

**SINGLE PHASE UNIDIRECTIONAL POWER/ENERGY  
METERING AND EARTH LEAKAGE PROTECTION IC**
**FEATURES**

- Earth leakage sensing with pulse rate output to allow user specific protection levels.
- Performs unidirectional power and energy measurement
- Meets the IEC 521/1036 Specification requirements for Class 1 AC Watt hour meters
- Power on reset and watchdog timer to ensure safety.
- Power consumption rating typically 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
- Protected against ESD

**DESCRIPTION**

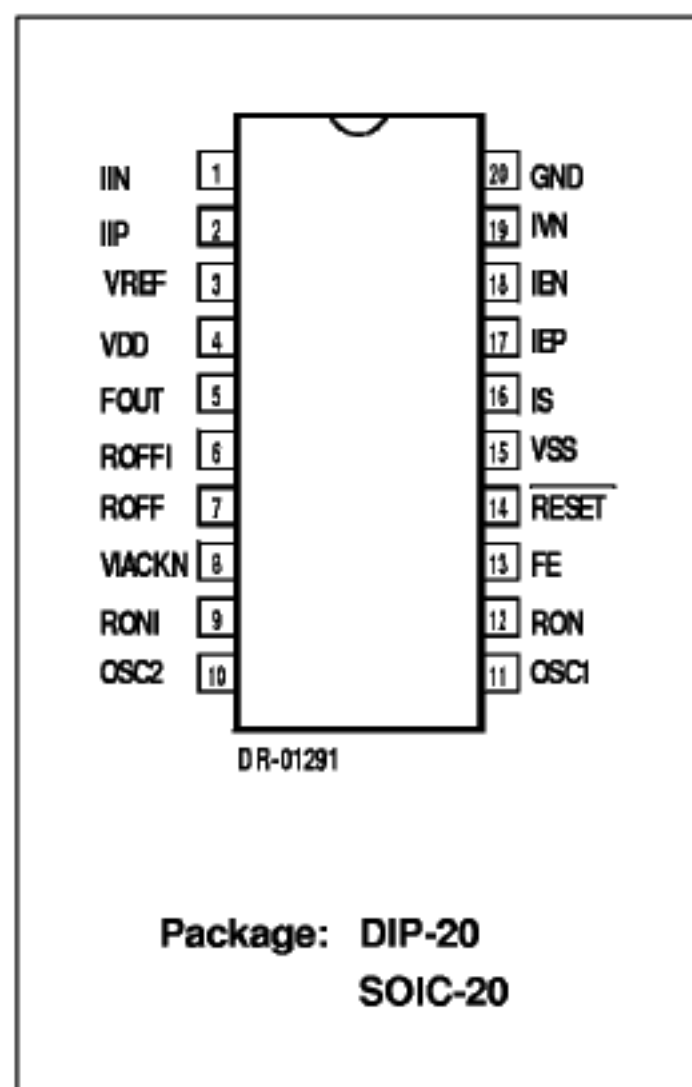
The SAMES SA9642E Single Phase Unidirectional Integrated Circuit provides a convenient method of power/energy metering and earth leakage protection in one device.

The metering section of the SA9642E generates a pulse rate output on pin FOUT, the frequency being proportional to the power consumption. Energy consumption may be determined by the power measurement being integrated over time.

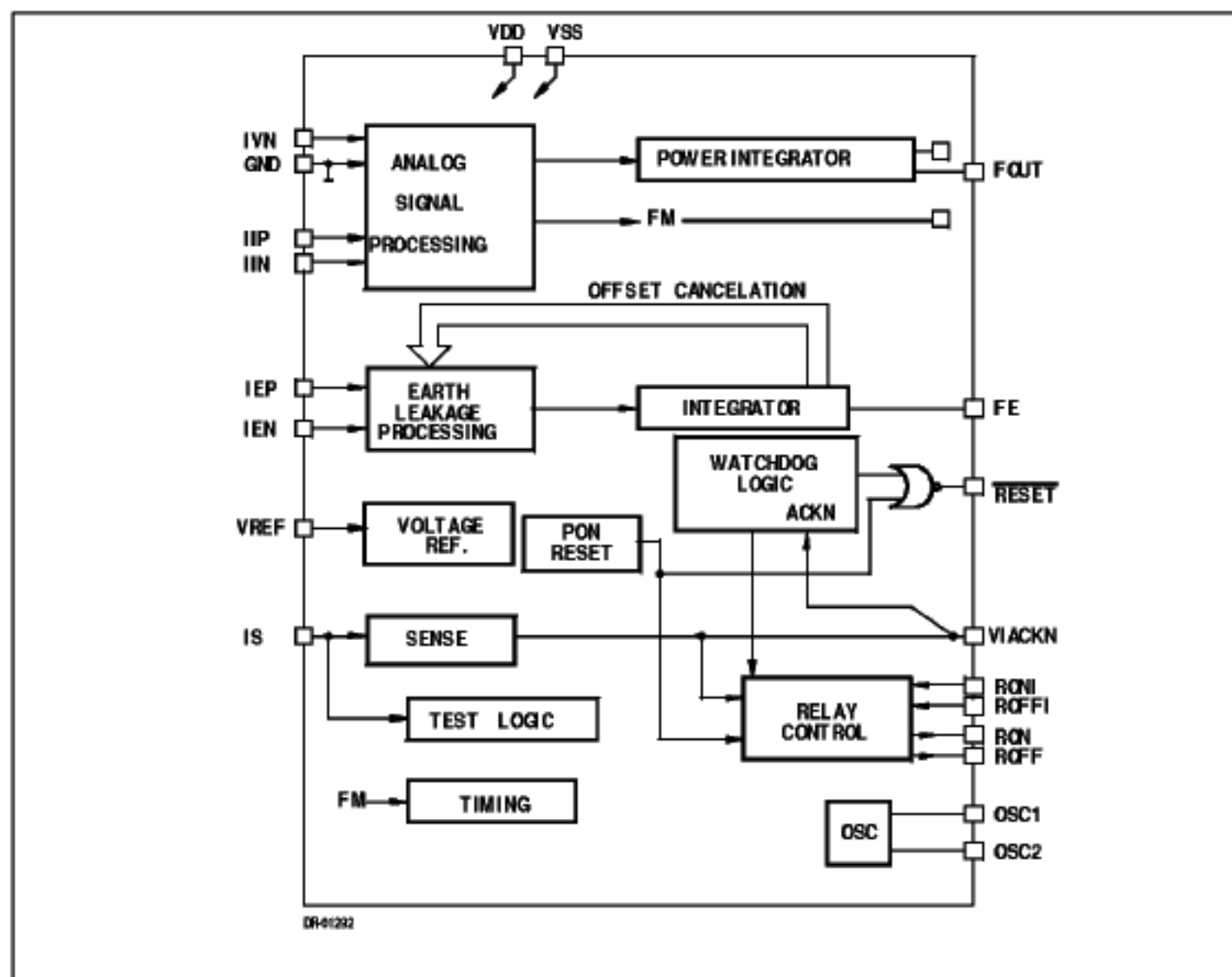
The earth leakage function generates a pulse rate output on pin FE. The frequency is proportional to earth leakage current. User specific protection levels may be achieved by external supervision of this pulse rate.

This innovative universal single phase integrated circuit, with energy metering and earth leakage protection, is ideally suited for use in applications where safety is an essential element.

The SA9642E integrated circuit is available in 20 pin dual-in-line plastic (DIP-20), as well as 20 pin small outline (SOIC-20) package types.

**PIN CONNECTIONS**


## BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS\*

Parameter	Symbol	Min	Max	Unit
Supply Voltage	$V_{DD} - V_{SS}$	-0.3	6.0	V
Current on any pin	$I_{PIN}$	-150	+150	mA
Storage Temperature	$T_{STG}$	-40	+125	°C
Operating Temperature	$T_O$	-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.

## ELECTRICAL CHARACTERISTICS

( $V_{DD} = 2.5V$ ,  $V_{SS} = -2.5V$ , over the temperature range  $-10^{\circ}C$  to  $+70^{\circ}C$ , unless otherwise specified.)

Parameter	Symbol	Min	Typ	Max	Unit	Condition
Operating temperature range #	$T_o$	-25		+85	$^{\circ}C$	
Supply Voltage: Positive	$V_{DD}$	2.25		2.75	V	
Supply Voltage: Negative	$V_{SS}$	-2.75		-2.25	V	
Supply Current: Positive	$I_{DD}$		5	6	mA	
Supply Current: Negative	$I_{SS}$		5	6	mA	
Current Sensor Inputs (Differential)						
Input Current Range	$I_{II}, I_{IE}$	-25		+25	$\mu A$	Peak value
Voltage Sensor Input (Asymmetrical)						
Input Current Range	$I_{IV}$	-25		+25	$\mu A$	Peak value
Pins FOUT, FE Output Low Voltage Output High Voltage	$V_{OL}$ $V_{OH}$	$V_{DD}-1$		$V_{SS}+1$	V V	$I_{OL} = 5mA$ $I_{OH} = -2mA$
Pulse Rate FOUT <sup>1</sup>	$f_P$	10 0.5		1160 3000	Hz Hz	Specified linearity Min and max limits
Pulse Rate FE	$f_{EL}$	0		1000	Hz	
Pins RONI, ROFFI Input Low Voltage Input High Voltage Pull-up Current	$V_{IL}$ $V_{IH}$ $-I_L$	$V_{DD}-1$ 50		$V_{SS}+1$ 150	V V $\mu A$	$V_{IN} = V_{SS}$
Pins ROFF, RON, $\overline{RESET}$ Output Low Voltage Output High Voltage	$V_{OL}$ $V_{OH}$	$V_{DD}-1$		$V_{SS}+1$	V V	$I_{OL} = 5mA$ $I_{OH} = -2mA$
Pin VIACKN Setup Time, IS Tri-State High Voltage Watchdog Acknowledge Output Low Voltage Output High Voltage	$V_{OH}$ $V_{OL}$ $V_{OH}$	$V_{DD}-1$ $V_{DD}-1$		$V_{SS}+1$	V V V	$I_{OH} = 100\mu A$ $I_{OL} = 4mA$ $I_{OH} = -2mA$

**ELECTRICAL CHARACTERISTICS (Continued)**

( $V_{DD} = 2.5V$ ,  $V_{SS} = -2.5V$ , over the temperature range  $-10^{\circ}C$  to  $+70^{\circ}C$ , unless otherwise specified.)

Parameter	Symbol	Min	Typ	Max	Unit	Condition
Pin IS, Relay Sense Current VS, Relay Sense Voltage			+25 $V_{SS}+1.2$		$\mu A$ V	Relay sense voltage input
Pin VREF Ref. Current Ref. Voltage	$-I_R$ $V_R$	45 1.1	50	55 1.3	$\mu A$ V	With $R = 24k\Omega$ connected to $V_{SS}$ Referred to $V_{SS}$
Oscillator	Recommended crystal: TV colour burst crystal $f = 3.5795$ MHz					

Note1: An additional bond out option of  $f_p/290$  is available on request.

# Extended Operating Temperature Range available on request.

**PIN DESCRIPTION**

PIN	Designation	Description
20	GND	Ground
4	$V_{DD}$	Positive Supply Voltage
15	$V_{SS}$	Negative Supply Voltage
19	IVN	Analogue Input for Voltage
1	IIN	Inputs for Current Sensor
2	IIP	
18	IEN	Inputs for Earth Leakage Sensor
17	IEP	
8	VIACKN	Acknowledge Input/Output Pin
14	RESET	RESET Signal Output
11	OSC1	Connections for Crystal or Ceramic Resonator (OSC1 = Input; OSC2 = Output)
10	OSC2	
5	FOUT	Energy Pulse Rate Output
13	FE	Earth Leakage Pulse Rate Output
16	IS	Input Supply Sense for Relay Control
6	ROFFI	Circuit Breaker Relay. Control Input
9	RONI	
7	ROFF	Circuit Breaker Relay. Control Output
12	RON	
3	VREF	Connection for Current Setting Resistor

## FUNCTIONAL DESCRIPTION

The SA9642E is a CMOS mixed signal Analog/Digital integrated circuit, which performs power/energy calculations across a power range of 1000:1, to an overall accuracy of better than Class 1. Earth leakage protection is achieved by setting the appropriate status on the relay control input pins and monitoring the associated pulse rate.

The integrated circuit includes all the required functions for 1-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 on-chip cancellation procedures. The SA9642E generates pulses, the frequency of which is proportional to the power consumption. The pulse rate follows the instantaneous power consumption measured.

An oversampling A/D converter is also used for the earth leakage protection resulting in a pulse rate. The frequency is proportional to the sensed earth leakage input current. In addition to the elimination of internal offsets, DC offsets on the earth leakage input pins are also eliminated by a cancellation method internal to the device.

Circuit breaker relay input pins allow an external supervisor to set the required status of the circuit breaker. Proper functionality of the supervisor circuit is ensured by correct maintenance of the watch dog signal on pin VIACKN. If the supervisor produces 16 consecutive wrong VIACKN signals, the  $\overline{\text{RESET}}$  to the supervisor locks and ROFF pulses are generated on a regular basis by the SA9642E. This ensures that the circuit breaker relay remains off. This state is only overridden when the supply voltage to the SA9642E is removed and then re-applied.

### 1. Power Calculation

In the Application Circuit (Figure 1), the mains voltage is converted to a current and applied to the voltage sense input pin IVN. The current level on the voltage sense input is divided down from the mains voltage (230VAC) through a divider to  $14V_{\text{RMS}}$ . The resulting current into the A/D converter is  $14\mu A_{\text{RMS}}$  through resistor R4.

For the current sense inputs, the voltage drop across the current transformer's terminating resistor is converted to a current of  $16\mu A_{\text{RMS}}$  for rated conditions, by means of resistors R1 and R2.

In this configuration, with a mains voltage of  $230V_{\text{RMS}}$  and rated current of  $80A_{\text{RMS}}$ , the output frequency of the SA9642E at FOUT is 1.16kHz. In this case one pulse will correspond to  $230 \times 80/1160 = 15.9\text{Ws}$ .

### Earth Leakage Calculation

When earth leakage current flows, the voltage drop across the earth leakage transformer termination resistor is converted to a current of  $16\mu A_{\text{RMS}}$  by means of resistors R8 and R9. For this level of earth leakage, the pulse rate on pin FE is 1000Hz.

## Relay Supply Voltage Calculation

The relay sense input to the SA9642E facilitates monitoring of the pre-regulator DC voltage used for the relay control. Different thresholds may be adjusted via R12, to accommodate the power supply requirements of the selected relay. The voltage level should be adjusted to ensure that sufficient energy is available to switch the relay on and then immediately off, (in the case of an earth fault) if required.

Presence of proper pre-regulator voltage is detected by the IS input if a current of greater than 25µA is present on the input.

The value of the sense resistor is calculated in the following manner:

$$R12 = \frac{V_{REL} - V_S}{I_S}$$

Where  $V_{REL}$  : Voltage necessary for correct operation of relay

$V_S$  : Relay sense voltage

$I_S$  : Relay sense current

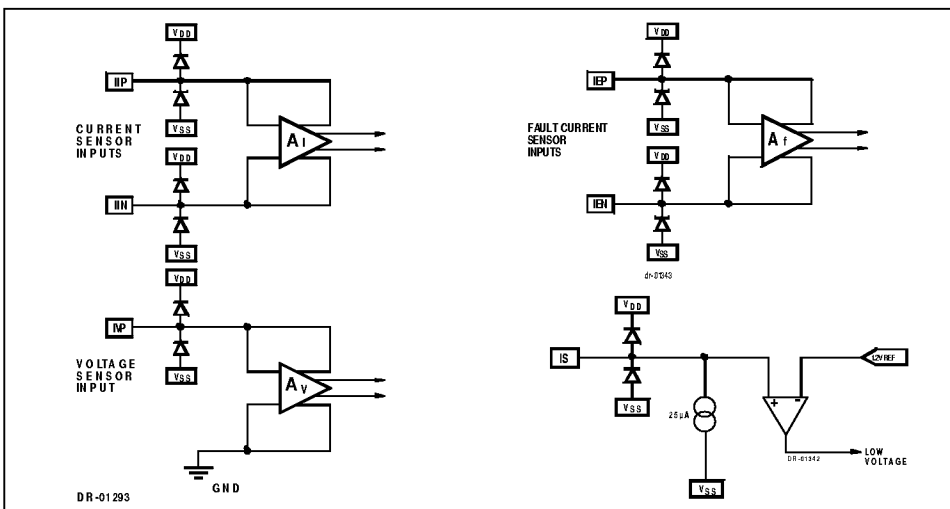
## 2. Analog Input Configuration

The input circuitry of the current, voltage and fault current sensor inputs are illustrated below.

These inputs are protected against electrostatic discharge through clamping diodes.

The feedback loops from the outputs of the amplifiers  $A_I$ ,  $A_V$  and  $A_f$  generate virtual shorts on the signal inputs. Exact duplications of the input currents are generated for the analog signal processing circuitry.

A current less than 25µA on the IS input signals a power supply low condition to the rest of the digital circuitry.



### 3. Electrostatic Discharge (ESD) Protection

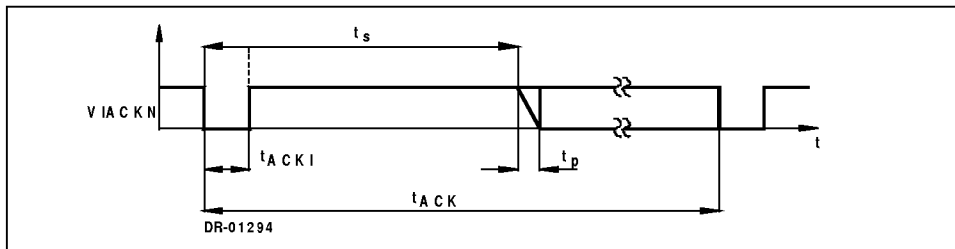
The SA9642E integrated circuit's inputs/outputs are protected against ESD.

### 4. Power Consumption

The power consumption rating of the SA9642E integrated circuit is typically less than 25mW.

### 5. Timing Signals

VIACKN is a dual purpose pin for watchdog acknowledge input and pre-regulator voltage sense output.



When the SA9642E device becomes operational, a watchdog acknowledge signal, from the  $\mu$ -controller must be received within a time period of  $t_{ACK}$ . If this acknowledge is not received within the time period, a reset pulse,  $t_{RES}$ , from the SA9642E is output on the RESET pin.

After 16 consecutive attempts of watchdog signalling for acknowledgement, the reset locks and only a power down of the SA9642E device can restart the operation.

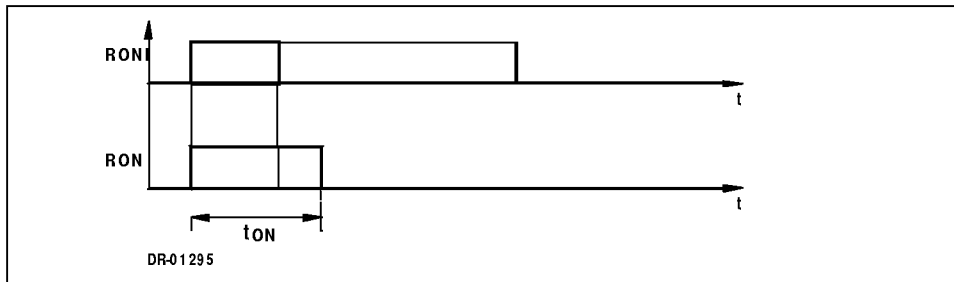
When the SA9642E is waiting for the acknowledge signal from the  $\mu$ -controller, the driving capability of the VIACKN pin is 100 $\mu$ A (max).

After the acknowledge signal has been received and a period of time ( $t_s$ ) has elapsed to allow the SA9642E to sense the pre-regulator voltage, the status of the pre-regulator voltage is signalled on the VIACKN pin. This signal is low if the pre-regulator voltage is not at the required level, and high if the pre-regulator voltage is at the required level. In the pre-regulator voltage state,  $t_s + t_p$ , the VIACKN pin can sink 4mA when low, and drive 2mA when high.

Signal	Symbol	Min	Typ	Max	Unit	Condition
Setup time	$t_s$		8.8		ms	
Watchdog Acknowledge	$t_{ACK}$	$8.8+t_p$		19.6	ms	
Reset signal	$t_{RES}$		1.2		ms	
Setup time to watchdog acknowledge change over	$t_p$		560		ns	
Acknowledge input pulse width	$t_{ACKI}$	1		100	$\mu$ s	

### RELAY CONTROL

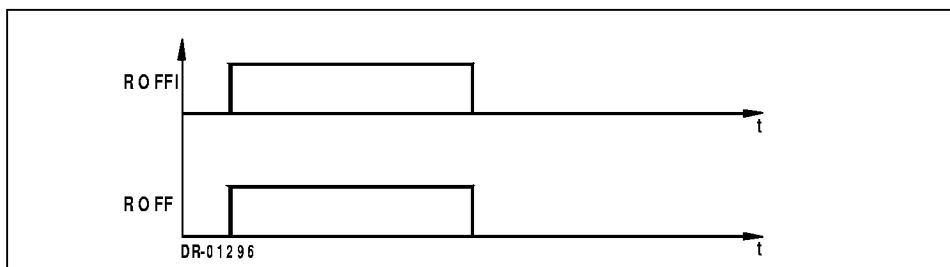
Circuit breaker relay operation is accomplished by two control inputs: RONI to switch the relay on, and ROFFI to switch the relay off. The two control signals to the SA9642E will result in output signals, RON and ROFF to the relay as shown in the plots below:



The RON output will be valid for the time that the RONI signal is high. To avoid the possibility of switching the relay to the on position for extended periods, the RON signal will stay in the on state for a maximum of 60mS, even if the RONI input is valid for a longer period.

Signal	Symbol	Min	Typ	Max	Unit	Condition
Output to Relay control	$t_{ON}$	RONI				
				60	mS	RONI overriden

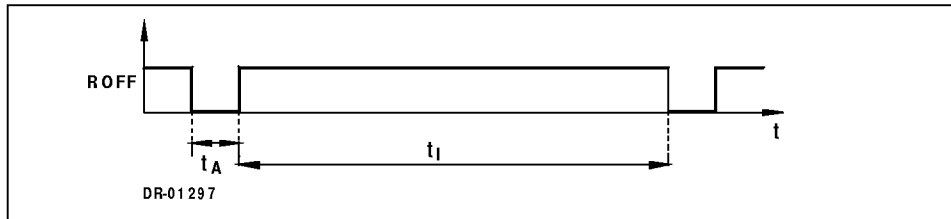
The off signal to the relay, ROFF, is active for the entire time period that the ROFFI signal is valid.





After the SA9642E has received 16 consecutive erroneous watchdog signals, the RESET pin goes low and the ROFF output displays an active high pulse for 54.9ms, every 2287.5ms period.

This is shown below:



Signal	Symbol	Min	Typ	Max	Unit	Condition
ROFF active	$t_A$		54.9		ms	Watchdog monitoring fault condition
ROFF inactive	$t_I$		2287.5		ms	

## TYPICAL APPLICATIONS

In the Application Circuit (Figure 1), the components required for power measurement and earth leakage applications, are shown.

### Energy Measurement

The current level on the voltage sense input is derived from the mains voltage ( $230V_{RMS}$ ) being divided down through voltage dividers to  $14V_{RMS}$ . The resulting input current into the A/D converter is  $14\mu A_{RMS}$  through resistor R5.

For the current sense input the voltage drop across the current transformer terminating resistor is converted to a current of  $16\mu A_{RMS}$  for rated conditions, by means of resistors R1 and R2.

In this configuration, with a mains voltage of  $230V_{RMS}$  and rated current of  $80A_{RMS}$ , the output frequency of the SA9642E energy metering integrated circuit at FOUT is 1.16kHz. In this case 1 pulse corresponds to an energy consumption of 15.9Ws.

The formula for calculating the output frequency is given below:

$$f = 11.16 * 1160 * \frac{FOSC}{3.58MHz} * \frac{I_I \cdot I_V}{I_R^2}$$

Where FOSC = Oscillator frequency (2MHz ..... 4MHz)

$I_I$  = Input current for current sense input ( $16\mu A$  at rated condition)

$I_V$  = Input current for voltage sense input ( $14\mu A$  at rated condition)

$I_R$  = Reference current (typically  $50\mu A$ )

## **Earth Leakage Protection**

The level of earth leakage protection is determined by selection of the earth leakage current transformer, the termination resistor (RSHEL) and the current setting resistors (R8 and R9 ) connected to the sensor inputs of the SA9642E. The resistors should be chosen such that the input current for earth leakage conditions is  $16\mu\text{A}_{\text{RMS}}$ . This input will result in a frequency output on FE of 1000Hz, under earth leakage fault conditions.

Monitoring of the pulse rate over a pre-determined time period allows a  $\mu$ -controller to trip the circuit breaker at the required level of earth leakage detected.

## **Pre-regulator Voltage Sence**

To ensure that the voltage level on the pre-regulator side of the supply is of a sufficient value to make the circuit breaker trip if necessary, the SA9642E allows confirmation of value. This is accomplished by sensing the pre-regulator voltage using R12 which is input to the supply sense pin, IS.

If the pre-regulator voltage must be at 6V, for example to ensure proper operation of the circuit breaker relay, this will require that the resistor R12 must have a value of

$$R12 = \frac{6 - 1.2}{25E - 6} = 180\text{k}\Omega$$

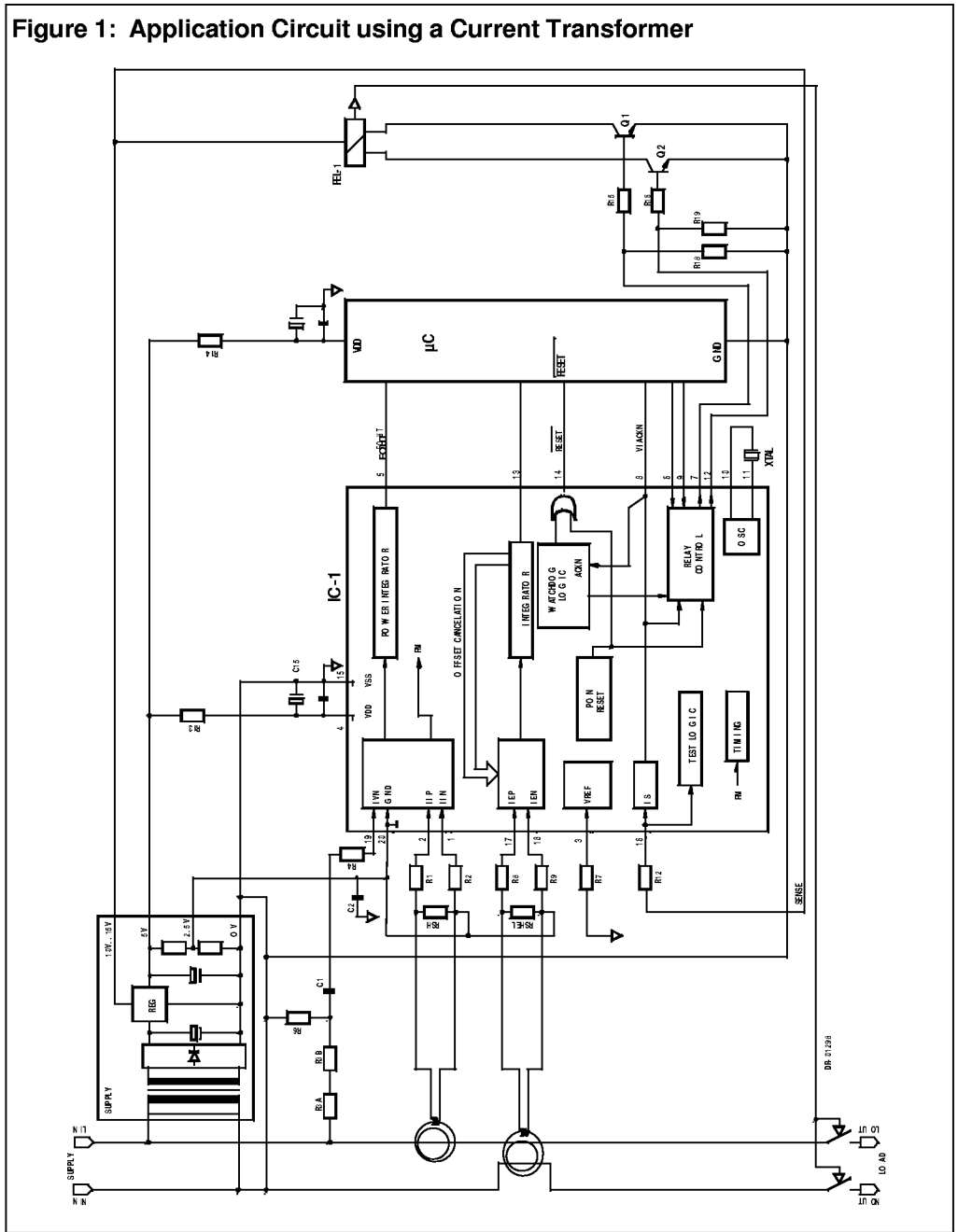
## **Bias and Reference Currents**

R7 defines all on-chip bias and reference currents. With  $R7 = 24\text{k}\Omega$ , optimum conditions are set. R7 may be varied with  $\pm 10\%$  for calibration purposes. Any change to R7 will affect the output quadratically (i.e.  $R7 = +5\%$ ,  $f_p = +10\%$ ).

## **Oscillator**

XTAL is a colour burst TV crystal ( $f = 3.5795 \text{ MHz}$ ) for the oscillator. The oscillator frequency is divided down to 1.7897 MHz on-chip, to supply the digital circuitry and the A/D converters.

Figure 1: Application Circuit using a Current Transformer



DB 01294

## Parts List for Application Circuit: Figure 1

Item	Symbol	Description	Detail
1	IC-1	SA9642E	DIP-20 / SOIC-20
2	XTAL	Crystal, 3.5795MHz	Colour burst TV
3	R1	Resistor, 1%, metal	Note 2
4	R2	Resistor, 1%, metal	Note 2
5	RSH	Resistor	Note 1
6	R8	Resistor, 1%, metal	Note 2
7	R9	Resistor, 1%, metal	Note 2
8	RSHEL	Resistor	Note 1
9	R3A	Resistor, 1%, 280k, (230VAC), metal	
10	R3B	Resistor, 1%, 110k, (230VAC), metal	
11	R4	Resistor, 1M, 1/4W, 1%, metal	
12	R6	Resistor, 24k, 1/4W, 1%, metal	
13	R7	Resistor, 24k, 1/4W, 1%, metal	
14	C15	Capacitor, 820nF	Note 3
15	R12	Resistor, 1%, metal	Note 4
16	C2	Capacitor, 100nF	
17	R18	Resistor, 22k	
18	R19	Resistor, 22k	
19	R15	Resistor, 2k2	
20	R16	Resistor, 2k2	
21	REL-1	Relay	
22	Q1, Q2	Transistors for relay control	

Note 1: See Typical Applications when selecting the values of RSH and RSHEL.

Note 2: Resistors R1 and R2 depend on the value of RSH, and resistors R8 and R9 depend on the value of RSHEL.

Note 3: Capacitor C15 to be positioned as close to supply pins (VDD and VSS) of IC-1, as possible.

Note 4: Selection of resistor R12 will depend upon the operating characteristics of the relay. See Typical Applications when selecting the value.

**ORDERING INFORMATION**

<b>Part Number</b>	<b>Package</b>
SA9642EPA	DIP-20
SA9642ESA	SOIC-20