate. The LED waveform is shown below:

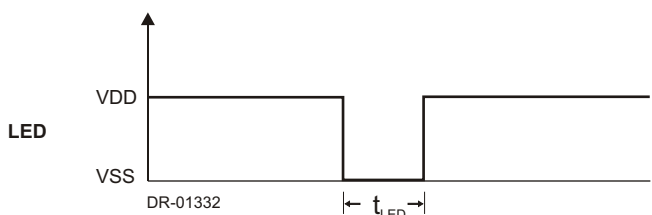


Figure 5: LED pulse output

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 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.

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

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

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 of both current channels on pin DIRO .

A logic 0 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 1.

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

Signal Output	Value	Description
DIRO	0	Reverse energy flow
	1	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 and 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 $16\mu A_{RMS}$ 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 $R_1 = R_2 = (I_L / 16\mu A_{RMS}) \times R_{10} / 2$
Current Channel 2 $R_3 = R_4 = (I_L / 16\mu A_{RMS}) \times R_{11} / 2$

Where:

- IL = Line current /CT-ratio
- R10 = Termination resistor
- R11 = Termination resistor

Voltage Sense Resistors

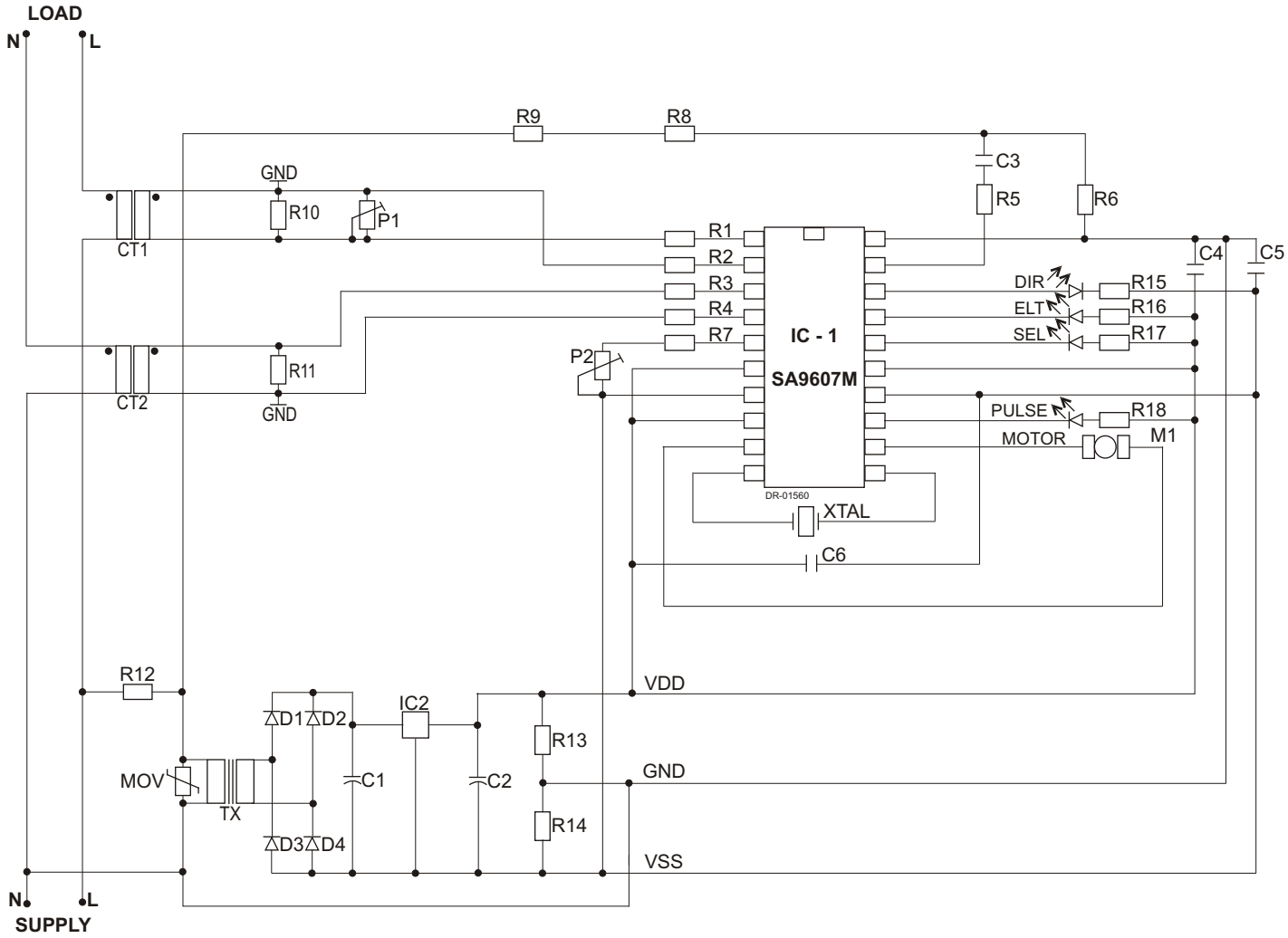
R9, R8, R6 and R5 set the current for the voltage sense input. the values should be selected so that the input current into the voltage sense input (virtual ground) is set to $14\mu A_{RMS}$.

Bias Resistor

R_7 defines all on-chip bias and reference currents. With $R_7 = 24k$ 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





Parts List for Application Circuit: Figure 7

Item	Symbol	Description	Detail
1	IC1	SA9607M	DIP-20/SOIC-20
2	D1	Diode, Silicon 1N4007	or Similar
3	D2	Diode, Silicon 1N4007	or Similar
4	D3	Diode, Silicon 1N4007	or Similar
5	D4	Diode, Silicon 1N4007	or Similar
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	
12	R2	Resistor, 1/4W, 1%, metal	
13	R3	Resistor, 1/4W, 1%, metal	
14	R4	Resistor, 1/4W, 1%, metal	
15	R5	Resistor, 1M, 1/4W, 1%, metal	
16	R6	Resistor, 24k, 1/4W, 1%, metal	
17	R7	Resistor, 22k, 1/4W, 1%, metal	Note 2
18	R8	Resistor, 180k, 1/4W, 1%, metal	Note 2
19	R9	Resistor, 200k, 1/4W, 1%, metal	Note 1
20	R10	Resistor, 1/4W, 1%, metal	Note 1
21	R11	Resistor, 1/4W, 1%, metal	Note 1
22	R12	Resistor, 10 , 2W, Wire wound	Note 1
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	Note 2
30	P2	Multi-turn, Trim pot, 5k	
31	C1	Capacitor, 100μF, 16V, electrolytic	Note 4
32	C2	Capacitor, 100μF, 16V, electrolytic	
33	C3	Capacitor	
34	C4	Capacitor, 220nF	Note 3
35	C5	Capacitor, 220nF	
36	C6	Capacitor, 820nF	
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 dependent upon the selected value of R10 and R11

Note 2: See TYPICAL APPLICATION when selected 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 1.5μF for normal CT5, approx. 100nF)



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