

# Single Phase Uni-directional Power / Energy Metering IC with Instantaneous Pulse Output



sames

## SA2002E

### ■ FEATURES

- Functionally compatible with the SA9602E with reduced external components
- Uni-directional power and energy measurement
- Meets the IEC 521/1036 Specification requirements for Class 1 AC Watt hour meters
- Protected against ESD
- Total power consumption rating below 25mW
- Adaptable to different types of current sensors
- Operates over a wide temperature range
- Precision voltage reference on-chip
- Precision oscillator on-chip

### DESCRIPTION

The SAMES SA2002E is an enhancement of the SA9602E, as the circuit contains the oscillator on chip.

The SAMES SA2002E single phase uni-directional power/energy metering integrated circuit generates a pulse rate output with a frequency proportional to the power consumption.

The SA2002E performs a calculation for active power. The method of calculation takes the power factor into account. Energy consumption can be determined by the power measurement being integrated over time.

This innovative universal single-phase power/energy metering integrated circuit is ideally suited for energy calculations in applications such as residential municipal metering and factory energy metering and control.

The SA2002E integrated circuit is available in 8, 14 and 20 pin dual-in-line plastic (DIP) as well as 16 and 20 pin small outline (SOIC) package types.

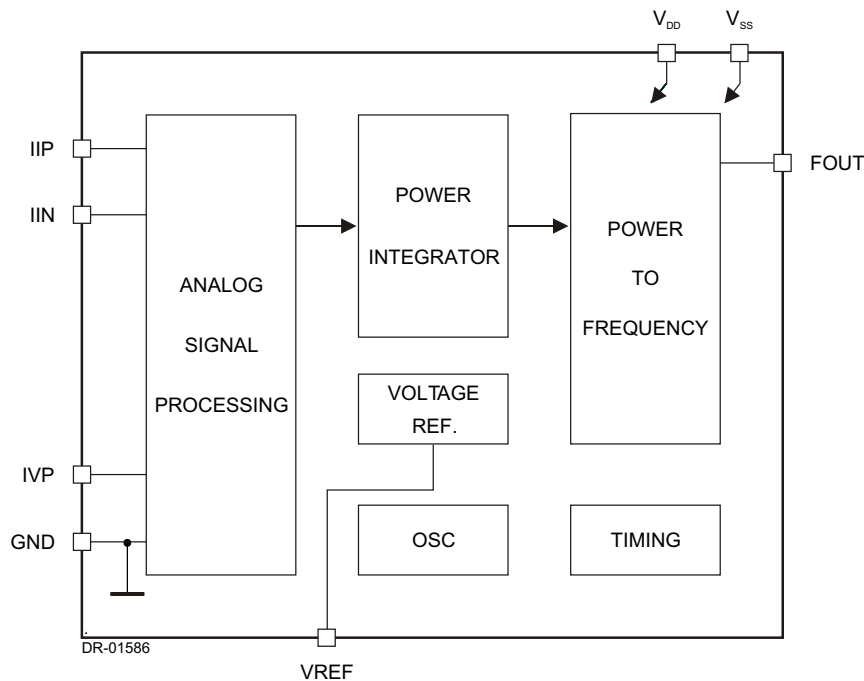


Figure 1: Block diagram

**ELECTRICAL CHARACTERISTICS**(V<sub>DD</sub> = 2.5V, V<sub>SS</sub> = -2.5V, over the temperature range -10°C to +70°C#, unless otherwise specified.)

| Parameter   | Symbol                             | Min                | Typ  | Max                | Unit           | Condition  |
|---|------------------------------------|--------------------|------|--------------------|----------------|--|
| Operating temp. Range                                 | T <sub>O</sub>                     | -25                |      | +85                | °C             |  |
| Supply Voltage: Positive                              | V <sub>DD</sub>                    | 2.25               |      | 2.75               | V              |  |
| Supply Voltage: Negative                              | V <sub>SS</sub>                    | -2.75              |      | -2.25              | V              |  |
| Supply Current: Positive                              | I <sub>DD</sub>                    |                    | 3    | 5                  | mA             |  |
| Supply Current: Negative                              | I <sub>SS</sub>                    |                    | 3    | 5                  | mA             |  |
| Current Sensor Inputs (Differential)                  |                                    |                    |      |                    |                |  |
| Input Current Range                                   | I <sub>II</sub>                    | -25                |      | +25                | µA             | Peak value   |
| Voltage Sensor Input (Asymmetrical)                   |                                    |                    |      |                    |                |  |
| Input Current Range                                   | I <sub>IV</sub>                    | -25                |      | +25                | µA             | Peak value   |
| Pin FOUT<br>Output High Voltage<br>Output Low Voltage | V <sub>OL</sub><br>V <sub>OH</sub> | V <sub>DD</sub> -1 |      | V <sub>SS</sub> +1 | V<br>V         |  |
| Pulse Rate FOUT                                       | f <sub>p</sub>                     | 5<br>0             | 1360 | 1600<br>3000       | Hz<br>Hz<br>Hz | At rated input conditions<br>Specified linearity<br>Min and Max frequency    |
| Pin VREF<br>Ref. Current<br>Ref. Voltage              | -I <sub>R</sub><br>V <sub>R</sub>  | 45<br>1.1          | 50   | 55<br>1.3          | µA<br>V        | With R = 24k<br>connected to V <sub>SS</sub><br>Reference to V <sub>SS</sub> |

# Extended Operating Temperature Range available on request.

**ABSOLUTE MAXIMUM RATINGS\***

| Parameter             | Symbol                           | Min  | Max  | Unit |
|-----------------------|----------------------------------|------|------|------|
| Supply Voltage        | V <sub>DD</sub> -V <sub>SS</sub> | -0.3 | 6.0  | V    |
| Current on any pin    | I <sub>PIN</sub>                 | -150 | +150 | mA   |
| Storage Temperature   | T <sub>STG</sub>                 | -40  | +125 | °C   |
| Operating Temperature | T <sub>O</sub>                   | -25  | +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.

**PIN DESCRIPTION**

| 8 Pin | 14 Pin | 16 Pin | 20 Pin | Designation | Description  |
|-------|--------|--------|--------|-------------|--|
| 8     | 14     | 16     | 20     | GND         | Analog Ground. The voltage to this pin should be mid-way between $V_{DD}$ and $V_{SS}$ .   |
| 4     | 5      | 5      | 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.                               |
| 6     | 10     | 12     | 14     | $V_{SS}$    | 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.                                |
| 7     | 13     | 15     | 19     | IVP         | Analog Input for Voltage. The current into the A/D converter should be set at $14\mu A_{RMS}$ at nominal mains voltage. The voltage sense input saturates at an input current of $\pm 25\mu A$ peak.                   |
| 1, 2  | 1, 2   | 1, 2   | 1, 2   | IIN, IIP    | Inputs for current sensor. The shunt resistor voltage from each channel is converted to a current of $16\mu A_{RMS}$ at rated conditions. The current sense input saturates at an input current of $\pm 25\mu A$ peak. |
| 3     | 3      | 3      | 3      | VREF        | This pin provides the connection for the reference current setting resistor. A 24k resistor connected to $V_{SS}$ set the optimum operating condition.   |
| 5     | 8      | 6      | 12     | FOUT        | Pulse rate output. Refer to pulse output format for a description of the pulse rate.   |
|       | 4      | 4      | 4      | TP1         | Leave pins unconnected.  |
|       | 6      | 7      | 5      | TP2         |  |
|       | 7      | 8      | 6      | TP3         |  |
|       | 9      | 9      | 7      | TP4         |  |
|       | 11     | 10     | 9      | TP5         |  |
|       | 12     | 11     | 10     | TP6         |  |
|       |        | 13     | 11     | TP7         |  |
|       |        | 14     | 13     | TP8         |  |
|       |        |        | 15     | TP9         |  |
|       |        |        | 16     | TP10        |  |
|       |        |        | 17     | TP11        |  |
|       |        |        | 18     | TP12        |  |

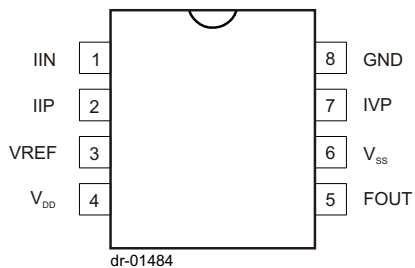


Figure 2: Pin connections: Package: DIP-8

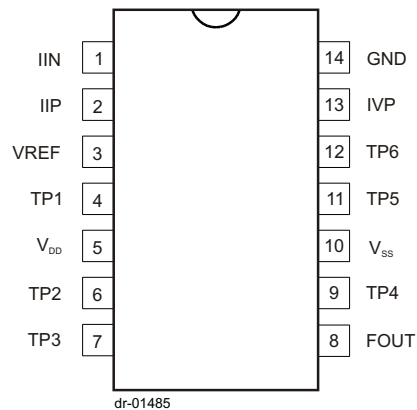


Figure 3: Pin connections: Package: DIP-14

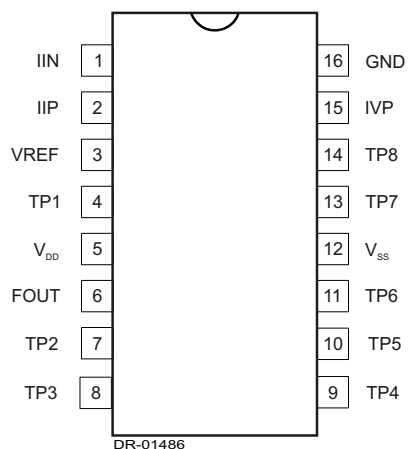


Figure 4: Pin connections: Package: SOIC-16

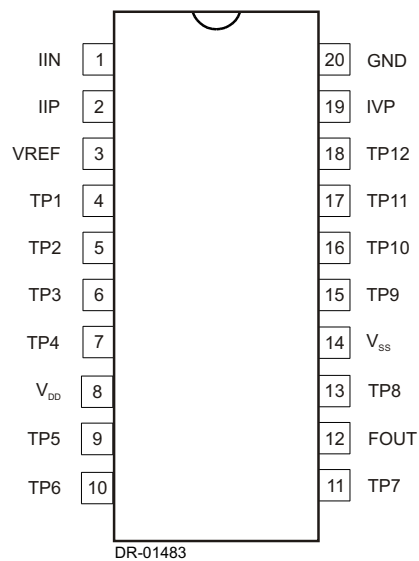


Figure 5: Pin connections: Package: DIP-20, SOIC-20

### ORDERING INFORMATION

| Part Number | Package |
|-------------|---------|
| SA2002EPA   | DIP-8   |
| SA2002EPA   | DIP-14  |
| SA2002EPA   | DIP-20  |
| SA2002ESA   | SOIC-16 |
| SA2002ESA   | SOIC-20 |



### FUNCTIONAL DESCRIPTION

The SA2002E 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.

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 cancellation procedures. The SA2002E generates pulses, the frequency of which is proportional to the measured power consumption. One frequency output (FOUT) is available. The pulse rate follows the instantaneous power consumption measured.

### POWER CALCULATION

In the application circuit (figure 6), the voltage drop across the shunt will be between 0 and 16mV<sub>RMS</sub> (0 to 80A through a shunt resistor of 200μ ) The voltage is converted to a current of between 0 and 16uA<sub>RMS</sub>, by means of resistors R1 and R2. The current sense inputs saturates at an input current of ±25μA peak.

For the voltage sensor input, the mains voltage (230VAC) is divided down through a divider (R3, R4 and P1) to 14V<sub>RMS</sub>. The current into the A/D converter input is set at 14μA<sub>RMS</sub> at nominal mains voltage, via resistor R5 (1M ). P1 may be varied for calibration purposes.

In this configuration, with a mains voltage of 230V and a current of 80A, the output frequency measured on the FOUT pin is 1360Hz. In this case one pulse on FOUT correspond to an energy consumption of 18.4kW/1360Hz = 13.53Ws.

### ANALOG INPUT CONFIGURATION

The input circuitry of the current and voltage sensor inputs is illustrated in figure 7. These inputs are protected against electrostatic discharge through clamping diodes. The feedback loops from the outputs of the amplifiers A<sub>i</sub> and A<sub>v</sub> generate virtual shorts on the signal inputs. Exact duplications of the input currents are generated for the analog signal processing circuitry.

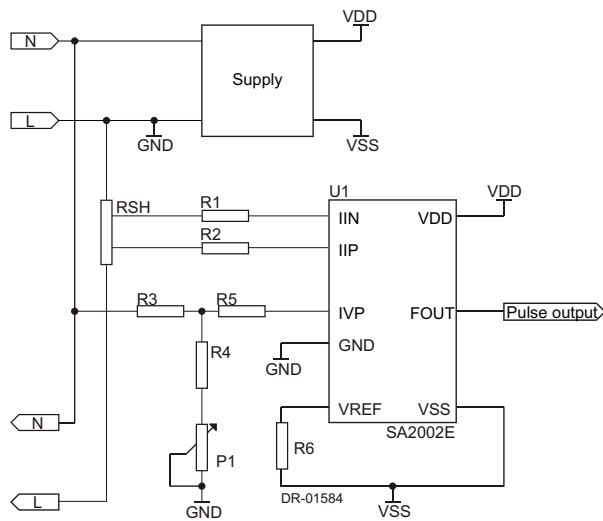
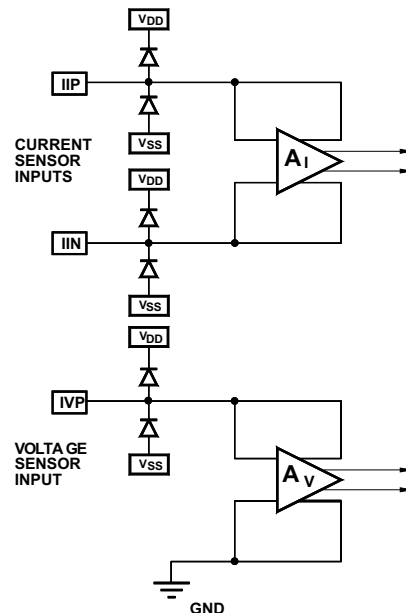


Figure 6: Application circuit



DR-01148

Figure 7: Internal analog input configuration



**ELECTROSTATIC DISCHARGE (ESD) PROTECTION**

The SA2002E integrated circuit's inputs/outputs are protected against ESD.

**POWER CONSUMPTION**

The power consumption rating of the SA2002E integrated circuit is less than 25mW.

**INPUT SIGNALS**

**VREF**

A bias resistor of 24k set optimum bias conditions on chip. Calibration of the SA2002E should be done on the voltage input as described in Typical Applications.

**Current sense input (IIP and IIN)**

Figure 6 shows the typical connections for the current sensor input. The resistor R1 and R2 define the current level into the current sense inputs of the SA2002E. At maximum rated current the resistor values should be selected for input currents of 16µA<sub>RMS</sub>.

Values for resistors R1 and R2 can be calculated as follows:

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

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 16mV<sub>RMS</sub> at rated currents.

**Voltage Sense Input (IVP)**

The current into the A/D converter should be set at 14µA<sub>RMS</sub> at nominal mains voltage. The voltage sense input saturates at an input current of ±25µA peak. Referring to figure 6 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<sub>RMS</sub>. The current into the A/D converter input is set at 14µA<sub>RMS</sub> via resistor R5.

**OUTPUT SIGNAL**

**Pulse output (FOUT)**

The output on FOUT is a pulse density signal representing the instantaneous power/energy measurement as shown in figure 8. The minimum timing characteristics are shown in the figure 9. The output frequency may be calculated using the following formula:

$f = 11.16 \times FOUT \times (I_L \times I_V) / I_R^2$

Where:

FOUT = Typical rated output frequency (1360Hz)

$I_L$  = Input current on current sense input (16µA at rated conditions)

$I_V$  = Input current on voltage sense input (16µA at rated conditions)

$I_R$  = Reference current on VREF typically 50µA

An integrated anti-creep function does not allow output pulses on FOUT if no power is measured by the device.

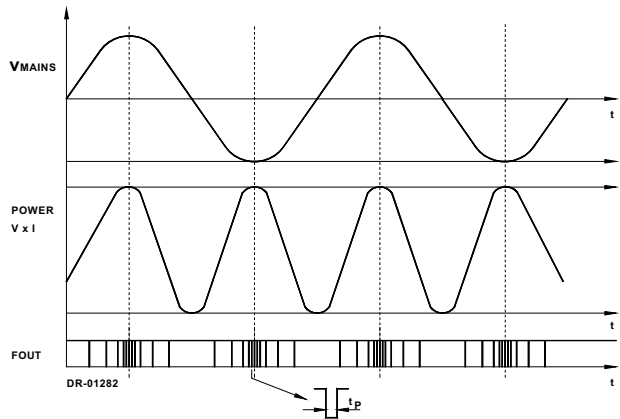


Figure 8: FOUT instantaneous pulse output

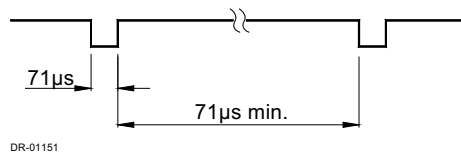


Figure 9: FOUT pulse width

**TYPICAL APPLICATION**

In figure 10, the components required for stand alone power metering application, is shown. The application uses a shunt resistor for the mains current sensing. The meter is designed for 220V/40A  $I_{MAX}$  operation. The most important external components for the SA2002E integrated circuit are the current sense resistors, the voltage sense resistors as well as the bias setting resistor.

**BIAS RESISTOR**

R13 defines all on-chip and reference currents. With R13=24k, 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. A shunt resistor with a value of 625 $\mu$  is chosen. The voltage drop across the shunt resistor is 25mV at rated conditions (Imax). The power dissipation in the current sensor is:

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

**CURRENT SENSE RESISTORS**

The resistors R6 and R7 define the current level into the current sense inputs of the device. The resistor values are selected for an input current of 16 $\mu$ A on the current inputs of the SA2002E at rated conditions. According to equation described in the Current Sense inputs section:

$$\begin{aligned} R6 = R7 &= (I_L / 16\mu A) \times RSH / 2 \\ &= 40A / 16\mu A \times 625\mu / 2 \\ &= 781.2 \end{aligned}$$

A resistor with value of 820 is chosen, the 5% deviation from the calculated value will be compensated for when calculating resistor values for the voltage path.

**VOLTAGE DIVIDER**

The voltage divider is calculated for a voltage drop of 14V + 5%(14.7V). Equations for the voltage divider in figure 9 are:

$$\begin{aligned} RA &= R1 + R2 + R3 \\ RB &= R12 || (R11+P1) \end{aligned}$$

Combining the two equations gives:  
(RA + RB) / 220V = RB / 14.7V

A 5k trimpot will be used in the voltage channel for meter calibration. The center position on the pot is used in the calculations. P1 = 2.5k and values for resistors R11 = 22k and R12 = 1M is chosen.

Substituting the values will result in:

$$\begin{aligned} RB &= 23.91k \\ RA &= RB \times (230V/14.7V - 1) = 333k \end{aligned}$$

so the resistor values of R1, R2 and R3 are chosen to be 110k

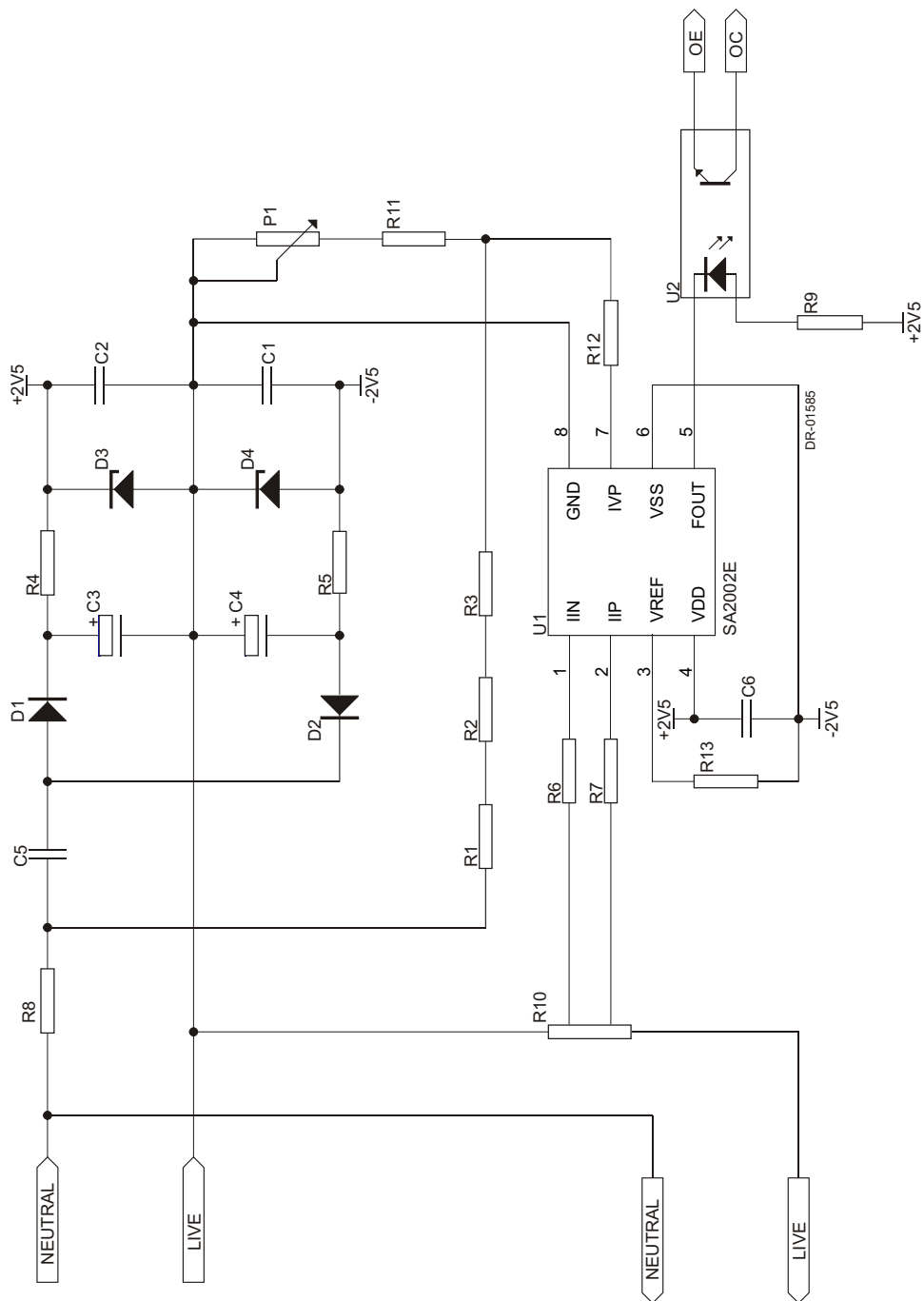


Figure 10: Application circuit using a shunt resistor for current sensing.



**Parts List for Application Circuit: Figure 10**

| Symbol | Description                         | Detail |
|--------|-------------------------------------|--------|
| U1     | SA2002E                             | DIP-8  |
| D1     | Diode, Silicon, 1N4002              |        |
| D2     | Diode, Silicon, 1N4002              |        |
| D3     | Diode, Zener, 2.4V                  |        |
| D4     | Diode, Zener, 2.4V                  |        |
| R1     | Resistor, 110k, 1/4W, 1% metal      |        |
| R2     | Resistor, 110k, 1/4W, 1% metal      |        |
| R3     | Resistor, 110k, 1/4W, 1%, metal     |        |
| R4     | Resistor, 680, 1/4W, 1%, metal      |        |
| R5     | Resistor, 680, 1/4W, 1%, metal      |        |
| R6     | Resistor, 820, 1/4W, 1%, metal      | Note 1 |
| R7     | Resistor, 820, 1/4W, 1%, metal      | Note 1 |
| R8     | Resistor, 47R, 2W, 5%, wire wound   |        |
| R9     | Resistor, 680, 1/4W, 5%, carbon     |        |
| R10    | Shunt resistor                      |        |
| R11    | Resistor, 22k 1/4W, 1%, metal       |        |
| R12    | Resistor, 1M, 1/4W, 1%, metal       |        |
| R13    | Resistor, 24k, 1/4W, 1%, metal      |        |
| P1     | Trim pot, 5k, Multi turn            |        |
| C1     | Capacitor, 220nF                    |        |
| C2     | Capacitor, 220nF                    |        |
| C3     | Capacitor, 100uF, 16V, electrolytic |        |
| C4     | Capacitor, 100uF, 16V, electrolytic |        |
| C5     | Capacitor, 330nF, 250VAC            |        |
| C6     | Capacitor, 820nF                    | Note 2 |
| U2     | 4N35, Opto Coupler                  |        |

Note 1: Resistor (R6 and R7) values are dependant on the selected shunt resistor (R14) value.

Note 2: Capacitor C6 to be positioned as close as possible to supply pins.

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