

# Programmable Single Phase Kilowatt-hour Energy IC for Mechanical Counter Application



**sames**

## SA2002P

### FEATURES

- Provides a single chip solution for energy meters with a mechanical display
- No external crystal or resonator required
- Precision on chip oscillator (<60ppm/°C drift)
- Direct stepper motor/impulse counter drive
- Calibration and setup stored on external EEPROM - no trim pots required
- Flexible programmable features
- Unidirectional and bi-directional power and energy measurement
- Can measure AC or DC energy.
- Meets the IEC 61036 Specification for Class 1 AC Watt hour meters
- Less than 1% error over a dynamic range of 1:1000
- Protected against ESD
- Total power consumption rating below 30mW
- Adaptable to different types of sensors
- Operates over a wide temperature range
- Precision on-chip voltage reference (<100ppm/°C drift)

### DESCRIPTION

The SAMES SA2002P provides a single chip solution for single phase mechanical counter based energy meters. A precision oscillator, that replaces an external crystal is integrated on chip.

The SA2002P does not require any external trim-pots. All required calibration and configuration data is read from a small external EEPROM. The data stored in the EEPROM consists of direction mode (unidirectional or bidirectional), calibration data, meter rated conditions, LED pulse rate, counter pulse width, counter resolution and creep threshold. A

programmable high frequency pulse output is available on the LED output for meter calibration purposes.

The SA2002P single phase kWh metering integrated circuit generates a pulse rate with a frequency proportional to the power consumption. The SA2002P performs active power measurement and takes the power factor into account.

The SA2002P integrated circuit is available in 16 pin dual-in-line plastic (PDIP16) and small outline (SOIC16) package types.

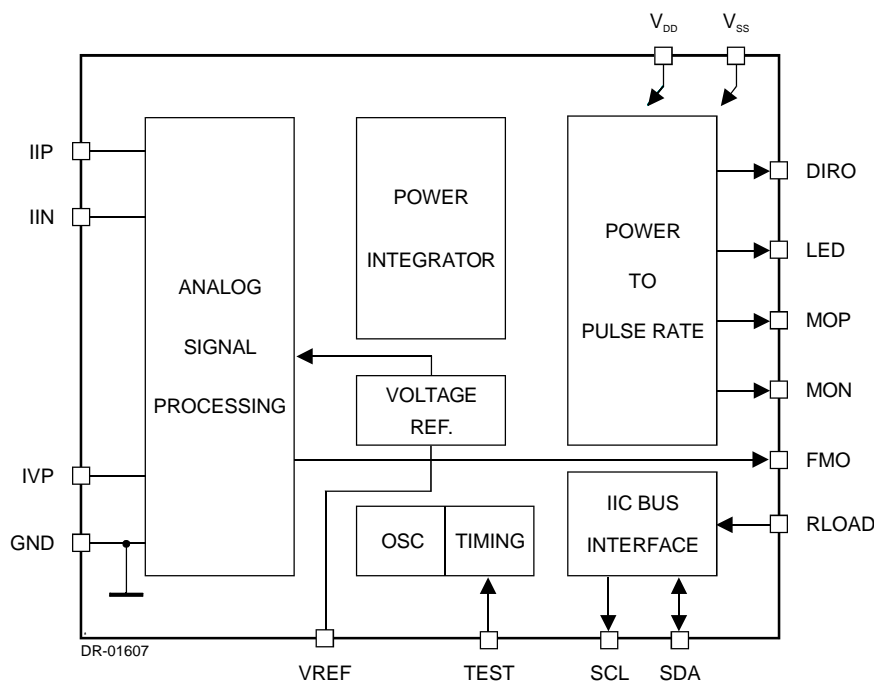


Figure 1: Block diagram

**ELECTRICAL CHARACTERISTICS**(V<sub>DD</sub> = 2.5V, V<sub>SS</sub> = -2.5V, over the temperature range -10°C to +70°C<sup>#</sup>, 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>		5	6	mA	
Supply Current: Negative	I <sub>SS</sub>		5	6	mA	
<b>Current Sensor Inputs (Differential)</b>						
Input Current Range	I <sub>II</sub>	-25		+25	µA	Peak value
<b>Voltage Sensor Input (Asymmetrical)</b>						
Input Current Range	I <sub>IV</sub>	-25		+25	µA	Peak value
Pin VREF Ref. Current Ref. Voltage	-I <sub>R</sub> V <sub>R</sub>	45 1.1	50	55 1.3	µA V	With R = 24kΩ connected to V <sub>SS</sub> Reference to V <sub>SS</sub>
<b>Digital I/O</b>						
Pins RLOAD, TEST, SDA Input High Voltage Input Low Voltage	V <sub>IH</sub> V <sub>IL</sub>	V <sub>DD</sub> -1		V <sub>SS</sub> +1	V V	
Pins MOP, MON, LED, FMO, SCL, DIRO Output High Voltage Output Low Voltage	V <sub>OH</sub> V <sub>OL</sub>	V <sub>DD</sub> -1		V <sub>SS</sub> +1	V V	I <sub>OH</sub> = -2mA I <sub>OL</sub> = 5mA
Pin SDA Pull up current	-I <sub>IL</sub>	24		54	µA	V <sub>I</sub> = V <sub>SS</sub>
Pin RLOAD, TEST Pull down current	I <sub>IH</sub>	48		110	µA	V <sub>I</sub> = V <sub>DD</sub>

<sup>#</sup>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>	3.6V	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>	-40	+85	°C

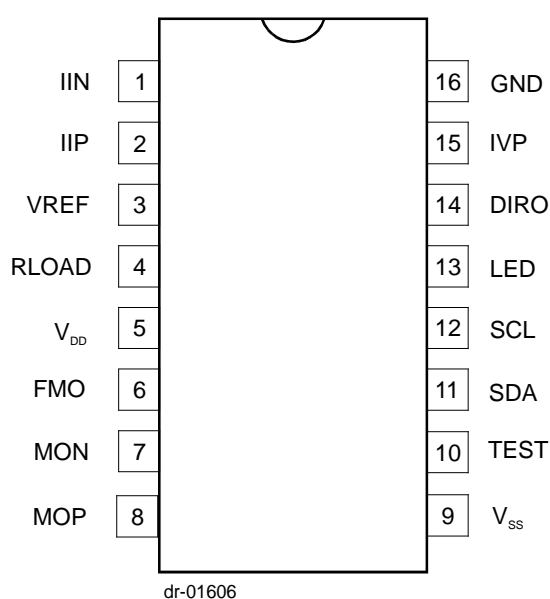
\*Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only. Functional operation of the device at these or any other condition above those indicated in the operational sections of this specification, is not implied. Exposure to Absolute Maximum Ratings for extended periods may affect device reliability.



**ATTENTION!**  
Electrostatic  
sensitive devices.  
Requires special  
handling.

**PIN DESCRIPTION**

Pin	Designation	Description
16	GND	Analog Ground. The voltage to this pin should be mid-way between $V_{DD}$ and $V_{SS}$ .
5	$V_{DD}$	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.
9	$V_{SS}$	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 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	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	VREF	This pin provides the connection for the reference current setting resistor. A $24k\Omega$ resistor connected to $V_{SS}$ set the optimum operating condition.
12	SCL	Serial clock output. This output is used to strobe data from the external EEPROM.
11	SDA	Serial data. Send and receive data from an external EEPROM.
7, 8	MON, MOP	Motor pulse outputs. These outputs can be used to drive an impulse counter or stepper motor directly.
10	TEST	Test input. For normal operation this pin must be connected to $V_{SS}$ .
13	LED	Calibration LED output. Refer to section LED Output (LED) for the pulse rate output options.
4	RLOAD	Triggers the SA2002P to reload data from the external EEPROM.
6	FMO	Mains zero crossing output.
14	DIRO	Direction output. This output indicates the energy flow direction.

**ORDERING INFORMATION**

Part Number	Package
SA2002PPA	PDIP16
SA2002PSA	SOIC16

Figure 2: Pin connections: Package: PDIP16, SOIC16



### FUNCTIONAL DESCRIPTION

The SA2002P 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 single 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.

Various pulse outputs (MOP, MON and LED) are available. The pulse rate on these pins follows the active power consumption measured.

A 5V stepper motor may be driven directly from the SA2002P by connecting it between the MOP and MON pins, alternatively an impulse counter may be driven directly by connecting it between MOP and V<sub>SS</sub>.

The SA2002P configures itself from an external low cost EEPROM that contains all meter configuration and calibration data. No external trimming is required. Calibration of the device may be fully automated.

### POWER CALCULATION

In Figure 9, the voltage drop across the shunt resistor should be more than 16mV at rated load current. The voltage is converted to current by means of resistors R<sub>10</sub> and R<sub>11</sub>. The current sense input saturates at an input current of ±25µA peak.

The mains voltage (230VAC) is divided down through a divider 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 R<sub>7</sub> (1MΩ).

See Device Configuration for more details on the processing of measured energy to frequency outputs.

### ANALOG INPUT CONFIGURATION

The input circuitry of the current and voltage sensor inputs are illustrated in figure 3. 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.

### AUTOMATIC DEVICE CONFIGURATION (BOOT UP)

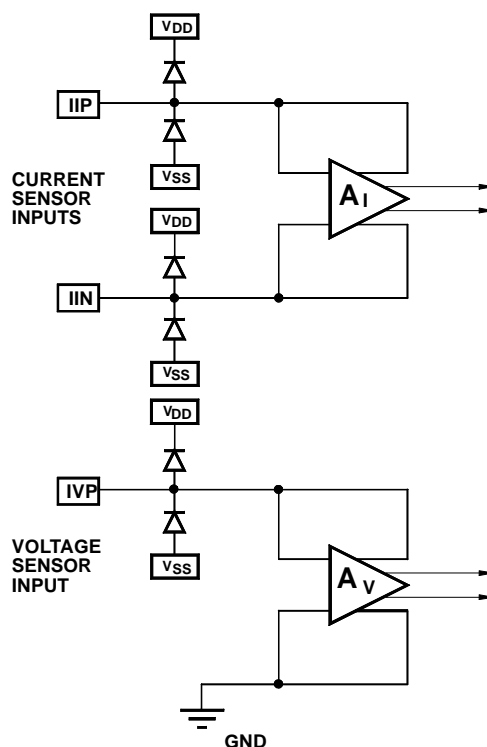
During power up, registers containing configuration and calibration information are updated from an external EEPROM. The device itself never writes to the EEPROM so any write protect features offered by manufacturer of EEPROM's may be used to protect the configuration and calibration constants of the meter. The device reloads its configuration every 1193 seconds from the external EEPROM in order to ensure correct operation of the meter. Every data byte stored in the EEPROM is protected with a checksum byte to ensure data integrity.

### ELECTROSTATIC DISCHARGE (ESD) PROTECTION

The SA2002P integrated circuit's input's/outputs are protected against ESD.

### POWER CONSUMPTION

The power consumption rating of the SA2002P integrated circuit is less than 30mW.



DR-01288

Figure 3: Analog input internal configuration



## INPUT SIGNALS

### VREF

A bias resistor of 24kΩ set optimum bias conditions on chip. Calibration of the SA2002P should be done as described in the Device Configuration section.

### Current sense input (IIP and IIN)

Figure 9 on page 11 shows the typical connections for the current sensor input. The resistor R6 and R7 define the current level into the current sense inputs of the SA2002P. At maximum rated current the resistor values should be selected for input currents of 16μA<sub>RMS</sub>.

The values for resistors R6 and R7 can be calculated as follows:

$$R6 = R7 = (IL/16\mu A) \times RSH/2$$

#### Where:

- IL = Line current or line current/CT ratio
- 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. This is to allow a variation of ±10% for the mains voltage without saturating the voltage sense input. The voltage sense input saturates at an input current of ±25μA peak. Referring to Figure 9 the typical connections for the voltage sense input is illustrated. Resistors R1, R2 and R3 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 R12.

### Serial Data (SDA)

The SDA pin connects directly to the SDA pin of an external EEPROM. The pin is used to transfer data between the EEPROM and the SA2002P. An external pull up resistor is not needed.

### Serial Clock (SCL)

The SCL pin connects directly to the SCL pin of an external EEPROM. The SCL output is used to strobe data at a rate of 50kHz out of the EEPROM. An external pull up resistor is not needed. The SCL output uses a soft driver and may be overdriven by the calibration equipment.

### Reload (RLOAD)

A falling edge on the RLOAD pin, will trigger a register update from the external EEPROM. This feature may be used during calibration to load updated register data in the SA2002P. For normal operation of the SA2002P the RLOAD pin may be left floating.

### Test Input (TEST)

The TEST input is the manufacturers test pin and must be connected to V<sub>SS</sub> for normal operation.

## OUTPUT SIGNALS

### Motor Output (MOP, MON)

The motor pulse width is programmable for 71ms, 142ms and 284ms. The MON pulse will follow the MOP pulse within the selected pulse width time. This prevents the motor armature being in the wrong position after a power failure. Both MOP and MON outputs are active high. One energy pulse is represented by a MOP pulse followed by a MON pulse. The motor drive wave forms are shown in figure 4.

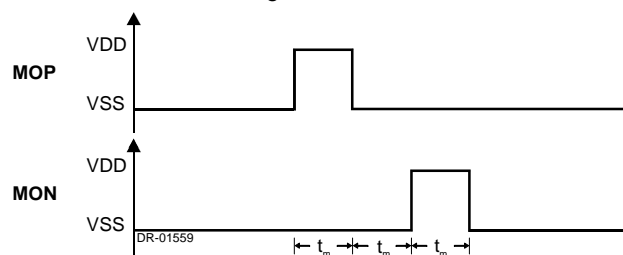


Figure 4: Motor drive on MON and MOP pins

### LED Output (LED)

The LED pin provides a pulse output and is intended for calibration purposes. Depending on register Cled the pulse rate can be either in slow mode or fast mode. When in slow mode the pulse rate is a low frequency and is proportional to the average power consumption. In fast mode the pulse rate is a programmable high frequency output proportional to the instantaneous power consumption. This mode is useful for fast calibration times or can be used to interface to a micro-controller. In slow mode the pulse width (tled) is 1ms and in fast mode tled is 71μs. The LED output is active low as shown in figure 5.

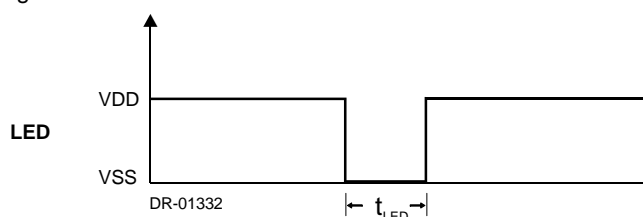


Figure 5: LED pulse output



**Mains Zero Crossing Indication (FMO)**

Figure 6 indicates the behavior of the FMO output relative to the voltage sense inputs. The square wave signal of FMO indicates the polarity of the mains voltage. Due to comparator offsets, the FMO low to high transition can occur within a range as shown in figure 6. The time between successive low to high transitions will be equal to the mains voltage period. The FMO output may be used during calibration.

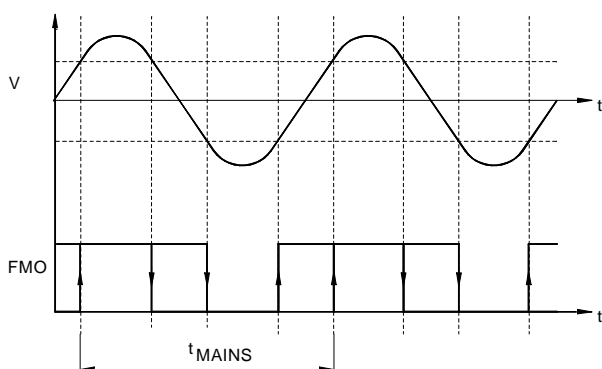


Figure 6: Mains zero crossing on FMO

**Direction Indication (DIRO)**

The SA2002P provides information about the energy flow direction on pin DIRO .

A logic 0 on pin DIRO indicates reverse energy flow. Reverse energy flow is defined as the condition where the voltage sense input and current sense input are out of phase (greater than 90 degrees).

Positive energy flow, when voltage sense and both current sense input are in phase, is indicated on pin DIRO as a logic 1 .

The DIRO pin may be used to drive a LED in order to indicate reverse energy.

Signal Output	Value	Description
DIRO	0	Reverse energy flow
	1	Forward energy flow

Figure 7 shows the behavior of DIR, when energy reversal takes place. The time period for the DIR signal to change state,  $t_{DIR}$ , is the time it takes for the internal integrator to count (down) from its present value to zero. Thus the energy consumption rate determines the speed of change on DIR.

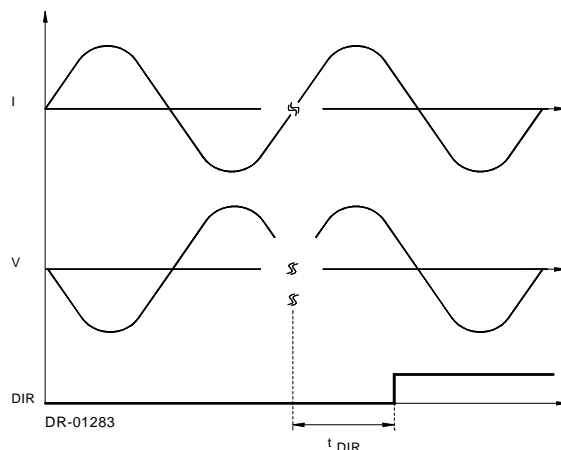


Figure 7: Measured energy direction on DIR



### DEVICE CONFIGURATION SIGNAL FLOW DESCRIPTION

The following is an overview of the SA2002P's registers. For a detailed description of each parameter please refer to parameter description section.

Figure 8 shows the various registers in the SA2002P's power to pulse rate block. The input to this block is a single bit pulse density modulated signal of 641454 pulses per second at rated conditions. The parameters *Cor*, *Ct*, *Kr*, *CresH*, *CresL*, *Pw*, *Cled*, *Dc* and *Ds* contain values which are read from the external EEPROM during power up.

The divider registers, *Pre-Divider* and *Rated Condition*, are used for gain calibration. The *Creep current threshold* register is used to set the SA2002P's creep threshold. The *Rated*

*Condition* register is also used to program the rated condition of the meter and feeds the registers *LED-constant* and *Counter Resolution* with the applicable pulse rate. These two registers are programmed to select the LED output rate and the counter resolution (pulses per kWh) respectively. The *Counter Pulse Width* register is used to program the pulse width for the mechanical counter driver output MOP and MON.

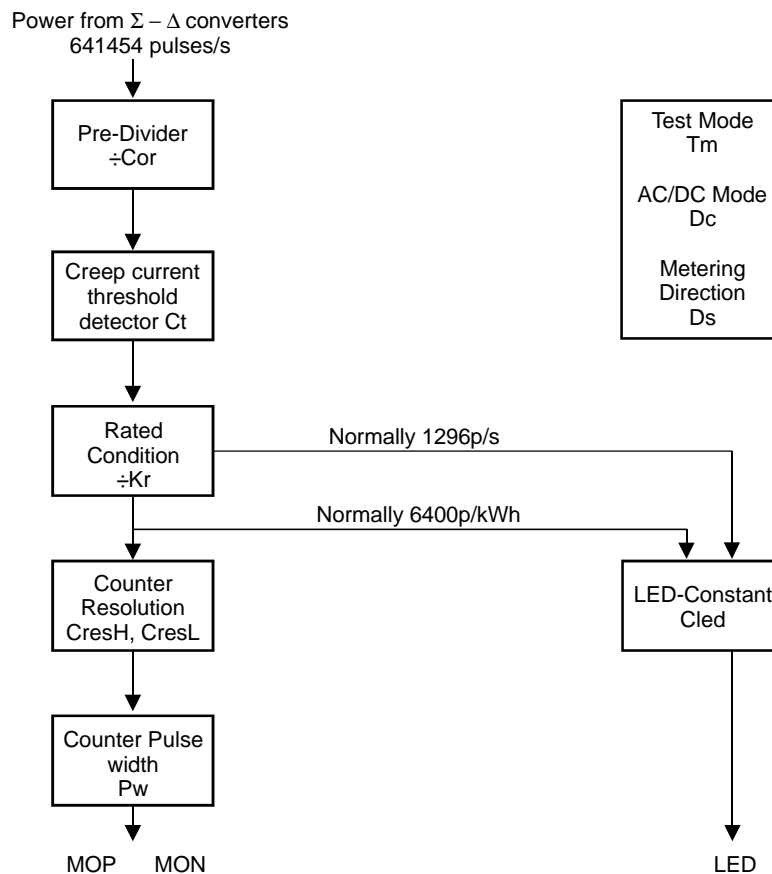


Figure 8: Signal flow block diagram

**EEPROM Memory Allocation**

The eeprom address range 0 to 11 contains a pre-amble, which is made up as follows:-

- even addresses contains 0x00 [0,2,4,6,8,10]
- odd addresses contains 0xff [1,3,5,7,9,11]

The following table shows the EEPROM memory allocated as well as the corresponding name. The odd address always contains the one's complement of the previous even address.

Description	E <sup>2</sup> Address	Contents	Bit [7:0]	Name
Pre-Divider	12	Cor	---v vvvv	D12
	13	NOT of ADDR 12	xxxx xxxx	
Creep current threshold	14	Ct	---- -v-	D14
Metering direction select	14	Ds	---- -v--	D14
DC or AC measurement mode	14	Dc	---- v---	D14
	15	NOT of ADDR 14	xxxx xxxx	
Rated Condition	16	Kr	vvvv vvvv	D16
	17	NOT of ADDR 16	xxxx xxxx	
Led Pulse-rate	18	Cled	---- -vv	D18
	19	NOT of ADDR 18	xxxx xxxx	
Counter Resolution (LSB)	20	CresL	vvvv vvvv	D20
	21	NOT of ADDR 20	xxxx xxxx	
Counter Resolution (MSB)	22	ClresH	---v vvvv	D22
Counter Pulse-Width	22	Pw	vv-- ----	
	23	NOT of ADDR 22	xxxx xxxx	

KEY: (- = DON'T CARE); (V = VALUE/PARAMETER); (0,1 = LOGICAL VALUE); (X = BIT-NOT)

*Table 1: EEPROM memory allocation map*

The eeprom address range 24 to 31 contains an epilogue, which is made up as follows:-

- even addresses contains 0x00 [24,26,28,30]
- odd addresses contains 0xff [25,27,29,31]



**PARAMETER DESCRIPTION**

Refer to the EEPROM memory allocation map table 1 as well as the Signal flow diagram figure 8, for a description of the registers used in this section.

**Pre-Divider (Cor), Rated Condition (Kr) and LED Pulse-rate (Cled) registers**

The Cor register divides the pulse-modulated signal with a programmable value of 495 with a variation of  $\pm 3.2\%$  (481 to 512). Only the 5 least significant bits are required for this register. The Kr register is used to program the rated conditions of the meter. This feature is required for correct counter increments using the same meter design for various meter ratings from less than 10A to several 100A.

The Kr register can have any integer value up to 128. The pulse rate is then further divided down by the Cled register to provide the required LED pulse rate. The Cled register provides 4 different dividing factors namely 1, 2, 4 and fast mode. In fast mode the LED pulse output is a programmable high frequency output and is proportional to the instantaneous power consumption. This mode is useful for faster calibration times or can be used to interface to a micro-controller. Refer to figure 5 for the LED output timing diagram.

The divider registers Cor and Kr are used for gain calibration. These two registers used together with the LED pulse-rate register (Cled) will generate the required meter constant (pulses per kWh). The following formula can be used to calculate Cor, Kr and Cled:

$$M = \frac{641454}{\text{Cor} \times \text{Kr}} \times \frac{3600}{((\text{Unom} \times \text{Imax})/1000)} \times \text{Cled}$$

**Where:**

- M = Meter constant (pulses per kWh)
- Unom = Meters nominal voltage
- Imax = Meters maximum current rating
- Cor = 495 default value, and can be varied by  $\pm 3.2\%$  (481 to 512, integer values only).
- Kr = 8 bit register having any integer value up to 128.

Cled depends on the two bits of byte D18:

D18[1]	D18[0]	Cled dividing factor
0	1	1
1	0	2
1	1	4
0	0	This sets the LED pulse rate to fast mode of 641454/ Cor pulses per second. Default would be 641454/495 = 1296 pulses/sec.

The initial value of Kr can be calculated from the above formula using Cor's default value 495 as follows:

$$\text{Krx} = 641454 / \text{Unom} / \text{Imax} / \text{M} \times 3600 \times 1000 / 495$$

The SA2002P's internal counter counts from zero so a one must be subtracted from Kr:

$$\text{Kr} = \text{Round}(\text{Krx}) - 1$$

**Where:**

Krx is the real value and Kr is the integer value.

Once Kr has been established Cor can be calculated as follows:

$$\text{Corr} = 495 \times (1 + (\text{Krx} - (\text{Kr} + 1)) / \text{Kr})$$

$$\text{Cor} = \text{Round}(\text{Corr}) - 1$$

Where Corr is the real value and Cor the integer value.

Cor is made up of bits 0 to 4 of byte D12

Kr is made up of 1 byte (D16)

For further information see the example on calculating Kr and Cor.

**Counter Resolution (Cres)**

A 13 bit divider divides the pulse rate from the rated conditions divider down to the desired counter resolution.

Cres can be calculated using the following formula:

$$\text{Counter pulses / kWh} = \frac{\text{LED pulses / kWh}}{\text{Cres}}$$

Cres is made up of bits 0 to 6 of byte D21 and byte D20.

D21[4:0]	D20[7:0]	Counter Resolution
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**Counter Pulse-Width (Pw)**

The pulse width for the mechanical counter driver output is selectable to accommodate various step-motor and impulse-counter requirements.

Pw is made up of bits 7 and 6 of byte D22.

D22[7]	D22[6]	Counter Pulse-Width
1	-	284 ms
0	1	142 ms
0	0	71 ms

**Creep Current Threshold (Cs)**

The creep threshold is expressed relative to the rated current of the meter. The SA2002P will not meter currents below the



creep threshold. The creep threshold is implemented to prevent the meter from accumulating energy when no load is connected.

Cs is made up of bit 0 of byte D14.

D14[0]	Creep threshold
0	0.02% of rated current
1	0.01% of rated current

#### Metering direction select (Ds)

The SA2002P may be configured to measure positive energy or positive and negative energy.

Ds is made up of bit 2 of byte D14.

D14[2]	Metering direction select
0	Bi-directional energy measurement
1	Positive energy measurement

#### DC or AC measurement mode (Dc)

The SA2002P may be configured to measure AC or DC energy. In case of AC measurement selection, the device will track the mains frequency for offset cancellation purposes. In DC measurement mode the device is locked to a fixed frequency for offset cancellation. The FMO output is switched to 28Hz in DC mode.

Dc is made up of bit 3 of byte D14.

D14[3]	DC or AC measurement mode
0	AC measurement mode
1	DC measurement mode

#### Example of calculating Kr and Cor values

Metering specifications:

Unom = 230V  
 I<sub>max</sub> = 80A  
 Meter constant = 6400 p/kWh

Calculate the Kr value:

$$Krx = 641454 / Unom / I_{max} / M \times 3600 \times 1000 / 495$$

$$Krx = 641454 / 230 / 80 / 6400 \times 3600 \times 1000 / 495$$

$$Krx = 39.61549$$

$$Krx = 40 \text{ (round Krx up to convert to integer)}$$

$$Kr = Krx - 1$$

$$Kr = 39$$

The value 39 is stored in the Kr register. The pre-divider (Cor) value is calculated next. Cor is programmable to divide between 481 and 512. Only the 5 least significant bits need to

be programmed. During the Kr calculation the value was rounded up and any rounding error is now taken into account. A ratio of the rounding "error" is calculated relative to the center of the variable range of Cor (481 - 512).

$$Corr = 495 \times (1 + (Krx - (Kr + 1)) / Krx)$$

$$Corr = 495 \times (1 + (39.61549 - 40) / 39.61549)$$

$$Corr = 495 \times 0.990294$$

$$Corr = 490.1955$$

$$Corr = 490 \text{ (Convert to Integer)}$$

$$Cor = Corr - 1$$

$$Cor = 489$$

Store the calculated values in the EEPROM

Ensure that the device reload its registers from the EEPROM by means of the RLOAD pin or power down the meter and power up again.

The meter is now set up with the correct register values but not yet calibrated.

#### The following example shows how to calibrate the meter

Measure the %Error with a Watt hour standard

$$\%Error = (Measured\ Energy - Real\ Energy) / Real\ Energy \times 100$$

The %Error will be worked back into the calculations above. For this example we will assume a 2.83% error between the correct energy value and energy measured by the SA2002P.

Recalculate the Kr value

$$Krx = 641454 / Unom / I_{max} / M \times 3600 \times 1000 / 495 \times (1 + \%Error / 100)$$

$$Krx = 641454 / 230 / 80 / 6400 \times 3600 \times 1000 / 495 \times 1.0283$$

$$Krx = 40.73661$$

$$Krx = 41 \text{ (Round up and make integer value)}$$

$$Kr = Krx - 1$$

$$Kr = 41 - 1$$

$$Kr = 40$$

The value 40 is stored in the Kr.

The Cor value must be recalculated.

$$Corr = 495 \times (1 + (Krx - (Kr + 1)) / Krx)$$

$$Corr = 495 \times (1 + (40.7366 - 41) / 40.7366)$$

$$Corr = 495 \times 0.993534$$

$$Corr = 491.7995$$

$$Corr = 492 \text{ (Convert to Integer)}$$

$$Cor = Corr - 1$$

$$Cor = 491$$

Store the calculated values in the EEPROM and the meter is calibrated.



## TYPICAL APPLICATION

The analog (metering) interface described in this section is designed for measuring 230V/40A with Class 1 precision.

The most important external components for the SA2002P integrated circuit are the current sense resistors, the voltage sense resistors and the bias setting resistor. The resistors used in the metering section should be of the same type so temperature effects are minimized.

### Reference Voltage Bias resistor

R6 defines all on chip and reference currents. With  $R13 = 24k\Omega$  optimum conditions are set.

### Shunt Resistor

The voltage drop across the shunt resistor at rated current should be at least 20mV. A shunt resistor with a value of  $625\mu\Omega$  is chosen. The voltage drop across the shunt resistor is 25mV at rated conditions ( $I_{max}$ ). The power dissipation in the current sensor is:

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

### 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 SA2002P at rated conditions.

According to equation described in the current sense inputs section:

$$\begin{aligned} R6 = R7 &= (I_i / 16\mu A) \times R_{SH} / 2 \\ &= 40A / 16\mu A \times 625\Omega / 2 \\ &= 781.25\Omega \end{aligned}$$

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

### Voltage Input IVP

The voltage input of the SA2002P (IVP) is driven with a current of  $14\mu A$  at nominal mains voltage. This voltage input saturates at approximately  $17\mu A$ . At a nominal voltage current of  $14\mu A$  allows for 20% overdriving. The mains voltage is divided with a voltage divider to 14V that is fed to the voltage input pins via a  $1M\Omega$  resistor.

### Voltage Divider

The voltage divider is calculated for a voltage drop of  $14V + 5\%$  (14.7V). Equations for the voltage divider in figure 4 are:

$$\begin{aligned} R_B &= R1 + R2 + R3 + R8 \\ R_B &= R11 \parallel R12 \end{aligned}$$

Combining the two equations gives:

$$(R_A + R_B) / 230V = R_B / 14.7V$$

Values for resistors  $R8 = 10\Omega$ ,  $R11 = 24k\Omega$  and  $R12 = 1M\Omega$  is chosen.

Substituting the values result in:

$$\begin{aligned} R_B &= 23.437k\Omega \\ R_A &= R_B \times (230V / 14.7V - 1) \\ R_A &= 343.27k\Omega. \end{aligned}$$

Standard resistor values of  $R1$ ,  $R2$  and  $R3$  are chosen to be  $150k\Omega$ ,  $150k\Omega$  and  $43k\Omega$ .

A combination for  $R1$ ,  $R2$  and  $R3$  with  $110k$ ,  $110k$  and  $110k$  would also be sufficient.

### Programming

In order for the meter to function correctly the EEPROM must be programmed with the relevant parameters eg. LED pulse rate, Motor pulse rate, Creep threshold, AC mode measurement direction and rated current.

The calibration is performed as described in the previous section.

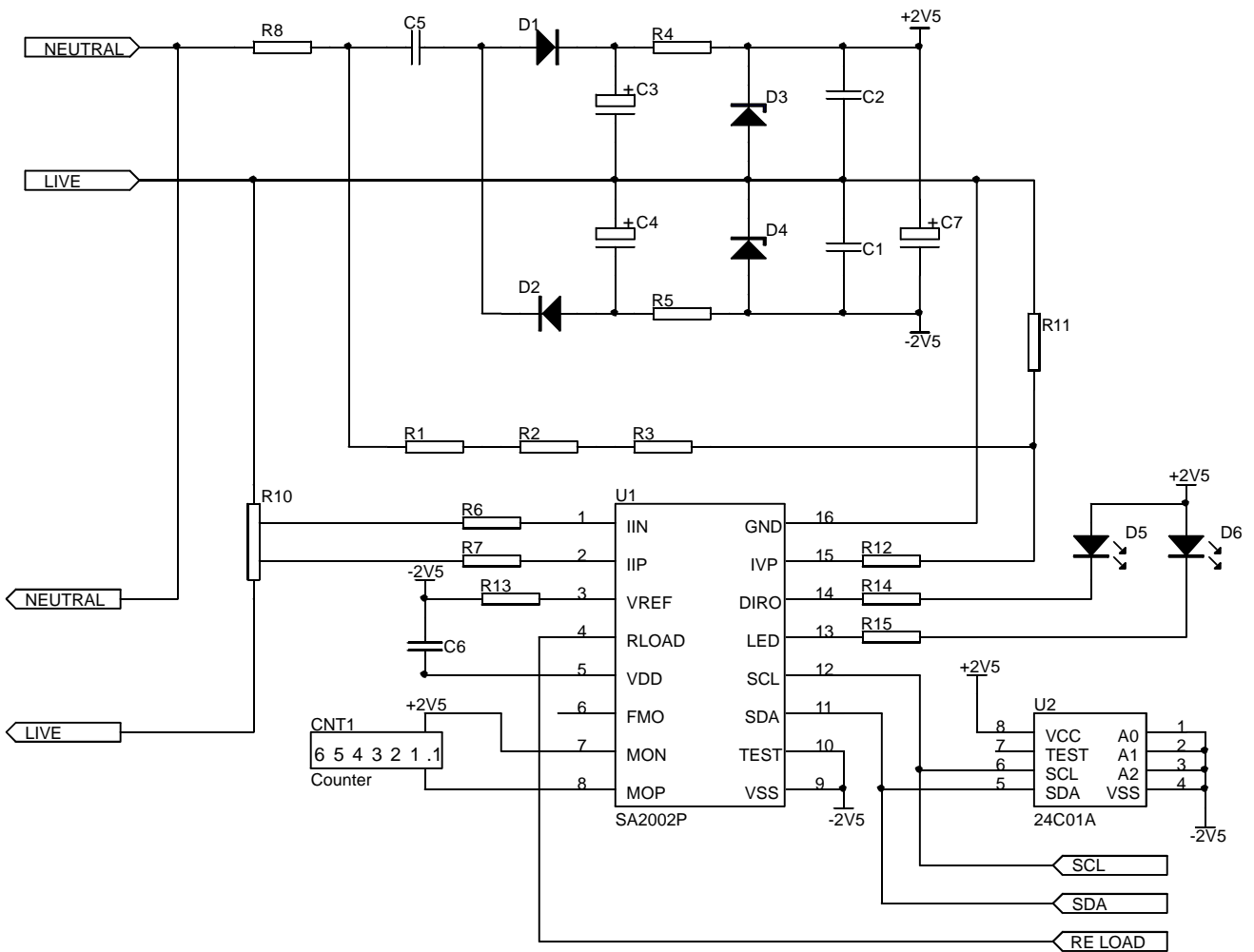


Figure 9: Typical application circuit



## Parts List for Application Circuit: Figure 7

Item	Symbol	Description	Detail
1	U1	SA2002P	PDIP16 / SOIC16
2	U2	AT24C01, or equivalent device	
3	D1	Diode, Silicon 1N4007	
4	D2	Diode, Silicon 1N4007	
5	D3	Diode, Zener, 2.4V	
6	D4	Diode, Zener, 2.4V	
7	D5	Light emitting diode, Red	
8	D6	Light emitting diode, Green	
9	R1	Resistor, 150k, 1/4W, 1%, metal	
10	R2	Resistor, 150k, 1/4W, 1%, metal	
11	R3	Resistor, 43k, 1/4W, 1%, metal	
12	R4	Resistor, 100Ω, 1/4W, 1%, metal	
13	R5	Resistor, 100Ω, 1/4W, 1%, metal	
14	R6	Resistor, 1/4W, 1%, metal	Note 1
15	R7	Resistor, 1/4W, 1%, metal	Note 1
16	R8	Resistor, 10Ω, 2W, Wire wound	
17	R10	Shunt resistor, 625μΩ	
18	R11	Resistor, 24k, 1/4W, 1%, metal	
19	R12	Resistor, 1M, 1/4W, 1%, metal	
20	R13	Resistor, 24k, 1/4W, 1%, metal	
21	R14	Resistor, 1k, 1/4W, 5%, carbon	
22	R15	Resistor, 1k, 1/4W, 5%, carbon	
23	C1	Capacitor, 220nF	
24	C2	Capacitor, 220nF	
25	C3	Capacitor, 200uF, 16V, electrolytic	
26	C4	Capacitor, 200uF, 16V, electrolytic	
27	C5	Capacitor, 470nF, 250VAC	
28	C6	Capacitor, 820nF	Note 2
29	C7	Capacitor, 2200μF, 25V, electrolytic	
30	CNT1	Bipolar step motor	

**Note 1:** See TYPICAL APPLICATION when selected the value of R6 and R7.

**Note 2:** Capacitor (C6) to be positioned as closed to Supply Pins ( $V_{DD}$  &  $V_{SS}$ ) of U-1, as possible.

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