Single Channel Single Phase Energy Metering IC

SA4104

sames

FEATURES

- Meets the IEC62053, CBIP-88 and IS137799-1999 Specification requirements for Class 1 AC static watt-hour meters for active energy
- The motor drive outputs (MOP, MON) provide the average Real Power information and can drive an electro-mechanical counter or an impulse counter directly
- LED pulse output for calibration purposes and can supply average Real Power information
- 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 (0.01% of Fmax)
- Low power consumption (<30mW typical)
- Measures AC inputs only

DESCRIPTION

The SA4104 is part of a single channel energy metering family consisting of the SA4102, SA4104 and SA4105, the SA4102 being the principle device with unique features and options. The SA4102 offers user selectable bi-directional or uni-directional energy measurement whereas the SA4104 and SA4105 devices provide only for bi-directional energy measurement. The SA4102 affords the user the option of selecting one of two methods of filtering the LED output whereas the SA4104 and SA4105 are each supplied with one of the two filter types. Refer to the SA4102 datasheet for a description of both filter types.

The SAMES SA4104* 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 chip has direct drive capability for electro-mechanical counters. The SA4104 does not require an external crystal. A precision oscillator, which supplies the circuitry with a stable frequency, is integrated on chip.

The SA4104 metering integrated circuit generates a pulse rate output, the frequency of which is proportional to the power consumption.

Programmable inputs allow the meter manufacturer to configure the SA4104 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 mode this output provides a high frequency pulse rate following the average power consumption and can be used for calibration or to interface with a micro-controller.

The SA4104 includes an anti-creep feature preventing any creep effects in the meter under no load conditions.

The SA4104 integrated circuit is available in 16 pin dual-inline plastic (PDIP16) and small outline (SOIC16) package types.

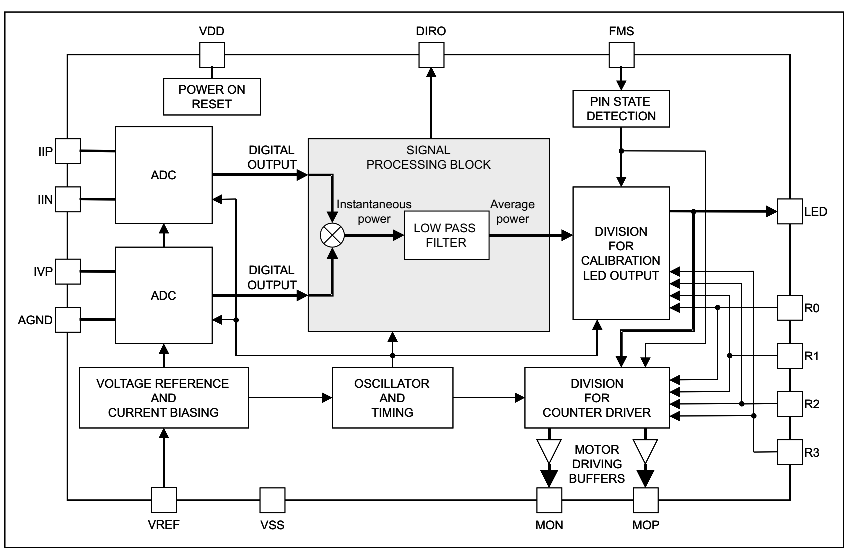


Figure 1: Block diagram

* Patents: PCT/IB03/02915; ZA2002/5873; ZA97/2075; IN1920/DEL/96; ZA94/0273; ZA93/1579; US5,396,447; EP0055949

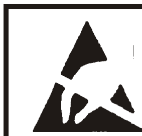
ELECTRICAL CHARACTERISTICS

(V_{DD} - V_{SS} = 5V ± 5%, 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		2.75	V	With respect to AGND
Supply Voltage: Negative	V_{SS}	-2.75		-2.25	V	With respect to AGND
Supply Current: Positive	IDD			6	mA	
Supply Current: Negative	ISS			6	mA	
Inputs						
Current Sensor Inputs (Differential)						
Input Current Range	IIP, IIN	-25		+25	µA	Peak value
Offset Voltage	IIN	-4		+4	mV	
Voltage Sensor Input (Asymmetrical)						
Input Current Range	IVP	-25		+25	µA	Peak value
Offset Voltage	IVP	-4		+4	mV	
Digital Inputs						
Change of state detection time for Digital inputs	TST			9.1	ms	
R3, R2, R1, R0, FMS Input high Voltage Input Low Voltage	V_{IH} V_{IL}	V_{DD}-1		V_{SS}+1	V V	
Outputs						
Digital Outputs						
LED Output Frequency	F_{MAX}	4.5	5	5.5	KHz	FAST mode at 16µA_{RMS} per channel
LED, DIRO Output High Voltage Output Low Voltage	V_{OH} V_{OL}	V_{DD}-1		V_{SS}+1	V V	I_{SOURCE} = 5mA I_{SINK} = 5mA
MON, MOP Output High Voltage Output Low Voltage	V_{OH} V_{OL}		V_{DD}-1 V_{SS}+0.4		V V	I_{SOURCE} = 20mA I_{SINK} = 20mA

Extended Operating Temperature Range available on request.

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 test equipment and can discharge without detection. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality during product handling.



ATTENTION!
Electrostatic sensitive devices. Requires special handling.

ELECTRICAL CHARACTERISTICS (continued)

(V_{DD} - V_{SS} = 5V ± 5%, 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
Reference Voltage Input VREF						
Ref. Current	$-I_R$	23.4	26.6	27.6	µA	
Ref. Voltage	V_R	1.1	1.25	1.3	V	With R = 47K connected to V_{SS}
Temperature coefficient			10		ppm/°C	
On-chip oscillator						
Oscillator frequency		3.28	3.58	4	MHz	
Temperature coefficient			70		ppm/°C	

Extended Operating Temperature Range available on request.

ABSOLUTE MAXIMUM RATINGS*

Parameter	Symbol	Min	Max	Unit
Supply Voltage	V_{DD}-V_{SS}	3.6	6	V
Operating temperature limits	Tlimit	-40	+85	°C
Storage Temperature	T_{STG}	-40	+125	°C
Specified operating range	T_O	-40	+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.

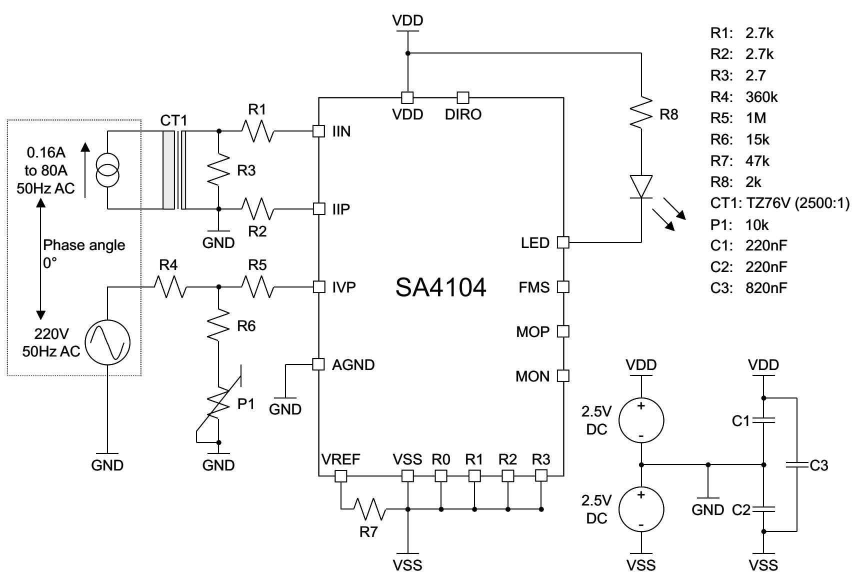


Figure 2: Test Circuit for Electrical Characteristics

PIN DESCRIPTION

Pin	Designation	Description
16	AGND	Analog Ground. The supply 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.
12	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.
15	IVP	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.
1,2	IIN, IIP	Analog input for current. The maximum current into the current sense input IIP pin should be set at 16µA_{RMS}. The current sense input saturates at ±25µA peak.
3	VREF	This pin provides the connection for the reference current setting resistor. A 47k resistor connected to V_{SS} sets the optimum operating condition.
9, 6, 5, 4	R0, R1, R2, R3	Rated Condition Select. These inputs are used for the different rated condition configuration. Refer to the Rated Condition Select section.
7	FMS	Fast Mode Select. This tri-state input is used to select between STANDARD and FAST mode and provides an extended selection of meter constants. Refer to the LED output section.
14	DIRO	Direction indicator output. This output indicates the energy flow direction.
11	LED	Calibration LED output. Refer to the Rated Condition Select section of the pulse rate output options
10,13	MOP, MON	Motor pulse outputs. These outputs can drive an electromechanical counter directly.

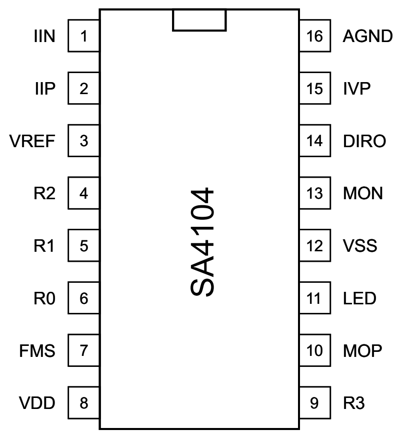


Figure 3: Pin connections: Package: PDIP16, SOIC16

ORDERING INFORMATION

Part Number	Package
SA4104APA	PDIP16
SA4104ASA	SOIC16

TERMINOLOGY

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.

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:

$$\%Error = \frac{\text{Energy registered by SA4104 - True energy}}{\text{True energy}} \times 100$$

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*

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)

Maximum Rated Mains Current is the 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 $16\mu A_{RMS}$ input current with zero phase shift are applied to the voltage and current inputs. Both the voltage and current input 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. In FAST mode the maximum output frequency of 5kHz is achieved under such conditions.

Repeatability of Error Test**

Test shall be carried out at 0.05Ib, Ib at UPF load under reference test conditions. Twenty error samples shall be taken at time intervals of 30 minutes. Identical test condition shall be maintained throughout the test. For acceptance test six error tests may be carried out at time interval of at least 5 min.

* IEC 61036, 2000. Alternating Current Static Watt-hour Meters for Active Energy. Edition 2.1
** IS13779-1999 Indian Standard AC Static Watthour Meters Class1 and 2 Specification Rev 1

PERFORMANCE GRAPHS

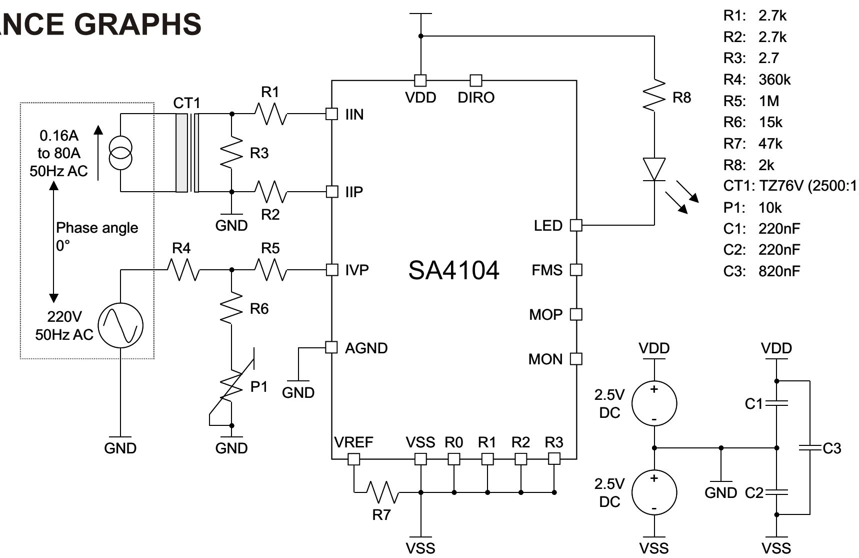
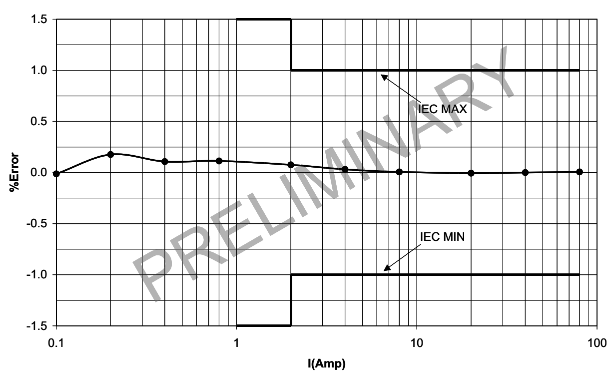
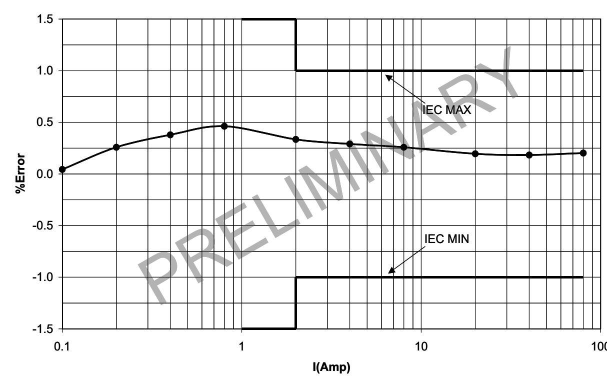


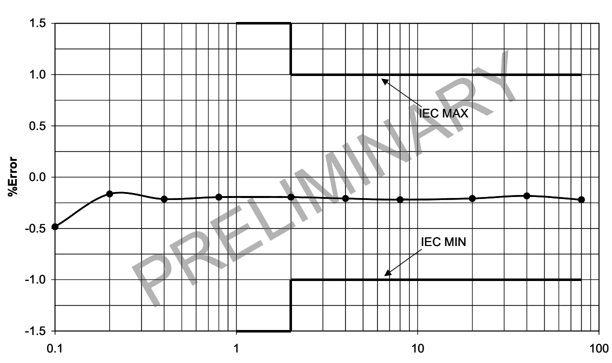
Figure 4: Test circuit for performance graphs



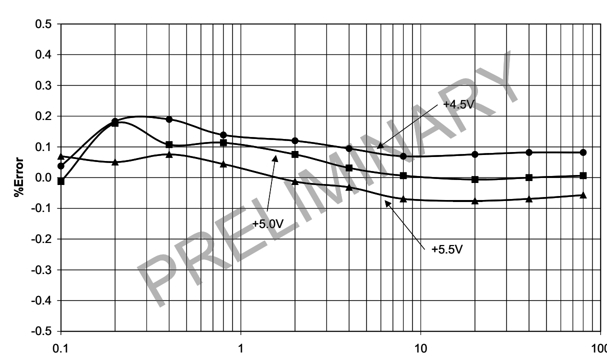
GRAPH 1 - Linearity PF=1,FREQ=50Hz,Vnom,TEMP=25°C



GRAPH 2 - Linearity PF=+0.5,FREQ=50Hz,Vnom,TEMP=25°C



GRAPH 3 - Linearity PF=-0.5,FREQ=50Hz,Vnom,TEMP=25°C



GRAPH 4 - Linearity PF=1,Supply=+5.5V,+5V,+4.5V

FUNCTIONAL DESCRIPTION

The SA4104 includes all the required functions for single channel single phase power and energy measurement. A/D converters sample the voltage and current inputs.

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:

Instantaneous power *p(t)* $= v(t) \quad i(t)$

$= V_M \sin(\quad t \quad) \quad I_M \sin(\quad t \quad)$

let $\quad , V_{RMS} \quad \frac{V_M}{\sqrt{2}}, I_{RMS} \quad \frac{I_M}{\sqrt{2}}$

P(t) $= V_M I_M \sin(\quad t \quad)\sin(\quad t \quad)$

$= V_M I_M \sin(\quad t \quad)\sin(\quad t \quad)$

$= V_{RMS} I_{RMS} [\cos \quad \cos(2(\quad t \quad) \quad)]$

where *v(t) is the instantaneous voltage*
i(t) is the instantaneous current,
V_M is the maximum amplitude of the voltage signal,
I_M is the maximum amplitude of the current signal,
is the voltage phase angle,
is the current phase angle and
$VI \quad \cos(2(\quad t \quad) \quad)$ *= 100Hz noise component on a 50Hz mains system.*

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

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

Where *p(t)* is the instantaneous power and
cos is the power factor.

ANALOG INPUT CONFIGURATION

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

Linearity

The SA4104 is a CMOS integrated circuit, which performs power/energy calculations across a dynamic range of 500:1 to an accuracy of less than 0.5% in the test circuit.

Analog Inputs

The 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 with internal offsets eliminated through the use of cancellation techniques.

Digital Outputs

The calculations required for power and energy are performed and converted to pulses on the LED, MON and MOP outputs. The complimentary output pins MOP and MON are provided for driving a stepper motor directly. The LED output is, in both STANDARD mode and FAST mode, proportional to the average power consumption measured. The FAST mode is intended for meter calibration purposes or when the LED pin is used as an input to a micro-controller.

Anti-Creep Threshold

An integrated anti-creep function prevents any output pulses on the LED or MON/MOP motor drive outputs if the measured power is less than 0.01% of F_{MAX} where IVP_{MAX} = 16uA$_{RMS}$ and IIP_{max} = 16uA$_{RMS}$.

Reverse Energy Flow Indication

The SA4104 assesses the phase difference between the voltage channel signal and the active current channel signal. If this phase difference is greater than 90 degrees then the DIRO signal will become active. This facility is designed to detect the wrongful connection of the meter. This operation is described fully in the Output Signal Section.

Starting Current

The SA4104 generates pulses on the LED and MON/MOP outputs for a power greater than 0.01% of F_{MAX}. This is to comply with the IEC requirement where the device is required to generate pulses for current greater than 0.4%Ib.

Calibration and Repeatability

The SA4104 provides an output (LED) that is used in STANDARD mode to allow calibration of the meter. The meter is calibrated by comparing the energy reading of the meter

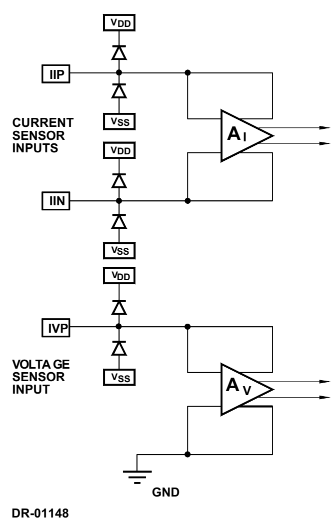


Figure 5: Analog input configuration

under test with the energy reading of the reference meter. The reference meter will have a considerably higher pulse rate than the meter under test. The accuracy to which the meter is calibrated will dictate how much higher the reference meter pulse rate should be. This reading is independent of time and should be repeatable so as to consistently achieve the required accuracy for the full input current range that needs to be measured to IEC62053 accuracy.

In Figure 6 the reference meter pulses are counted between two pulses of the meter under test. The meter under test is then adjusted so as to reflect the expected number of counted pulses. A worst-case scenario is for measurements obtained for only two pulses of the Meter Under Test and N pulses from the Reference Meter. In this case the measurement resolution will be:

$$\text{Measurement Resolution} = (1/N) * 100 \ [\%]$$

The corresponding calibration and repeatability results can never be better than this measurement resolution.

Power on Reset

The SA4104 has a power on reset circuitry that activates whenever the voltage between V_{DD} and V_{SS} is less than 3.6V.

Power Consumption

The power consumption of the SA4104 integrated circuit is less than 30mW.

INPUT SIGNALS

Voltage Reference (V_{REF})

A bias resistor of 47k sets optimum bias and reference conditions on chip. Calibration of the SA4104 should be done on the voltage input and not on the V_{REF} input.

Current sense input (IIP and IIN)

Figure 7 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 SA4104. At Maximum Rated Mains current (I_{MAX}) the resistor values should be selected for an input current of 16µA_{RMS}. The values for resistors R1 and R2 can be calculated as follows:

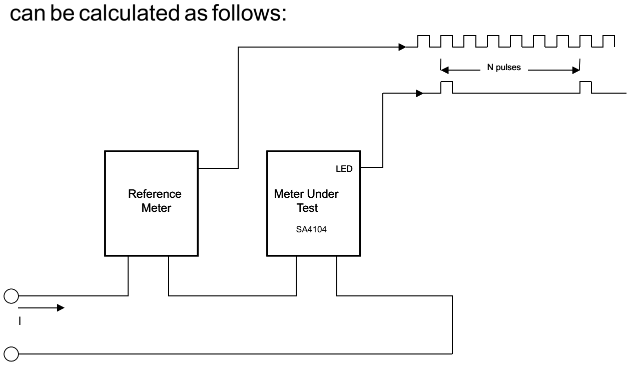


Figure 6: Calibration and Repeatability Setup

$$R1 = R2 = (I_L / 16\mu A) \times RSH/2$$

Where I_L = Line current
RSH = Shunt resistor or termination resistor if a CT is used as the current sensor.

The value of RSH, if used as the CT's termination resistor, should be less than the DC resistance of the CT's secondary winding. The voltage drop across RSH should not be less than 20mV_{RMS} and not greater than 200mV_{RMS} at I_{MAX}.

Voltage Sense Input (IVP)

The voltage sense input saturates at an input current of ±17.6µA_{RMS} (±25µA_{peak}). Current into the A/D converter should be set at between 11µA_{RMS} to 12µA_{RMS} at nominal mains voltage (V_{NOM}) to allow for mains variation of up to +30% and -50% without saturating the voltage sense input. Typical V_{NOM} values and the corresponding IVP input current shown in the following table:

$V_{(NOM)}$	IVP input (µA_{RMS})
240	12
230	11.5
220	11
120	12
115	11.5
110	11

Referring to Figure 7 the typical connections for the voltage sense input is illustrated. The voltage divider circuit consists of resistors, R3, R4 and P1. R5 defines the current level into the voltage sense input of the SA4104. The resistor values should be selected for an input current at V_{NOM} as per the above table. For a 220V meter this translates to a nominal input current of

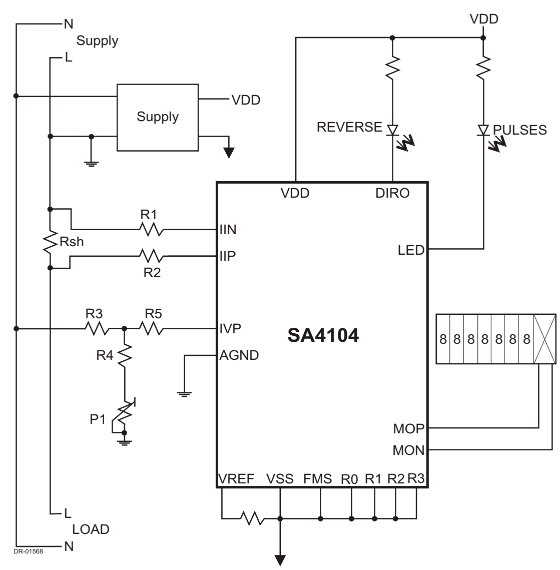


Figure 7: Application Circuit

11µA. Typically R5 is chosen to be 1M. The voltage required over R5 is therefore 11V. P1 is used for calibration purposes. Refer to the voltage divider description under the Typical Application section on page 13 for further information on calculating the resistor values.

Fast Mode Select (FMS)
The FMS pin is used to select between STANDARD and FAST mode and allows the selection of a multitude of meter constants and motor drive dividing ratios. Connecting this pin to V_{DD} or V_{SS} enables the STANDARD mode of operation.

Leaving this pin floating enables the FAST mode of operation. 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, R2 and R3) together with the FMS pin are used to select different LED output frequencies which in turn selects the applications meter constant. Refer to figure 10 for the LED output timing diagram in STANDARD mode. When the FAST mode is enabled the LED output generates pulses at a frequency of 5000Hz at I_{MAX} and V_{MAX}. In this mode the pulse frequency is proportional to the average power consumption measured. This mode can also be used when interfacing to a micro-controller.

When FMS is floating the LED pin outputs fast mode pulses. The motor pulses occur as usual based on the last FMS before floating condition was detected (logic 0 if floating condition is detected at startup) and the current states of R0 to R3.

Rated Condition Select (R0, R1, R2, R3)
The Rated Condition Select Inputs R0, R1, R2, R3 along with Fast Mode Select Input (FMS) are used for obtaining various LED Division Factor (DF_LED) and Motor Division Factor (DF_MO). The values of DF_LED and DF_MO for different inputs of R0, R1, R2, R3, FMS are given in Table 1. These different values of DF_LED & DF_MO are used in Equations 2 & 4 described in the "Calculation of LED Output Pulse Rate" paragraph on page 11 for obtaining different LED Output Pulse Rate and Motor Drive Pulse Rate.

OUTPUT SIGNALS

LED Output (LED)
The LED output pin provides a pulse output with a frequency proportional to the average energy when in STANDARD and FAST mode. A complex filtering scheme is applied to the instantaneous energy output directly after multiplication that allows all instantaneous component to be removed. The output is pure average energy. This results in a constant output frequency at a constant energy input, even over a short period of time. The delay of the filter is about 200ms. Figure 8 illustrates the output of the filter in FAST mode compared to what it would have been without filtering.

This output is primarily used for calibration purposes. The Rated Conditions Select pins (R0, R1, R2, R3) allow different frequencies to be selected. The LED output is active low. Figure 9 shows the LED waveform.

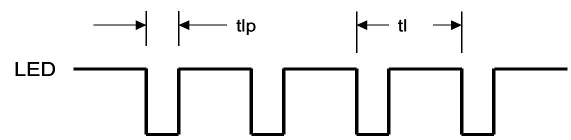


Figure 9: LED pulse output in STANDARD mode

Timing values are based on the internal oscillators "typical" frequency value.

tl as per equation 1
tlp = 91.5ms when tl > 183ms
= tl/2 when tl < 183ms
69µs in FAST mode

In FAST mode the LED pulse output is set as a high frequency of 5000Hz at an input current of 16µA_{RMS} for both the current and voltage channels. This mode is useful for calibration and can be used to interface to a micro-controller. The LED output will remain HIGH when inactive.

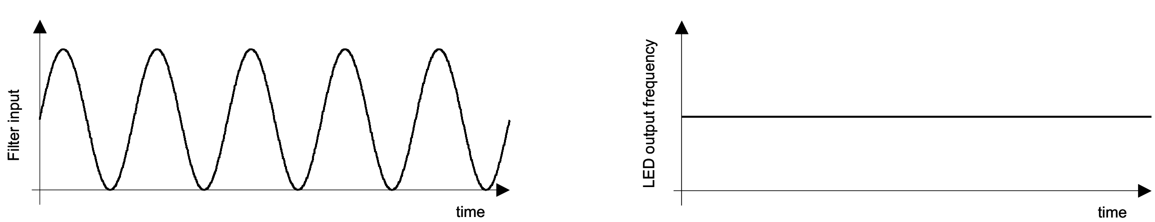


Figure 8: Operation of filter

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, R2, R3) allow the selection of different output frequencies corresponding to different Meter Constants. Figure 10 indicates the timing of these signals.

FMS	R3	R2	R1	R0	DF_LED	DF_MO
0	0	0	0	0	220	256
0	0	0	0	1	440	128
0	0	0	1	0	880	64
0	0	0	1	1	1760	32
0	0	1	0	0	220	128
0	0	1	0	1	440	64
0	0	1	1	0	880	32
0	0	1	1	1	1760	16
0	1	0	0	0	220	64
0	1	0	0	1	440	32
0	1	0	1	0	880	16
0	1	0	1	1	1760	8
0	1	1	0	0	220	32
0	1	1	0	1	440	16
0	1	1	1	0	880	8
0	1	1	1	1	1760	4
1	0	0	0	0	1464	64
1	0	0	0	1	2928	32
1	0	0	1	0	352	64
1	0	0	1	1	704	32
1	0	1	0	0	584	32
1	0	1	0	1	1168	16
1	0	1	1	0	352	32
1	0	1	1	1	704	16
1	1	0	0	0	584	16
1	1	0	0	1	1168	8
1	1	0	1	0	352	16
1	1	0	1	1	704	8
1	1	1	0	0	292	16
1	1	1	0	1	584	8
1	1	1	1	0	234	16
1	1	1	1	1	468	8

Table 1: DF_LED and DF_MO dividing factors

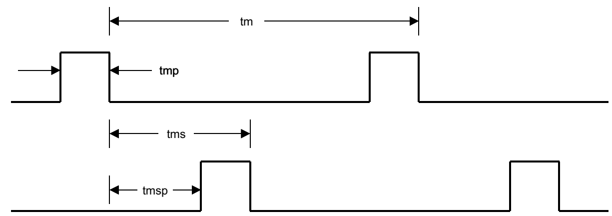


Figure 10: Motor output MON and MOP

Timing values are based on the internal oscillators "typical" frequency value.

tm as per equation 3

tmp = 220ms when tm > 440ms
= tm/2 when tm < 440ms

tms = tm/2

tmsp = tms - tmp when tm > 440ms
= 6.7µs when tm < 440ms

Direction Indicator Output (DIRO)

The direction of the energy flow may be ascertained by monitoring the DIRO pin. Logic 0 on this pin indicates negative energy flow. Positive energy flow is indicated by logic 1. See Figure 11. Should the energy (either negative or positive) be less than a fixed threshold then this output will retain its previous state. This prevents a flickering output in the case of no or very low current flow. The DIRO pin may be used to drive an LED. The state of the DIRO pin is updated at the internal FAST mode frequency regardless of whether the device is set to FAST or STANDARD mode. A power-on-reset will set DIRO high.

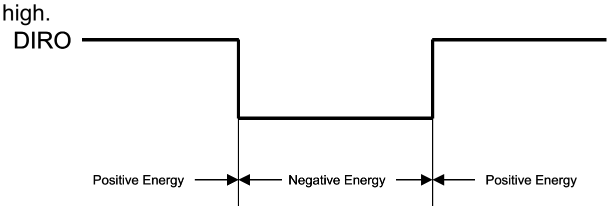


Figure 11: DIRO output

Energy	Phase Angle	DIRO
< Fmin	0° - 360°	Previous State
> Fmin	< 90°	HIGH
> Fmin	> 90°	LOW

Table 2: Operation of DIRO

Where Fmin = 0.01% of Fmax

Calculation of LED Output Pulse Rate (LED pulses / kWh)

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

$$tl = \frac{DF\_LED}{(IVP/16)(IIP/16) \times 5000} \quad .... \mathbf{1}$$

where:

IVP, IIP = The analog input current in µA.

$$\text{LED pulses / kWh} = (IVP/16.0)*5000*x(1/DF\_LED) \times \frac{3600}{(V_{NOM} \times I_{MAX}) / 1000} \quad .... \mathbf{2}$$

Where:

IVP = The analog input current in µA at Vnom. (refer to the Voltage Sense Input (IVP) section on page 8)

I_{MAX} = Maximum Rated Mains current

V_{NOM} = Nominal Mains Voltage

DF_LED is the LED dividing factor and depends on the selection of R3, R2, R1, R0 and FMS given in Table 1.

At V_{NOM} of 230 Volts the analog input current in IVP is set as 11.5µA. For Nominal voltages of 220 Volts and 240 Volts the analog input current in IVP is set as 11µA and 12µA respectively.

Calculation of Motor Drive Pulse Rate (Motor pulses/kWh)

To calculate the Motor Drive pulse rate for any meter ratings (I_{MAX} and V_{NOM}) the following formula can be used:

$$tm = tl \times DF\_MO \quad .... \mathbf{3}$$

$$\text{Motor pulses/kWh} = \frac{\text{LED pulses/kWh}}{DF\_MO} \quad .... \mathbf{4}$$

Where:

LED pulses/kWh as calculated in formula 2

DF_MO is the dividing factor and depends on R3, R2, R1, R0,and FMS given in Table 1.

By using the above Formulae 2 & 4 and using the various LED Division Factor and Motor Division Factor given in Table 1, Table 3 shows various LED Output Pulse Rate and Motor Drive Pulse Rates achievable for different Current Ratings (I_{MAX}).

Note that Table 3 is based on a V_{NOM} of 230V. Using a V_{NOM} of 115V will double the meter constant values.

Imax	Dividing Factors		LED output	Motor output
	DF_LED	DF_MO	(p/kWh)	(p/kWh)
6	1464	64	6400	100
6	2928	32	3200	100
10	220	256	25600	100
10	440	128	12800	100
10	880	64	6400	100
10	1760	32	3200	100
10	220	128	25600	200
10	440	64	12800	200
10	880	32	6400	200
10	1760	16	3200	200
10	220	64	25600	400
10	440	32	12800	400
10	880	16	6400	400
10	1760	8	3200	400
10	220	32	25600	800
10	440	16	12800	800
10	880	8	6400	800
10	1760	4	3200	800
20	220	128	12800	100
20	440	64	6400	100
20	880	32	3200	100
20	1760	16	1600	100
20	220	64	12800	200
20	440	32	6400	200
20	880	16	3200	200
20	1760	8	1600	200
20	220	32	12800	400
20	440	16	6400	400
20	880	8	3200	400
20	1760	4	1600	400
25	352	64	6400	100
25	704	32	3200	100
25	352	32	6400	200
25	704	16	3200	200
25	352	16	6400	400
25	704	8	3200	400

Imax	Dividing Factors		LED output	Motor output
	DF_LED	DF_MO	(p/kWh)	(p/kWh)
30	584	32	3200	100
30	1168	16	1600	100
30	584	16	3200	200
30	1168	8	1600	200
30	292	16	6400	400
30	584	8	3200	400
40	220	64	6400	100
40	440	32	3200	100
40	880	16	1600	100
40	1760	8	800	100
40	220	32	6400	200
40	440	16	3200	200
40	880	8	1600	200
40	1760	4	800	200
50	352	32	3200	100
50	704	16	1600	100
50	352	16	3200	200
50	704	8	1600	200
60	584	16	1600	100
60	1168	8	800	100
60	292	16	3200	200
60	584	8	1600	200
80	220	32	3200	100
80	440	16	1600	100
80	880	8	800	100
80	1760	4	400	100
100	352	16	1600	100
100	704	8	800	100
120	292	16	1600	100
120	584	8	800	100
150	234	16	1600	100
150	468	8	800	100

Table 3: Meter constants achievable for some of the common I_{MAX} currents (V_{NOM} = 230V)

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TYPICAL APPLICATION

In Figure 12, 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 operation.

The critical external components for the SA4104 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. With R12=47k , optimum conditions are set. 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. If a shunt resistor of 625μ is chosen the voltage across the shunt at I_{MAX} will be 25mV then the power dissipation in the current sensor is:

$P = I^2R$
$= (40A)^2 \times 625\mu$
$= 1W.$

CURRENT SENSE RESISTORS

The resistors R10 and R11 define the current level into the current sense inputs of the device. The resistor values are selected for an input current of 16μA on the current inputs of the SA4104 at I_{MAX}.

According to equation described in the Current Sense inputs section:

$R10 = R11 = (I_L / 16\mu A) \times R_{SH}/2$
$= 40A / 16\mu A \times 625\mu/2$
$= 781.25$

A resistor with value of 820 is chosen, the 5% deviation from the calculated value can be compensated during calibration of the voltage divider.

VOLTAGE DIVIDER

The voltage divider circuit defines the current level into the voltage sense input of the device. The resistor values should be selected for an input current at V_{NOM} according to the recommendations on page 9, Voltage Sense Input (IVP).

For a 220V meter this translates to a nominal input of 11μA. Typical R8 is chosen to be 1M The voltage required over R8 is therefore 11V. This voltage is set by the voltage divider implemented as follows;

RA = R4 + R5 + R6 and
RB = R8 || (P1 + R7).

The effect of R8 in the above equation can typically be ignored as long as R8 is very large in comparison to (P1 + R7). A trimpot is used for calibration purposes. Using the center position of the trimpot and choosing R7 = 15k the value of RA can be calculating using

RB/(RA + RB) = 11V/220V,

resulting in RA = 380k . The trimpot allows for some variation. So set R4 = R5 = R6 = 120k . This application allows a wide tuning range on the input current (8.8μA when P1 is set to 0k to 14.3μA when P1 is set to 10k). A narrower tuning range can be obtained by decreasing the ratio between P1 and R7.

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TYPICAL APPLICATION

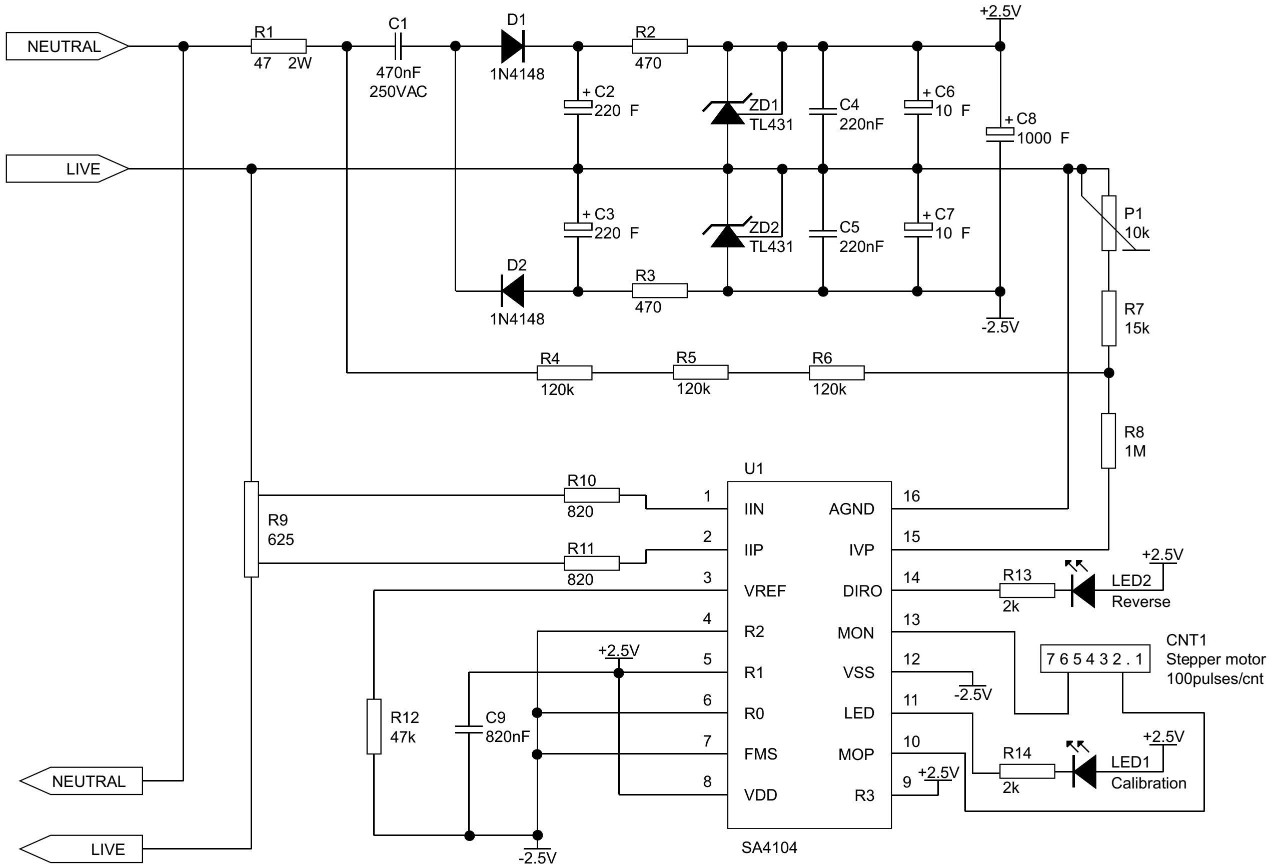


Figure 12: Typical Application

Parts List for Application Circuit: Figure 12

Symbol	Description	Detail
U1	SA4104	PDIP16/SOIC16
D1	Diode, Silicon, 1N4148	
D2	Diode, Silicon, 1N4148	
ZD1	Shunt Regulator TL431	
ZD2	Shunt Regulator TL431	
R1	Resistor, 47R, 2W, 5%, wire wound	
R2	Resistor, 470, 1/4W, 1%, metal	
R3	Resistor, 470, 1/4W, 1%, metal	
R4	Resistor, 120k, 1/4W, 1%, metal	
R5	Resistor, 120k, 1/4W, 1%, metal	
R6	Resistor, 120k, 1/4W, 1%, metal	
R7	Resistor, 15k 1/4W, 1%, metal	
R8	Resistor, 1M, 1/4W, 1%, metal	
R9	Shunt resistor 625µ	Note 1
R10	Resistor, 820, 1/4W, 1%, metal	Note 1
R11	Resistor, 820, 1/4W, 1%, metal	Note 1
R12	Resistor, 47k, 1/4W, 1%, metal	
R13	Resistor, 2K, 1/4W	
R14	Resistor, 2K, 1/4W	
P1	Trim pot, Multi turn, 10k	
C1	Capacitor, 470nF, 250VAC	
C2	Capacitor, 220uF, 16V, electrolytic	
C3	Capacitor, 220uF, 16V, electrolytic	
C4	Capacitor, 220nF, Ceramic	Note 2
C5	Capacitor, 220nF, Ceramic	Note 2
C6	Capacitor, 10µF, 16V	
C7	Capacitor, 10µF, 16V	
C8	Capacitor, 1000µF, 16V	
C9	Capacitor, 820nF, Ceramic	Note 2
LED1	3mm Light emitting diode	
LED2	3mm Light emitting diode	
CNT1	Stepper Motor	

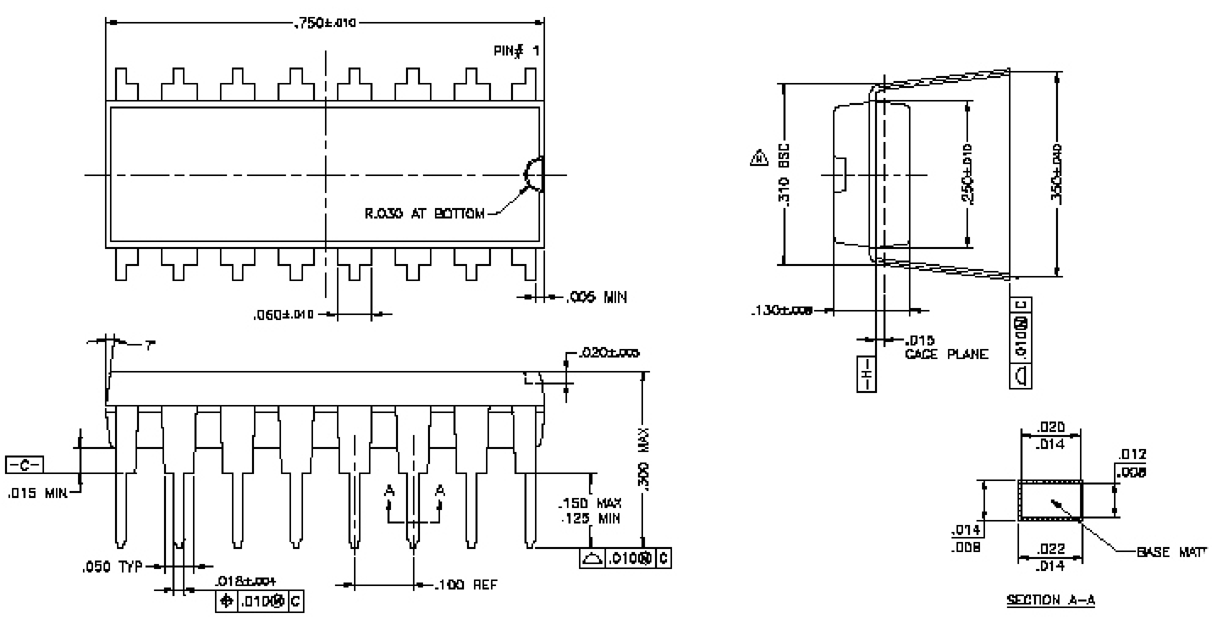
Note 1: Resistor (R10 and R11) values are dependant on the selected shunt resistor (R9) value.
Note 2: Capacitors C4, C5 and C9 to be positioned as close as possible to supply pins.

PACKAGE DIMENSIONS

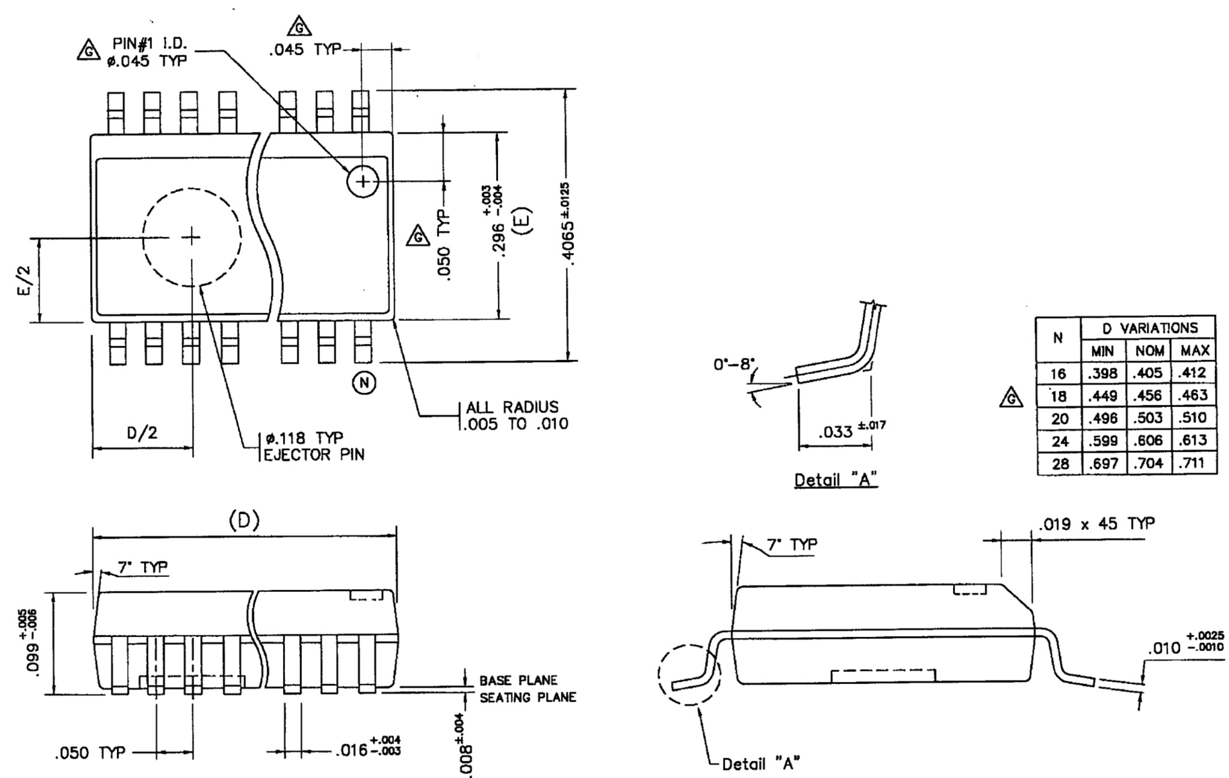
Dimensions shown in inches.

PDIP16 Outline Package

D=



SOIC16 Outline Package



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

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