Three Phase Power/Energy Metering IC with Instantaneous Pulse Output

SA9605A

ICDC

FEATURES

- Functionally similar to the SA9105E and SA9105F, with reduced number of external components
- Output frequency represents the absolute sum of energy on all three phases
- Performs one, two or three phase power and energy measurement
- Meets the IEC 521/1036 Specification requirements for Class 1 AC Watt hour meters
- Operates over a wide temperature range
- Current transformers for sensing
- Excellent long term stability
- Easily adaptable to different signal levels
- Precision voltage reference on-chip
- Pin selectable pulse rates
- Supports tamper detection

DESCRIPTION

The SA9605A is an enhancement of the SA9105E and SA9105F, as no external capacitors are needed for the A/D converters.

The SA9605A three phase power/energy metering integrated circuit generates a pulse rate output, the frequency of which is proportional to the absolute power consumption. The SA9605A performs the calculation for active power. The method of calculation takes the power factor into account. Energy consumption is determined by the power measurement being integrated over time.

The output of this innovative universal three phase power/energy metering integrated circuit, is ideally suited for applications such as residential and industrial energy metering and control.

The SA9605A integrated circuit is available in a 20 pin small outline (SOIC20) RoHS compliant package.

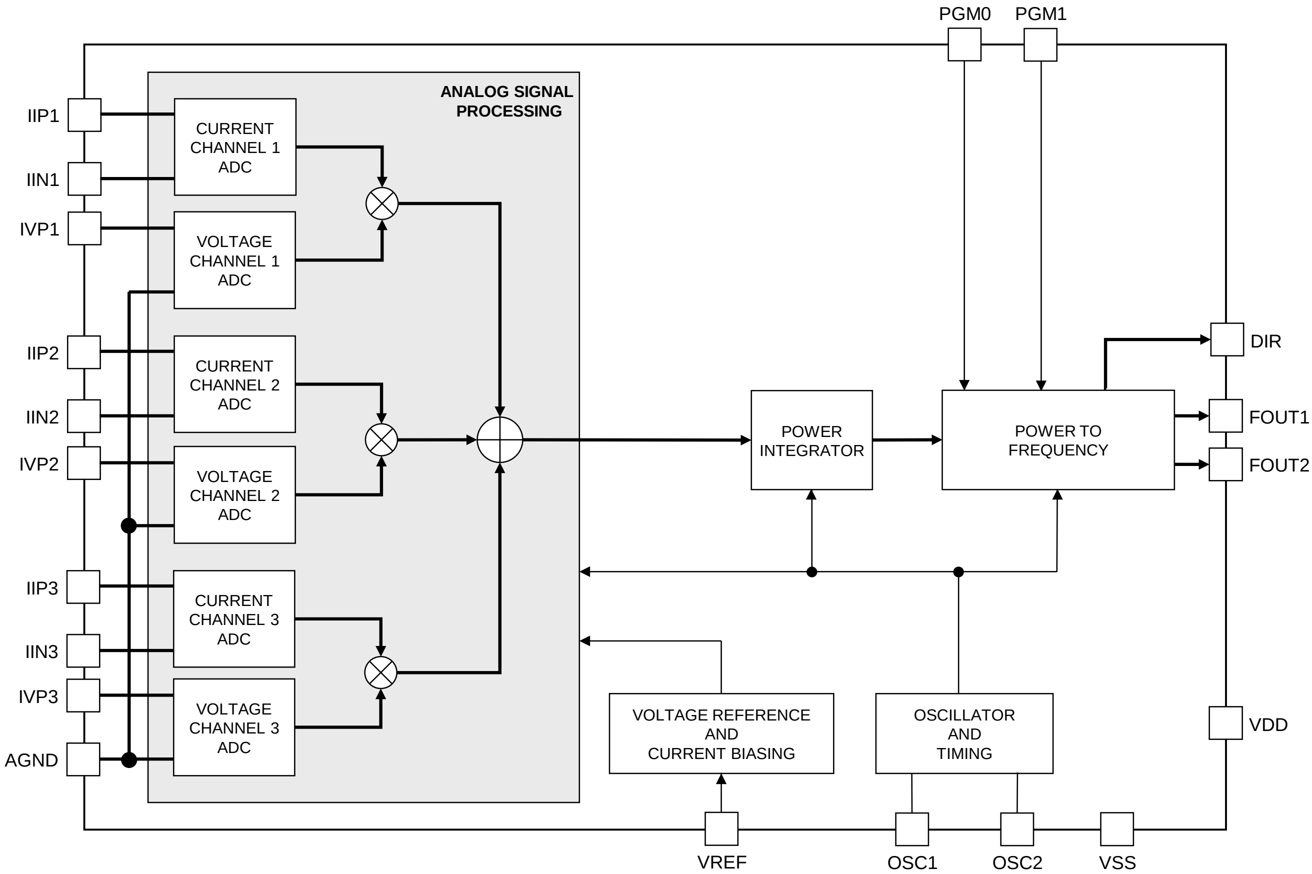


Figure 1: Block diagram

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}		8	12	mA	
Supply Current: Negative	I_{SS}		-8	-12	mA	
Analog Inputs						
Current Sensor Inputs (Differential)						
Input Current Range	IR_{IIP1}, IR_{IIP2}, IR_{IIP3}, IR_{IIN1}, IR_{IIN2}, IR_{IIN3}	-25		25	µA	Peak value
Offset Voltage	VO_{IIP1}, VO_{IIP2}, VO_{IIP3}, VO_{IIN1}, VO_{IIN2}, VO_{IIN3}	-4		4	mV	With R = 4.7kΩ connected to AGND
Voltage Sensor Inputs (Asymmetrical)						
Input Current Range	IR_{IVP1}, IR_{IVP2}, IR_{IVP3}	-25		25	µA	Peak value
Offset Voltage	VO_{IVP1}, VO_{IVP2}, VO_{IVP3}	-4		4	mV	With R = 4.7kΩ connected to AGND
Digital Outputs						
FOUT1, FOUT2, 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 FOUT1	f_P		1160		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

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	16	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	6	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.
IVP1, IVP2, IVP3	17, 20, 3	Analog Inputs for Voltages. The maximum current into the voltage sense inputs IVP should not exceed 16µA_{RMS}. At nominal voltage an input current of 14µA_{RMS} is recommended. The voltage sense inputs saturate at an input current of ±25µA peak.
IIP1, IIN1, IIP2, IIN2, IIP3, IIN3	18, 19, 1, 2, 4, 5	Analog Inputs for Currents. 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	15	This pin provides the connection for the reference current setting resistor. A 24kΩ resistor connected to V_{SS} sets the optimum operating conditions.
FOUT1	7	First pulse output. Refer to the Pulse Output Signals section for further information.
FOUT2	8	Second pulse output. Refer to the Pulse Output Signals section for further information.
DIR	9	Direction output to indicate direction of energy flow. Refer to the Pulse Output Signals section.
OSC1, OSC2	10, 11	Connection for crystal
PGM0, PGM1	12, 13	Programming pins for pulse output FOUT2. Refer to the Pulse Output Signals section for further information

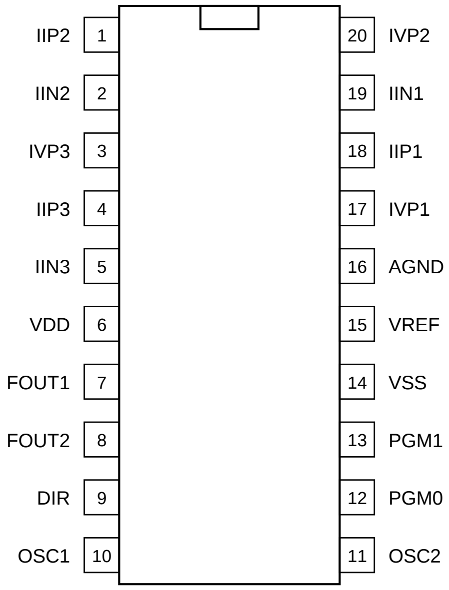


Figure 2: Pin connections for SOIC20 package

ORDERING INFORMATION

Part Number	Package
SA9605ASAR	SOIC20 (RoHS compliant)

FUNCTIONAL DESCRIPTION

The SA9605A is a CMOS mixed signal integrated circuit, which performs three phase power/energy calculations over a range of 500:1, to an overall accuracy of Class 1.

The SA9605A is functionally similar to the SA9105E and SA9105F with the advantage of no external loop capacitors.

The integrated circuit includes all the required functions for three phase power and energy measurement such as oversampling A/D converters for the voltage and current sense inputs, power calculation and energy integration. Internal offsets are eliminated through the use of cancellation procedures. The SA9605A generates pulses, the frequency of which is proportional to the power consumption. Two frequency outputs (FOUT1 and FOUT2) are available. The pulse rate follows the instantaneous power measured.

POWER CALCULATION

In the application circuit (see Figure 3), the mains voltages from L1, L2 and L3, are converted to currents and applied to the voltage sense inputs IVP1, IVP2 and IVP3. The current levels on the voltage sense inputs are derived from the mains voltage (3 x 220 VAC) being divided down through voltage dividers to 14V. The resulting input currents into the A/D converters are $14\mu A_{RMS}$ through the resistors R5 (1MΩ each). The trimpots P1 are used for calibration purposes. The capacitors C1 are used to compensate the phase shift of the current transformers.

For the current sense inputs the voltage drop across the current transformer's terminating resistors RT are converted to currents of $16\mu A_{RMS}$ for rated conditions, by means of resistors R1 and R2. The signals providing the current information are applied to the paired current sensor inputs, IIP1/IIN1, IIP2/IIN2 and IIP3/IIN3. The current sense inputs saturate at an input current of ±25µA peak.

In this configuration, with the mains voltage of 3 x 220 V and rated currents of 80A, the output frequency of the SA9605A energy metering integrated circuit at FOUT1 is 1160Hz. In this case 1 pulse will correspond to an energy consumption of 3 x 17.6kW/1160Hz = 45.5Ws.

The output frequency at FOUT1 and FOUT2 represents the absolute sum of the energy measured on all three phases, regardless of the direction of energy flow through the current sensors. This measurement method will assist meter manufacturers to circumvent meter tampering by reversal of the phases.

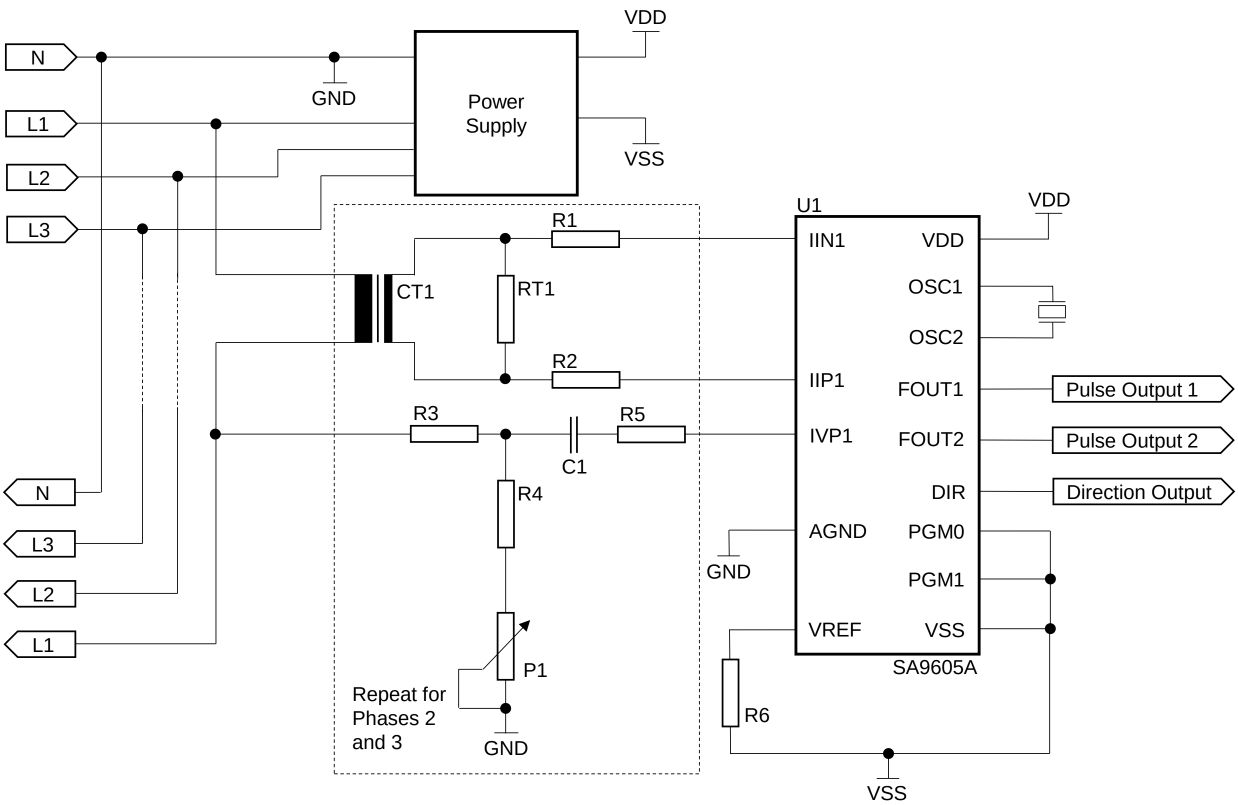


Figure 3: Application Circuit

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.

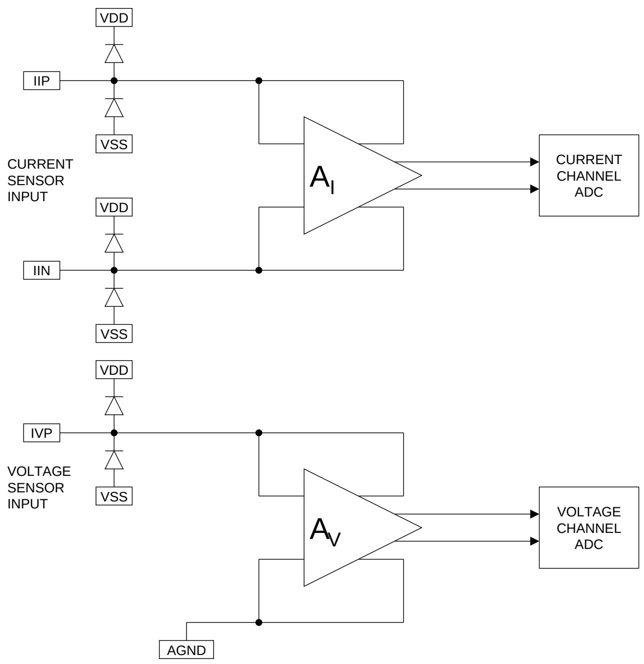


Figure 4: Internal analog input configuration

ELECTROSTATIC DISCHARGE (ESD) PROTECTION

The SA9605A integrated circuits inputs and outputs are protected against ESD.

POWER CONSUMPTION

The power consumption rating of the SA9605A integrated circuit is less than 75mW.

INPUT SIGNALS

VREF

A bias resistor of 24kΩ sets optimum bias conditions on chip. Calibration of the SA9605A should be done on the voltage input as described in Typical Applications.

Current Sense Inputs (IIP1/IIN1, IIP2/IIN2, IIP3/IIN3)

Figure 3 shows the typical connections for the current sensor inputs. The resistors R1 and R2 define the current level into the current sense inputs of the SA9605A. 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:

$$R1 = R2 = \frac{I_L}{N_{CT} \times 16\mu A} \times \frac{RT}{2}$$

where
I_L is the line current,
N_{CT} is the current transformer winding ratio and
RT is the current transformer termination resistor.

The value of RT should be less than the DC resistance of the secondary winding of the CT. The voltage drop across RT should be in the order of 100mV_{RMS} at rated currents.

Voltage Sense Inputs (IVP1, IVP2, IVP3)

The current into the voltage A/D converters should be set at 14µA_{RMS} at nominal mains voltage. The voltage sense inputs saturate 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 resistors R5.

OUTPUT SIGNALS

Pulse and Direction Output (FOUT1, DIR)

Waveforms displaying the FOUT1 and DIR signal information for each of the three phases are shown in Figure 5.

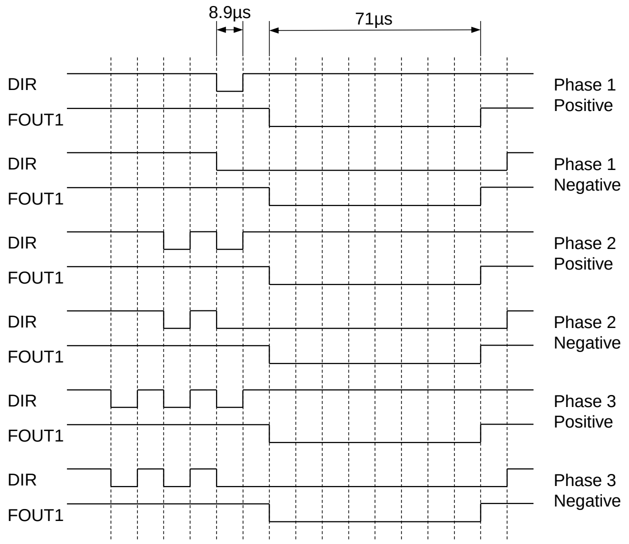


Figure 5: FOUT1 and DIR waveforms

These waveforms demonstrate how to establish the direction of energy flow as well as the phase from which the energy is measured. The direction of energy is indicated on the DIR pin, it is high for positive energy flow and low for negative energy flow. The state of DIR is valid for the entire low period of the FOUT1 pulse. The phase to which the pulse on the FOUT1 pin refers to, can be ascertained by counting the number of falling edges on the DIR pin prior to the falling edge of the FOUT1 pulse.

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

$$f = 12946 \times \frac{|I_{I1} \times I_{V1}| + |I_{I2} \times I_{V2}| + |I_{I3} \times I_{V3}|}{3 \times {I_R}^2} \times \frac{f_{CRYSTAL}}{3.5795}$$

where
I_{IX} is the input current on the current sense inputs on the respective channel in RMS (16µA at rated conditions),
I_{VX} is the input current on the voltage sense input on the respective channel 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.

Pulse Output (FOUT2)

Although FOUT1 has a fixed frequency output, the table below shows the various frequencies selectable for different rated conditions on FOUT2.

Table 1: User selectable FOUT2 frequency

PGM1	PGM0	Divider	FOUT2 Frequency (Hz)
V_{SS}	V_{SS}	227	5.110
V_{SS}	V_{DD}	303	3.833
V_{DD}	V_{SS}	454	2.555

The frequencies shown in the above table were chosen to allow a 4 - 3 - 2 scaling ratio for rated conditions. This facility provides ease of interface with applications which use the same post divider with mechanical counter or unchanged microcontroller software for different current rated kWh meters.

For example, a meter manufacturer may wish to build meters for 3 system configurations with rated current loading of 80A, 60A and 40A.

The only changes which have to be implemented to interface the device to different rated systems are to change the current sense resistors and select the required PGM0 and PGM1. No change to the post divider or microcontroller software is required if the FOUT2 pin is used.

OSCILLATOR

The SA9605A 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 current transformers for the mains current sensing. The meter is designed for 220V/80A I_{MAX} operation. The most important external components for the SA9605A integrated circuit are the current sense resistors, the voltage sense resistors as well as the bias setting resistor.

Bias Resistor

R25 defines all on-chip and reference currents. Optimum conditions are set by using R25=24kΩ. Device calibration is done on the voltage inputs of the device.

Current Transformer Termination Resistor

The voltage drop across the termination resistors of the current transformers at rated current should be at in the order of 100mV. Assuming a transformer winding ratio of 2500, selecting termination resistor values of R24=R23=R22=2.7Ω ensures that the voltage across the termination resistor at maximum rated current is

$$V_T = \frac{80A}{2500} \times 2.7\Omega = 86.4mV$$

Current Sense Resistors

The resistors R16 to R21 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 SA9605A at rated conditions. According to equation described in the Current Sense Inputs section:

$$RIN = \frac{I_L}{N_{CT} \times 16\mu A} \times \frac{RT}{2} = \frac{80A}{2500 \times 16\mu A} \times \frac{2.7\Omega}{2} = 2.7k\Omega$$

Voltage Divider

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

$$RA = R1 + R2 + R3$$
$$RB = R13 \,||\, (R10 + P1)$$

Combining the two equations gives:

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

A 5kΩ trimpot will be used on the voltage channels 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 R13=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.

The capacitor C4 is used to compensate for any phase shift caused by the current transformers. A typical good quality current transformer will have a phase shift of about ϕ_{CT}=0.18º. The capacitor value is calculated as follows:

$$C = \frac{1}{2 \times \pi \times f_{MAINS} \times R13 \times \tan \phi_{CT}}$$

$$C = \frac{1}{2 \times \pi \times 50Hz \times 1M\Omega \times \tan 0.18} = 1.013\mu F$$

A capacitor of C4=1µF can therefore be used to compensate the phase shift of the current transformer.

Identical values for all components are used on the remaining two channels of the device.

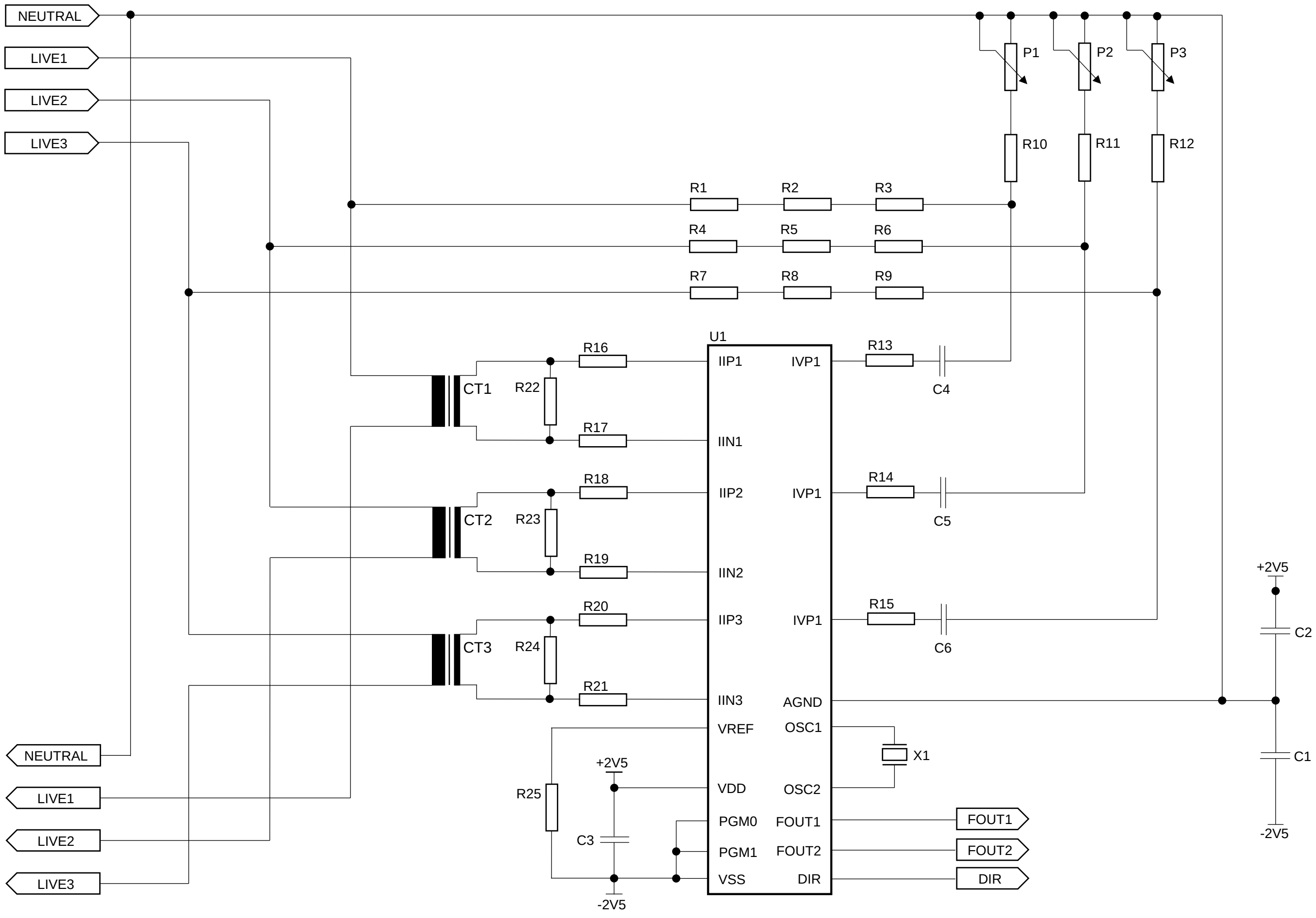


Figure 6: Typical application circuit

Table 2: Component list for typical application

Symbol	Description
U1	Energy metering device, SA9605A
R1, R2, R3	Resistor, 120kΩ, 1%, metal film
R4, R5, R6	Resistor, 120kΩ, 1%, metal film
R7, R8, R9	Resistor, 120kΩ, 1%, metal film
R10, R11, R12	Resistor, 22kΩ, 1%, metal film
R13[1], R14[1], R15[1]	Resistor, 1MΩ, 1%, metal film
R16[1], R17[1], R18[1]	Resistor, 2.7kΩ, 1%, metal film
R19[1], R20[1], R21[1]	Resistor, 2.7kΩ, 1%, metal film

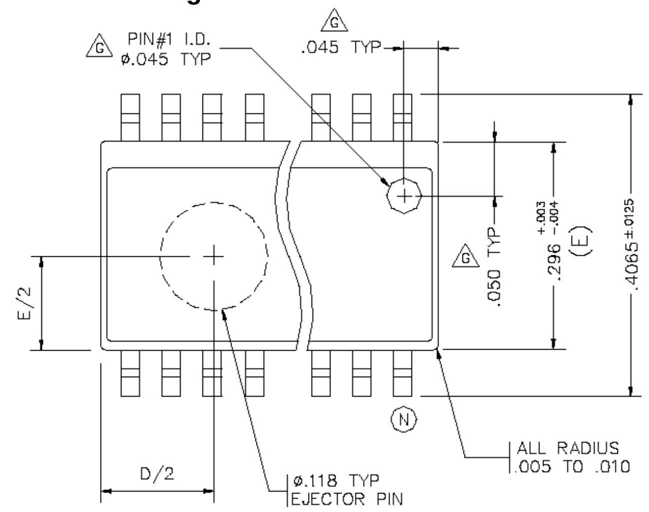
Symbol	Description
R22, R23, R24	Resistor, 2.7Ω, 1%, metal film
R25[1]	Resistor, 24kΩ, 1%, metal film
P1, P2, P3	Trim-pot, 25 turns, 5kΩ
X1	Crystal, 3.5795MHz
C1[2], C2[2]	Capacitor, 220nF, ceramic
C3[2]	Capacitor, 820nF, ceramic
C4, C5, C6	Capacitor, 1µF, ceramic
CT1, CT2, CT3	Current Transformer, TZ76V

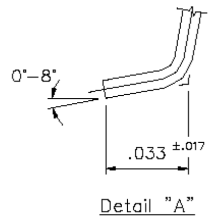
Note 1: Resistors R13 to R21 and R25 must be positioned as close as possible to the respective device pins
Note 2: Capacitors C1, C2 and C3 must be positioned as close as possible to the V_{DD} and V_{SS} power supply pins

PACKAGE DIMENSIONS

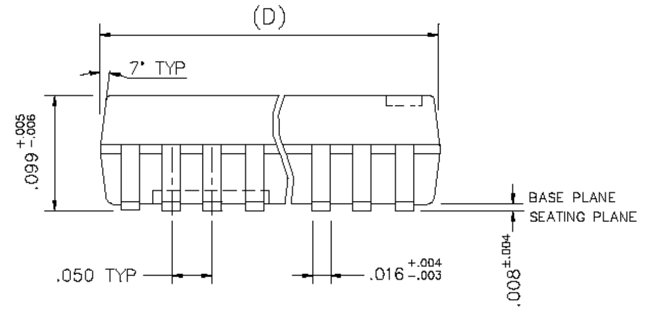
SOIC20 Package

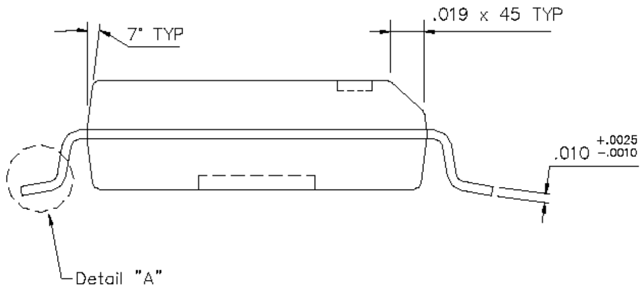
Dimensions are shown in inches





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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