Single Phase Bidirectional Power/Energy Metering IC with Instantaneous Pulse Output

SA2002H

ICDC

FEATURES

- Functionally compatible with the SA9602H with reduced external components
- Bidirectional power and energy measurement
- Meets the IEC 521/1036 Specification requirements for Class 1 AC Watt hour meters
- Protected against ESD
- Total power consumption rating below 25mW
- Adaptable to different types of current sensors
- Operates over a wide temperature range
- Precision voltage reference on-chip
- Precision oscillator on-chip

DESCRIPTION

The SA2002H is an enhancement of the SA9602H, as the circuit contains the oscillator on chip.

The SA2002H single phase bidirectional power/energy metering integrated circuit generates a pulse rate output with a frequency proportional to the power consumption.

The SA2002H performs a calculation for active power. The method of calculation takes the power factor into account. Energy consumption can be determined by the power measurement being integrated over time.

This innovative universal single phase power/energy metering integrated circuit is ideally suited for energy calculations in applications such as residential municipal metering and factory energy metering and control.

The SA2002H integrated circuit is available in 8 pin dual inline (PDIP8) as well as 20 pin and 16 pin small outline (SOIC20, SOIC16) RoHS compliant package options.

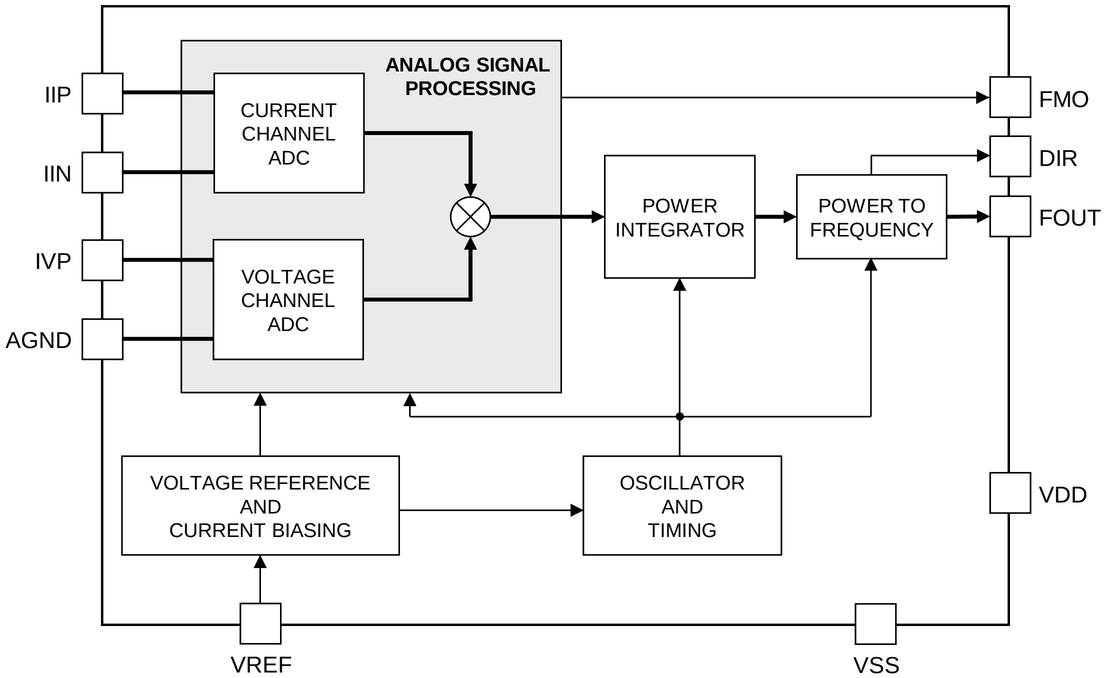


Figure 1: Block diagram

*FMO and DIR not available in PDIP8 package type

ELECTRICAL CHARACTERISTICS

(V_{DD} - V_{SS} = 5V ± 10%, over the temperature range -40°C to +85°C, unless otherwise specified.)

Parameter	Symbol	Min	Typ	Max	Unit	Condition
General						
Supply Voltage: Positive	V_{DD}	2.25	2.5	2.75	V	With respect to AGND
Supply Voltage: Negative	V_{SS}	-2.75	-2.5	-2.25	V	With respect to AGND
Supply Current: Positive	I_{DD}		3	5	mA	
Supply Current: Negative	I_{SS}		-3	-5	mA	
Analog Inputs						
Current Sensor Inputs (Differential)						
Input Current Range	IR_{IIP}, IR_{IIN}	-25		25	µA	Peak value
Offset Voltage	VO_{IIP}, VO_{IIN}	-4		4	mV	With R = 4.7kΩ connected to AGND
Voltage Sensor Inputs (Asymmetrical)						
Input Current Range	IR_{IVP}	-25		25	µA	Peak value
Offset Voltage	VO_{IVP}	-4		4	mV	With R = 4.7kΩ connected to AGND
Digital Outputs						
FOUT, FMO, DIR Output High Voltage Output Low Voltage	 V_{OH} V_{OL}	 V_{DD}-1		 V_{SS}+1	 V V	 I_{SOURCE} = 5mA I_{SINK} = 5mA
Pulse Rate FOUT	f_p		1160		Hz	At rated input conditions
Pulse Width FOUT	t_{pp} t_{pn}		71 143		µs µs	Positive energy flow Negative energy flow
On-chip Voltage Reference						
Reference Voltage	V_R	1.1		1.3	V	
Reference Current	$-I_R$	45	50	55	µA	With R = 24kΩ connected to V_{SS}
Temperature Coefficient	TC_R		10	70	ppm/ºC	
On-chip Oscillator						
Oscillator Frequency	f_{OSC}	3.15	3.57	4.00	MHz	
Temperature Coefficient	TC_{OSC}		70	200	ppm/ºC	

During manufacturing, testing and shipment we take great care to protect our products against potential external environmental damage such as Electrostatic Discharge (ESD). Although our products have ESD protection circuitry, permanent damage may occur on products subjected to high-energy electrostatic discharges accumulated on the human body and/or test equipment that can discharge without detection. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality during product handling.

ATTENTION: Electrostatic sensitive device. Requires special handling.

ABSOLUTE MAXIMUM RATINGS*

Parameter	Symbol	Min	Max	Unit
Supply Voltage	V_{DD} - V_{SS}		6	V
Current on any Pin	I_{PIN}	-150	150	mA
Storage Temperature	T_{STG}	-60	+125	ºC
Specified Operating Temperature Range	T_O	-40	+85	ºC
Limit Range of Operating Temperature	T_{limit}	-40	+85	ºC

*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

Designation	8 Pin	16 Pin	20 Pin	Description
AGND	8	16	20	Analog Ground. This is the reference pin for the current and voltage signal sensing networks. The supply voltage to this pin should be mid-way between V_{DD} and V_{SS}.
VDD	4	5	8	Positive Supply Voltage. The voltage to this pin should be +2.5V ± 10% with respect to AGND.
VSS	6	9	14	Negative Supply Voltage. The voltage to this pin should be -2.5V ± 10% with respect to AGND.
IVP	7	15	19	Analog Input for Voltage. The maximum current into the voltage sense input IVP should not exceed 16µA_{RMS}. At nominal voltage an input current of 14µA_{RMS} is recommended. The voltage sense input saturates at an input current of ±25µA peak.
IIP, IIN	2, 1	2, 1	2, 1	Analog Inputs for Current. The maximum current into the current sense inputs IIP/IIN should be set at 16µA_{RMS}. The current sense inputs saturate at an input current of ±25µA peak.
VREF	3	3	3	This pin provides the connection for the reference current setting resistor. A 24kΩ resistor connected to V_{SS} sets the optimum operating conditions.
FOUT	5	6	12	Pulse output. Refer to the Pulse Output section for information on the pulse output.
DIR		7	13	Direction output. This output indicates the direction of energy flow.
FMO		11	15	Mains Voltage Crossover output. The FMO output generates pulses on every rising edge of the mains voltage.
NC		4, 8, 10, 12-14	4-7, 9-11, 16-18	No connection, leave unconnected.

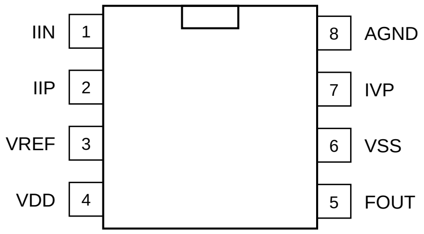


Figure 2: Pin connections for PDIP8 package

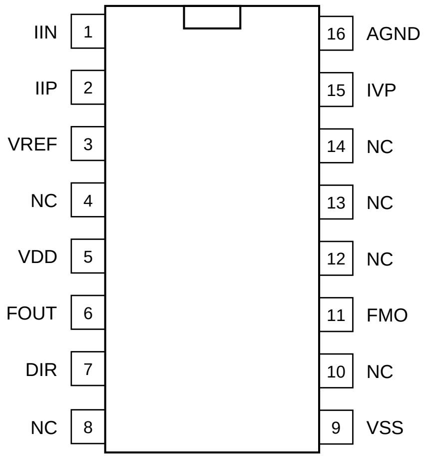


Figure 3: Pin connections for SOIC16 package

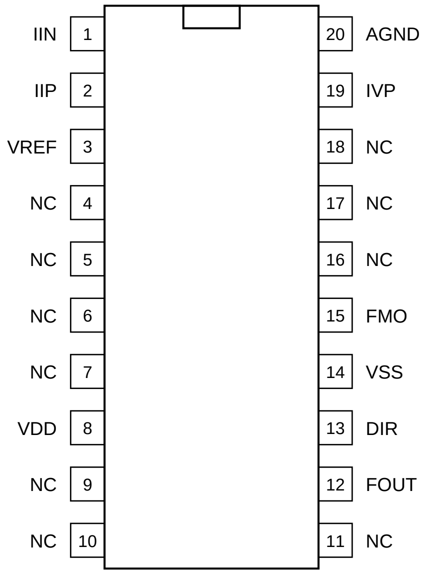


Figure 4: Pin connections for SOIC20 package

ORDERING INFORMATION

Part Number	Package
SA2002HPAR-8	PDIP8 (RoHS compliant)
SA2002HSAR-16	SOIC16 (RoHS compliant)
SA2002HSAR-20	SOIC20 (RoHS compliant)

FUNCTIONAL DESCRIPTION

The SA2002H is a CMOS mixed signal analog/digital integrated circuit, which performs power/energy calculations across a power range of 500:1, to an overall accuracy of better than Class 1.

The integrated circuit includes all the required functions for single phase power and energy measurement such as two 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 SA2002H generates pulses, the frequency of which is proportional to the measured power consumption. One frequency output (FOUT) is available. The pulse rate follows the instantaneous power consumption measured.

POWER CALCULATION

In the application circuit (see Figure 5), the voltage drop across the shunt (RSH) will be between 0 and 16mV$_{RMS}$ (0 to 80A through a shunt resistor of 200µΩ). This voltage is converted to a current of between 0 and 16µA$_{RMS}$, by means of resistors R1 and R2. The current sense inputs saturate at an input current of ±25µA peak.

For the voltage sensor input, the mains voltage (220VAC) is divided down through a divider (R3, R4 and P1) to 14V. The current into the A/D converter input is set at 14µA$_{RMS}$ at nominal mains voltage, via resistor R5 (1MΩ). P1 may be varied for calibration purposes.

In this configuration, with a mains voltage of 220V and a current of 80A, the output frequency measured on the FOUT pin is 1160Hz. In this case, one pulse on FOUT will correspond to an energy consumption of 17.6kW/1160Hz = 15.17Ws.

ANALOG INPUT CONFIGURATION

The input circuitry of the current and voltage sensor inputs is illustrated in Figure 6. 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.

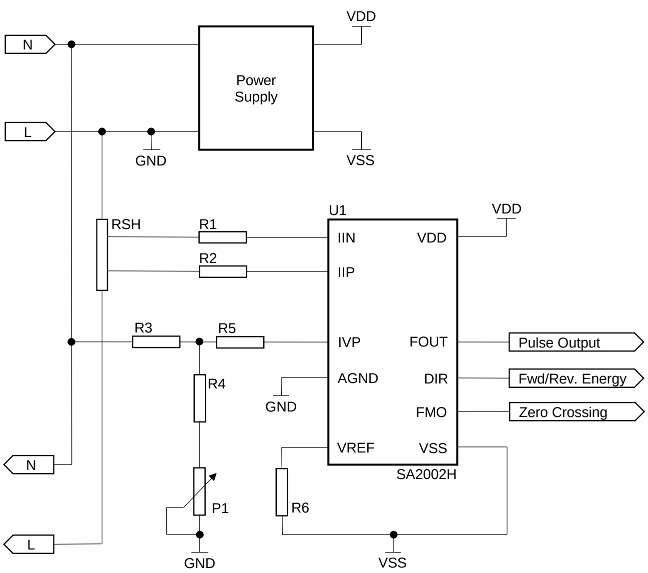


Figure 5: Application Circuit

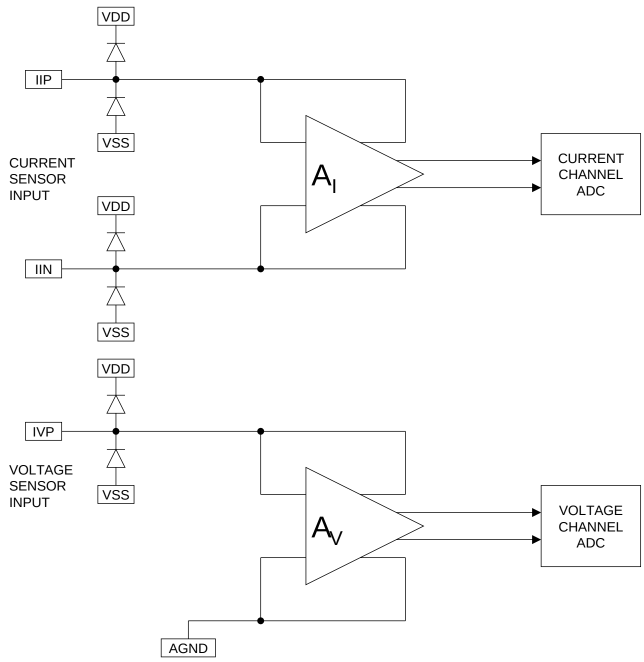


Figure 6: Internal analog input configuration

ELECTROSTATIC DISCHARGE (ESD) PROTECTION

The SA2002H integrated circuits inputs and outputs are protected against ESD.

POWER CONSUMPTION

The power consumption rating of the SA2002H integrated circuit is less than 25mW.

INPUT SIGNALS

VREF

A bias resistor of 24kΩ sets optimum bias conditions on chip. Calibration of the SA2002H should be done on the voltage input as described in Typical Applications.

Current Sense Inputs (IIP and IIN)

Figure 5 shows the typical connections for the current sensor input. The resistors R1 and R2 define the current level into the current sense inputs of the SA2002H. At maximum rated current the resistor values should be selected for input currents of $16\mu A_{RMS}$.

Values for resistors R1 and R2 can be calculated as follows:

$$R1 = R2 = \frac{I_L}{16\mu A} \times \frac{RSH}{2}$$

where

I_L is the line current and

RSH is the shunt resistor or termination resistor if a CT (current transformer) is used as the current sensor.

The value of RSH, if used as a CT termination resistor, should be less than the DC resistance of the secondary winding of the CT. The voltage drop across RSH should not be less than $16mV_{RMS}$ at rated currents.

Voltage Sense Input (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. Referring to Figure 5, the typical connections for the voltage sense input is illustrated. Resistors R3, R4 and R5 set the current for the voltage sense input. The mains voltage is divided down to $14V_{RMS}$. The current into the A/D converter input is set at $14\mu A_{RMS}$ via resistor R5.

OUTPUT SIGNALS

Pulse Output (FOUT)

The output on FOUT is a pulse density signal representing the instantaneous power/energy measurement as shown in Figure 7. The pulse width on FOUT changes with the direction of energy measurement by the device. The pulse width (t_P) is 71,5µs for positive energy and doubles if negative energy is measured. The output frequency may be calculated using the following formula:

$$f = 11.16 \times FOUT \times \frac{I_I \times I_V}{{I_R}^2}$$

where

FOUT is the typical rated output frequency (1160Hz),

I_I is the input current on the current sense inputs in RMS (16µA at rated conditions),

I_V is the input current on the voltage sense input in RMS (14µA at rated conditions) and

I_R is the reference current on VREF, typically 50µA.

An integrated anti-creep function does not allow output pulses on FOUT if no power is measured by the device.

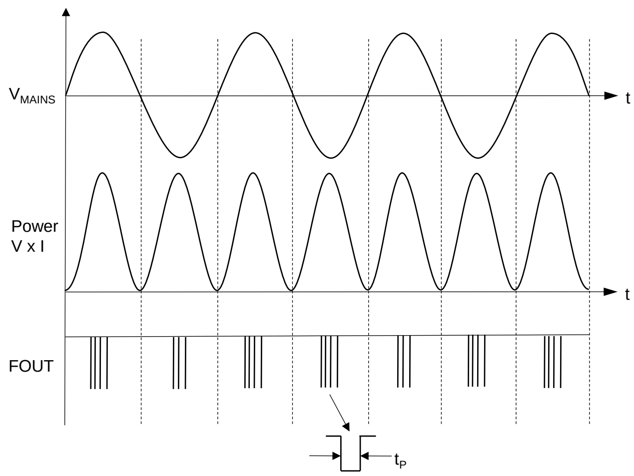


Figure 7: Instantaneous pulse output

Direction Indication (DIRO)

The direction output DIR can be used to determine the direction of energy flow. The pin is high for positive energy and low when negative energy is measured. Figure 8 shows the behavior of the direction output DIR, when energy reversal takes place. The time period for the DIR signal to change state, t_{DIR}, is the time it takes for the internal integrator to count (down) from its present value to zero. Thus the energy consumption rate determines the speed of change on

DIR. Note that the DIR output is not available in the PDIP8 package type.

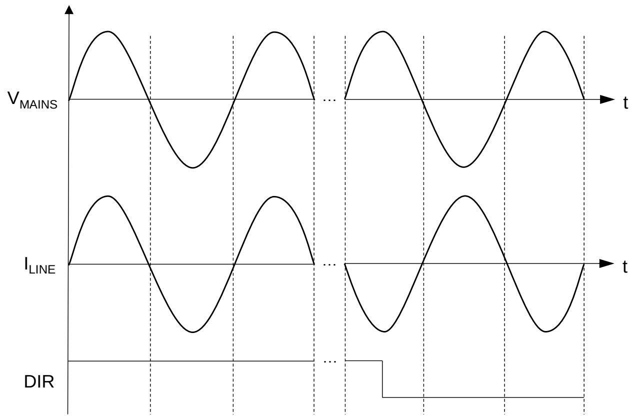


Figure 8: Behaviour of direction output DIR

Mains Zero Crossing Indication (FMO)

The square wave signal of FMO indicates the polarity of the mains voltage. Due to comparator offsets, the FMO low to high transition can occur within a range as shown in Figure 9. The time between successive low to high transitions will be equal to the mains voltage period. Note that the FMO output is not available in the PDIP8 package type.

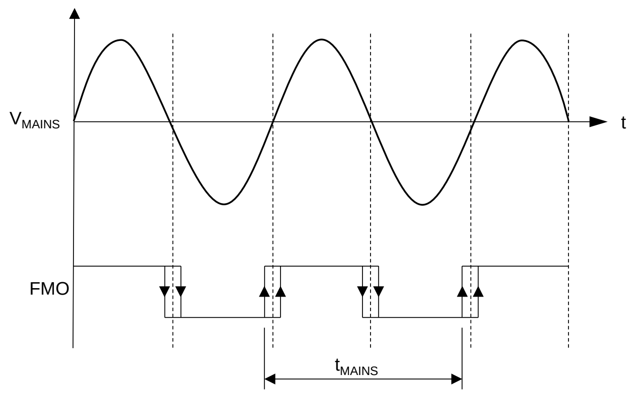


Figure 9: Mains zero crossings on FMO

TYPICAL APPLICATION

In Figure 10 the components required for a stand-alone power metering application are shown. The application uses a shunt resistor for the mains current sensing. The meter is designed for 220V/40A I_{MAX} operation. The most important external components for the SA2002H integrated circuit are the current sense resistors, the voltage sense resistors as well as the bias setting resistor.

Bias Resistor

R12 defines all on-chip and reference currents. Optimum conditions are set by using R12=24kΩ. Device calibration is done on the voltage input of the device.

Shunt Resistor

The voltage drop across the shunt resistor at rated current should be at least 20mV. A shunt resistor with a value of 625µΩ is chosen. The voltage drop across the shunt resistor is therefore 25mV at rated conditions (I_{MAX}). The maximum power dissipation in the current sensor is:

$$P = (40A)^2 \times 625\mu\Omega = 1W$$

Current Sense Resistors

The resistors R6 and R7 define the current level into the current sense inputs of the device. The resistor values are selected for an input current of 16µA$_{RMS}$ on the current inputs of the SA2002H at rated conditions. According to equation described in the Current Sense Inputs section:

$$R6 = R7 = \frac{I_L}{16\mu A} \times \frac{RSH}{2} = \frac{40A}{16\mu A} \times \frac{625\mu\Omega}{2} = 781.25\Omega$$

A resistor with value of 820Ω is chosen, the 5% deviation from the calculated value will be compensated for when calculating resistor values for the voltage path.

Voltage Divider

The voltage divider is calculated for a voltage drop of 14V+5% (14.7V). Equations for the voltage divider in Figure 10 are:

$$RA = R1 + R2 + R3$$
$$RB = R11 \mid\mid (R10 + P1)$$

Combining the two equations gives:

$$\frac{(RA + RB)}{220V} = \frac{RB}{14.7}$$

A 5kΩ trimpot will be used in the voltage channel for meter calibration. The center position on the pot is used in the calculations. Therefore P1=2.5kΩ and values for resistors R10=22kΩ and R11=1MΩ are chosen.

Substituting the values will result in RB=23.91kΩ and RA=334kΩ. Therefore R1, R2 and R3 are chosen to be 110kΩ.

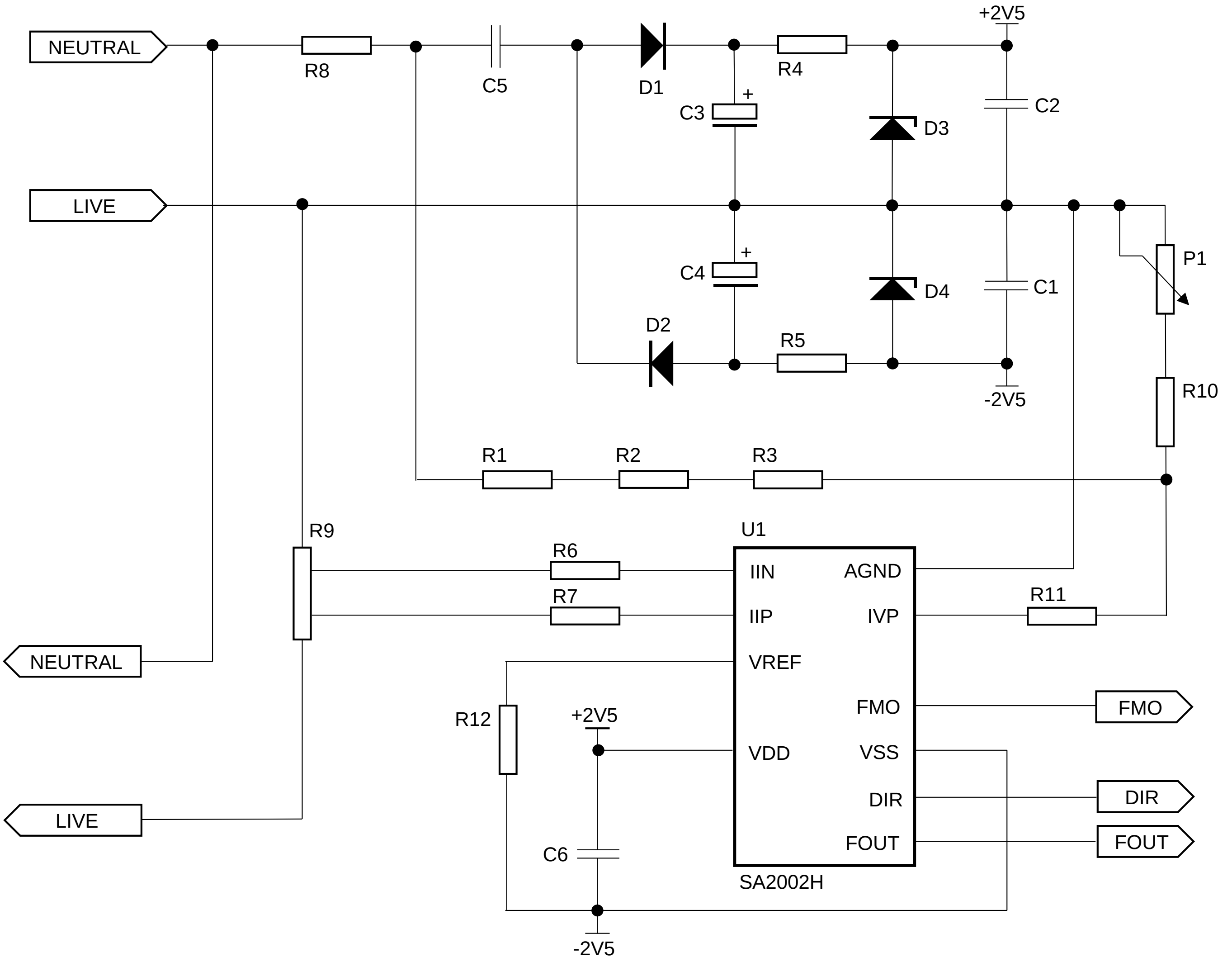


Figure 10: Typical application circuit

Table 1: Component list for typical application

Symbol	Description
U1	Energy metering device, SA2002H
D1, D2	Diode 1N4002
D3, D4	Zener diode, 2.4V
R1, R2, R3	Resistor, 110kΩ, 1%, metal film
R4, R5	Resistor, 680Ω, 1%, metal film
R6[1], R7[1]	Resistor, 820Ω, 1%, metal film
R8	Resistor, 47Ω, 5%, 2W, wire wound
R9	Shunt resistor, 625µΩ

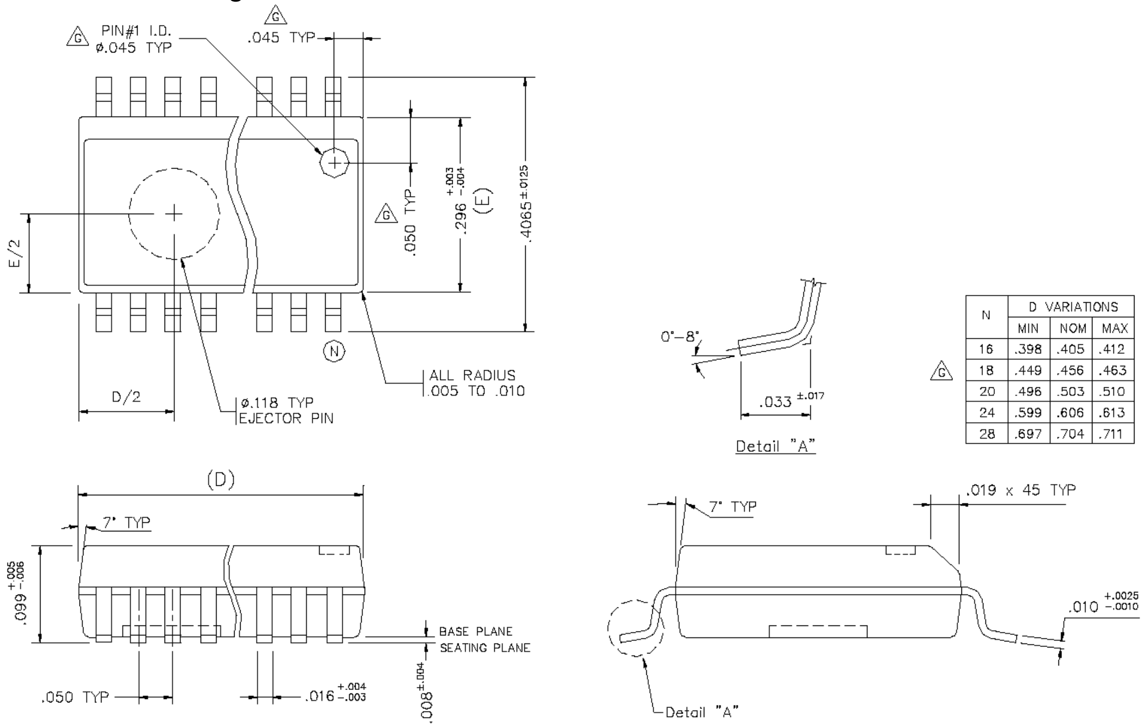
Symbol	Description
R10	Resistor, 22kΩ, 1%, metal film
R11[1]	Resistor, 1MΩ, 1%, metal film
R12[1]	Resistor, 24kΩ, 1%, metal film
P1	Trim-pot, 25 turns, 5kΩ
C1[2], C2[2]	Capacitor, 220nF, ceramic
C3, C4	Capacitor, 100µF, 16V, electrolytic
C5	Capacitor, 330nF, 250VAC
C6[2]	Capacitor, 820nF, ceramic

Note 1: Resistors R6, R7, R12 and R13 must be positioned as close as possible to the respective device pins
Note 2: Capacitors C1, C2 and C6 must be positioned as close as possible to the VDD and VSS power supply pins

PACKAGE DIMENSIONS

SOIC16 and SOIC20 Packages

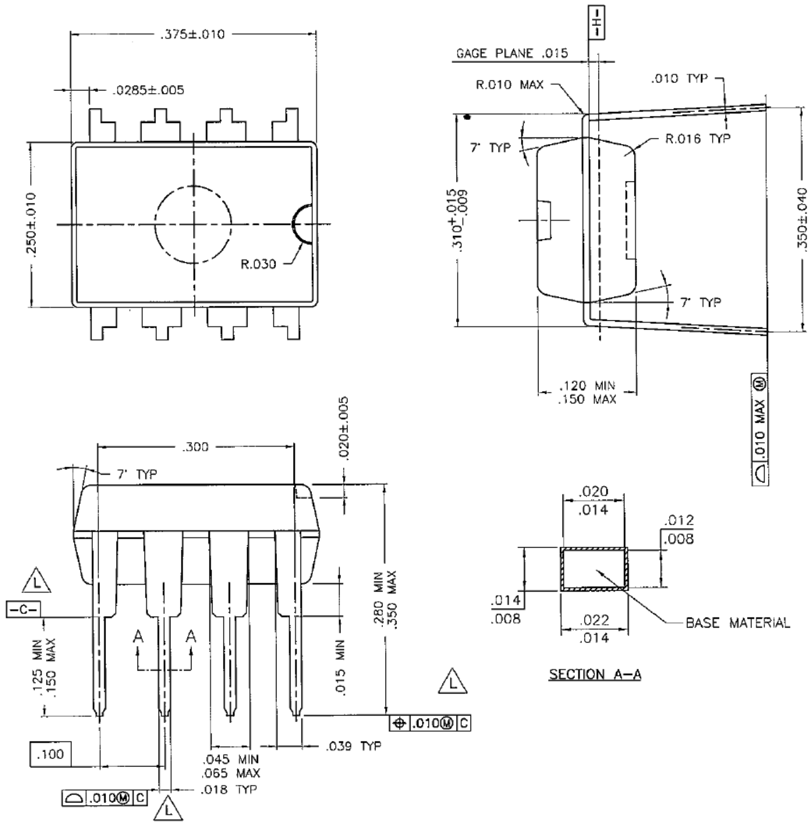
Dimensions are shown in inches



N	D VARIATIONS MIN	NOM	MAX
16	.398	.405	.412
18	.449	.456	.463
20	.496	.503	.510
24	.599	.606	.613
28	.697	.704	.711

PDIP8 Package

Dimensions are shown in inches



NOTES

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