Single Phase Kilowatt-hour Metering IC

SA4101A

FEATURES

- Meets the IEC61036 specification requirements for Class 1 AC static watt-hour meters for active energy
- Less than 0.5% Error over a dynamic range of 1:500
- The motor drive outputs (MOP, MON) provide the average power information and can drive an electro-mechanical counter directly
- LED pulse output for calibration purposes
- Bidirectional and unidirectional energy measurement
- Configurable for different meter ratings
- Precision on-chip oscillator (70ppm/°C drift)
- Precision on-chip voltage reference (10ppm/°C drift)
- On-chip anti-creep function (0.02% of I_{MAX})
- Low power consumption (<25mW typical)
- Measures AC inputs only

DESCRIPTION

The SA4101A is an accurate single phase power/energy metering integrated circuit providing a single-chip solution for energy meters. Very few external components are required and the device has direct drive capability for electro-mechanical counters. The SA4101A does not require an external crystal. A precision oscillator, which supplies the circuitry with a stable frequency, is integrated on chip. The SA4101A metering integrated circuit generates a pulse rate output, the frequency of which is proportional to the power consumption. The SA4101A performs the calculation for active power. The method of calculation takes the power factor into account.

Programmable inputs allow the meter manufacturer to configure the SA4101A for different meter maximum currents (I_{MAX}) and nominal voltages (V_{NOM}) without having to change the stepper motor or impulse counter gear ratio. The LED pulse output follows the average power consumption measured and is intended for meter calibration purposes. In fast calibration mode this output provides a high frequency pulse rate following the instantaneous power consumption and can be used for fast calibration or to interface with a microcontroller. The SA4101A includes an anti-creep feature preventing any creep effects in the meter. The SA4101A can be configured for positive, negative or bidirectional energy measurement.

The SA4101A integrated circuit is available in a 20 pin small outline (SOIC20) RoHS compliant package.

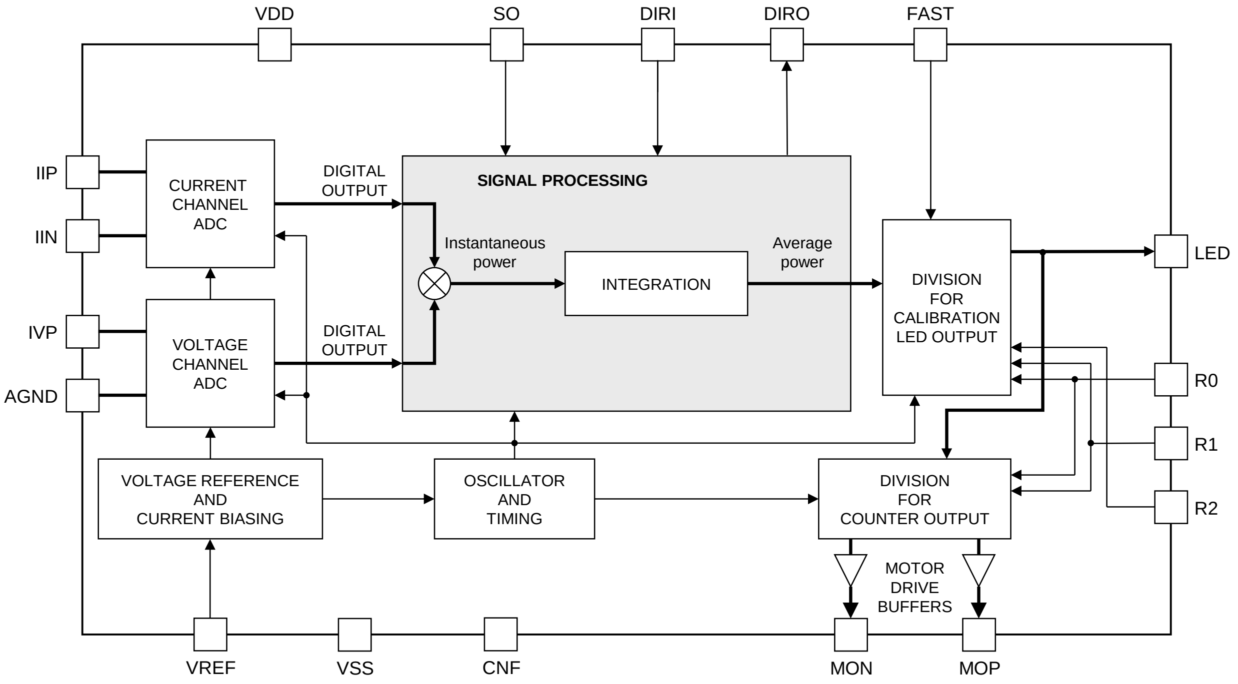

Figure 1: Block diagram

ELECTRICAL CHARACTERISTICS

(V_{DD} - V_{SS} = 5V ± 10%, over the temperature range -40°C to +85°C, unless otherwise specified. Refer to Figure 2 “Test circuit for electrical characteristics”.)

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}	2.5	3.6	5.0	mA	
Supply Current: Negative	I_{SS}	-2.5	-3.6	-5.0	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 Inputs						
DIRI Input Leakage	I_L			1.0	µA	
Pull-down Current on R2, R1, R0, FAST, CNF, SO	I_{PD}	80		140	µA	
R2, R1, R0, FAST, CNF, SO						
Input High Voltage	V_{IH}	V_{DD}-1			V	
Input Low Voltage	V_{IL}			V_{SS}+1	V	
Digital Outputs						
LED Output Frequency in FAST Mode	F_{MAX}	1050	1160	1275	Hz	14µA_{RMS} and 16µA_{RMS} input current on voltage and current channel respectively
LED, DIRO, ACST						
Output High Voltage	V_{OH}	V_{DD}-1			V	I_{SOURCE} = 5mA
Output Low Voltage	V_{OL}			V_{SS}+1	V	I_{SINK} = 5mA
MOP, MON						
Output High Voltage	V_{OH}		V_{DD}-1		V	I_{SOURCE} = 15mA
Output Low Voltage	V_{OL}		V_{SS}+1		V	I_{SINK} = 15mA

ELECTRICAL CHARACTERISTICS (continued)

(V_{DD} - V_{SS} = 5V ± 10%, over the temperature range -40°C to +85°C, unless otherwise specified. Refer to Figure 2 “Test circuit for electrical characteristics”.)

Parameter	Symbol	Min	Typ	Max	Unit	Condition
On-chip Voltage Reference						
Reference Voltage	V_R	1.15		1.25	V	
Reference Current	$-I_R$	24.4	25.5	26.6	µA	With R = 47kΩ 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	

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.

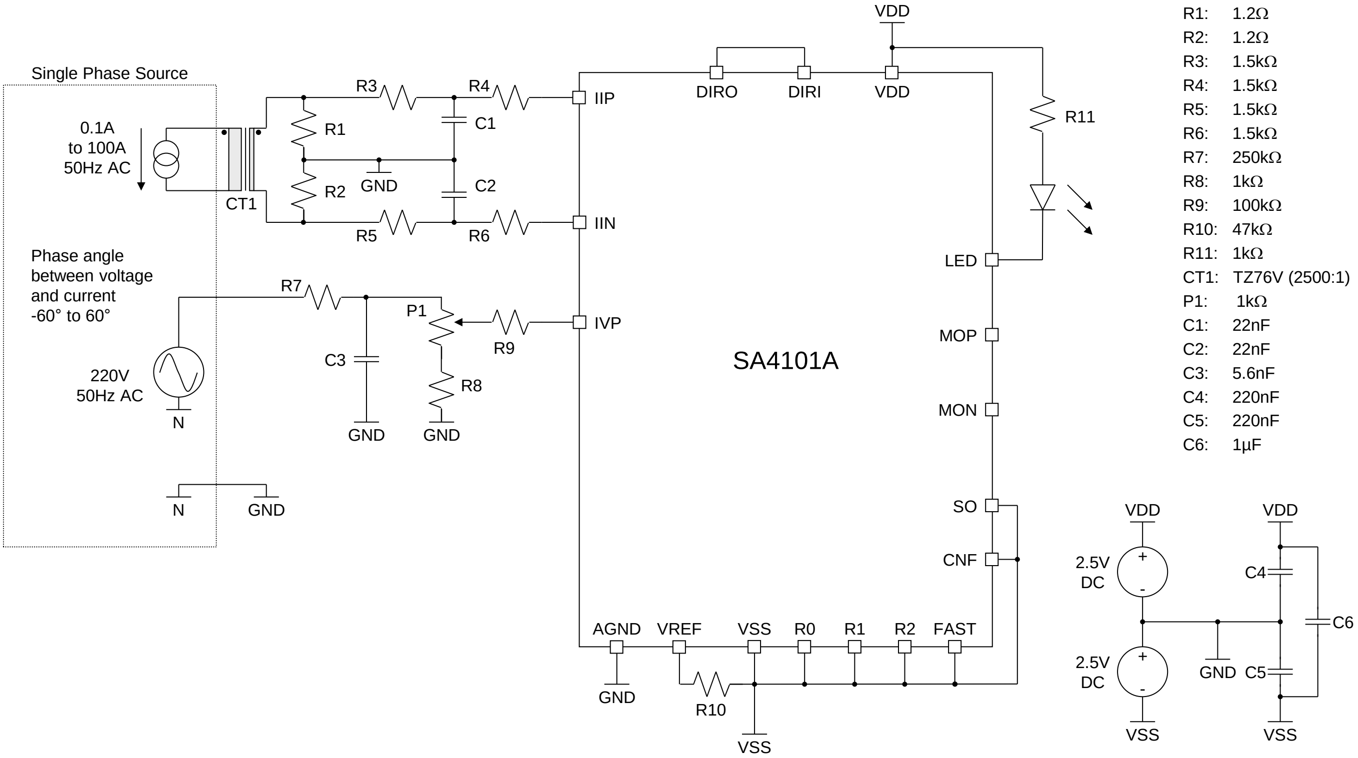

Figure 2: Test circuit for electrical characteristics

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 be set at 16µA$_{RMS}$. 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 47kΩ resistor connected to V_{SS} sets the optimum operating conditions.
R0, R1, R2	6, 5, 4	Rated Condition Select inputs. These input pins are used for selecting between the different rated condition configurations. Refer to the Rated Condition Select section.
FAST	7	Fast Mode Select input. This input is used to select between STANDARD and FAST mode. Refer to the LED Output section.
DIRI	18	Direction Select input. This input is used to enable either bidirectional or unidirectional energy measurement.
DIRO	17	Direction Indicator output. This output indicates the direction of energy flow.
LED	13	Calibration LED output. Refer to the Rated Condition Select section for the pulse rate output options.
MON, MOP	15, 12	Motor pulse outputs. These outputs can drive an electro-mechanical counter directly. Refer to the Rated Condition Select section for the pulse rate output options.
SO	11	Select Output. When fast mode is selected this input can be used to enable or disable the internal pulse stability circuitry for the LED output pulses. Refer to the Select Output section.
CNF	9	Manufacturers test pin. Tie to V_{SS} for optimum protection against transients.
NC	10, 16	No connection.

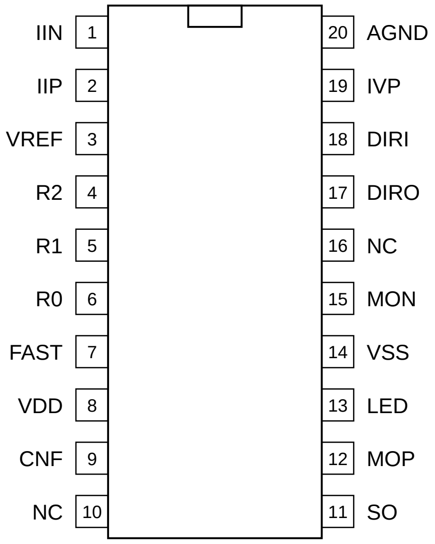

Figure 3: Pin connections

ORDERING INFORMATION

Part Number	Package
SA4101ASAR	SOIC20 (RoHS compliant)

TERMINOLOGY

Bidirectional and Unidirectional Measurement

In the bidirectional configuration the LED, MON and MOP outputs generate pulses at a frequency that is proportional to the energy measured in both forward and reverse directions. In the unidirectional configuration the LED, MON and MOP outputs generate pulses at a frequency that is proportional to the energy measured only if the energy flow is in the same direction as selected by the DIRI pin. No output pulses are generated for energy flowing counter to the DIRI pin selection. The DIRI pin can select either positive or negative energy flow.

Anti-Creep Threshold

The anti-creep threshold is defined as the minimum energy threshold below which no energy is registered and therefore no pulses are generated on the LED or motor drive outputs.

Positive Energy

Positive energy is defined when the phase difference between the input signals IIP and IVP is less than 90 degrees (-90..90 degrees).

Negative Energy

Negative energy is defined when the phase difference between the input signals IIP and IVP is greater than 90 degrees (90..270 degrees).

Percentage Error*

Percentage error is given by the following formula:

$$\%Error = \frac{Energy\ registered - True\ Energy}{True\ Energy} \times 100$$

NOTE: Since the true value cannot be determined, it is approximated by a value with a stated uncertainty that can be traced to standards agreed upon between manufacturer and user or to national standards.

Rated Operating Conditions*

Set of specified measuring ranges for performance characteristics and specified operating ranges for influence quantities, within which the variations or operating errors of a meter are specified and determined.

Specified Measuring Range*

Set of values of a measured quantity for which the error of a meter is intended to lie within specified limits.

Specified Operating Range*

A range of values of a single influence quantity, which forms a part of the rated operating conditions.

Limit Range of Operation*

Extreme conditions which an operating meter can withstand without damage and without degradation of its metrological characteristics when it is subsequently operated under its rated operating conditions.

Maximum Rated Mains Current (I_{MAX})

Maximum rated mains current is the specified maximum current flowing through the energy meter at rated operating conditions.

Constant*

Value expressing the relation between the active energy registered by the meter and the corresponding value of the test output. If this value is a number of pulses, the constant should be either pulses per kilowatt-hour (imp/kWh) or watt-hours per pulse (Wh/imp).

Nominal Mains Voltage (V_{NOM})

Nominal mains voltage (V_{NOM}) is the voltage specified for the energy meter at rated operating conditions.

Maximum Output Frequency (F_{MAX})

The maximum output frequency (F_{MAX}) is the output frequency in FAST mode when $14\mu A_{RMS}$ and $16\mu A_{RMS}$ input current with zero phase shift are applied to the voltage and current inputs respectively. Both the voltage and current inputs saturate at an input current magnitude of 25µA, or at $17.68\mu A_{RMS}$ when using sine waves. The maximum input current on each channel is therefore defined to be $16\mu A_{RMS}$, which leaves about 10% headroom to the saturation point. An additional headroom of 15% is reserved on the voltage channel to account for mains voltage fluctuations. In FAST mode the nominal maximum output frequency of 1160Hz is achieved under such conditions.

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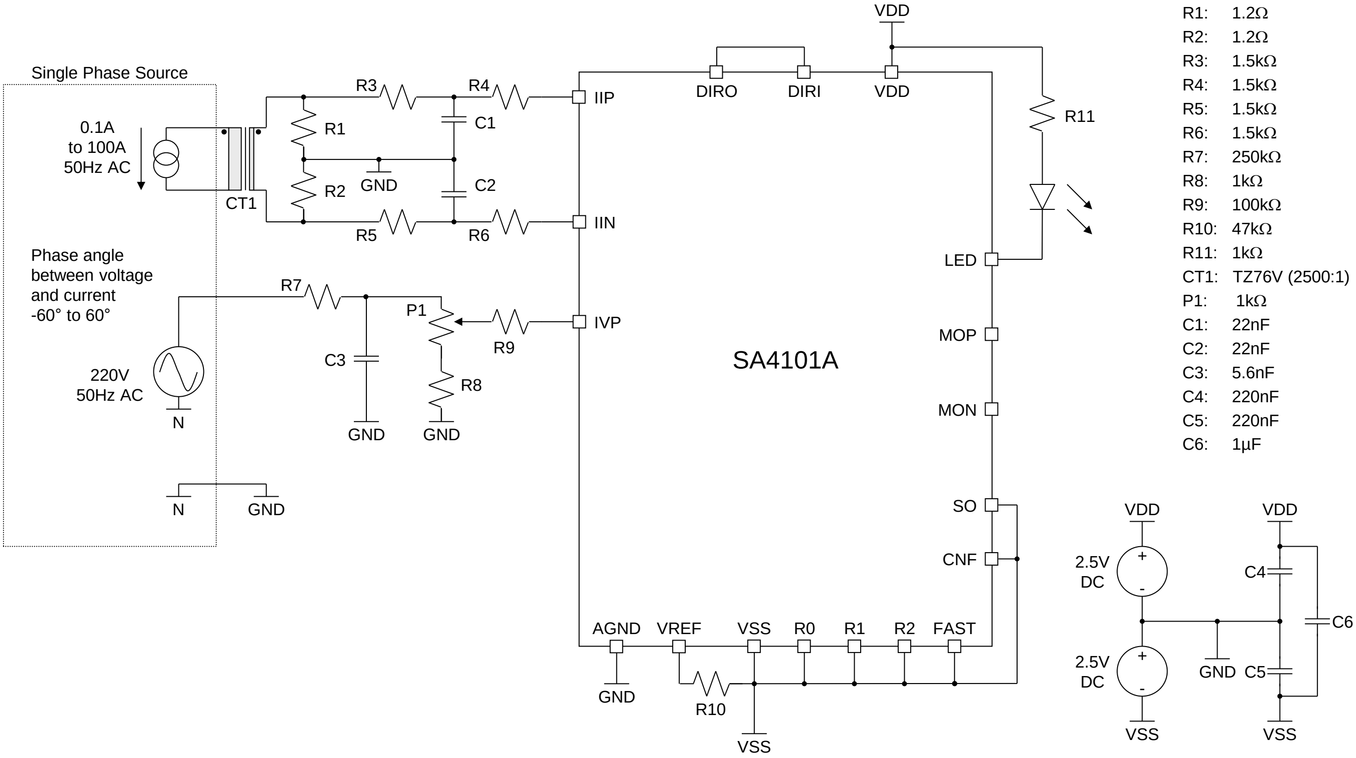
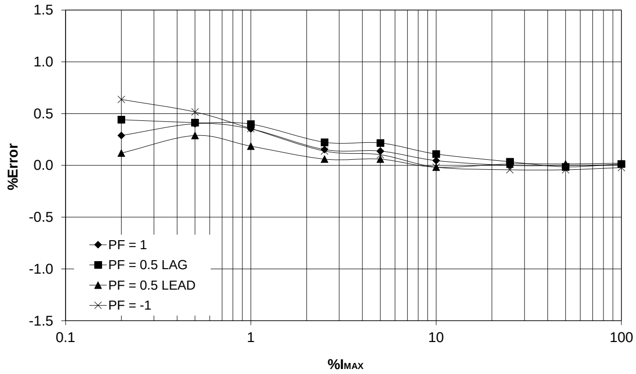
* IEC 62052-11, 2003. Electricity Metering Equipment (AC) – General Requirements, Test and Test Conditions – Part 11: Metering Equipment

PERFORMANCE GRAPHS

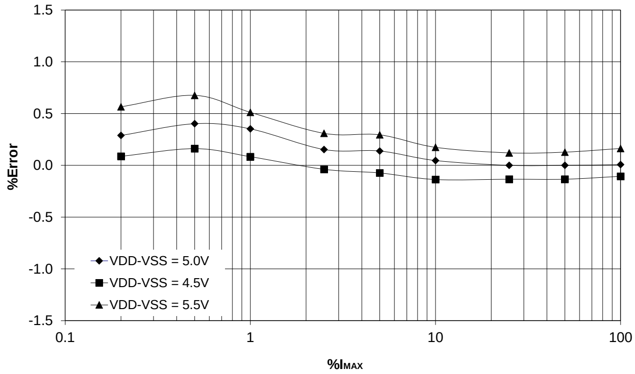


R1:	1.2Ω
R2:	1.2Ω
R3:	1.5kΩ
R4:	1.5kΩ
R5:	1.5kΩ
R6:	1.5kΩ
R7:	250kΩ
R8:	1kΩ
R9:	100kΩ
R10:	47kΩ
R11:	1kΩ
CT1:	TZ76V (2500:1)
P1:	1kΩ
C1:	22nF
C2:	22nF
C3:	5.6nF
C4:	220nF
C5:	220nF
C6:	1µF

Figure 4: Test circuit for performance graphs



Graph 1: Freq = 50Hz, VMains = V_{NOM}, Temp = 25°C, V_{DD}-V_{SS} = 5.0V



Graph 2: PF = 1, Freq = 50Hz, VMains = V_{NOM}, Temp = 25°C

FUNCTIONAL DESCRIPTION

Theory of Operation

The SA4101A is a CMOS integrated circuit, which performs power/energy calculations across a dynamic range of 500:1 to an accuracy that exceeds the IEC 61036 Class 1 specification.

The integrated circuit includes all the required functions for single phase power and energy measurement. Two A/D converters sample the voltage and current inputs. The calculations required for power and energy are performed and pulses on the LED, MON and MOP outputs represent the results.

Internal offsets are eliminated through the use of cancellation techniques. The SA4101A generates pulses at a frequency that is proportional to the power consumption. Complimentary output pins MOP and MON are provided for driving a stepper motor. A MOP pulse followed immediately by a MON pulse represents an energy pulse. This minimizes the risk of (after power up) losing the first energy pulse as a result of the stepper motor residing in the wrong phase.

The LED output is normally proportional to the average power consumption measured. When in FAST mode, the LED output is proportional to the instantaneous active power consumption. The FAST mode is intended for meter calibration purposes.

The two A/D converters convert the signals on the voltage and current sense inputs to a digital format for further processing. The current sense inputs (IIP and IIN) are identical and balanced. An input signal with a range of 1:500 is measured at these inputs.

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

The two digital signals, accurately representing the current and voltage inputs, are multiplied using digital multiplication. The output of the multiplier is the instantaneous power. For voltage and current in phase instantaneous power is calculated by:

$$p(t) = v(t) \times i(t)$$
$$p(t) = V_M \cos(\omega t + \theta) \times I_M \cos(\omega t + \psi)$$

Let $\phi = \theta - \psi$, and $V_{RMS} = \frac{V_M}{\sqrt{2}}$ and $I_{RMS} = \frac{I_M}{\sqrt{2}}$ then

$$p(t) = V_M \cos(\omega t + \theta) \times I_M \cos(\omega t + \theta - \phi)$$
$$p(t) = V_{RMS} I_{RMS} (\cos\phi + \cos(2(\omega t + \theta) - \phi))$$

where
p(t) is the instantaneous power,
v(t) is the instantaneous voltage signal,
i(t) is the instantaneous current signal,
V_M is the amplitude of the voltage signal,
I_M is the amplitude of the current signal,
θ is the phase angle of the voltage signal and
ψ is the phase angle of the current signal.

This instantaneous power is then integrated over time to provide the average power information:

$$P = \frac{1}{T}\int_0^T p(t)dt$$
$$P = V_{RMS} I_{RMS} \cos\phi$$

where
P is the average power and
$\cos\phi$ is the power factor.

Analog Input Configuration

The input circuitry of the current and voltage sensor inputs is illustrated in Figure 5.

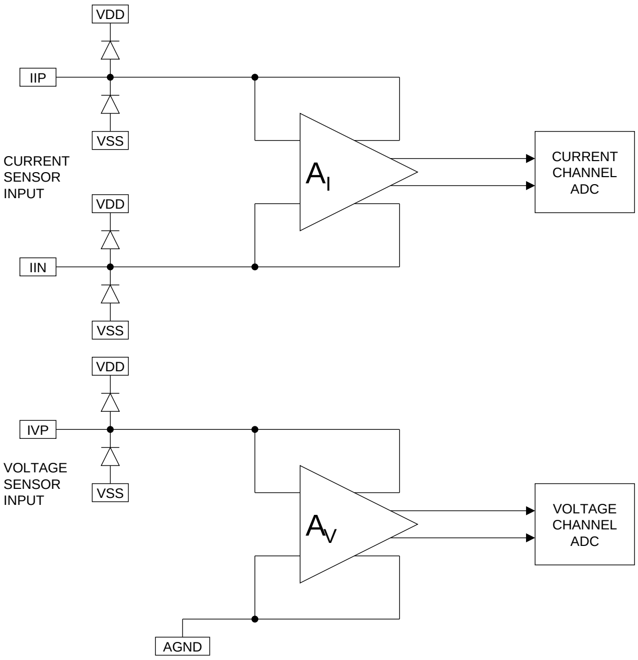


Figure 5: Analog input configuration

These inputs are protected against electrostatic discharge through clamping diodes.

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

The current and voltage sense inputs are both identical. Both inputs are differential current driven up to ±25µA peak. One input of the voltage sense amplifier is internally connected to AGND. This is possible because the voltage sense input is much less sensitive to externally induced parasitic signals compared to the current sense inputs.

Power Consumption

The power consumption of the SA4101A integrated circuit is less than 25mW.

INPUT SIGNALS

Voltage Reference (VREF)

A bias resistor of 47kΩ sets optimum bias and reference conditions on chip. Calibration of the SA4101A should be done on the voltage input and not on the VREF input.

Current Sense Inputs (IIP and IIN)

Figure 6 shows the typical connections for the current sensor input when using a shunt or a current transformer as a current sensing element. At maximum rated mains current (I_{MAX}) the resistor values should be selected for an input current of $16\mu A_{RMS}$. The current sense inputs saturate at an input current of $\pm 17.6\mu A_{RMS}$ ($\pm 25\mu A_{PEAK}$), so this allows about 10% headroom until saturation occurs.

The resistor RSH is the shunt resistor. The voltage drop across RSH at maximum rated mains current (I_{MAX}) should not be less than $5mV_{RMS}$ and not exceed $100mV_{RMS}$.

The resistors RA and RB form the current transformers termination resistor. The reference level is connected in the centre of the termination resistor to achieve purely differential input currents. The voltage drop across the termination resistors at maximum rated mains current (I_{MAX}) should be in the order of $100mV_{RMS}$. The termination resistance should also be significantly smaller than the DC resistance of the current transformers secondary winding.

The resistors R1 to R4 define the current flowing into the device. For best performance the SA4101A requires anti-alias filters on the current sense inputs. These filters are realized by means of the capacitors C1 and C2. The typical cut-off frequency of these filters should be between 10kHz and 20kHz. The optimum input network is achieved by setting the input resistors equal, i.e. setting R1 = R2 = R3 = R4 = R_C. This sets the equivalent resistance associated with each capacitor to $R_C/2$.

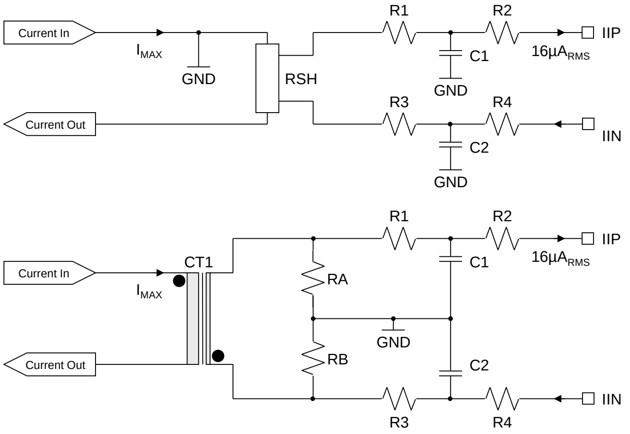


Figure 6: Current sense input configuration

Voltage Sense Input (IVP)

Figure 7 shows the voltage sense input configuration. The voltage sense input saturates at an input current of $\pm 17.6\mu A_{RMS}$ ($\pm 25\mu A_{PEAK}$). The current into the voltage sense input at nominal mains voltage V_{NOM} should be set to $14\mu A_{RMS}$ For best performance the SA4101A also requires an anti-alias filter on the voltage sense input. Referring to Figure 7, the capacitor C1 is used to implement the anti-alias filter. If a current transformer is used as a current sensing element then C1 is also used to compensate for any phase shift caused by the current transformer. The resistor R4 defines the input current into the device. The optimum input network is achieved by setting R4 smaller than 100kΩ. If R4 is made too large the capacitor C1 will be very small and the phase shift of the input network could be affected by stray capacitances. The potentiometer P1 is used for calibration purposes.

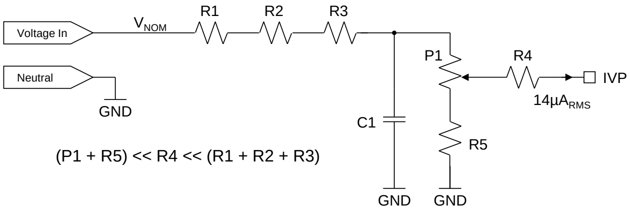


Figure 7: Voltage sense input configuration

Fast Mode Select (FAST)

The FAST pin is used to select between STANDARD and FAST mode. Leaving this pin open or connecting to V_{SS} enables the STANDARD mode and connecting to V_{DD} enables FAST mode.

When STANDARD mode is enabled the LED output pulses at a low frequency. This low frequency allows a longer accumulation period and the output pulses are therefore proportional to the average power consumption measured.

The Rated Select Condition pins (R0, R1 and R2) are used to select different LED output frequencies which in turn selects the applications meter constant. Refer to Figure 9 for the LED output timing diagram in STANDARD mode.

When the FAST mode is enabled the LED output generates pulses at a frequency of 1160Hz at I_{MAX} and V_{NOM}. In this mode the pulse frequency is proportional to the instantaneous power consumption measured. This mode is used for meter calibration purposes and can also be used when interfacing to a microcontroller. Refer to Figure 10 for the LED output timing diagram in FAST mode.

Select Output (SO)

The SA4101A has unique internal circuitry that can be user enabled to stabilize the LED output. When in FAST mode, connecting the SO input pin to V_{DD} will enable the LED pulse stability feature. Stabilizing the LED pulse output allows for shorter meter calibration times. Leaving the SO pin open or connecting to V_{SS} will disable the LED pulse stability circuitry. Figure 10 indicates the operation of pulse stability.

Rated Condition Select (R0, R1, R2)

The Rated Condition Select pins R0, R1 and R2 are inputs pins used to configure the SA4101A for different Maximum Rated Mains Currents and Nominal Mains Voltages. This feature allows for the use of different stepper motor gear ratios.

To calculate the LED output pulse rate (in STANDARD mode) and motor drive pulse rate for any meter ratings (I_{MAX} and V_{NOM}) the following formulae can be used:

$$LED\ imp/kWh = \frac{1160}{DF\_LED} \times \frac{1000 \times 3600}{V_{NOM} \times I_{MAX}} \quad ...(1)$$

where

I_{MAX} is the maximum rated mains current,

V_{NOM} is the nominal mains voltage and

DF_LED is the dividing factor for the LED output that depends on R2, R1 and R0 as specified in Table 1.

Equation 1 is based on the assumption that the input current into the IIP/IIN current sense input is set to 16µA_{RMS} at I_{MAX}.

Table 1: LED output constants

R2	R1	R0	DF_LED
V_{SS}	V_{SS}	V_{SS}	322
V_{SS}	V_{SS}	V_{DD}	322
V_{SS}	V_{DD}	V_{SS}	322
V_{SS}	V_{DD}	V_{DD}	322
V_{DD}	V_{SS}	V_{SS}	225
V_{DD}	V_{SS}	V_{DD}	214
V_{DD}	V_{DD}	V_{SS}	214

$$Motor\ imp/kWh = \frac{LED\ imp/kWh}{DF\_MO} \quad ...(2)$$

where

LED imp/kWh is the LED constant as calculated using Equation 1 and

DF_MO is the dividing factor for the motor output that depends on R1 and R0 as specified in Table 2.

Table 2: MOTOR output constants

R1	R0	DF_MO
V_{SS}	V_{SS}	8
V_{SS}	V_{DD}	32
V_{DD}	V_{SS}	16
V_{DD}	V_{DD}	8

Table 3 shows some of the meter constants available for several maximum currents (I_{MAX}) and with a line voltage of 220V while in STANDARD mode.

Note that the values calculated using Equations 1 and 2 are close approximations to the values listed in Table 3. The SA4101A has to be calibrated (using the voltage input) to give the exact value listed.

Table 3: Examples of various meter constants

R2	R1	R0	V_{NOM}/I_{MAX}	LED Output	Motor Outputs
V_{SS}	V_{SS}	V_{DD}	220V / 20A	3200	100
V_{SS}	V_{DD}	V_{SS}	220V / 40A	1600	100
V_{SS}	V_{DD}	V_{DD}	220V / 80A	800	100
V_{DD}	V_{SS}	V_{SS}	220V / 100A	800	100
V_{DD}	V_{SS}	V_{DD}	220V / 30A	3200	100
V_{DD}	V_{DD}	V_{SS}	220V / 60A	1600	100

Direction Select Input (DIRI)

Depending on the state of the DIRI pin the energy to be measured can be in the positive direction only, in the negative direction only, or in both directions.

Connecting DIRI to V_{DD} will result in energy only being measured in the positive direction. Energy flowing in the negative direction will not be measured. Connecting DIRI to V_{SS} will result in energy only being measured in the negative direction. Energy flowing in the positive direction will not be measured. Connecting the DIRI pin to the DIRO output pin enables bidirectional mode where energy is measured regardless of direction.

OUTPUT SIGNALS

Motor pulse output (MOP, MON)

The MOP and MON pins are complimentary outputs with a frequency proportional to the average power consumption measured. These outputs can be used to either directly drive a stepper motor counter or an electro-mechanical impulse counter. The Rated Conditions Select pins (R0, R1 and R2) allow the selection of different output frequencies corresponding to different meter constants. Figure 8 indicates the timing of these signals.

$t_1 = t_2 = t_3 = 213$ms
t_4 is proportional to the average power and can be calculated using Equation 2 and the motor output constants in Table 2.

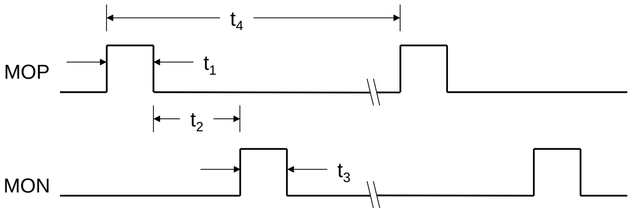


Figure 8: Motor outputs MON and MOP

LED Output (LED)

The LED output pin provides a pulse output with a frequency proportional to the average energy when in STANDARD mode and the instantaneous energy when in FAST mode. This output is primarily used for calibration purposes. The Rated Conditions Select pins (R2, R1 and R0) allow different frequencies to be selected. The LED output is active low. Figure 9 shows the LED waveform when in STANDARD mode.

$t_1 = 90$ms
t_2 is proportional to the average power and can be calculated using Equation 1 along with the appropriate LED output constant in Table 1.

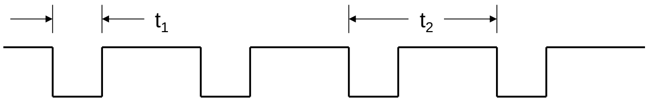


Figure 9: LED pulse output in STANDARD mode

In FAST mode the LED pulse output is set at a high frequency of 1160Hz at I_{MAX} and V_{NOM}. This mode is useful for fast calibration and can be used to interface to a microcontroller. Figure 10 indicates the LED output signal in FAST mode.

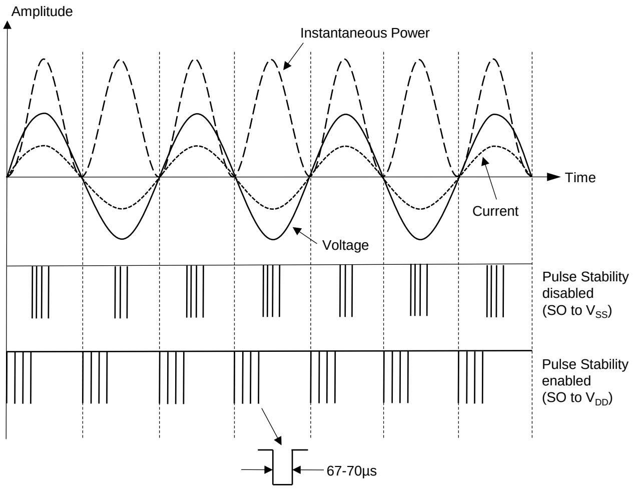


Figure 10: LED pulse output in fast mode

To convert pulses per kilowatt-hour to frequency (in Hz) or vice versa the following equations can be used:

$$Frequency = P/kWh / \left(\frac{1000 \times 3600}{V \times I}\right)$$

$$P/kWh = Frequency \times \left(\frac{1000 \times 3600}{V \times I}\right)$$

where
P/kWh is the LED or MON/MOP pulse constant
I is the current in amperes
V is the voltage (normally V_{NOM})

Direction Indicator Output (DIRO)

The direction of energy flow may be ascertained by monitoring the DIRO pin. A low level on this pin indicates negative energy flow. Positive energy flow is indicated on pin DIRO as a logic high. The DIRO pin may be used to drive an LED.

TYPICAL APPLICATION

The following description outlines the basic process required to design a typical single phase energy meter using the SA4101A and a shunt resistor as a current sensing element. The meter is capable of measuring 220V/40A/50Hz with a precision better than Class 1. It uses a stepper motor counter with 100imp/kWh and the calibration LED has a constant of 1600imp/kWh.

The most important external circuits required for the SA4101A are the current input network, the voltage input network as well as the bias resistor. All resistors should be 1% metal film resistors of the same type to minimize temperature effects.

Bias Resistor

A bias resistor of R10 = 47kΩ sets optimum bias and reference currents on chip. Calibration of the meter should be done using the voltage input and not by means of the bias resistor.

Current Input Network

The voltage drop across the shunt resistor at maximum rated current should not be less than 5mV$_{RMS}$ and not exceed 100mV$_{RMS}$. A 320µΩ shunt is chosen which sets the voltage drop at maximum rated current to 12.8mV and the maximum power dissipation in the shunt to 0.5W. The voltage across the shunt resistor is converted to the required differential input currents through the current input resistors. Anti-alias filters are incorporated on these input resistors to filter any high frequency signal components that could affect the performance of the SA4101A.

The four current input resistors (R1, R2, R3, R4) should be of equal size to optimize the input networks low pass filtering characteristics, so the values can be calculated as follows:

$$R1 = R2 = R3 = R4 = I_{MAX} \times \frac{R_{SH}}{4 \times 16\mu A} = 200\Omega = R_C$$

For optimum performance the cut-off frequency of the anti-alias filter should be between 10kHz and 20kHz. The equivalent resistance associated with each capacitor is $R_C/2$ so the capacitor values should be in the order of

$$C1 = C2 = \frac{1}{\pi f_{CI} R_C} = \frac{1}{\pi \times 15kHz \times 200\Omega} \approx 100nF = C_C$$

where f_{CI} is the cut-off frequency of the anti-alias filter of the current input network.

Voltage Input Network

The voltage sense input requires an input current of 14µA$_{RMS}$ at V_{NOM} (220V). The mains voltage is divided by means of a voltage divider to a lower voltage that is converted to the required input current by means of the input resistor. Once again an anti-alias filter is required to remove any high frequency signals that could affect the performance of the SA4101A. A shunt typically has very little phase shift so phase compensation is not required.

The input resistor R8 sets the current input into the device. This resistor should not be too large else the capacitor for the anti-alias filter will be quite small which could cause inaccurate phase shift due to parasitic capacitances. Therefore R8 = 100kΩ is chosen and the voltage at the centre of the trimpot should be 1.4V (14µA x 100kΩ). The calibration range of the voltage input network should be about ±15% to ensure that all component tolerances can be catered for, so the total tuning range can be set to ±0.22V. Therefore the voltage across the trimpot and R9 is 1.62V. Choosing a 1kΩ trimpot results in

$$R9 = \frac{1k\Omega}{(2 \times 0.22)} \times (1.62 - 2 \times 0.22) \approx 2.7k\Omega$$

The effect of R8 can be ignored in the above equation, given the fact that R8 is significantly larger than P1 and R9. Now let R_A = R5 + R6 + R7 and

$$R_A = (P1 + R9) \times \left(\frac{220V}{1.62V} - 1\right) \approx 499k\Omega$$

so choose R5 = R6 = 200kΩ and R7 = 100kΩ.

The cut-off frequency of the anti-alias filter is adjusted so that it is identical to that of the current input network anti-alias filters. This ensures that the phase shift caused by the anti-alias filters is identical on the current and voltage input networks. Therefore

$$\frac{1}{\pi C_C \times R_C} = \frac{1}{2\pi(P1 + R9) \times C3}$$

and so C3 = 2.7nF.

PROGRAMMING

The resistor values are calculated for a 40A rated meter. The LED pulse rate must be set accordingly by programming pins R0, R1 and R2. Using the Rated Conditions Select section, pins R0 and R2 is set to V_{SS} and R1 set to V_{DD}. These settings will configure the SA4101A for 220V/40A operation with a LED pulse rate of 1600 pulses/kWh. The FAST pin is set to V_{SS} for STANDARD operation.

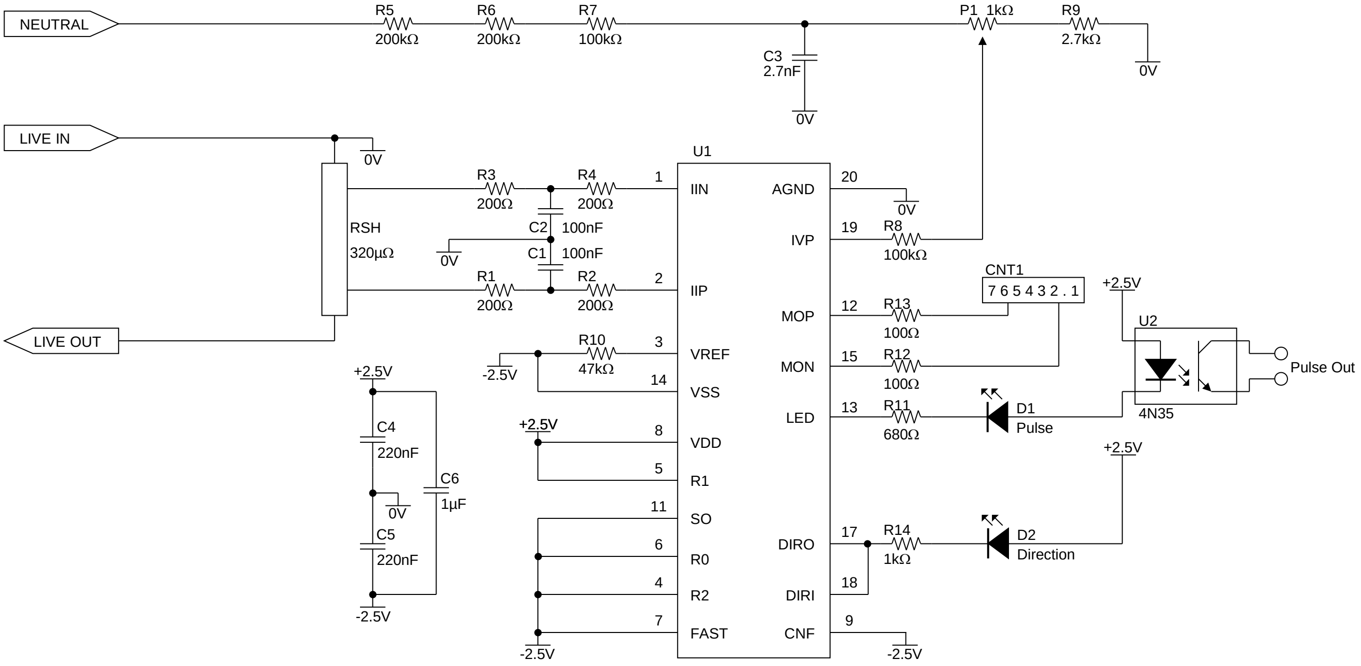


Figure 11: Typical application circuit

Table 4: Component list for typical application

Symbol	Description
U1	Energy metering device, SA4101ASAR
U2	Opto-coupler, 1N35
RSH	Shunt Resistor, 40A, 320µΩ
R1, R2[1], R3, R4[1]	Resistor, 200Ω, 1%, metal film
R5, R6	Resistor, 200kΩ, 1%, metal film
R7, R8[1]	Resistor, 100kΩ, 1%, metal film
R9	Resistor, 2.7kΩ, 1%, metal film
R10[1]	Resistor, 47kΩ, 1%, metal film
R11	Resistor, 680Ω, 5%, carbon film

Symbol	Description
R12, R13	Resistor, 100Ω, 5%, carbon film
R14	Resistor, 1kΩ, 5%, carbon film
P1	Trim-pot, 25 turns, 1kΩ
C1, C2	Capacitor, 100nF, ceramic
C3	Capacitor, 2.7nF, ceramic
C4[2], C5[2]	Capacitor, 220nF, ceramic
C6[2]	Capacitor, 1µF, ceramic
D1	Light emitting diode, pulse output
D2	Light emitting diode, direction output
CNT1	Stepper motor counter, 100imp/kWh

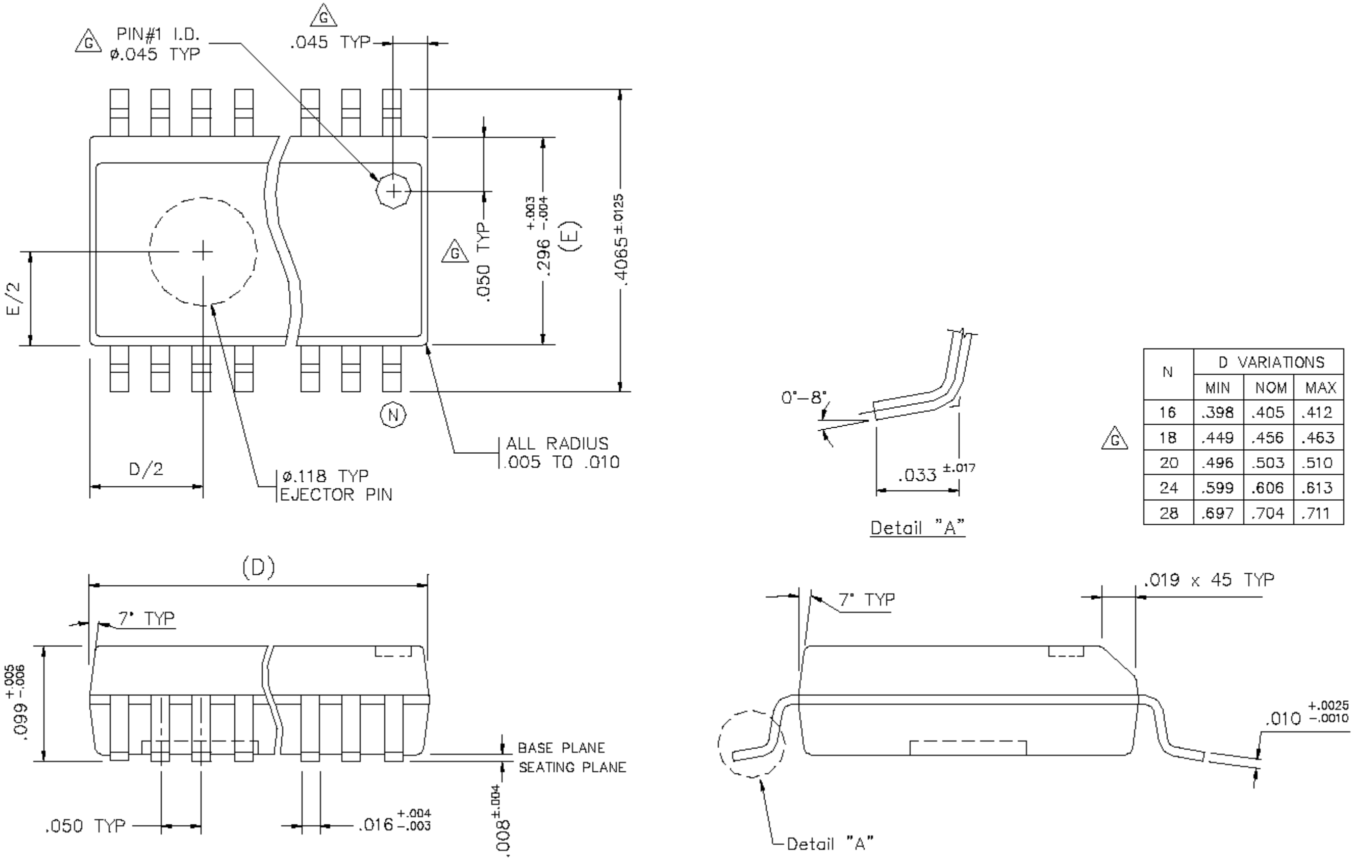
Note 1: Resistors R2, R4, R8 and R10 must be positioned as close as possible to the respective device pins

Note 2: Capacitors C4, C5 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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