

# Programmable Three Phase Power / Energy Metering IC for Stepper Motor / Impulse Counter Applications



**sames**

## SA2005P

### FEATURES

- Direct drive for electro-mechanical counters or stepper motors
- Calibration and setup stored on external EEPROM - no trim-pots required
- Flexible programmable features providing ease of implementation for meter manufacturers
- Per phase energy direction and voltage fail indication
- Precision oscillator on chip
- Meets the IEC 521/1036 Specification requirements for Class 1 AC Watt hour meters
- Operates over a wide temperature range
- Easily adaptable to different signal levels
- Adaptable to different types of sensors
- Precision voltage reference on-chip
- Protected against ESD

### DESCRIPTION

The SAMES SA2005P provides a single chip active energy metering solution for three phase mechanical counter-based meter designs.

The SA2005P does not require any external trim-pots or resistor ladders for meter calibration. Calibration and meter configuration information is stored on a small external EEPROM.

Meter setup stored on the EEPROM includes various metering direction modes (total sum, absolute sum, positive or negative energy) phase calibration data, rated metering conditions, LED pulse rate, counter pulse width, counter resolution and creep current.

A programmable rate pulse output is available for meter calibration purposes. Per phase voltage fail and voltage sequence faults as well as energy direction indication are available as LED outputs. Programmable dividers enable various mechanical counter or stepper motor counter resolutions.

A precision oscillator, that replaces an external crystal, is integrated on chip. A voltage reference is integrated on chip.

The SA2005P integrated circuit is available in 24-pin dual in line plastic (DIP-24) and small outline (SOIC-24) package options.

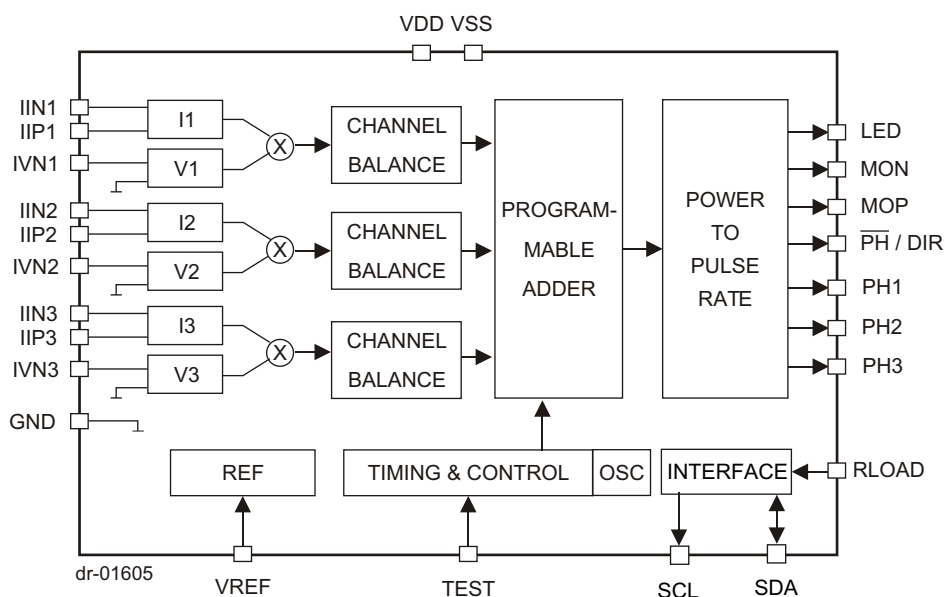


Figure 1: Block diagram

**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>		15	16	mA	
Supply Current: Negative	I <sub>SS</sub>		15	16	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 = 24k 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, SCL, PH/DIR, PH1, PH2, PH3 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>
Pins TEST, RLOAD Pull down current	I <sub>IH</sub>	48		110	µA	V <sub>I</sub> = V <sub>DD</sub>

#Extended Operating Temperature Range available on request.

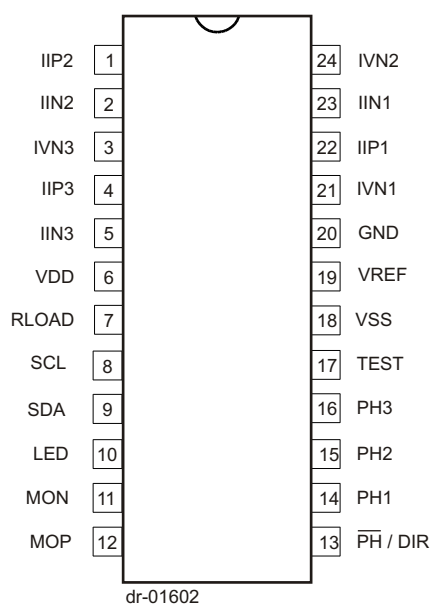
**ABSOLUTE MAXIMUM RATINGS\***

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>	-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.

**PIN DESCRIPTION**

PIN	Designation	Description
20	GND	Analog Ground. The voltage to this pin should be mid-way between $V_{DD}$ and $V_{SS}$ .
6	$V_{DD}$	Positive supply voltage. Typically +5V if a current transformer is used for current sensing.
18	$V_{SS}$	Negative supply voltage. Typically 0V if a current transformer is used for current sensing.
21, 24, 3	IVN1, IVN2, IVN3	Voltage sense inputs. 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.
23, 22, 2, 1, 5, 4	IIN1, IIP1, IIN2, IIP2, IIN3, IIP3	Inputs for current sensors. The termination resistor voltage from each current transformer 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.
19	VREF	This pin provides the connection for the reference current setting resistor. A 24k resistor connected to $V_{SS}$ sets the optimum operating condition.
8	SCL	Serial clock output. This output is used to strobe data from the external EEPROM.
9	SDA	Serial data. Send and receive data from an external EEPROM.
17	TEST	Test input. For normal operation connect this pin to $V_{SS}$ .
10	LED	Calibration LED output. Refer to section Led Output (LED) for the pulse rate output options.
11, 12	MON, MOP	Motor pulse outputs. These outputs can be used to drive an impulse counter or stepper motor directly.
13	$\overline{PH}$ / DIR	Multiplexed phase or direction driver output.
7	RLOAD	Triggers a data reload from the external EEPROM.
14, 15, 16	PH1, PH2, PH3	Multiplexed LED drivers for direction and mains fail indication.

**ORDERING INFORMATION**

Part Number	Package
SA2005PPA	DIP-24
SA2005PSA	SOIC-24

Figure 2: Pin connections: Package: DIP-24, SOIC-24



### FUNCTIONAL DESCRIPTION

The SAMES SA2005P is a CMOS mixed signal analog/digital integrated circuit that performs three phase 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 3-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 integrated circuit includes all the required functions for a three phase mechanical counter-based meter design. A precision oscillator, that replaces an external crystal, is integrated on chip providing a temperature stable time base for the digital circuitry. A temperature stable voltage reference integrated on chip generates the reference current used by the analog circuitry.

Voltage and currents are sampled simultaneously by means of a sigma delta modulator type ADC and power is calculated for each individual phase. A programmable channel balance on each channel is used for individual channel calibration.

The scaled power is fed to a programmable adder that allows the representation of the measured energy to be either total sum or absolute sum.

The summed power is integrated and divided down to represent integrated energy. Pulses on the LED output and on the mechanical counter outputs represent measured amounts of energy. The programmable dividers provide flexible counter and calibration LED resolutions.

Outputs for phase voltage fail and voltage sequence faults and energy direction are available.

The SA2005P does not require any external trim-pots or resistor ladders as meter calibration and configuration data is stored on a small external EEPROM. The SA2005P configures itself from the EEPROM during power up. These features enables meter manufacturers flexible meter designs from a single integrated circuit.

### AUTOMATIC DEVICE CONFIGURATION (BOOT UP)

During power up, registers containing configuration and calibration information is 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 constant 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 SA2005P integrated circuit's inputs/outputs are protected against ESD.

### POWER CONSUMPTION

The overall power consumption rating of the SA2005P integrated circuit is less than 80mW with a 5V supply.

### INPUT SIGNALS

#### ANALOG INPUT CONFIGURATION

The current and voltage sensor inputs are illustrated in figure 3. These inputs are protected against electrostatic discharge through clamping diodes, in conjunction with the amplifiers input configuration. 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 processing circuitry. The current and voltage sense inputs are identical. Both inputs are differential current driven up to  $\pm 25\mu A$  peak. One of the voltage sense amplifiers input terminals is internally connected to GND. This configuration is possible because the voltage sense input is much less sensitive to externally induced parasitic signals compared to the current sense inputs.

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

The current sense inputs connect to a termination resistor connected across the terminals of a current transformer. At

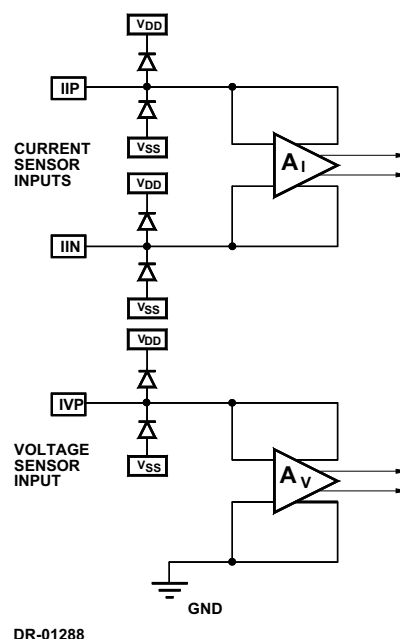


Figure 3: Analog input internal configuration



rated current the resistor values should be selected for input currents of  $16\mu A_{RMS}$ . Referring to figure 8, the resistors R1 and R2 on current channel 1, resistors R3 and R4 on current channel 2 and resistors R5 and R6 on current channel 3, define the current level into the current sense inputs of the SA2005P. The current sense inputs saturates at an input current of  $\pm 25\mu A$  peak. Resistors R29, R30 and R31 are used as current transformer termination resistors. The voltage drop across the termination resistors should be at least 20mV at rated conditions. Values for the current sense inputs are calculated as follows:

$$R_1 = R_2 = ( I_L / 16\mu A_{RMS} ) \times R_{29} / 2$$

$$R_3 = R_4 = ( I_L / 16\mu A_{RMS} ) \times R_{30} / 2$$

$$R_5 = R_6 = ( I_L / 16\mu A_{RMS} ) \times R_{31} / 2$$

Where:

$I_L$  = Line current/CT-ratio

In case a current transformer is used for current sensing the value of the termination resistors should be less than the resistance of the CT's secondary winding.

### Voltage Sense Inputs (IVN1, IVN2, IVN3)

The mains voltage are measured by means of a resistor divider and the divided voltage are converted to a current. The current into the voltage sense inputs (virtual ground) should be set to  $14\mu A_{RMS}$  at rated voltage conditions. The individual mains voltages are divided down to  $14V_{RMS}$  per phase. The resistors R12, R13 and R14 (figure 8) set the current for the voltage sense inputs. The voltage sense inputs saturate at an input current of  $\pm 25\mu A$  peak.

### Voltage Reference Connection (VREF)

A bias resistor of 24k provides an optimum bias conditions on chip. Calibration of the SA2005P is done by means of divider ratios stored on an external EEPROM. This is described in the Device Configuration section.

### 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 SA2005P. An external pull-up resistor is not needed.

### Serial Clock (SCL)

The SCL pin connects directly to the SCL 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 SA2005P. For normal operation of the SA2005P the RLOAD pin may be left floating.

### Test Inputs (TEST)

The TEST input is the manufacturers test pin and must be connected to VSS in a metering application.

## OUTPUT SIGNALS

### LED Output (LED)

Four options for the LED output pulse rate are available, 6400, 3200, 1600 pulses per kWh, and a pulse rate of 1252 pulses per second at rated conditions. At 1252 pulses per second  $t_{LED}$  is  $71\mu s$ , for the other options  $t_{LED}$  is 10ms. The LED output is active low as shown in figure 4.

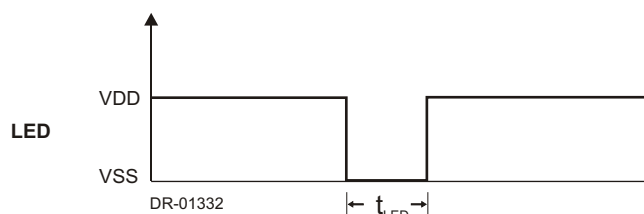


Figure 4: LED pulse output

### 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. A MOP pulse followed by a MON pulse represents one energy pulse. The motor drive waveforms are shown in figure 5.

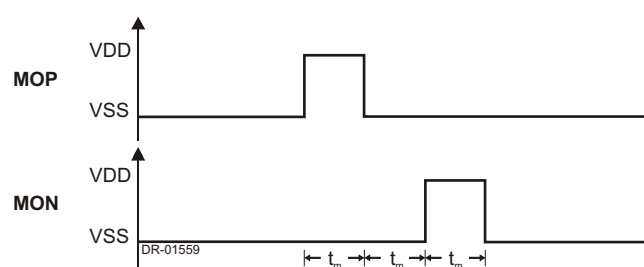


Figure 5: Motor drive on MON and MOP pins of device

### Multiplex Output (PH/ DIR)

The PH/DIR output enables either direction or voltage information on the phase LED driver outputs (PH1, PH2 and PH3). This multiplex output switches between logic 1 and 0 at a frequency of approximately 280Hz. A logic 1 enables energy direction information on the LED driver outputs and a logic 0 enables voltage information.



The  $\overline{\text{PH/Dir}}$  output is used in conjunction with the LED driver outputs to display information about each individual phase, see figure 6.

**Phase LED Drivers (PH1, PH2, PH3)**

The LED driver outputs present either direction information or voltage information. The three LED driver outputs are used in conjunction with the  $\overline{\text{PH/Dir}}$  output to display information about each individual phase (refer to figure 6) as follows:

**$\overline{\text{PH/Dir}} = 1$  (Direction indication)**

When  $\overline{\text{PH/Dir}}$  is high (logic 1) energy direction information for each individual phase is available on PH1, PH2 and PH3. A logic 0 indicates reverse energy flow and a logic 1 indicates positive energy flow. Reverse energy flow is defined as the condition where the voltage sense input and the current sense

inputs are out of phase (greater than 90 degrees). Positive energy flow is defined as the condition where the voltage sense and current sense inputs are in phase.

**$\overline{\text{PH/Dir}} = 0$  (Voltage fail / phase sequence error)**

When  $\overline{\text{PH/Dir}}$  is low (logic 0) voltage information is available on PH1, PH2 and PH3. A logic 0 on any of these pins indicates a voltage failure, the SA2005P does not detect a zero crossing on the applicable voltage sense input. Referring to figure 6 the voltage fail LED will be on when the voltage phase is present and off when the voltage phase is missing.

In the case of a phase sequence error all three LED driver outputs PH1, PH2 and PH3 will pulse with a repetition rate of approximately 1Hz.

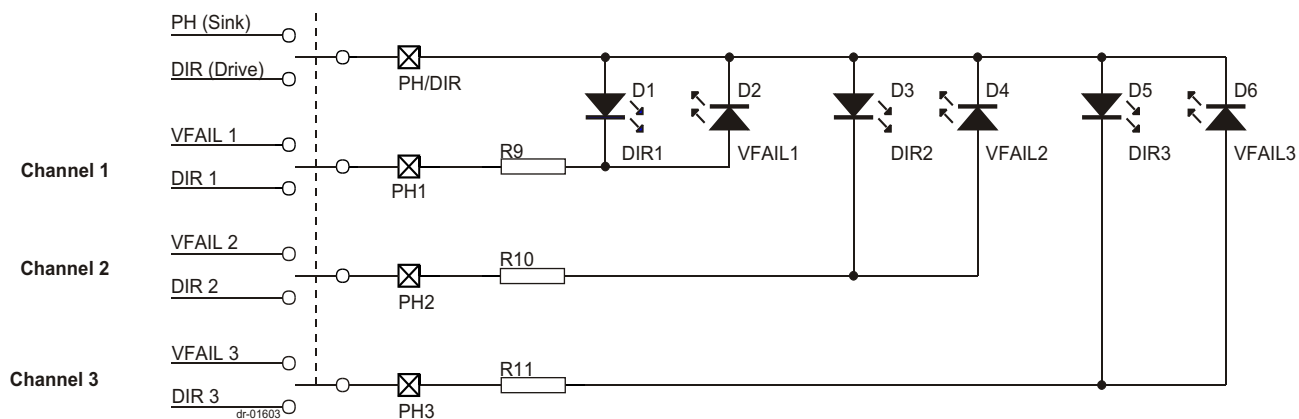


Figure 6: Multiplexing of the LED Drivers

**ANTI-TAMPER CONDITIONS**

The SA2005P cater for the following meter tamper conditions and are indicated as follows:

<b>Method</b>	<b>Description</b>	<b>Result</b>
Phase Voltages	One LED is provided for each phase to indicate abnormal operating conditions.	During normal conditions, the LEDs are continuously switched on.
Phase Failure, no voltage	In case of a phase failure, the corresponding LED is switched off.	The SA2005P will record the energy consumption accurately under this condition
Phase Sequence Error	In case of phase sequence error, all LEDs are flashing with a repetition rate of approximately 1 Hz. A connection of a line voltage to the neutral terminal would be indicated in the same way.	The SA2005P will record the energy consumption accurately under this condition
Input / Output Terminals Interchanged	One LED is provided for each current sensor to indicate reverse energy flow. If detected, the corresponding LED is switched on. The SA2005P can be configured to accumulate the absolute energy consumption for each phase measured, irrespective of the direction of the energy flow.	The SA2005P will record the energy consumption accurately under this condition
Missing Neutral Connection	The architecture of the meter should provide for a good "phantom neutral" in cases where the neutral is disconnected from the meter.	In this case, the meter would register the energy consumption correct.
Return through Earth	The SA2005P will therefore record the energy consumption accurately under this condition.	A indication for this condition could be realized external to the IC.
Load Imbalance		The SA2005P will record the energy consumption accurately under this condition
Calibration	The calibration data is stored in an EEPROM. There are no trim-pots required in this design.	The meter can not be re-adjusted, only reprogrammed.



**DEVICE CONFIGURATION  
SIGNAL FLOW DESCRIPTION**

The following is an overview of the SA2005P's registers. For a detailed description of each parameter please refer to parameter description section. Figure 7 shows the various registers in the SA2005P's power to pulse rate block. The inputs to this block are three single bit pulse density modulated signals, each having a pulse rate of 641454 pulses per second at rated conditions. The parameters *Cb1*, *Cb2*, *Cb3*, *Sum*, *Ct*, *Kr*, *CresH*, *CresL*, *Cled* and *Pw* contain values that are read from the external EEPROM during power up.

The *Pre-Divider* registers are used for calibration and to balance the gain of each channel. The *Programmable Adder* is used to select between the total sum or absolute sum of the measured energy. The *Creep current threshold detector* selects the creep current which is relative to the meters rated current. The *Rated Condition* register is 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.

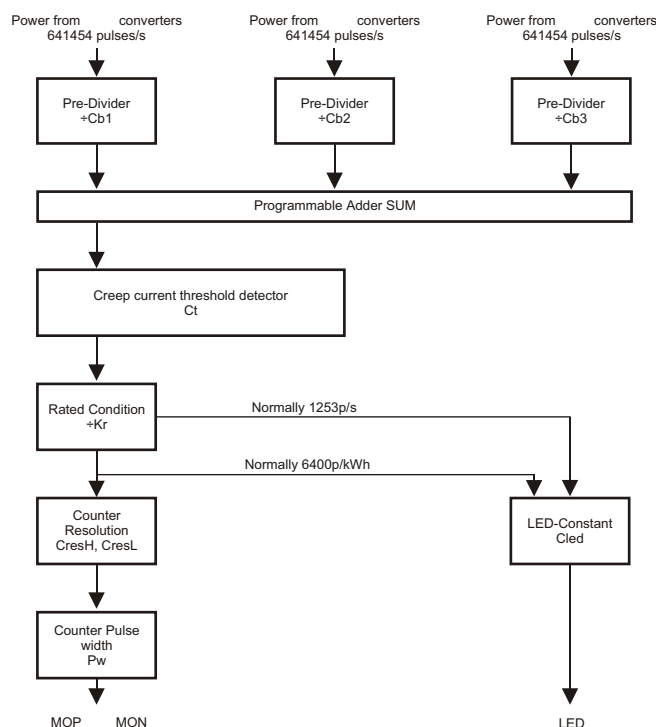


Figure 7: Signal flow block diagram

**EEPROM Memory Allocation**

The following table shows the EEPROM memory allocation as well as the corresponding name. The uneven byte always

contains a XORed byte of the previous even byte. This is the checksum byte used by the SA2005P to ensure data integrity.

Description	E <sup>2</sup> Address	Contents	Bit [7:0]	Name
Channel Balance 3	10	Cb3	---v vvvv	D10
	11	XOR of ADDR 10	xxxx xxxx	
Channel Balance 1	12	Cb1	---v vvvv	D12
	13	XOR of ADDR 12	xxxx xxxx	
Channel Balance 2	14	Cb2	---v vvvv	D13
	15	XOR of ADDR 14	xxxx xxxx	
Summing mode	16	SUM	---- -vv	D16
Creep current threshold	16	Ct	v---- ----	D16
	17	XOR of ADDR 16	xxxx xxxx	
Rated Condition	20	Kr	vvvv vvvv	D20
	21	XOR of ADDR 20	xxxx xxxx	
Led Pulse-rate	22	Cled	---- -vv	D22
	23	XOR of ADDR 22	xxxx xxxx	
Counter Resolution (LSB)	24	CresL	vvvv vvvv	D24
	25	XOR of ADDR 24	xxxx xxxx	
Counter Resolution (MSB)	26	CresH	---v vvvv	D26
Counter Pulse-Width	26	Pw	vv-- ----	D26
	27	XOR of ADDR 26	xxxx xxxx	

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





### PARAMETER DESCRIPTION

Refer to the EEPROM memory allocation map as well as the Signal flow diagram figure 7, for a description of the registers used in this section.

#### Rated Condition (Kr)

Kr is used to program the rated condition of the meter. Rated conditions from less than 10A to several 100A are possible. The rated conditions divider as well as the pre-divider is used to compensate for individual phase calibration. The three phases are calibrated to the phase with the lowest gain.

Kr is calculated as follows:

$$Krx=642\ 000/Rated\ volt/Rated\ current/6400x3600x1000/512$$

The SA2005P's internal counters count from 0 so 1 must be subtracted from Kr:

$$Kr = round(Krx)-1$$

Where:

- Krx is the real value
- Kr is the integer value
- Kr is made up of 1 byte (D20)

#### Pre-divider (Cb1, Cb2, Cb3)

The channel balance (Cb) value is used to balance the three phases. The rated conditions divider ratio must be calculated. Error measurements per phase are done with channel balance values set to zero. The measured error values are used to correct the error measurements of the three phases. The rounding error in the rated conditions divider is also compensated for in the channel balance calculations. One count on the channel balance value represent 100%/256.

$$Gain = ((Krx-Kr+1) / Krx) x 100$$

Gain calculates the rounding error made by the rated conditions divider.

$$Cb1 = (CHB1 - CBMIN + Gain) x 256 / 100$$

$$Cb2 = (CHB2 - CBMIN + Gain) x 256 / 100$$

$$Cb3 = (CHB3 - CBMIN + Gain) x 256 / 100$$

CHB1, CHB2, CHB3 is the measured channel balance %error that will be corrected

CBMIN is the lowest channel balance %error measured between the three phases.

#### LED Pulse-Rate (Cled)

Two bits of byte D22 allow for the selection of 4 different LED-Pulse-rates. The LED pulse-width is 10ms. In fast pulse mode, the pulse-width is set to 71µs.

D22[1]	D22[0]	Calibration LED - Output
0	1	6400 p/kWh
1	0	3200 p/kWh
1	1	1600 p/kWh
0	0	1252 pulses/second @ rated for fast calibration

#### Counter Resolution (Cres)

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

Cres is made up of bits 0 of 4 of byte D26 and byte D27.

D26[4:0]	D27[7:0]	Counter Resolution

#### 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 D26.

D26[7]	D26[6]	Counter Pulse-Width
1	-	284 ms
0	1	142 ms
0	0	71 ms

#### Creep current threshold (Ct)

The creep current is expressed relative to the rated current of the meter. The SA2005P will not meter currents below the creep current. The creep current is implemented to prevent the meter from accumulating energy when no load is connected.

Cs is made up of bit 7 of byte D16

D16[7]	Creep threshold
0	0.02% of rated current
1	0.01% of rated current



**Programmable adder mode (SUM)**

The SA2005P can be programmed to sum the energy measurement as follows:

**Total sum**

This represents the total sum of the energy measured on all three phases flowing through the current sensors. Negative energy flow is taken into consideration.

$$\text{Energy} = \text{Energy phase 1} + \text{Energy Phase 2} + \text{Energy Phase 3}$$

**Absolute sum**

This represents the sum of the energy measured on all three phases, regardless of the direction of energy flow through the current sensors.

$$\text{Power} = \text{abs (Energy phase 1)} + \text{abs (Energy phase 2)} + \text{abs (Energy phase 3)}$$

During calibration the device may be programmed to use only a specific phase for energy measurement. This can be used for channel balancing.

D16[2]	D16[1]	D16[0]	Counter Resolution
0	0	0	Total sum all three phases
0	0	1	Only phase 1 measurement
0	1	0	Only phase 2 measurement
0	1	1	Only phase 3 measurement
1	0	0	Absolute sum of all three phases
1	0	1	Only phase 1 measurement
1	1	0	Only phase 2 measurement
1	1	1	Only phase 3 measurement

**Example of calculating rated conditions and channel balance values**

Meter rating = 80A / 230V (The SA2005P only uses integer values)

Calculate the rated conditions:

$$\text{Krx} = 642\ 000 / \text{Rated volt} / \text{Rated current} / 6400 \times 3600 \times 1000 / 512$$

$$\text{Krx} = 642\ 000 / 230 / 80 / 6400 \times 3600 \times 1000 / 512$$

$$\text{Krx} = 38.3327$$

$$\text{Krx} = 38 \text{ (round Krx) - convert to integer}$$

$$\text{Kr} = 38 - 1 = 37$$

The value 37 is stored in the rated register (Kr).

Calculate the Channel balance values:

During the rated conditions calculation the rated condition register was rounded and any rounding errors is now taken into account:

$$\text{Gain} = ((\text{Krx} - \text{Kr} + 1) / \text{Krx}) \times 100$$

$$\text{Gain} = ((38.3327 - 38) / 38.3327) \times 100$$

$$\text{Gain} = 0.8679$$

The real channel balance errors still need to be measured so CHB1, CHB2, CHB3 and CBMIN are set to 0 for all phases.

Calculate the Pre-divider values:

$$\text{Cb1} = (\text{CHB1} - \text{CBMIN} + \text{Gain}) \times 256 / 100$$

$$\text{Cb1} = (0\% - 0\% + \text{Gain}) \times 256 / 100$$

$$\text{Cb1} = \text{Gain} \times 256 / 100$$

$$\text{Cb1} = 0.8679 \times 256 / 100$$

$$\text{Cb1} = 2.2218$$

Convert to integer

$$\text{Cb1} = 2$$

At this stage all three channels will be set with the same values, Cb1= Cb2= Cb3. Store the calculated values in the EEPROM. Ensure that the SA2005P reload's its registers from the EEPROM by means of the reload pin (RLOAD) 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**

Use the rated conditions divider value and the channel balance values calculated above and program the EEPROM. Set the programmable adder for a single phase to be measured. Measure the %error for each individual phase without changing any of the calibration constants.

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

The %Error will be worked back into the calculations above. For the example we will assume a 1.5%, 5.2%, and 3.2% for the three individual phases. The rated conditions value is recalculated relative to the phase with the lowest error. Phase 1 has the lowest error so 1.5% = MinError;



Recalculate the rated conditions

$$Krx = 642\,000 / \text{Rated volt} / \text{Rated current} / 6400 \times 3600 \times 1000 / 512 \times (1 + \%MinError / 100)$$
$$Krx = 642\,000 / 230 / 80 / 6400 \times 3600 \times 1000 / 512 \times 1.015$$
$$Krx = 38.9077$$
$$Kr = 38 - 1 = 37$$

The 37 are stored in the rated register.

The channel balance values are adjusted to make provision for the rounding error.

$$Gain = ((Krx - Kr + 1) / Krx) \times 100$$
$$Gain = ((38.9077 - 38) / 38.9077) \times 100$$
$$Gain = 2.33$$

The channel balance pre-divider value must be recalculated. (BMIN will be the lowest %error value, in this case 1.5%, CHB1, CHB2 and CHB3 are the individual phase %errors measured.

$$Cb1 = (CHB1 - CBMIN + Gain) \times 256 / 100$$
$$Cb1 = (1.5 - 1.5 + 2.33) \times 256 / 100 = 5.97 = 5$$

$$Cb2 = (CHB2 - CBMIN + Gain) \times 256 / 100$$
$$Cb2 = (5.2 - 1.5 + 2.33) \times 256 / 100 = 15.43 = 15$$

$$Cb3 = (CHB3 - CBMIN + Gain) \times 256 / 100$$
$$Cb3 = (3.2 - 1.5 + 2.33) \times 256 / 100 = 10.316 = 10$$

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



### TYPICAL APPLICATION

#### CALCULATION OF EXTERNAL RESISTOR VALUES

In figure 8, all the components required for a three-phase power/energy metering section, is shown. The application uses current transformers for current sensing. The 4-wire meter section is capable of measuring 3x230V/80A with precision better than Class 1

The most important external components for the SA2005P integrated circuit are the current sense resistors, the voltage sense resistors as well as the bias setting resistor.

#### Bias Resistor

R7 defines all on-chip and reference currents. With R7=24k , optimum conditions are set.

#### CT Termination Resistor

The voltage drop across the CT termination resistor at rated current should be at least 20mV. The CT's used have low phase shift and a ratio of 1:2500. The CT is terminated with a 2.7 resistor giving a voltage drop across the termination resistor 864mV at rated conditions (Imax for the meter).

#### Current Sense Resistors

The resistors R1 and R2 define the current level into the current sense inputs of phase one of the device. The resistor values are selected for an input current of 16µA on the current inputs at rated conditions.

According to equation described in the Current Sense inputs section:

$$R1 = R2 = ( I_L / 16\mu A ) \times R_{SH} / 2$$
$$= 80A / 2500 / 16\mu A \times 2.7 / 2$$
$$= 2.7k$$

I<sub>L</sub> = Line current / CT Ratio

The three current channels are identical so R1 = R2 = R3 = R4 = R5 = R6.

#### Voltage Divider

The three voltage divider for voltage measurement are identical so resistor values for one phase will be calculated. The voltage divider is calculated for a voltage drop of 14V. Equations for the voltage divider in figure 5 are:

$$R_A = R16 + R19 + R22$$
$$R_B = R8 || R13$$

Combining the two equations gives:

$$(R_A + R_B) / 230V = R_B / 14V$$

Resistor values R11 = R12 = R13= 24k and R8 =1M is chosen.

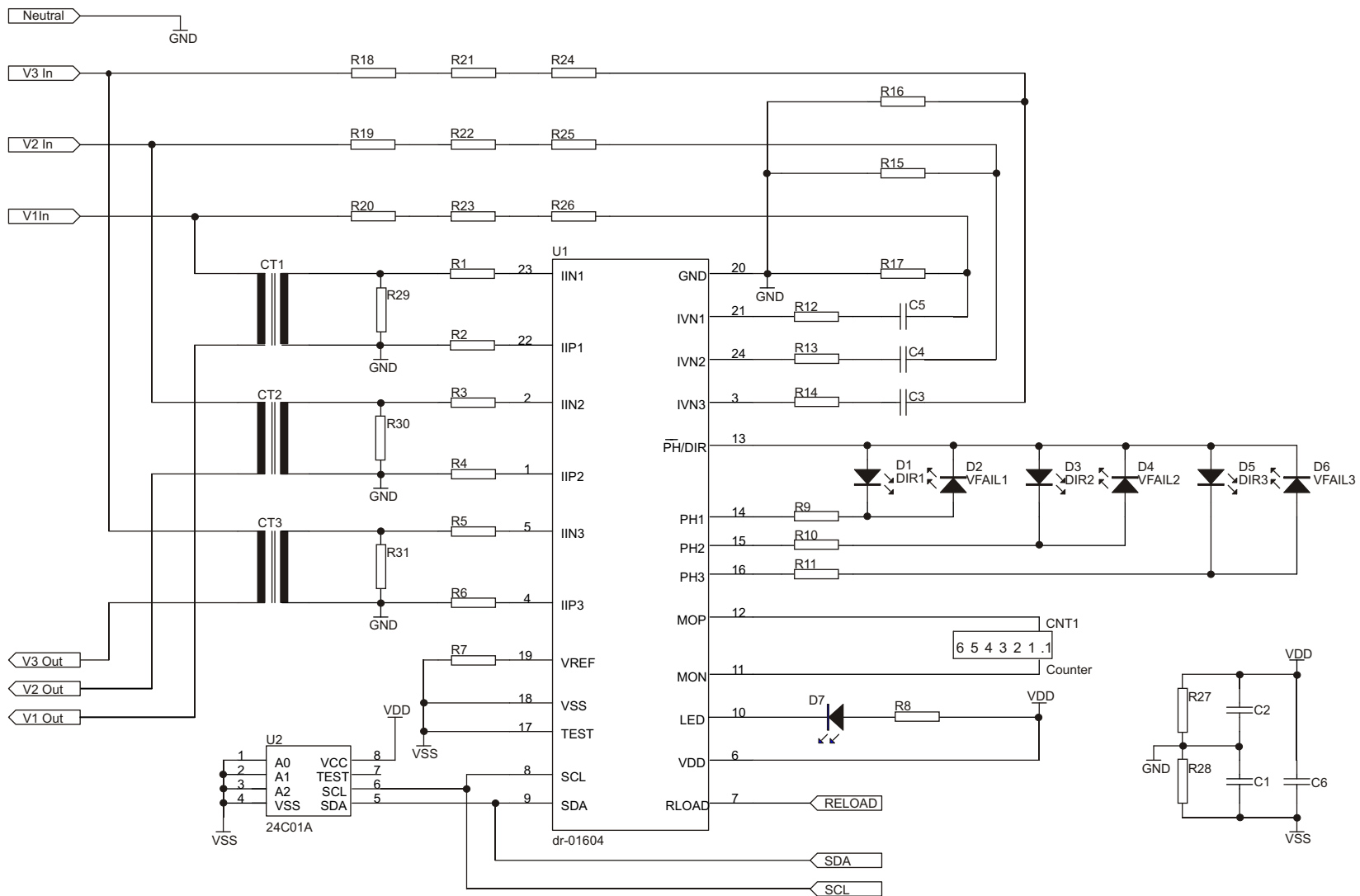
Substituting the values result in:

$$R_B = 23.4375k$$
$$R_A = R_B \times (230V / 14V - 1)$$
$$R_A = 361.607k$$

Resistor values of R16, R19 and R22 is chosen to be 130k, 130k and 100k.

The three voltage channels are identical so R14= R15= R16 , R17 = R18 = R19 and R20 = R21= R22.

Figure 8: Typical application circuit



**SA2005P****Parts List for Application Circuit: Figure 7**

Symbol	Description	Detail
U1	SA2005P	DIP-24 / SOIC-24
R1	Resistor, 2.7k, 1/4W, 1%, metal	Note 1
R2	Resistor, 2.7k, 1/4W, 1%, metal	Note 1
R3	Resistor, 2.7k, 1/4W, 1%, metal	Note 1
R4	Resistor, 2.7k, 1/4W, 1%, metal	Note 1
R5	Resistor, 2.7k, 1/4W, 1%, metal	Note 1
R6	Resistor, 2.7k, 1/4W, 1%, metal	Note 1
R7	Resistor, 24k, 1/4W, 1%, metal	
R8	Resistor, 1k, 1/4W, 5%, carbon	
R9	Resistor, 1k, 1/4W, 5%, carbon	
R10	Resistor, 1k, 1/4W, 5%, carbon	
R11	Resistor, 1k, 1/4W, 5%, carbon	
R12	Resistor, 1M, 1/4W, 1%, metal	
R13	Resistor, 1M, 1/4W, 1%, metal	
R14	Resistor, 1M, 1/4W, 1%, metal	
R15	Resistor, 24k, 1/4W, 1%, metal	
R16	Resistor, 24k, 1/4W, 1%, metal	
R17	Resistor, 24k, 1/4W, 1%, metal	
R18	Resistor, 130k, 1/4W, 1%, metal	
R19	Resistor, 130k, 1/4W, 1%, metal	
R20	Resistor, 130k, 1/4W, 1%, metal	
R21	Resistor, 130k, 1/4W, 1%, metal	
R22	Resistor, 130k, 1/4W, 1%, metal	
R23	Resistor, 130k, 1/4W, 1%, metal	
R24	Resistor, 100k, 1/4W, 1%, metal	
R25	Resistor, 100k, 1/4W, 1%, metal	
R26	Resistor, 100k, 1/4W, 1%, metal	
R27	Resistor, 1k, 1/4W, 1%, metal	
R28	Resistor, 1k, 1/4W, 1%, metal	
R29	Resistor, 2.7 , 1/4W, 1%, metal	Note 1
R30	Resistor, 2.7 , 1/4W, 1%, metal	Note 1
R31	Resistor, 2.7 , 1/4W, 1%, metal	Note 1
C1	Capacitor, 220nF	
C2	Capacitor, 220nF	
C3	Capacitor, 1.5μF, 16V, electrolytic	Note 2
C4	Capacitor, 1.5μF, 16V, electrolytic	Note 2
C5	Capacitor, 1.5μF, 16V, electrolytic	Note 2
C6	Capacitor, 820nF	Note 3
D1	3mm Light emitting diode	Direction indicator
D2	3mm Light emitting diode	V1 Fail indicator
D3	3mm Light emitting diode	Direction indicator
D4	3mm Light emitting diode	V2 Fail indicator
D5	3mm Light emitting diode	Direction indicator
D6	3mm Light emitting diode	V3 Fail indicator
U2	24C01A, 1kbit EEPROM	
CNT1	Mechanical stepper motor counter	
CT1	Current Transformer, TZ76	2500:1
CT2	Current Transformer, TZ76	2500:1
CT3	Current Transformer, TZ76	2500:1

**Note 1:** Resistor (R1 to R6) values are dependent on the selection of the termination resistors (R29 to R31) and CT combination

**Note 2:** Capacitor values may be selected to compensate for phase errors caused by the current transformers.

**Note 3:** Capacitor C6 to be positioned as close as possible to supply pins  $V_{DD}$  and  $V_{SS}$  of U1 as possible.



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SA2005P

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