sames

SA9110A

MONOCHIP THREE PHASE BIDIRECTIONAL KILOWATT HOUR METERING IC

FEATURES

- Performs bidirectional energy metering and directly drives a LCD with 7 digits plus announciators
- 4 externally selectable on-chip tariff registers
- An additional total energy register
- Meets the IEC 521/1036 Specification requirements for Class 1 AC Watt hour meters
- Optical interface for electronic reading according to IEC1107 Mode D
- Pulse output for calibration
- Total power consumption rating below 40mW
- Adaptable to different types of current sensors
- Operates over a wide temperature range
- Precision voltage reference on-chip
- Protected against ESD

DESCRIPTION

The SAMES SA9110A Three Phase bidirectional energy metering integrated circuit has an integrated Liquid Crystal Display (LCD) driver for a 7 digit (7 segment) display as well as 4 multiple tariff registers. The SA9110A performs the active power calculation.

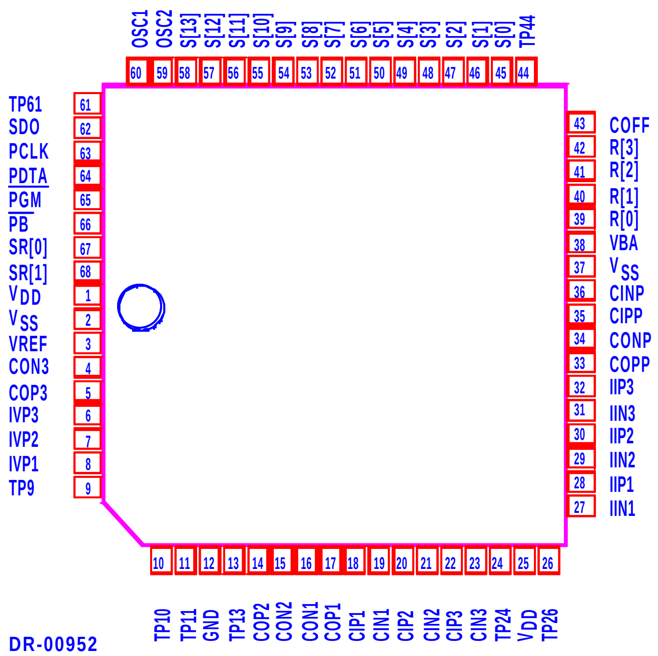
The method of calculation takes the power factor into account.

The measured energy is displayed in kilo Watt hours (kWh). The SA9110A is capable of driving a display having a resolution of 1/10 kWh.

This innovative universal energy metering integrated circuit is ideally suited for energy measurement in three phase systems.

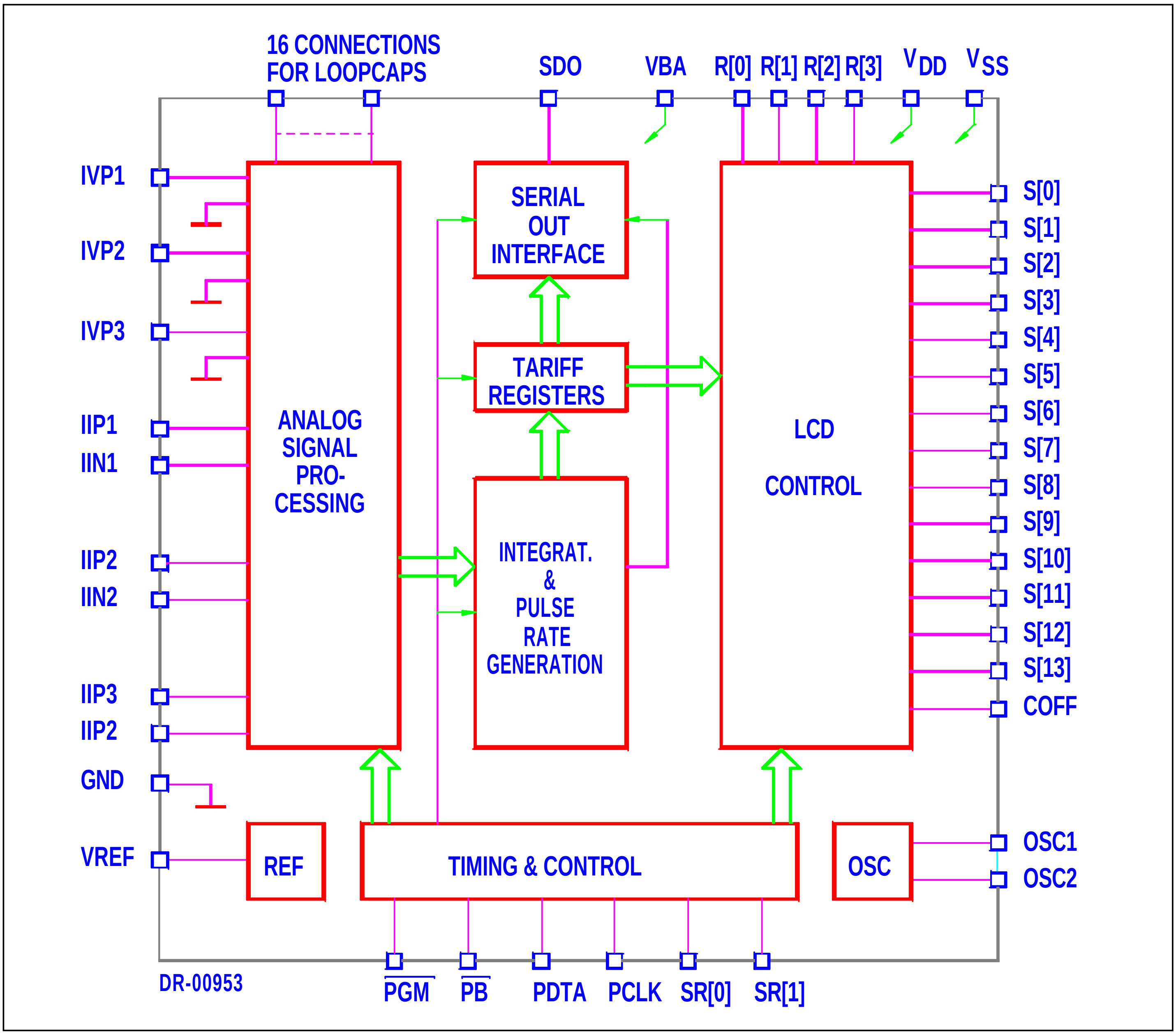
The SA9110A integrated circuit is available in a 68 pin plastic leaded chip carrier (PLCC-68) package type.

PIN CONNECTIONS



Package: PLCC-68

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	-10	+70	°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

(Over the temperature range -10°C to +70°C#, unless otherwise specified.)

Parameter	Symbol	Min	Typ	Max	Unit	Condition
Supply Voltage	V_{DD}-V_{SS}	4.5		5.5	V	
Supply Current	I_{DD}			15	mA	
Nonlinearity of power calculation		-0.3		+0.3	%	1% - 100% of rated power
Current Sensor Inputs (Differential)						
Input Current Range	I_{II}	-25		+25	µA	Peak value
Voltage Sensor Inputs (Asymmetric)						
Input current Range	I_{IV}	-25		+25	µA	Peak value
LCD backplane Voltage	V_B		V_{DD} & V_{SS}		V	R[0] .. R[3]
LCD segment Voltage	V_S		1/3 V_{DD} 2/3V_{DD}		V	S[0] .. S[15]
Pin SDO						
Pulse rate	f_P		3.5		Hz	Default[1]
				80	Hz	Programmed[1]
Output Voltage Low	V_{OL}			V_{SS}+1	V	I_{OL} = 5mA
Output Voltage High	V_{OH}	V_{DD}-1			V	I_{OH} = -2mA
Oscillator	Recommended crystal: TV colour burst crystal f = 3.5795 MHz					
Pin VREF						With R_7 = 24kΩ
Ref. Current	$-I_R$	45	50	55	µA	connected to V_{SS}
Ref. Voltage	V_R	1.1		1.3	V	Referred to V_{SS}
Pins $\overline{PB}$, SR[0], SR[1], $\overline{PGM}$						
Input Voltage High	V_{IH}	4			V	
Input Voltage Low	V_{IL}			1	V	
Pullup Current			30		µA	V_{IN} = V_{SS}
Pin PCLK						
Input Voltage High	V_{IH}	4			V	
Input Voltage Low	V_{IL}			1	V	
Input Current High/ Low			±30		µA	V_{IN}=V_{SS}..V_{DD}
Pin V_{BA}	I_{MAX}			50	nA	Power down mode
	V_{MIN}	1.1			V	

Extended Operating Temperature Range available on request

Note 1: At rated conditions

PIN DESCRIPTION

Pin	Designation	Type	Description
12	GND	Supply	Ground
1	V_{DD}	Supply	Positive Supply Voltage
25	V_{DD}	Supply	
2	V_{SS}	Supply	Negative Supply Voltage
37	V_{SS}	Supply	
38	VBA	Supply	Battery back-up. Negative Supply Voltage
8	IVP1	Analog in	Input for voltage sense : Phase 1
7	IVP2	Analog in	Input for voltage sense : Phase 2
6	IVP3	Analog in	Input for voltage sense : Phase 3
27	IIN1	Analog in	Inputs for current sensor : Phase 1
28	IIP1	Analog in	
29	IIN2	Analog in	Inputs for current sensor : Phase 2
30	IIP2	Analog in	
31	IIN3	Analog in	Inputs for current sensor : Phase 3
32	IIP3	Analog in	
60	OSC1	Input	Connections for crystal or ceramic resonator
59	OSC2	Output	(OSC1 = Input; OSC2 = Output)
39	R[0]	Output	Liquid crystal display (LCD) backplane drivers
40	R[1]	Output	
41	R[2]	Output	
42	R[3]	Output	
45	S[0]	Output	Liquid crystal display (LCD) segment drivers
46	S[1]	Output	
47	S[2]	Output	
48	S[3]	Output	
49	S[4]	Output	
50	S[5]	Output	
51	S[6]	Output	
52	S[7]	Output	
53	S[8]	Output	
54	S[9]	Output	
55	S[10]	Output	
56	S[11]	Output	
57	S[12]	Output	
58	S[13]	Output	
43	COFF	Output	Connection for all unused LCD segments, to ensure off status

PIN DESCRIPTION (continued)

Pin	Designation	Type	Description
16	CON1	Analog	Connections for outer loop capacitors of A/D converters
17	COP1	Analog	
15	CON2	Analog	
14	COP2	Analog	
4	CON3	Analog	
5	COP3	Analog	
34	CONP	Analog	
33	COPP	Analog	
19	CIN1	Analog	Connections for inner loop capacitors of A/D converters
18	CIP1	Analog	
21	CIN2	Analog	
20	CIP2	Analog	
23	CIN3	Analog	
22	CIP3	Analog	
36	CINP	Analog	
35	CIPP	Analog	
3	VREF	Analog	Connection for reference current setting resistor
62	SDO	Open drain	Pulse rate output. Serial data output when $\overline{PB}$ is low
67	SR[0]	Input	Control for tariff register selection (on-chip pull-up)
68	SR[1]	Input	Control for tariff register selection (on-chip pull-up)
66	$\overline{PB}$	Input	Push Button: Display select/start serial data transmission on SDO (on-chip pull-up)
65	$\overline{PGM}$	Input	Programming Mode . It is recommended that pin PGM be connected to VDD via a 470Ω resistor to guard against transients or noise.
64	PDTA	Input	Programming Data (on-chip pull-down)
63	PCLK	Input	Programming Clock
9	TP9		Manufacturer's test pins (Leave unconnected)
10	TP10		
11	TP11		
13	TP13		
24	TP24		
26	TP26		
44	TP44		
61	TP61		

FUNCTIONAL DESCRIPTION

The SA9110A is a CMOS mixed signal Analog/Digital integrated circuit, which performs three phase energy calculations across a power range of 1000:1, to an overall accurancy of better than Class 1. An on-chip LCD driver directly drives a 7 digit (7 segment) LCD. Also included on-chip, are 4 x tariff registers externally selectable for multi-tariff energy metering applications and a fifth register which retains the total energy consumption.

The integrated circuit includes all the required functions such as two oversampling A/D converters for the voltage and current sense inputs, power calculation and energy integration. Offset is eliminated through the use of internal cancellation procedures.

1. Power Calculation

In the Application Circuit (Figure 1), the mains voltage from Line 1, Line 2 and Line 3, are converted to currents and applied to the voltage sense inputs IVP1, IVP2 and IVP3.

The current levels on the voltage sense inputs are derived from the mains voltage (3 x 230 VAC) being divided down through voltage dividers to 14V. The resulting input currents into the A/D converters are 14µA through the resistors R_{15}, R_{16} and R_{17}.

For the current sense inputs the voltage drop across the current transformers terminating resitors are converted to currents of 16µA for rated conditions, by means of resistors R_8, R_9 (Phase 1); R_{10}, R_{11} (Phase 2) and R_{12}, R_{13} (Phase 3).

The signals providing the current information are applied to the current sensor inputs IIN1, IIP1, IIN2, IIP2 and II3, IIP3.

A pulse rate output for calibration purposes is available on SDO (Pin 62), the pulse rate being proportional to the active energy consumption.

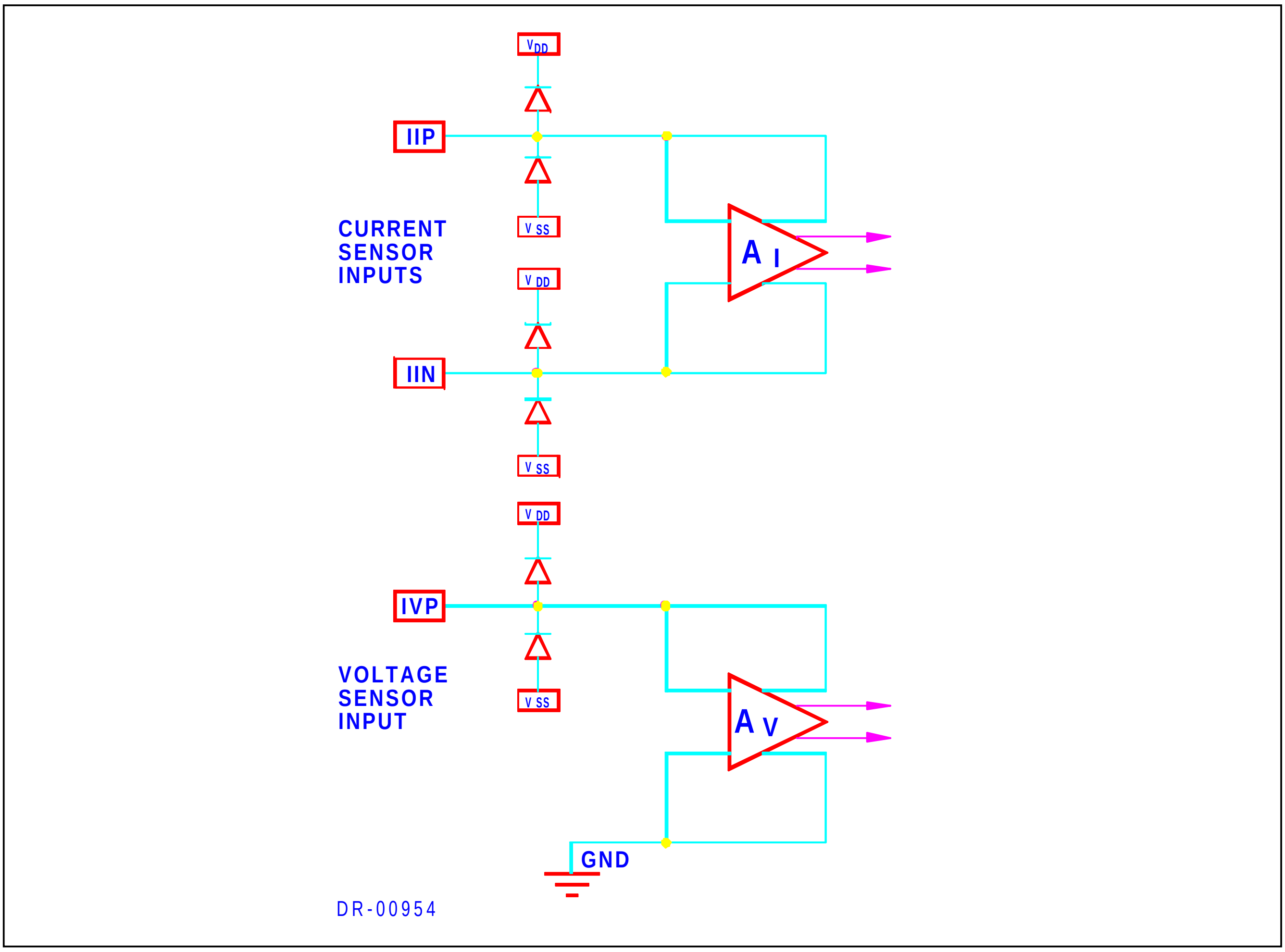
The integrated anti-creep function ensures no metering when no line current is present.

2. Analog Input Configuration

The input circuitry of the current and voltage 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 and A_V generate virtual shorts on the signal inputs. Exact duplications of the input currents are generated for the analog signal processing circuitry.



3. LCD Driver

The SA9110A has an on-chip LCD driver capable of driving a 4 backplane, 7 digit (7 segment) display, as well as 6 announciators.

The backplane repitition frequency is approximately 90Hz.

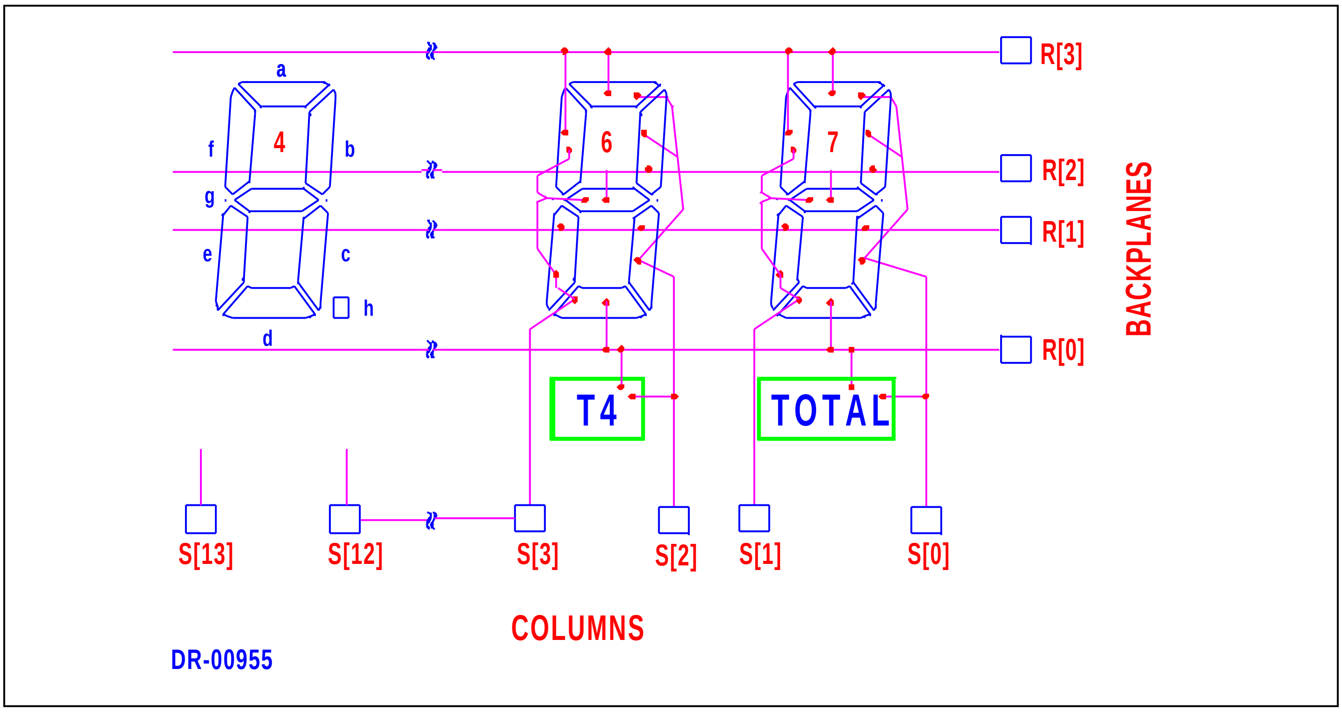
The most significant digit is addressed by columns S[13] and S[12] and the least significant digit by S[1] and S[0]. Announciators for the total register, 4 tariff registers and energy direction indication are available on the 'h' segments of the 6 least significant digits. The display segments are addressed via the column outputs given in the table below:

LCD Segment Address Table

Digit	Column	R[0]	R[1]	R[2]	R[3]
10^{-1} LSD	S[0]	Total	c	b	a
	S[1]	d	e	g	f
10^{0}	S[2]	T4	c	b	a
	S[3]	d	e	g	f
10^{1}	S[4]	T3	c	b	a
	S[5]	d	e	g	f
10^{2}	S[6]	T2	c	b	a
	S[7]	d	e	g	f
10^{3}	S[8]	T1	c	b	a
	S[9]	d	e	g	f
10^{4}	S[10]	Dir	c	b	a
	S[11]	d	e	g	f
10^{5} MSD	S[12]	h	c	b	a
	S[13]	d	e	g	f

LCD Layout

The LCD display is given in the diagram below:



The kWh values of the LCD display digits, are given in the table below. The resolution of the Least Significant Digit is normally programmed to 0.1kWh:

10^{5}	10^{4}	10^{3}	10^{2}	10^{1}	10^{0}	10^{-1}	kWh

4. Device Programming

The SA9110A contains on-chip registers which enables the meter manufacturer to store various data:

Slope Adjustment

The slope of the device may be adjusted by programming a slope constant (K_S) into the device during calibration. The output frequency at SDO (f_P) is calculated by means of the following formula:

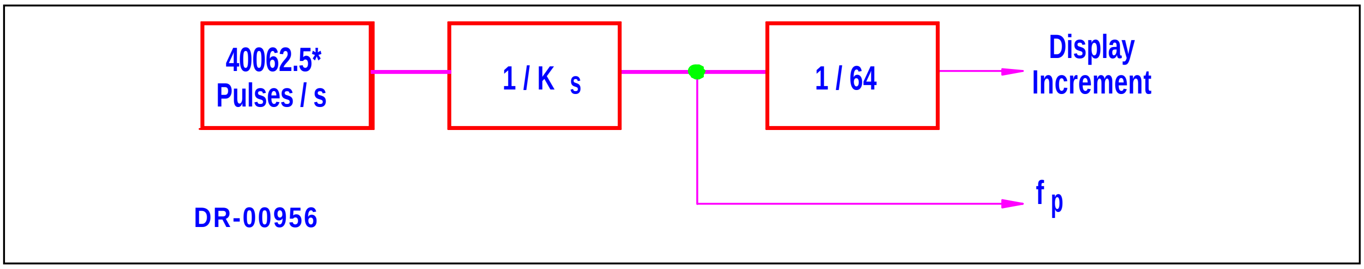
$$f_P = 11.16 * \frac{FOSC}{3.5795MHz} * \frac{40062.5}{K_S} * \frac{(I_{I1} * I_{V1}) + (I_{I2} * I_{V2}) + (I_{I3} * I_{V3})}{3 * I_R^2}$$

Where

FOSC	=	Oscillator frequency (2MHz ...... 4MHz)
I_{I1}, I_{I2}, I_{I3}	=	Input current for current sensor input (16µA at rated line current)
I_{V1}, I_{V2}, I_{V3}	=	Input current for voltage sensor input (14µA at rated line voltage)
I_R	=	Reference current (typically 50µA)
K_S	=	Slope constant (1025 ... 16384)
		(The default value is 11389)

By changing the slope of the device the resolution of the LCD together with the pulse rate on SDO may be changed by up to an order. The block diagram below illustrates the display update rate.

Programmable slope divider



* At rated conditions

The display is incremented after every 64th pulse on SDO.

Display Resolution

From the above formula for f_p it can be derived that the slope constant, K_s, is given by the following expression:-

$$K_s = (626 * 3600 * 1000 * E_{KWh}) / (3 * V_L * I_L)$$

Where E_{kWh} = energy for 1 Display increment in kWh
V_L = rated line voltage
I_L = rated line current

This formula is valid only if 16µA flows into each of the current sense inputs for rated line current (I_L) and 14µA flows into the voltage sense inputs for rated line voltage (V_L).

Offset Adjustment

The precision of this device does not require any offset adjustment for Class 1 metering. This facility has been provided to compensate for poor PCB layout or circumstances requiring precision well beyond a Class 1 rating.

The offset of the device may be adjusted by programming a different offset into the device during calibration. To calaculate the offset the following procedure should be followed:

Measure the linearity error at the current where offset correction is needed.

$$K_O = \frac{I_M * E_{RR}}{I_R * 6 * 10^{-6}}$$

Where I_M = Measured current on the current sensor
I_R = Rated current on the current sensor
E_{RR} = Error ratio between the device and the Wh standard
K_O = Offset constant (-127 ... 127)

Note that K_O must be programmed as a integer value.

Meter/Manufacturers Identification Data

A total of eleven 4 bit words are available to store relevant data such as the meter and manufacturer identification codes. For the optical interface protocol, the 4-bit words are converted to 8-bit words (ASCII-format).

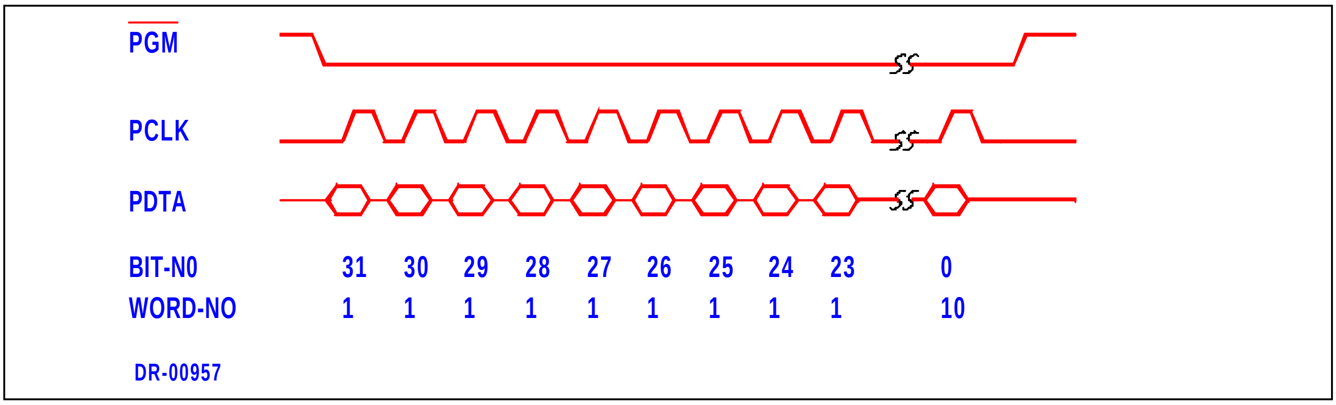
Writing to RAM

The memory is configured as ten 32 bit words. The programming data must be written to the device as a bitstream containing a total of 320 bits. ROM-locations will not be overwritten.

Word number	Bit number	Function	Description
1	31..28	Sign of Register 1	A '1' indicates a negative register value
1	27..0	Register 1	Contents of register 1 in binary coded decimal
2	31..28	Sign of Register 2	A '1' indicates a negative register value
2	27..0	Register 2	Contents of register 2 in binary coded decimal
3	31..28	Sign of Register 3	A '1' indicates a negative register value
3	27..0	Register 3	Contents of register 3 in binary coded decimal
4	31..28	Sign of Register 4	A '1' indicates a negative register value
4	27..0	Register 4	Contents of register 4 in binary coded decimal
5	31..28	Sign of Register 'Total'	A '1' indicates a negative register value

Word number	Bit number	Function	Description
5	27..0	Register 'Total'	Registers 1, 2, 3 and 4 are added and stored in the register 'Total'
6	31..16	ROM	Don't care
6	15..0	Manufacturers Identification	16 bits are available for the manufacturer of the metering system as a system identification
7	31..28	ROM	Don't care
7	27..0	System Identification	28 bits are available for the manufacturer of the metering system as a system identification
8	31..0	ROM	Don't care
9	31	Programmed slope select	Programmed slope select bit must be set if the default slope in ROM is not used
9	30..25	ROM	Don't care
9	24-22	SAMES defined register	Bits must be set to 0 for correct functionality
9	21	Sign of offset	By setting the sign bit a negative value is indicated
9	20..14	Offset	Offset of the device in binary
9	13	Sign of slope	By setting the sign bit a negative value is indicated
9	12..0	Slope	Slope of the device in binary. (default = 11389)
10	31..0	ROM	Don't care

The first bit of the programming data is written to word number 1, bit 31. The last bit is written to word number 10, bit 0.



Programming procedure:

The PGM pin is pulled low and the PCLK pin should be clocked with an external clock. The programming data on the PDTA pin must be stable during the rising edge of the clock signal on PCLK.

The clock signal on PCLK should not exceed 200 kHz and does not have to be synchronised with the oscillator frequency (FOSC).

Programming mode is interrupted if $\overline{PGM}$ goes high.

Memory Reset

In programming mode (while $\overline{\text{PGM}}$ is pulled low) if PCLK is left floating and PDTA=0, the internal clock of the SA9110A will ensure that default values are set. For default conditions all of the RAM locations are set to 0 and the value of the slope is set to 11389.

The minimum time period for a complete reset cycle is determined by:

$$t_{min} = 322 * \frac{64}{FOSC}$$

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

If the recommended crystal frequency of 3.5795MHz is used, this will result in a minimum reset time of 5.8ms.

The specified signal levels on pins $\overline{\text{PGM}}$, PCLK and PDTA must remain stable for the entire reset cycle period.

5. Tariff Registers

A multiple tariff facility is provided on-chip by means of 4 tariff registers, which are externally selectable via the SR[0] and SR[1] inputs. The registers may be selected by programming the SR[0] and SR[1] inputs as follows:

SR[1]	SR[0]	Register
0	0	Register 1
0	1	Register 2
1	0	Register 3
1	1	Register 4

The 4 tariff registers as well as the total register may be sequentially displayed by activating the Push Button (PB). The minimum Push Button make time is 5mS. The contents of the register selected for display is retained on the display for a period of 10 seconds, provided that the push button is not activated during this period. After the 10 seconds has elapsed, the display defaults to the "active" register defined by the status of the SR[0] and SR[1] inputs.

The register selected for display via the push button ($\overline{\text{PB}}$) is indicated by the relevant announciator.

6. Optical Interface

The SA9110A device contains an interface for automatic meter reading, according to the IEC1107 Mode D standard. The IEC1107 Mode D is a single baud rate of 2400. For the optical interface protocol, the 4-bit words are converted to 8-bit words (ASCII-format).

After initiation of a serial transmission by pulling $\overline{PB}$ (pin 66) low, the data format transmitted on SDO, is given below:

Code	Description
/	Start transmission
XXX	ID
3	Baud rate identification
YYYYYYYY	ID
<cr><lf><cr><lf>	Data header
0(nnnnnnnn)	Data of Reg. 1 (sign, $10e^{5}$, $10e^{4}$ ...$10e^{0}$, $10e^{-1}$)
1(nnnnnnnn)	Data of Reg. 2
2(nnnnnnnn)	Data of Reg. 3
3(nnnnnnnn)	Data of Reg. 4
4(nnnnnnnn)	Data of Reg. 'Total' = Sum of registers 1 to 4
!<cr><lf><cr><lf>	End transmission

7. Power Failure/Battery Backup

A battery backup facility is available on VBA. This feature is provided to ensure retention of the information stored in the registers, in case of power breaks.

The VSS supply to the analog circuitry and digital circuitry has been separated. In the event of a power failure, the supply to the analog circuitry falls to 0V. The digital circuitry is switched to a power down mode, to minimise the supply current from an external battery backup. During this procedure, the following events take place:

- All inputs are disabled
- All outputs are placed in high impedance mode
- The oscillator is inhibited
- The LCD driver is disabled
- The contents of the RAM is retained by means of an external power source.

8. Electrostatic Discharge (ESD) Protection

The SA9110A integrated circuits inputs/outputs are protected against ESD.

9. Power Consumption

The power consumption rating of the SA9110A integrated circuit is less than 40mW with a 5V supply.

TYPICAL APPLICATION

In the Application Circuit (Figure 1), the components required for a three phase power metering application are shown. Terminated current transformers are used for current sensing.

The most important external components for the SA9110A integrated circuit are:

C_7, C_9, C_{10} and C_{11} are the outer loop capacitors for the integrated oversampling A/D converters. The typical value of C_7 is 2.2nF and the value of C_9, C_{10} and C_{11} is 560pF.

The actual values determine the signal to noise and stability performance. The tolerances should be within ± 10%.

C_4, C_5, C_6 and C_8 are the inner loop capacitors for the integrated oversampling A/D converters. The typical value of C_4, C_5, C_6 and C_8 is 3.3nF. Values smaller than 0.5nF and larger than 5nF should be avoided.

Terminated current sensors (current transformers) are connected to the current sensor inputs of the SA9110A through current setting resistors (R_8 ..R_{13}).

The resistor values should be selected for an input current of $16\mu A_{RMS}$ into the SA9110A, at the rated line current.

The values of these resistors should be calculated as follows:

Phase 1:

$R_8 = R_9 = (I_{L1}/16\mu A_{RMS}) * R_{18}/2$

Phase 2:

$R_{10} = R_{11} = (I_{L2}/16\mu A_{RMS}) * R_{19}/2$

Phase 3:

$R_{12} = R_{13} = (I_{L3}/16\mu A_{RMS}) * R_{20}/2$

Where I_{LX} = Secondary CT current at rated conditions.

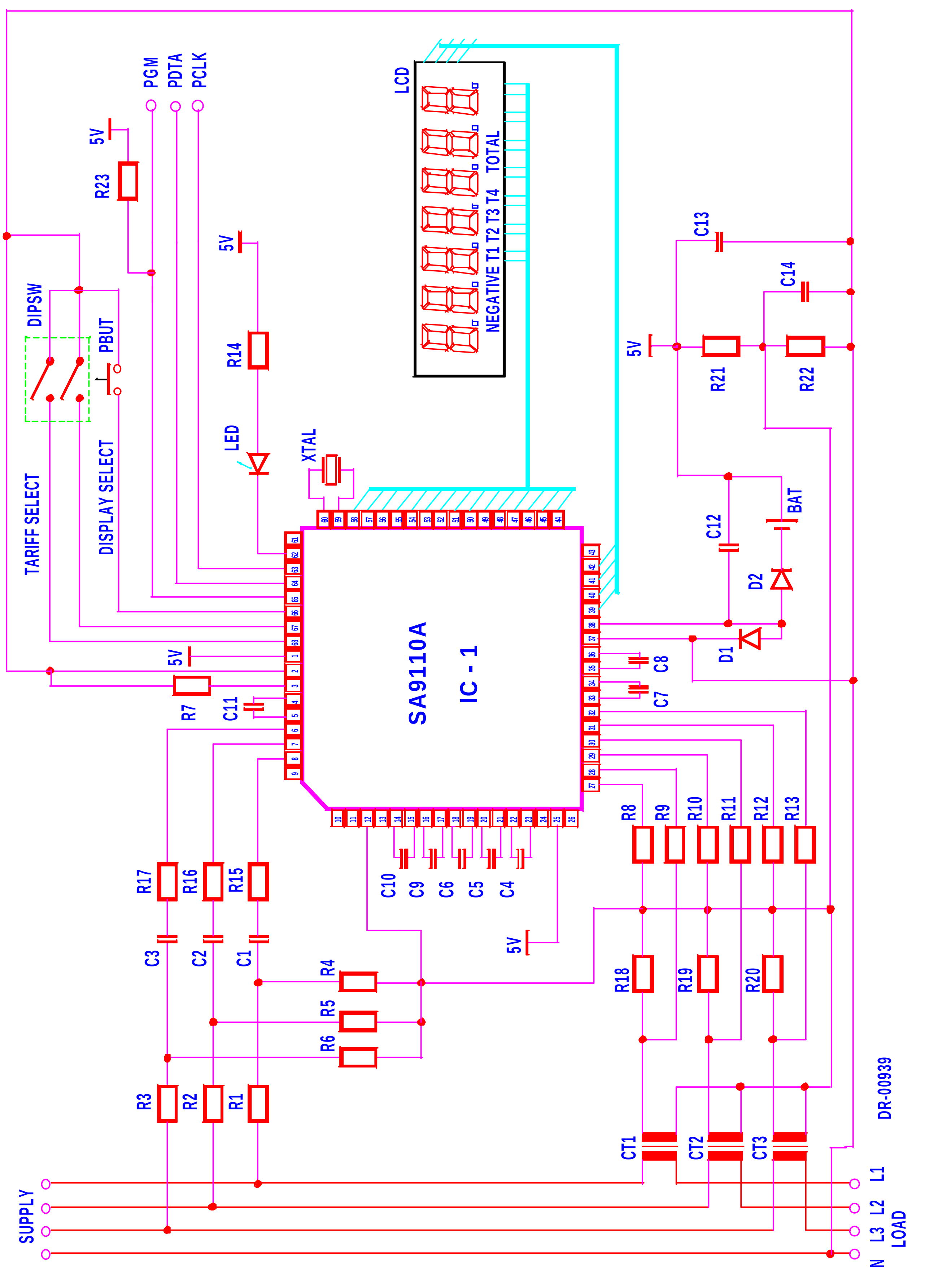
R_{18}, R_{19} and R_{20} = Current transformer termination resistors for the three phases.

R_1, R_4 and R_{15} set the current for the phase 1 voltage sense input. R_2, R_5 and R_{16} set the current for phase 2 and R_3, R_6 and R_{17} set the current for phase 3. The values should be selected so that the input currents into the voltage sense inputs (virtual ground) are set to $14\mu A_{RMS}$ for nominal line voltage. Capacitors C1, C2 and C3 are for decoupling and phase compensation.

R_7 defines all on-chip bias and reference currents (I_R). With $R_7 = 24k\Omega$, optimum conditions are set. R_7 may be varied within ± 10% for calibration purposes. Any changes to R_7 will affect the output quadratically (i.e: $\Delta R = +5\%$, $\Delta f = +10\%$).

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

Figure 1: Application circuit using current transformers for current sensing.



Parts List for Application Circuit: Figure 1

Item	Symbol	Description	Detail
1	IC-1	SA9110AFA	PLCC-68
2	XTAL	Crystal, 3.5795 MHz	Colour burst TV
3	R1	Resistor, 390k, 1%, ¼W	Note 1
4	R2	Resistor, 390k, 1%, ¼W	Note 1
5	R3	Resistor, 390k, 1%, ¼W	Note 1
6	R4	Resistor, 24k, 1%, ¼W	Note 1
7	R5	Resistor, 24k, 1%, ¼W	Note 1
8	R6	Resistor, 24k, 1%, ¼W	Note 1
9	R7	Resistor, 24k, 1%, ¼W	
10	R8	Resistor	Note 2
11	R9	Resistor	Note 2
12	R10	Resistor	Note 2
13	R11	Resistor	Note 2
14	R12	Resistor	Note 2
15	R13	Resistor	Note 2
16	R14	Resistor, 820Ω, 1%, ¼W	
17	R15	Resistor, 1M, 1%, ¼W	Note 1
18	R16	Resistor, 1M, 1%, ¼W	Note 1
19	R17	Resistor, 1M, 1%, ¼W	Note 1
20	R18	Resistor	Note 2
21	R19	Resistor	Note 2
22	R20	Resistor	Note 2
23	R21	Resistor, 820Ω, 1%, ¼W	
24	R22	Resistor, 820Ω, 1%, ¼W	
25	R23	Resistor, 470Ω	
26	C1	Capacitor, electrolytic, 1µF, 16V	Note 3
27	C2	Capacitor, electrolytic, 1µF, 16V	Note 3
28	C3	Capacitor, electrolytic, 1µF, 16V	Note 3
29	C4	Capacitor, 3.3nF	
30	C5	Capacitor, 3.3nF	
31	C6	Capacitor, 3.3nF	
32	C7	Capacitor, 2.2nF	
33	C8	Capacitor, 3.3nF	
34	C9	Capacitor, 560pF	
35	C10	Capacitor, 560pF	
36	C11	Capacitor, 560pF	
37	C12	Capacitor, 100nF	
38	C13	Capacitor, 820nF	Note 4
39	C14	Capacitor, 100nF	
40	BAT	Battery (1.2V)	

Parts List for Application Circuit: Figure 1 (Continued)

Item	Symbol	Description	Detail
41	LED	Light emmitting diode	
42	D1	Diode, Shottkey	
43	D2	Diode, 1N4148	
44	DIPSW	DIP swich, 2 poles	
45	PBUT	Push button	

Note 1 : Resistor values are dependant upon the rated mains voltage (230V in this case)

Note 2 : Resistor (R_8, R_9, R_{10}, R_{11}, R_{12} and R_{13}) values are dependant upon the selected values of the current transformer termination resistors R_{18}, R_{19} and R_{20}.

Note 3 : Capacitor values may be selected to compensate for phase errors caused by the current transformers.

Note 4 : Capacitor (C13) to be positioned as close to supply pins (V_{DD} & V_{SS}) of IC-1, as possible.

ORDERING INFORMATION

Part Number	Package
SA9110AFA	PLCC-68

Any Sales or technical questions may be posted to our e-mail address below:
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For the latest updates on datasheets, please visit out web site:
http://www.sames.co.za

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