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

SA9602E

FEATURES

- Pin and functionally compatible with the SA9102E with reduced external components
- Performs unidirectional 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
- Different pulse rate options available

DESCRIPTION

The SA9602E is an enhancement of the SA9102E, as no external capacitors are required for the A/D converters.

The SA9602E single phase unidirectional power/energy metering integrated circuit generates a pulse rate output, the frequency of which is proportional to the power consumption. The SA9602E performs the 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 SA9602E integrated circuit is available in a 20 pin small outline (SOIC20) RoHS compliant package.

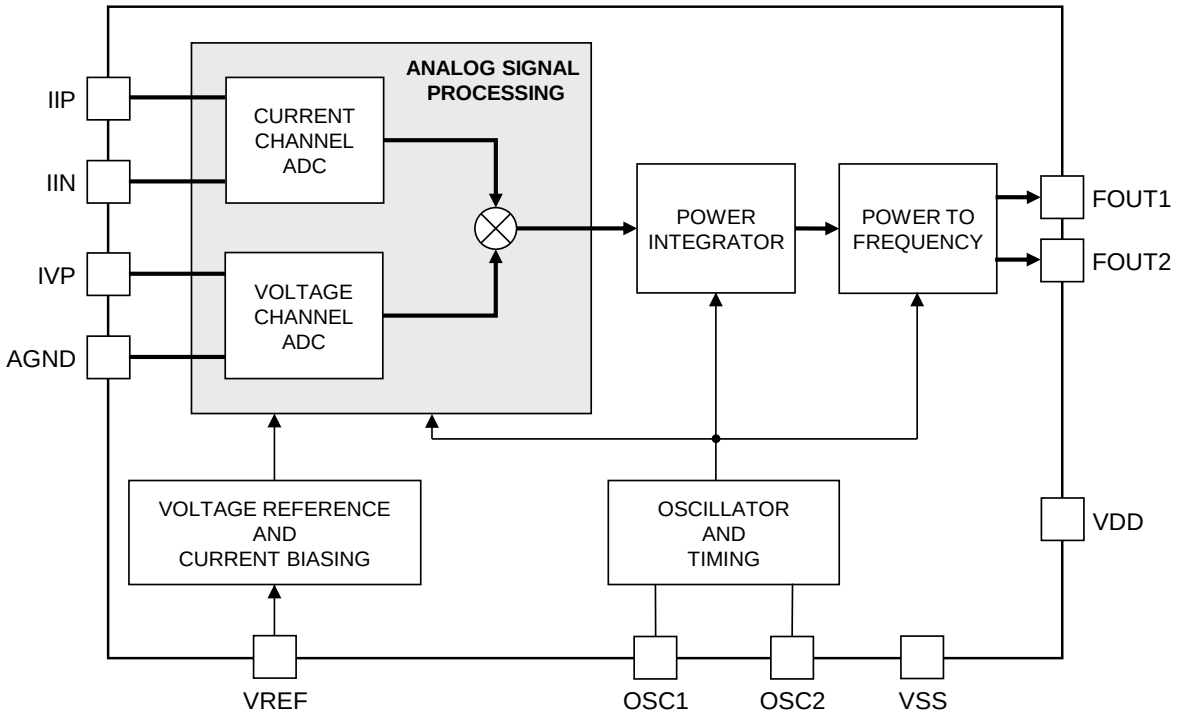


Figure 1: Block diagram

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						
FOUT1, FOUT2 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 FOUT1 FOUT2[1]	 f_{P1} f_{P2}		 1160 f_{P1}/290		 Hz Hz	At rated input conditions
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	
Oscillator						
Recommended crystal	f_{OSC}		3.5795		MHz	TV colour burst crystal

Note1: Two additional bondout options of FOUT2 are available on request: $f_{P1}/4$ and $f_{P1}/16$

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	Pin No.	Description
AGND	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	8	Positive Supply Voltage. The voltage to this pin should be +2.5V ± 10% with respect to AGND.
VSS	14	Negative Supply Voltage. The voltage to this pin should be -2.5V ± 10% with respect to AGND.
IVP	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	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	This pin provides the connection for the reference current setting resistor. A 24kΩ resistor connected to V_{SS} sets the optimum operating conditions.
FOUT1	12	First pulse output. Refer to the Pulse Output Signals section for further information.
FOUT2	13	Second pulse output. Refer to the Pulse Output Signals section for further information.
OSC1, OSC2	11, 10	Connection for crystal
TEST	7	Manufacturers test pin. Tie to V_{SS} for optimum protection against transients.
NC	4-6, 9, 15-18	No connection, leave unconnected.

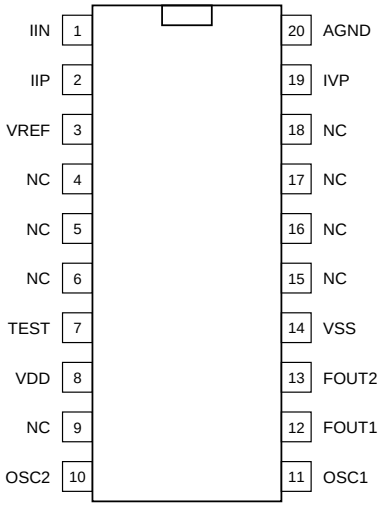


Figure 2: Pin connections for SOIC20 package

ORDERING INFORMATION

Part Number	Package
SA9602ESAR	SOIC20 (RoHS compliant)

FUNCTIONAL DESCRIPTION

The SA9602E is a CMOS mixed signal integrated circuit, which performs power/energy calculations across a power range of 500:1, to an overall accuracy of Class 1.

The SA9602E in is a direct replacement for the SA9102E with the advantage of no external loop capacitors.

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 SA9602E generates pulses, the frequency of which are proportional to the power consumption. Two frequency outputs (FOUT1 and FOUT2) are available, with additional frequency options available on request. The pulse rate follows the instantaneous power consumption measured.

POWER CALCULATION

In the application circuit (see Figure 3), 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.

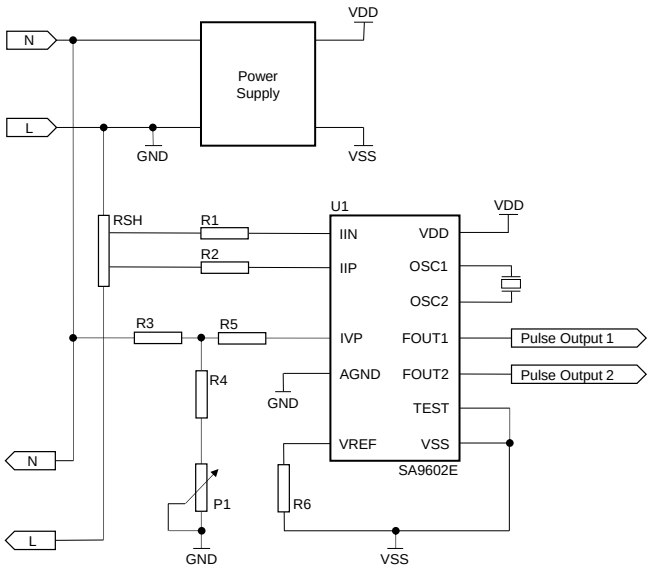


Figure 3: Application Circuit

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 of the SA9602E power meter chip on FOUT1 is 1160Hz. In this case, one pulse will correspond to an energy consumption of 17.6kW/1160Hz = 15.17Ws. The output frequency on FOUT2 is FOUT1/290 (i.e. the frequency output at FOUT1 divided by 290).

ANALOG INPUT CONFIGURATION

The input circuitry of the current and voltage sensor inputs is illustrated in Figure 4. 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.

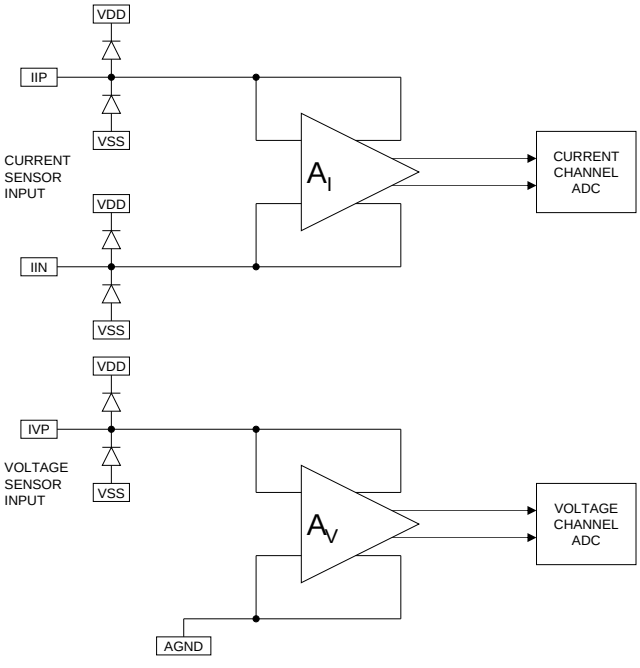


Figure 4: Internal analog input configuration

ELECTROSTATIC DISCHARGE (ESD) PROTECTION

The SA9602E integrated circuits inputs and outputs are protected against ESD.

POWER CONSUMPTION

The power consumption rating of the SA9602E integrated circuit is less than 25mW.

INPUT SIGNALS

VREF

A bias resistor of 24kΩ sets optimum bias conditions on chip. Calibration of the SA9602E should be done on the voltage input as described in Typical Applications.

Current Sense Inputs (IIP and IIN)

Figure 3 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 SA9602E. At maximum rated current the resistor values should be selected for input currents of 16μA_{RMS}. The current sense inputs saturate at an input current of ±25μA peak.

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 14μA_{RMS} at nominal mains voltage. The voltage sense input saturates at an input current of ±25μA peak. Referring to Figure 3, 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 14μA_{RMS} via resistor R5.

OUTPUT SIGNALS

Pulse Outputs (FOUT1 and FOUT2)

The output on FOUT1 and FOUT2 is a pulse density signal representing the instantaneous power/energy measurement as shown in Figure 5. The pulse width (t_p) is 71μs. The output frequency may be calculated using the following formula:

$$f = 11.16 \times FOUT_X \times \frac{I_I \times I_V}{{I_R}^2} \times \frac{f_{CRYSTAL}}{3.5795}$$

where
$FOUT_X$ is the typical rated output frequency (1160Hz on FOUT1 and 4Hz on FOUT2),
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),
I_R is the reference current on VREF, typically 50μA, and
$f_{CRYSTAL}$ is the frequency of the crystal used in MHz.

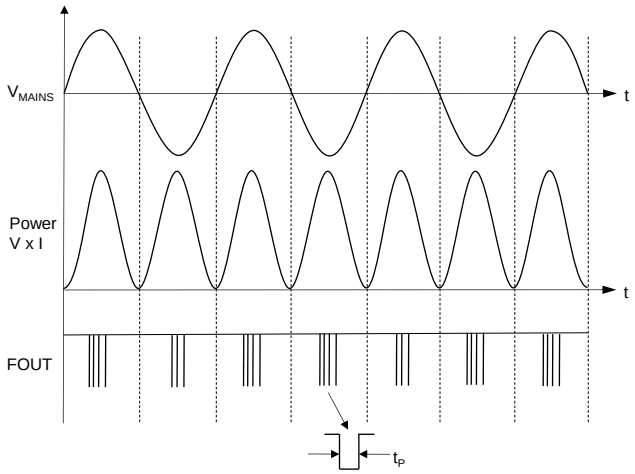


Figure 5: Instantaneous pulse output

OSCILLATOR

The SA9602E contains a crystal oscillator driver circuit requiring only an external crystal to be connected between OSC1 and OSC2. All other components are integrated on the device. The recommended crystal is a TV colour burst crystal (3.5795MHz).

TYPICAL APPLICATION

In Figure 6 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/80A I_{MAX} operation. The most important external components for the SA9602E 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 250μΩ 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:

$$P = (80A)^2 \times 250\mu\Omega = 1.6W$$

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 SA9602E at rated conditions. According to the equation described in the Current Sense Inputs section:

$$R6 = R7 = \frac{I_L}{16\mu A} \times \frac{RSH}{2} = \frac{80A}{16\mu A} \times \frac{250\mu\Omega}{2} \approx 620\Omega$$

Voltage Divider

The voltage divider is calculated for a voltage drop of 14V. Equations for the voltage divider in Figure 6 are:

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

Combining the two equations gives:

$$\frac{(RA + RB)}{220V} = \frac{RB}{14}$$

A 5kΩ trimpot will be used on 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=352kΩ. Therefore R1, R2 and R3 are chosen to be 120kΩ.

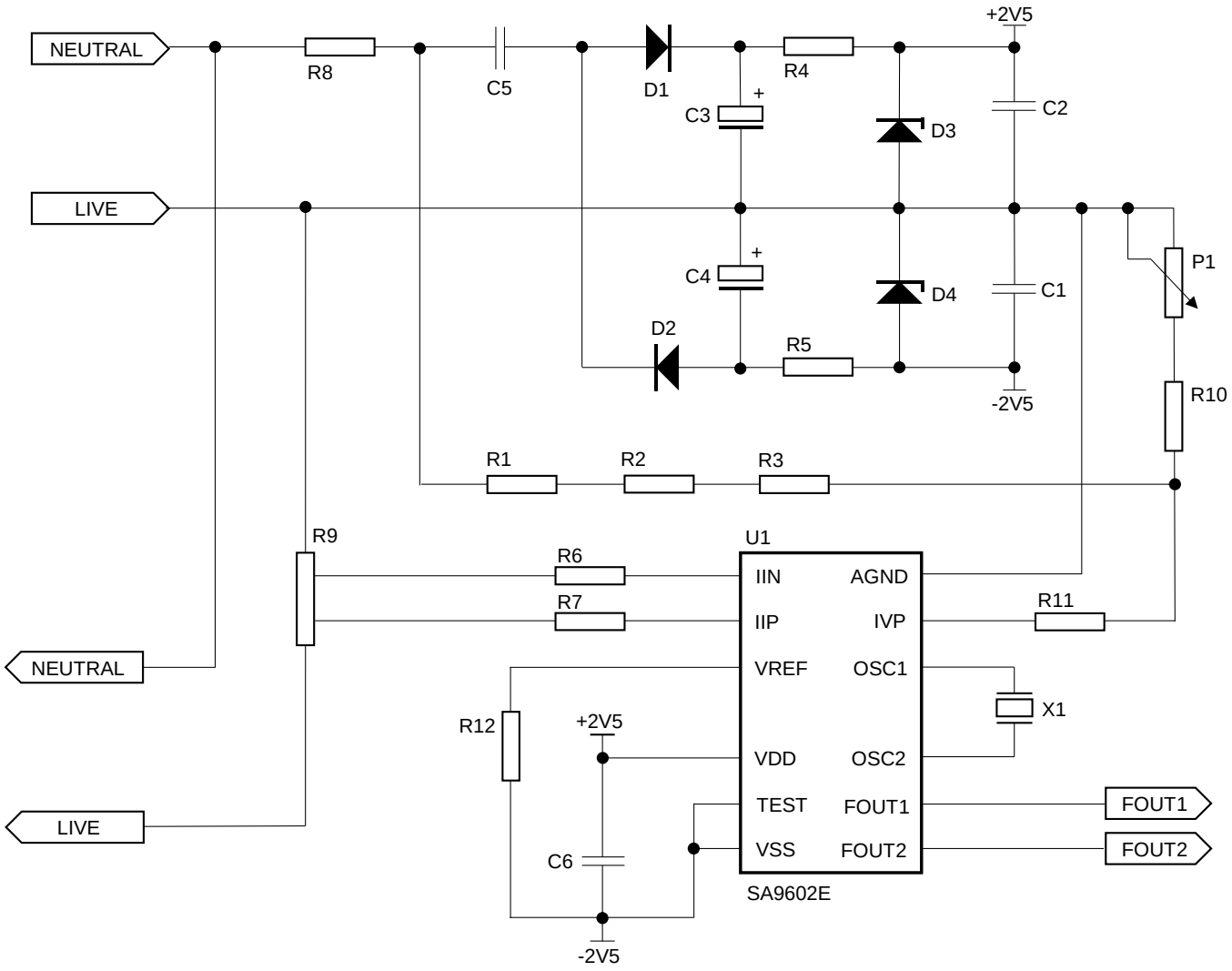


Figure 6: Typical application circuit

Table 1: Component list for typical application

Symbol	Description
U1	Energy metering device, SA9602E
D1, D2	Diode 1N4002
D3, D4	Zener diode, 2.4V
R1, R2, R3	Resistor, 120kΩ, 1%, metal film
R4, R5	Resistor, 680Ω, 1%, metal film
R6[1], R7[1]	Resistor, 620Ω, 1%, metal film
R8	Resistor, 47Ω, 5%, 2W, wire wound
R9	Shunt resistor, 250μΩ
R10	Resistor, 22kΩ, 1%, metal film

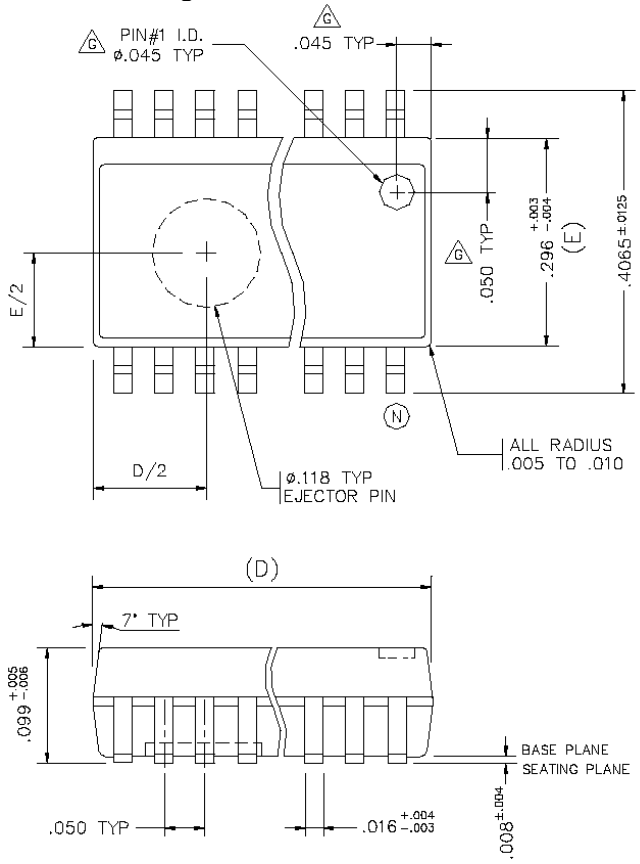
Symbol	Description
R11[1]	Resistor, 1MΩ, 1%, metal film
R12[1]	Resistor, 24kΩ, 1%, metal film
P1	Trim-pot, 25 turns, 5kΩ
X1	Crystal, 3.5795MHz
C1[2], C2[2]	Capacitor, 220nF, ceramic
C3, C4	Capacitor, 100μF, 16V, electrolytic
C5	Capacitor, 330nF, 250VAC
C6[2]	Capacitor, 820nF, ceramic

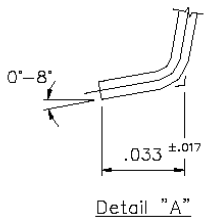
Note 1: Resistors R6, R7, R12 and R13 must be positioned as close as possible to the respective device pins
Note 2: Capacitors C1, C2 and C6 must be positioned as close as possible to the VDD and VSS power supply pins

PACKAGE DIMENSIONS

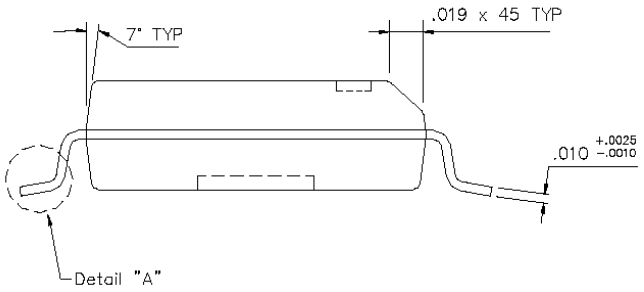
SOIC20 Package

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



NOTES

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INTEGRATED CIRCUIT DESIGN CENTRE (PTY) LTD
a division of
SOUTH AFRICAN MICRO-ELECTRONIC SYSTEMS (PTY) LTD

Tel: 012 333 6021
Tel Int: 00 27 12 333 6021
Fax: 012 333 6393
Fax Int: 00 27 12 333 6393

PO BOX 15888
LYNN EAST 0039
REPUBLIC OF SOUTH AFRICA

UNIT 4, PERSEQUOR CLOSE
49 DE HAVILLAND CRESCENT
PERSEQUOR TECHNOPARK
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