BL0939 datasheet

BL0939 Calibration-Free Metering Chip Data Sheet

Version update instructions

Version	date	content	Revised by
V1.0	2018/06/07	create	Liao Kang, HCJ
V1.1	2019/12/25	Errata	Liao Kang, HCJ
V1.2	2020/9/7	Errata	Liao Kang, HCJ

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1 Product description

1.1 Function introduction

BL0939 is a calibration-free energy metering chip with a built-in clock. It is suitable for applications such as single-phase multi-function energy meters, smart sockets, smart home appliances, and electric bicycle charging piles. It has a high cost performance.

BL0939 integrates 3 high-precision Sigma-Delta ADCs, which can measure 2 currents and 1 voltage at the same time.

BL0939 can measure current, voltage RMS, active power, active energy and other parameters, and can output fast current RMS (for leakage monitoring or overcurrent protection), as well as temperature detection, waveform output and other functions, output through UART/SPI interface The data can fully meet the needs of smart sockets, smart home appliances, single-phase multi-functional electric energy meters, electric bicycle charging piles, and big data collection of electricity consumption information.

BL0939 has a patented anti-creep design, combined with a reasonable external hardware design, it can ensure that the noise power is not included in the energy pulse when there is no current.

1.2 main feature

- Three independent Sigma-Delta ADCs for measuring two currents and one voltage.
- RMS current range (10mA~35A) @1mohm
- Active energy (1w~7700w) @1mohm@220V
- Can output current, voltage RMS, fast current RMS, active power, current and voltage waveform phase angle
- batch factory gain error is less than 1%, and the external components can be exempted from calibration if they meet certain conditions
- Both current channels have leakage / overcurrent monitoring function, monitoring threshold and response time can be set
- Voltage zero-crossing signal output
- Built-in waveform register, which can output waveform data for load type analysis
- Integrated temperature sensor to meet the needs of product over-temperature monitoring, high-current node preset temperature alarm, ambient temperature measurement, etc.

- integr Fastest Rate Support 900KHz)/UART(4800bps)communication method ,UART Supported SP multi-chip communication with address (SSOP20L
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packag
e)
- Internal power down monitoring, below 2.7V, the chip enters the reset state.
- Built-in 1.218V reference voltage source
- Built-in oscillation circuit, the clock is about 4MHz
- Chip single working power supply 3.3V, low power consumption 10mW (typical value)
- SSOP20L/SOP16L encapsulation

1.3 System Block Diagram

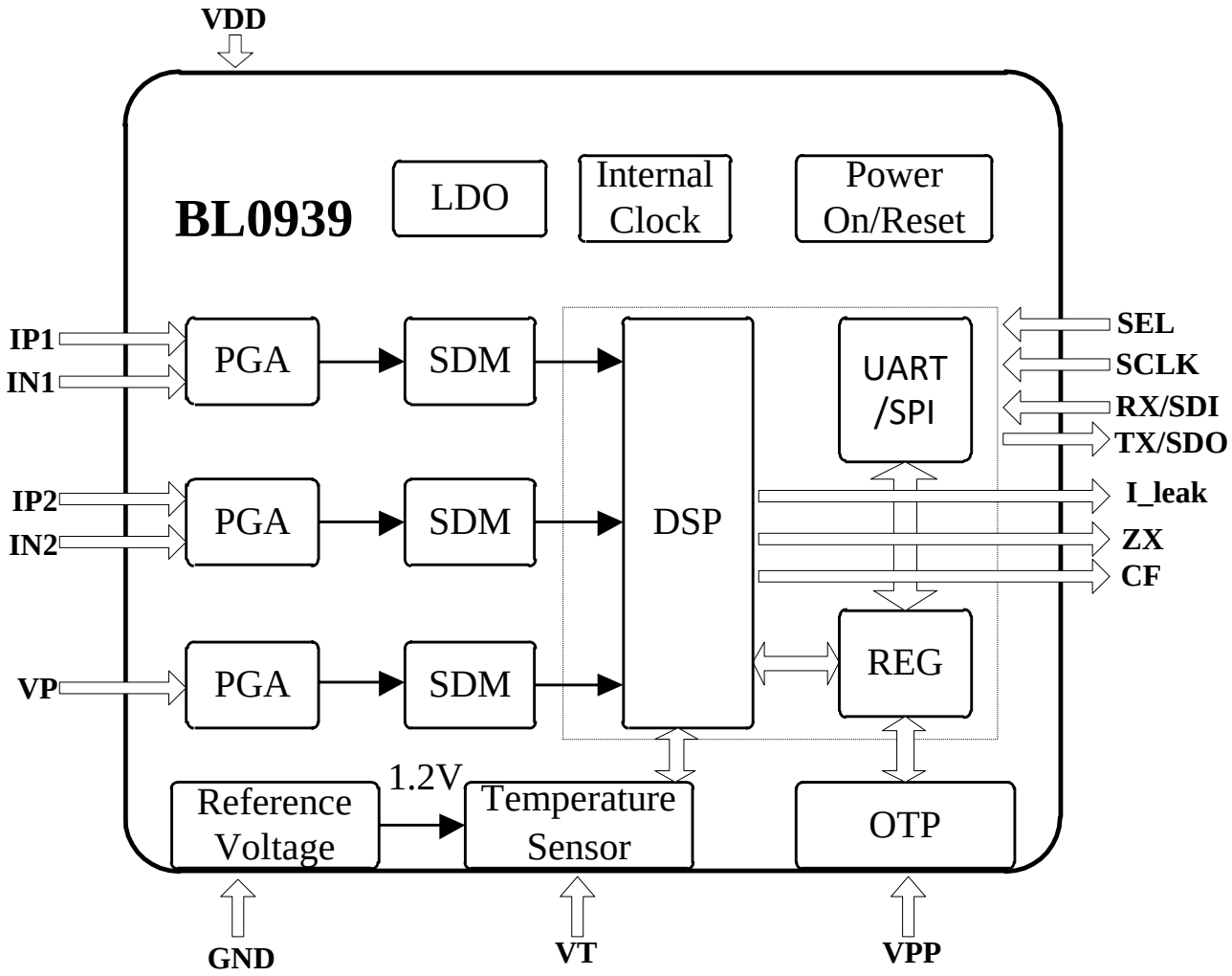
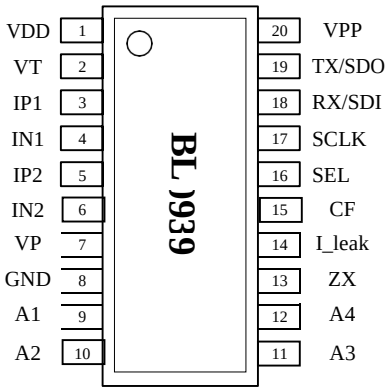


Figure 1

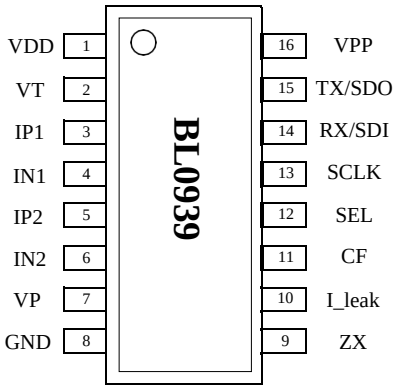
1.4 Package and Pin Description

The BL0939 is available in two packages.



SSOP20L

picture 2



SOP16L

pictures 3

Pin Description (SSOP20L)

pin number	symbol	illustrate
1	VDD	Power supply (+3.3V)
2	VT	External temperature sensor signal input
3,4	IP1, IN1	Analog input of the current A channel, the maximum differential voltage of the pins is ±50mV (35mV rms)
5,6	IP2, IN2	Analog input of current channel B, the maximum differential voltage of the pins is ±50mV (35mV rms)
7	VP	Voltage signal positive input terminal, maximum differential voltage ±100mV (70mV rms)
8	GND	chip ground
9	A1	The address setting pin of the chip, in UART multi-chip communication mode, is used to set the address of the chip, A4/A3/A2/A1 binary code (0000~1111) , can set the address 0~15; inside the pin is Pull-down resistor, if it is suspended, it is 0 level, and the pin is directly connected to VDD , it is high level . Matches the device address in the UART communication protocol
10	A2	
11	A3	
12	A4	
13	ZX	Voltage zero-crossing indication
14	I_leak	Leakage/overcurrent alarm output of current B channel
15	CF	Energy pulse output, see the description of the MODE register for the multiplexing function

16	SEL	UART/SPI Communication mode selection (0: UART 1: SPI), internal pull- down resistor, Floating is 0 level (UART) , and the pin is directly connected to VDD to be high level (SPI)
17	SCLK	SPI mode clock input; in UART communication mode, it can be suspended
18	RX/SDI	UART/SPI multiplexing pin, UART RX/SPI DIN
19	TX/SDO	UART/SPI multiplexing pin, UART TX/SPI DOUT, requires an external pull-up resistor
20	VPP	Keep it in the air

Pin Description（SOP16L）

pin number	symbol	illustrate
1	VDD	Power supply (+3.3V)
2	VT	External temperature sensor signal input
3,4	IP1, IN1	Analog input of the current A channel, the maximum differential voltage of the pins is ± 50mV (35mV rms)
5,6	IP2, IN2	Analog input of the current B channel, the maximum differential voltage of the pins is ± 50mV (35mV rms)
7	VP	Voltage signal positive input terminal, maximum differential voltage ±100mV (70mV rms)
8	GND	chip ground
9	ZX	Voltage zero-crossing indication
10	I_leak	Leakage/overcurrent alarm output of current B channel
11	CF	Energy pulse output, see the description of the MODE register for the multiplexing function
12	SEL	UART/SPI Communication mode selection (0: UART 1: SPI), internal pull- down resistor , Floating is 0 level (UART) , and the pin is directly connected to VDD to be high level (SPI)
13	SCLK	SPI mode clock input, in UART communication mode, just leave it floating
14	RX/SDI	UART/SPI multiplexing pin, UART RX/SPI DIN
15	TX/SDO	UART/SPI multiplexing pin, UART TX/SPI DOUT, requires an external pull-up resistor
16	VPP	Keep it in the air

1.5 register list

address	name	external read/write	internal read/write	bit width	Defaults	describe
Electric parameter register (read only)						
0x00	IA_FAST_RMS	R	W	twenty four	0x000000	A channel fast rms, unsigned
0x01	IA_WAVE	R	W	20	0x000000	A channel current waveform register, signed
0x02	IB_WAVE	R	W	20	0x000000	B channel current waveform register, signed
0x03	V_WAVE	R	W	20	0x000000	Voltage waveform register, signed
0x04	IA_RMS	R	W	twenty four	0x000000	A channel current RMS register, unsigned
0x05	IB_RMS	R	W	twenty four	0x000000	B channel current RMS register, unsigned
0x06	V_RMS	R	W	twenty four	0x000000	Voltage rms register, unsigned
0x07	IB_FAST_RMS	R	W	twenty four	0x000000	B channel fast rms, unsigned
0x08	A_WATT	R	W	twenty four	0x000000	A channel active power register, signed
0x09	B_WATT	R	W	twenty four	0x000000	B channel active power register, signed
0x0A	CFA_CNT	R	W	twenty four	0x000000	A channel active energy pulse count, unsigned
0x0B	CFB_CNT	R	W	twenty four	0x000000	B channel active energy pulse count, unsigned
0x0C	A_CORNER	R	W	16	0x0000	A channel current voltage waveform phase angle register
0x0D	B_CORNER	R	W	16	0x0000	B channel current voltage waveform phase angle register
0x0E	TPS1	R	W	10	0x000	Internal temperature detection

						register, unsigned
0x0F	TPS2	R	W	10	0x000	External temperature detection register, unsigned
User operation register (read and write)						
0x10	IA_FAST_RMS_CTRL	R/W	R	16	0xFFFF	A channel fast rms control register
0x13	IA_RMSOS	R/W	R	8	0x00	Current A channel RMS small signal correction register
0x14	IB_RMSOS	R/W	R	8	0x00	Current B channel RMS small signal correction register
0x15	A_WATTOS	R/W	R	8	0x00	A channel active power small signal correction register
0x16	B_WATTOS	R/W	R	8	0x00	B channel active power small signal correction register
0x17	WA_CREEP	R/W	R	8	0x0B	Active power anti-passage register
0x18	MODE	R/W	R	16	0x0000	User Mode Select Register
0x19	SOFT_RESET	R/W	R	twenty four	0x000000	When writing 0x5A5A5A, the user area register is reset
0x1A	USR_WRPROT	R/W	R	8	0x00	User write-protect setting register. After writing 0x55 , use The user operation register can be written; write other values, the user operation register area cannot be written
0x1B	TPS_CTRL	R/W	R	16	0x07FF	Temperature Mode Control Register
0x1C	TPS2_A	R/W	R	8	0x0000	External Temperature Sensor Gain Coefficient Correction Register
0x1D	TPS2_B	R/W	R	8	0x0000	External Temperature Sensor Offset Coefficient Correction Register
0x1E	IB_FAST_RMS_CTRL	R/W	R	16	0xFFFF	B channel fast rms control register

1.6 Special Register Description

1.6.1 User Mode Select Register

0x18	MODE	Operating Mode Register		
No.	name	default value	description	
[7:0]	reserved	0b00000000	reserve	
8	RMS_UPDATE_SEL	0b0	RMS register refresh time selection choose	0: 400ms 1: 800ms
9	AC_FREQ_SEL	0b0	AC frequency selection	0: 50Hz 1: 60Hz
10	reserved	0b0	reserve	
11	CF_SEL	0b0	CF pin output energy pulse selection	0: A channel 1: B channel
12	CF_UNABLE	0b0	CF pin output function selection	0: energy pulse, MODE[11] The configuration is valid 1: alarm function, TPS_CTRL[14] is configured with effect
[15:13]	reserved	0b000	reserve	

1.6.2 Temperature Mode Control Register

0x1B	TPS_CTRL	Temperature Mode Control Register		
No.	name	default value	description	
0x1B	TPS_CTRL	0x07FF	[15] Temperature measurement switch, default 0b0, open Start measuring temperature	0: open
				1: off
			[14] Alarm switch, default 0b0,	0: Temperature alarm is on
				1 : Current A channel overcurrent / leakage report alarm on
			[13:12] Temperature measurement selection, default 0b00 automatic temperature measurement	00: automatic temperature measurement
				01: Same as 00
				10: Internal temperature measurement
				11: External temperature measurement
			[11:10] Temperature measurement time interval selection, default 0b01 100ms	00: 50ms
				01: 100ms
				10: 200ms
				11: 400ms
			[9:0] External temperature measurement alarm threshold setting Set, the default setting is 0x3FF, no alarm	The TPS2 register value is greater than or equal to the report Alarm value, generate an alarm

1.7 Performance

1.7.1 Electrical parameter performance

（ VDD =3.3V， GND = 0V， on-chip reference voltage source, built-in crystal oscillator, 25 ℃, electric energy is measured through CF output）

Measurement items	symbol	Measurement conditions	the smallest	typical	maximum	unit
Power supply VDD	VDD		3.0		3.6	V
power consumption	Iop	VDD=3.3V		3		mA
Measuring range		4000:1 input drive state range				
Active energy measurement accuracy (big signal)		35A~100mA output Into @ 1mohm sampling resistor		0.2		%
Active energy measurement accuracy (small signal)		100mA~50mA input @ 1mohm sampling resistance		0.4		%
Active energy measurement accuracy (tiny signal)		50mA~10mA input Into @ 1mohm sampling resistor		0.6		%
RMS measurement accuracy (big signal)		35A~100mA input @ 1mohm sampling resistance		0.2		%
RMS measurement accuracy (small signal)		100mA~50mA input @ 1mohm sampling resistance		2		%
RMS measurement accuracy (tiny signal)		50mA~10mA input @ 1mohm sampling resistance		6		%
Fast RMS response	50Hz	Can be set to	10		40	M

time	60Hz	cycle/ half cycle	8.3		33	M
Zero-crossing signal output delay				571		u
The phase angle between channels causes measurement errors Poor (capacitive)	PF08err	Phase lead 37 (PF=0.8)			0.5	%
The phase angle between channels causes measurement errors Poor (sensibility)	PF05err	Phase lag 60 (PF=0.5)			0.5	%
AC Power Supply Rejection (Output Frequency rate amplitude change)	ACPSRR	IP/N=100mV			0.1	%
DC supply rejection (output frequency rate amplitude change)	DCPSRR	VP/N=100mV			0.1	%

Measurement items	symbol	Measurement conditions	the smallest	typical	maximum	unit
Analog input level (current)		Current differential input (peak)			50	mV
Analog input level (voltage)		Voltage differential input (peak)			200	mV
Analog input impedance				370		kΩ
SEL pull-down resistor		SEL (pull down)		56.9		kΩ
Analog input bandwidth		(-3dB)		3.5		kHz
Internal Voltage Reference	Vref			1.218		V
logic input high		VDD=3.3V±5%	2.6			V
Logic input low		VDD=3.3V±5%			0.8	V
logic output high		VDD=3.3V±5% IOH=5mA	VDD-0.5			V
Logic output low level		VDD=3.3V±5% IOL=5mA			0.5	V

1.7.2 limit range

（T = 25° C）

project	symbol	extremum	unit
Power supply voltage VDD	VDD	-0.3 ~ +4	V
Analog input voltage (relative to GND)	IP1, IP2, VP	-4 ~ +4	V
Digital input voltage (relative to GND)	A1~A4, UART_SEL, RX/SDI	-0.3 ~ VDD+0.3	V
Digital output voltage (relative to GND)	CF, I_Leak, TX/SDO	-0.3 ~ VDD+0.3	V
Operating temperature	Topr	-40 ~ +105	℃
storage temperature	Tstr	-55 ~ +150	℃

2 Functional description

BL0939 is mainly divided into analog signal processing and digital signal processing. The analog part mainly includes three-channel PGA, three-channel Sigma-Delta ADC, built-in clock (internal clock), power on/reset monitoring (Power on/reset), temperature detection (temperature sensor), LDO and other related analog modules, and the digital part is a digital signal processing module (DSP).

2.1 Current and voltage transient waveform measurement

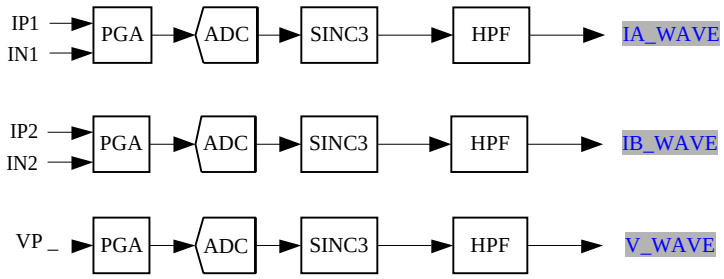


Figure 4

As shown in the figure above, two channels of current and one channel of voltage pass through the analog module amplifier (PGA) and high-precision analog-to-digital conversion (ADC) respectively to obtain three channels of 1bit PDM for the digital module, and the digital module passes through the down-sampling filter (SINC3), Qualcomm Filter (HPF), channel offset correction and other modules to obtain the required current waveform data and voltage waveform data (IA_WAVE, IB_WAVE, V_WAVE).

BL0939 has three high-precision ADCs, and the current adopts double-ended differential signal input: A current channel IP1/IN1, B current channel IP2/IN2, voltage channel VP.

The collected load current and voltage waveform data are updated at a rate of 7.8k, and each sampled data is a 24bit signed number, which is stored in the waveform register (IA_WAVE, IB_WAVE, V_WAVE) respectively, and the SPI rate configuration is greater than 375Kbps, which

can be read continuously Waveform value for one channel.

Note: The register is 24bit, if the number of digits is insufficient, the high bits are filled with zeros;

address	name	external read/write	internal read/write	bit width	Defaults	describe
0x01	IA_WAVE	R	W	twenty four	0x000000	A channel current waveform register
0x02	IB_WAVE	R	W	twenty four	0x000000	B channel current waveform register
0x03	V_WAVE	R	W	twenty four	0x000000	Voltage Waveform Register

2.2 active power

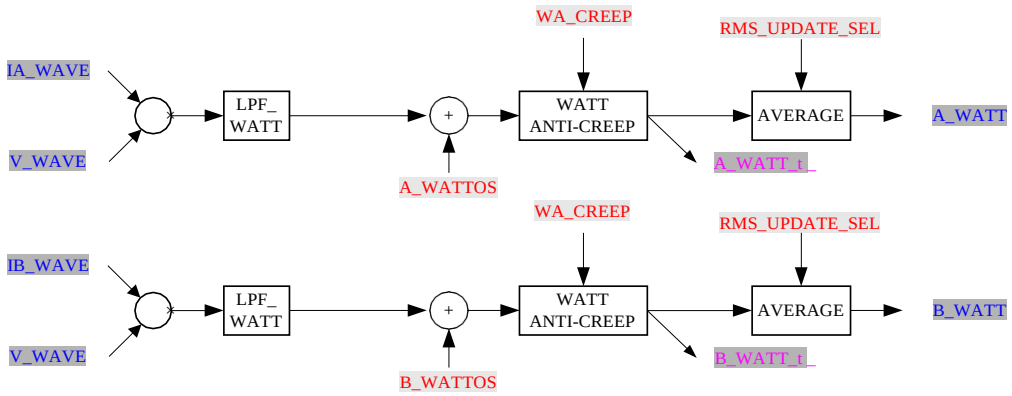


Figure 5

address	name	external read/write	internal read/write	bit width	Defaults	describe
0x08	A_WATT	R	W	twenty four	0x000000	A channel active register
0x09	B_WATT	R	W	twenty four	0x000000	B channel active register

Active power calculation formula： A/B_WATT = $\frac{4046*I(A)*V(V)*\mathrm{Cos}(\varphi)}{Vref^2}$

Among them, $I(A)$, $V(V)$ is the effective value (mV) of the channel pin input signal, φ is the phase angle of the I(A) and V(V) AC signals, Vref is the built-in reference voltage, typical value is 1.218V.

These two registers indicate whether the current active power is positive work or negative work, Bit [23] is the sign bit, Bit[2 3] = 0 , the current power is positive work, Bit[2 3] = 1 , the current power is negative work , in complement form.

2.3 Active Power Offset Calibration

BL0939 contains two 8 -bit active power offset correction registers (A_WATTOS , B_WATTOS), the default value is 00H . They use the data in 2 's complement form to eliminate the deviation of active power when measuring electric energy, and Bit[7] is the sign bit. The

deviation here may be due to board-level noise or crosstalk. Offset correction can make the value in the active power register close to 0 at no load .

address	name	external read/write	internal read/write	bit width	Defaults	describe
0x15	A_WATTOS	R/W	R	8	0x00	A channel power small signal correction register
0x16	B_WATTOS	R/W	R	8	0x00	B channel power small signal correction register

$$WATTOS = \frac{WATT - WATT0}{8 \times 3.05172}$$

WATT is the active power after correction, and WATT0 is the active power before correction.

2.4 Active power anti-creep

BL0939 has a patented power anti-submersion function, which ensures that the board-level noise power will not accumulate power when there is no current input.

active anti-creep threshold register (WA_CREEP), is an 8bit unsigned number, and the default is 0BH . The corresponding relationship between this value and the active power register value is shown in the following formula. When the absolute value of the input active power signal is less than this value, the output active power is set to 0 . This can make the value output to the active power register be 0 in the case of no load, even if there is a small noise signal, and the electric energy will not accumulate.

address	name	external	internal	bit width	Defaults	describe
		read/write	read/write			
0x17	WA_CREEP	R/W	R	8	0x0B	Active power anti-passage register

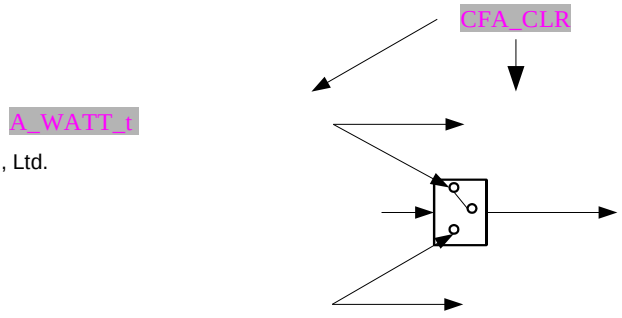
set according to the value of the power register A_WATT/B_WATT , and their corresponding relationship

$$WA\_CREEP = \frac{WATT}{3.0517578125*8}$$

Note: When the channel is in the anti-submarine state, the effective value of the current of the channel is not measured, and it is also cut to 0 .

2.5 Energy Metering

BL0939 provides two-channel energy pulse metering. The active instantaneous power of the two channels is integrated according to time to obtain active energy, and the calibration pulse CF is output in proportion . The CFA_CNT and CFB_CNT registers store the number of output energy pulse CF , as shown in the figure below Show.



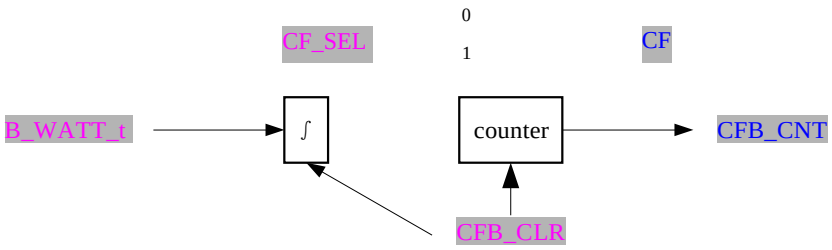


Figure 6

0x18	MODE	Operating Mode Register		
No.	name	default value	description	
10	reserved	0b0	reserve	
11	CF_SEL	0b0	CF pin output energy pulse pass Road selection	0: A channel 1: B channel
12	CF_UNABLE	0b0	CF pin output selection	0: Energy pulse MODE[11] configuration is valid 1: Temperature measurement/leakage alarm TPS[14] configuration is valid

First set MODE[12]=0 to select the CF pin to output energy pulse, and then set MODE[11] to choose to output the energy pulse of channel A or channel B.

address	name	external read/write	internal read/write	bit width	Defaults	describe
0x0A	CFA_CNT	R	W	twenty four	0x000000	A channel active energy pulse count, unsigned
0x0B	CFB_CNT	R	W	twenty four	0x000000	B channel active energy pulse count, unsigned

The counting of active energy pulses is applied to the applied energy, and the results are stored in two registers, CFA_CNT and CFB_CNT, and can also be accessed through I/O interrupt directly counts the number of pulses from the CF pin. When the period of CF is less than 180ms, it is a pulse with a 50% duty cycle, which is greater than or equal to 180ms, the high level fixed pulse width is 90ms.

Note: CFA_CNT and CFB_CNT registers are the algebraic and accumulation methods of electric energy pulses, that is, positive power is added and negative power is subtracted.

$$\frac{1638.4*256}{}$$

The accumulation time for each CF pulse $t_{CF} = \frac{}{WATT}$

Where WATT is the corresponding active power register value (A_WATT, B_WATT).

2.6 RMS value of current and voltage

The effective value of the three channels, as shown in the figure below, passes through the square circuit (X^2), low-pass filter (LPF_RMS), and root circuit (ROOT) to obtain the instantaneous value RMS_t of the effective value, and then obtains the average of the three channels by averaging values (A_RMS, B_RMS, and V_RMS).

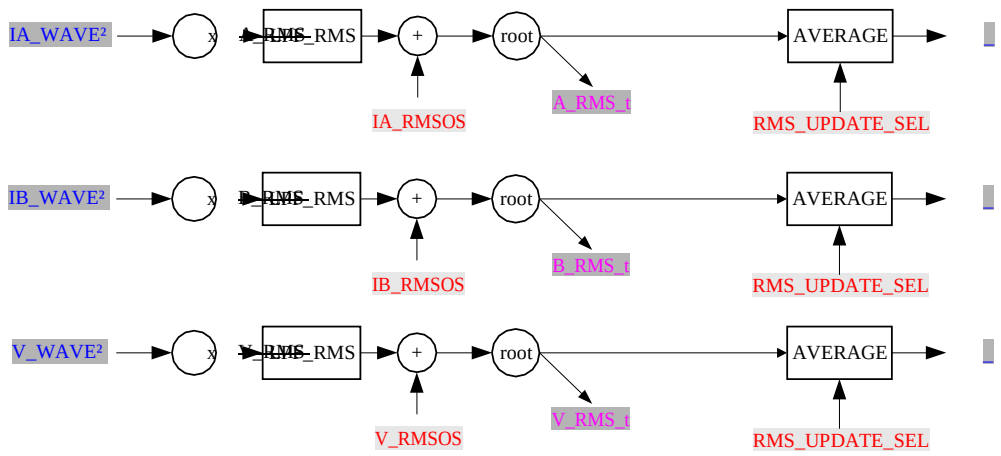


Figure 7

address	name	external read/write	internal read/write	bit width	Defaults	describe
0x04	IA_RMS	R	W	twenty four	0x000000	A channel current RMS register, unsigned
0x05	IB_RMS	R	W	twenty four	0x000000	B channel current RMS register, unsigned
0x06	V_RMS	R	W	twenty four	0x000000	Voltage rms register, unsigned

0x18	MODE	Operating Mode Register		
No.	name	default value	description	
8	RMS_UPDATE_SEL	0b0	RMS update speed selection	0: 400ms
				1: 800ms

Set MODE[8].RMS_UPDAT_SEL, you can choose the average refresh time of the effective value to be 400ms or 800ms, and the default is 400ms. When a current channel is in the anti-submarine state, the effective value of the current channel is zero.

Current RMS conversion formula: IA/B_RMS = $\frac{324004*I(A)}{Vref}$

Voltage RMS conversion formula: V_RMS =

7 $\frac{1*V(V)}{Vref}$
9
9
3

$Vref$ is the reference voltage, the typical value is 1.218V.

Note: I(A) is the input signal (mV) between IP1 and IN1 pins , V(V) is the input signal (mV) of VP pin .

2.7 Current Voltage RMS Offset Calibration

BL0939 contains two 8 -bit RMS offset registers (IA_RMSOS and IB_RMSOS), their default value is 00H , and they use 2 's complement code form data to adjust the deviation in RMS calculation. This deviation may come from input noise. Offset correction can make the value in the rms register close to 0 at no load .

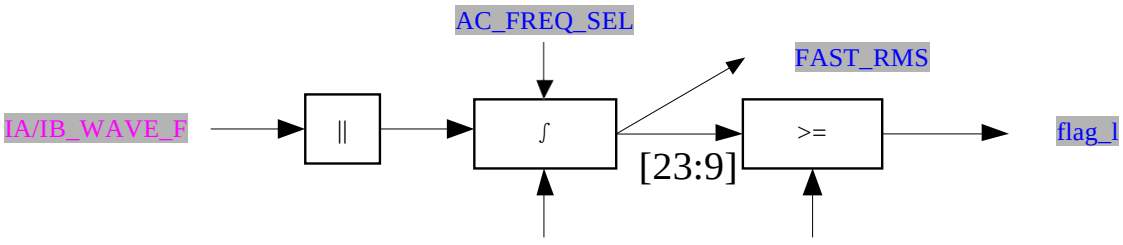
address	name	external read/write	internal read/write	bit width	Defaults	describe
0x13	IA_RMSOS	R/W	R	8	0x00	IA current RMS small signal correction register
0x14	IB_RMSOS	R/W	R	8	0x00	IB Current RMS Small Signal Correction Register

Calibration formula : $RMSOS = \frac{RMS^2 - RMS0^2}{9.3132 \times 2^{15}}$

Here RMS0 is the effective value before correction, and RMS is the effective value after correction.

2.8 Leakage / overcurrent detection

and B of BL0939 have fast RMS registers, which can detect half cycle or cycle RMS. This function can be used for leakage or overcurrent detection. For the source of the leakage waveform I_WAVE , refer to the channel waveform block diagram. After taking the absolute value of IA/IB_WAVE_F , the half cycle or cycle time is accumulated, which is selected by FAST_RMS_CTRL[15] . The default value is 1 to select cycle accumulation, and the response time is up to 40ms (50Hz) or 33mS (60Hz), note that the jump of the x_FAST_RMS register is relatively large when the half cycle is accumulated . To distinguish the half cycle time of 50Hz and 60Hz (AC_FREQ_SEL).



FAST_RMS_CTRL [15]

FAST_RMS_CTRL [14:0]

Figure 8

address	name	external read/write	internal read/write	bit width	Defaults	describe
0x10	IA_FAST_RMS_CTRL	R/W	R	16	0xFFFF	A channel fast rms control register
0x1E	IB_FAST_RMS_CTRL	R/W	R	16	0xFFFF	B channel fast rms control register

Through two fast RMS control registers, IA_FAST_RMS_CTRL and IB_FAST_RMS_CTRL, the refresh time can be selected as half cycle or cycle, and the fast RMS threshold (that is, leakage or overcurrent threshold) can be set .

		Channel Fast RMS Register		
No.	name	default value	description	
0x10	IA_FAST_RMS_CTRL	0xFFFF	[15] A channel fast RMS register refresh time	0: half cycle 1: Cycle
			[14:0] A channel fast RMS threshold	
0x1E	IB_FAST_RMS_CTRL	0xFFFF	[15] B channel fast RMS register refresh time	0: half cycle 1: Cycle
			[14:0] B channel fast RMS threshold	

0x18	MODE	Operating Mode Register		
No.	name	default value	description	
9	AC_FREQ_SEL	0b0	AC frequency selection	0: 50Hz 1: 60Hz

Set AC frequency by MODE[9].

address	name	external read/write	internal read/write	bit width	Defaults	describe
0x00	IA_FAST_RMS	R	W	twenty four	0x000000	A channel fast rms, unsigned
0x07	IB_FAST_RMS	R	W	twen	0x000000	B channel fast rms, unsigned

				ty fo ur		

24 -bit unsigned fast effective value register according to the cycle or half cycle , compare Bit[23:9] of the FAST_RMS register with the leakage / overcurrent threshold FAST_RMS_CTRL [14:0] , if it is greater than or equal to the set threshold, the leakage / Overcurrent alarm output indicates that the pin outputs a high level.

B leakage /overcurrent alarm output indication pin is I_leak, which can be output directly without configuration.

leakage /overcurrent alarm output indication pin of channel A is CF, you need to set MODE[12]=1 first, and then set TPS_CTRL[14]=1.

0x18	MODE	Operating Mode Register		
No.	name	default value	description	
12	CF_UNABLE	0b0	CF pin output selection	0: Energy pulse MODE[11] configuration is valid
				1: Temperature measurement/leakage alarm TPS[14] configuration is valid

0x1B	TPS_CTRL	Temperature Mode Control Register		
No.	name	default value	description	
14	ALERT_CTRL	0b0	alarm switch	0: Temperature alarm is on
				1: Current A channel overcurrent/leakage alarm is on

Since the fast effective value is updated by cycle or half cycle, the response time of I_leak is up to 2 cycles or 2 half cycles.

2.9 Phase angle calculation

BL0939 can be used for phase angle measurement, and the phase angle CORNER_A/CORNER_B between A/B two-phase current and voltage indicates the reactive quadrant . The calculation is obtained by the positive zero-crossing time difference of the current and the voltage. When the current is positively zero-crossing, it is updated to the register CORNER_A/CORNER_B , and each register is a 16 -bit unsigned number.

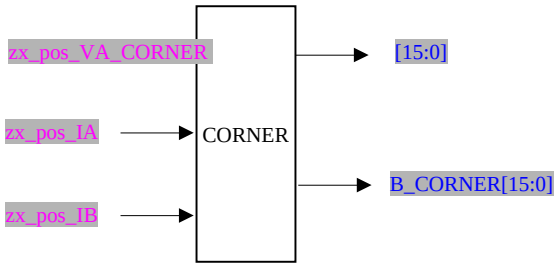


Figure 9

address	name	external read/write	internal read/write	bit width	Defaults	describe
0x0C	A_CORNER	R	W	16	0x0000	A channel current voltage waveform phase angle register
0x0D	B_CORNER	R	W	16	0x0000	B channel current voltage waveform phase angle register

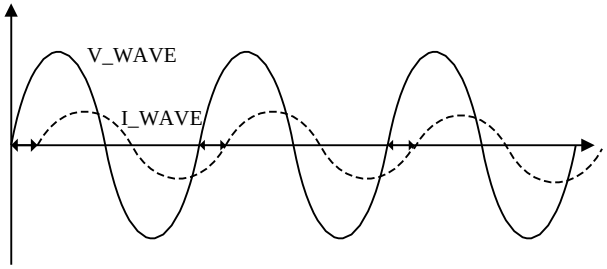


Figure 10

Phase angle conversion formula: $2*pi*A/B\_CORNER*\frac{f_c}{f_0}$ unit is radian

Among them , f_c is the measurement frequency of the AC signal source, the default is 50Hz, f_0 is the sampling frequency, the typical value is 1MHz.

2.10 Zero-crossing detection

BL0939 provides voltage zero-crossing detection, and the zero-crossing signal is directly output from the pin ZX. ZX is 0, which means the positive half cycle of the waveform, and ZX is 1, which means the negative half cycle of the waveform. The time delay with the actual input signal is 570us.

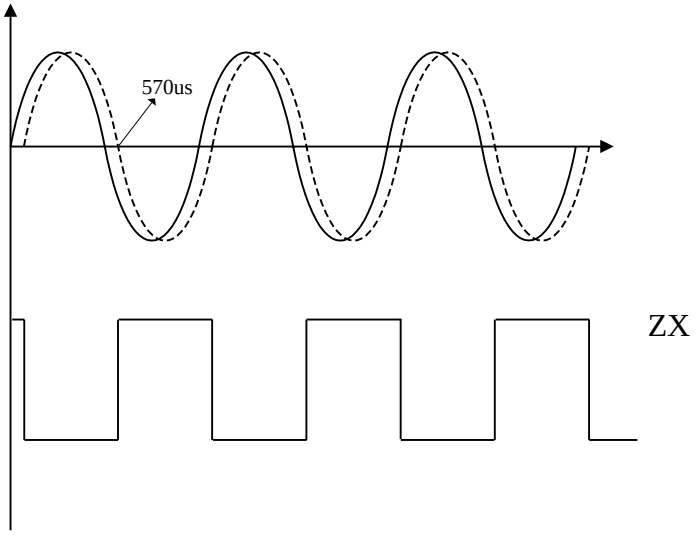


Figure 11

2.11 Thermometer

BL0939 provides internal temperature measurement and off-chip temperature measurement.

When the external temperature is measured, the optional output alarm indication, when the alarm function is turned on, the CF pin can be reused as an output alarm signal, when TPS2 is greater than or equal to the alarm threshold, the CF pin outputs a high level, and the temperature indication alarm. When the temperature value is lower than the alarm value or the alarm function is turned off, the alarm indication will be exited.

<table>
<tr><td>0x1B</td><td>TPS_CTRL</td><td colspan="3">Temperature Mode Control Register</td></tr>
<tr><td>No.</td><td>name</td><td>default value</td><td colspan="2">description</td></tr>
<tr><td rowspan="11">0x1B</td><td rowspan="11">TPS_CTRL</td><td rowspan="11">0x07FF</td><td rowspan="2">[15] Temperature measurement switch, default 0b0, open
Start measuring temperature</td><td>0: open</td></tr>
<tr><td>1: off</td></tr>
<tr><td rowspan="2">[14] Alarm switch, default 0b0,</td><td>0: Temperature alarm is on</td></tr>
<tr><td>1 : Current A channel overcurrent / Leakage alarm on</td></tr>
<tr><td rowspan="4">[13:12] Temperature measurement selection, default 0b00 automatic temperature measurement</td><td>00: automatic temperature measurement</td></tr>
<tr><td>01: Same as 00</td></tr>
<tr><td>10: Internal temperature measurement</td></tr>
<tr><td>11: External temperature measurement</td></tr>
<tr><td rowspan="4">[11:10] Temperature measurement time interval selection, default 0b01 100ms</td><td>00: 50ms</td></tr>
<tr><td>01: 100ms</td></tr>
<tr><td>10: 200ms</td></tr>
<tr><td>11: 400ms</td></tr>
<tr><td>[9:0] External temperature measurement alarm threshold setting</td><td></td></tr>
</table>

			set, the default setting is 0x3FF	

First set MODE[12]=1, and then set TPS_CTRL[14]=0, the CF pin can be turned on to output an external temperature alarm indicator.

0x18	MODE	Operating Mode Register		
No.	name	default value	description	
12	CF_UNABLE	0b0	CF pin output selection	0: Energy pulse MODE[11] configuration is valid
				1: Temperature measurement alarm TPS[14] configuration is valid

External and internal temperature readings are stored in two registers, TPS1 and TPS2, respectively.

address	name	external read/write	internal read/write	bit width	Defaults	describe
0x0E	TPS1	R	W	10	0x0000	Internal temperature value register, unsigned
0x0F	TPS2	R	W	10	0x0000	External temperature value register, unsigned

Internal temperature measurement formula: Tx=(170/448)(TB/2-32)-45

TB is the TPS1 register value;

The external test temperature adopts SAR ADC, the maximum input signal of VT pin is 0.55*VDD (V), and the value of TPS2 register is the corresponding AD sampled value, full scale 1024,

address	name	external read/write	internal read/write	bit width	Defaults	describe
0x1C	TPS2_A	R/W	R	8	0x00	External Temperature Sensor Gain Coefficient A Correction Register
0x1D	TPS2_B	R/W	R	8	0x00	External Temperature Sensor Bias Coefficient B Correction Register

3 Communication Interface

register data is sent in 3 bytes (24bit). For the register data less than 3 bytes, the unused bits are filled with 0, and 3 bytes are sent.

3.1 SPI

- Through the pin UART_SEL choose , with UART reuse
- ●♦●♋❖♏ mode
- Half-duplex communication , the communication rate can be configured , the maximum communication rate 900khz
- 8-bit data transfer, MSB First , LSB is behind
- ●☞♓☒ a clock polarity / phase (CPOL=0, CPHA=1)

3.1.1 Operating mode

The master device works in Mode1: CPOL=0, CPHA=1, that is, in the idle state, SCLK is at low level, and data transmission is at the first edge, that is, the transition of SCLK from low level to high level, So data sampling is on the falling edge, and data transmission is on the rising edge.

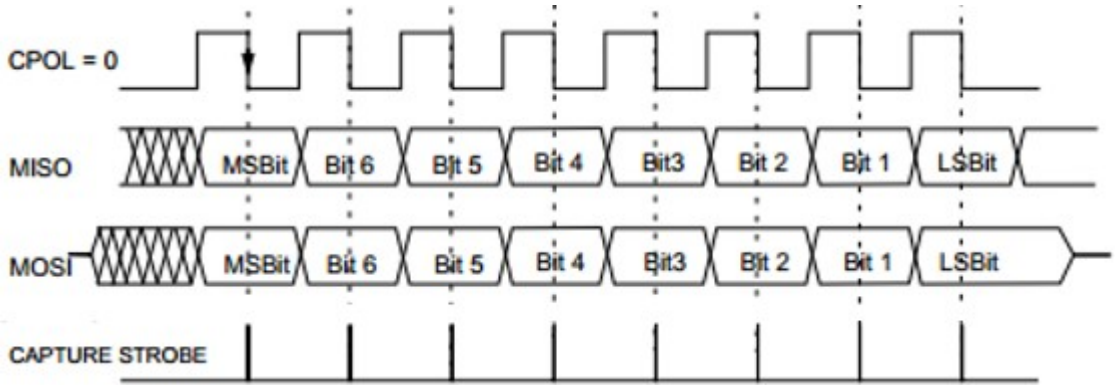


Figure 12

3.1.2 frame structure

In communication mode, first send 8bit identification byte (0x55) or (0xA5), (0x55) is the identification byte for read operation, (0xA5) is the identification byte for write

operation , and then send the register address byte to decide to access the register address (see BL0939 Register List) . The figure below shows the data transfer sequence for read and write operations, respectively. After one frame of data transmission is completed, BL0939 re-enters the communication mode. The number of SCLK pulses required for each read / write operation is 48 bits.

There are two frame structures, which are described as follows:

1）Write operation frame

write frame	0xA5	ADDR[7:0]	DATA_H[7:0]	DATA_M[7:0]	DATA_L[7:0]	CHECKSUM[7:0]

Among them, the checksum byte CHECKSUM is（(0xA5 + ADDR + DATA_H + DATA_M+ DATA_L）&0xFF）and then reversed bit by bit.

2）Read operation frame

read command frame	0x55	ADDR[7:0]

return data	DATA_H[7:0]	DATA_M[7:0]	DATA_L[7:0]	CHECKSUM[7:0]

Among them, the checksum byte CHECKSUM is（(0x55 + ADDR + DATA_H + DATA_M+ DATA_L）&0xFF）and then reversed bit by bit. Note: The data is a fixed 3 bytes（the high byte is in front, the low byte is in the back, if the data valid byte is less than 3 bytes, the invalid bit is filled with 0）

3.1.3 Write Operation Timing

The serial write sequence is performed as follows. The frame identification byte {0xA5} indicates that the data communication operation is to write data, and ADDR is the address of the register that needs to write data. The MCU will prepare the data bits that need to be written into BL0939 before the falling edge of SCLK , and start shifting in the register data at the falling edge of the clock of SCLK . All remaining bits of the register data are also shifted left on the falling edge of this SCLK (Fig. 13).

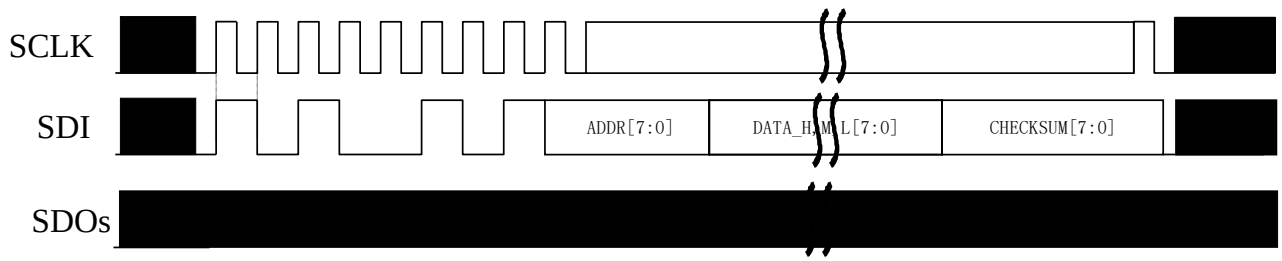


Figure 13

3.1.4 Read Operation Timing

During the data read operation of BL0939 , on the rising edge of SCLK , BL0939 outputs the corresponding data bit to the SDO logic output pin, and the SDO value remains unchanged during the next SCLK is 1 , that is, in the next On the falling edge, an external device can sample the SDO value. During the data read operation, the MCU must first send a read command frame.

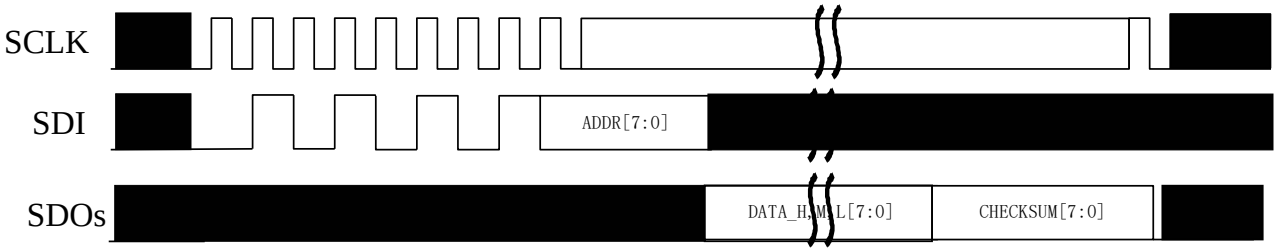


Figure 14

When BL0939 is in the communication mode, the frame identification byte {0x55} indicates that the data communication operation is read data. followed by the bytes ADDR is the address of the target register to be read. After the BL0939 receives the register address, it starts to shift out the data in the register on the rising edge of SCLK（Figure 14）. All remaining bits of the register data are shifted out on subsequent SCLK rising edges. Therefore, on the falling edge of SCLK, the external device can sample the output data of SPI. Once the read operation is complete, the serial interface re-enters communication mode. At this time, SDO output goes into a high-impedance state on the falling edge of the last SCLK signal.

3.1.5 SPI Interface fault tolerance mechanism

1）The soft reset function of the SPI interface can reset the SPI interface independently by sending 6 bytes of 0xFF through the SPI interface .

Note: SPI communication does not support chip selection. If you choose a 20pin package, you need to connect A4A2 to ground and A3A1 to high level.

3.2 UART

3.2.1 overview

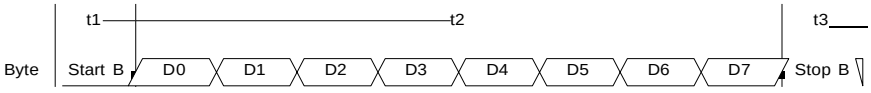
BL0939 can use UART communication. The UART interface only needs two low-speed optocouplers to realize isolated communication. Fixed baud rate 4800bps, N, 8, 1.5, working in slave mode, half-duplex communication.

Both packages have UART communication, and the 20 pin package has a chip select address [A4 A3 A2 A1], and the device address 00~15 can be set.

3.2.2 describe

UART port settings: communication baud rate 4800bps, no parity, stop bit 1.5.

3.2.3 format per byte



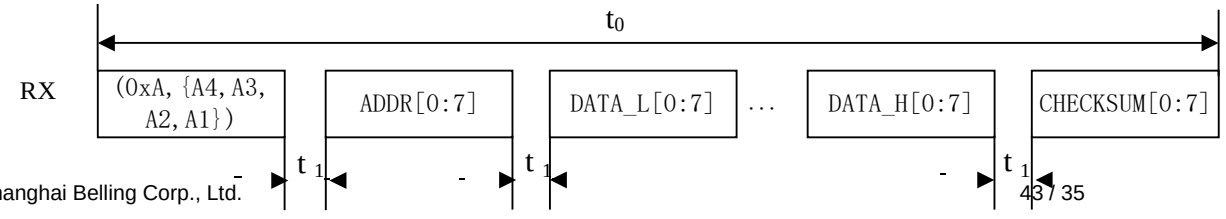
Start bit low level duration t1=208us

Valid data bit time lasts t2=208*8=1664us

Stop bit high level duration t3=208us+104us

3.2.4 write timing

host UART write data sequence is shown in the figure below. The host first sends the command byte (0xA,{A4,A3,A2,A1}), and then needs to write the data register address (ADDR), and then sends the data byte (The low byte is in front, the high byte is in the back, and the valid data bytes are insufficient 3 byte, invalid bits are filled with 0), and finally the checksum byte.

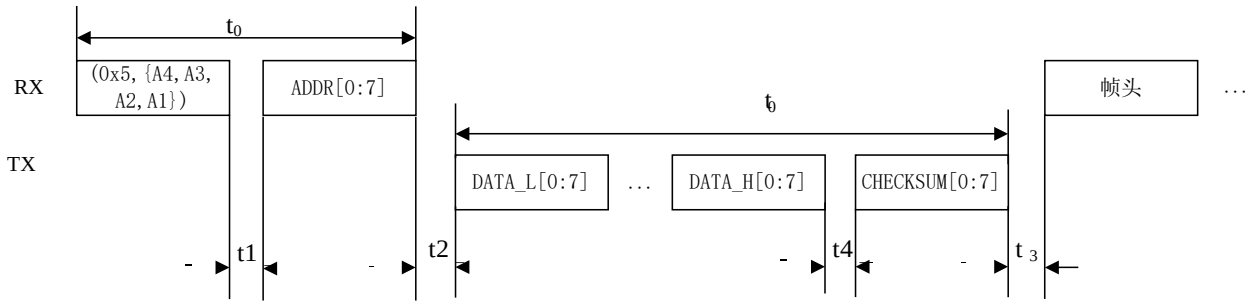


(0xA,{A4,A3,A2,A1}) is the frame identification byte of the write operation, if [A4 A1]=01 01, the device address is 5, and the frame identification byte is 0xA5. ___

ADDR is the internal register address of BL0939 corresponding to the write operation. The CHECKSUM byte is (((0xA,{A4,A3,A2,A1})+ADDR+Data_L+Data_M+Data_H) & 0xFF) and then reversed bit by bit. Note: The device address of BL0939-SOP16L is 5, that is, the first byte is 0xA5.

3.2.5 read timing

host UART read data sequence is shown in the figure below, the host first sends the command byte (0x5,{A4,A3,A2,A1}), then sends the register address (ADDR) to be read, and then BL0939 sends the data byte in turn (The low byte is in front, the high byte is in the back, if the data valid byte is less than 3 bytes, the invalid bit is filled with 0), and the last checksum byte.



(0 x 5, { A 4, A 3, A 2, A 1 }) is the frame identification byte of the read operation; if [A 4 A1] = 0 1 0 1, the device address 5, the frame identification byte is 0 x 5 5; ADDR is the internal register address of BL0939 corresponding to the read operation; CHECKSUM The byte is (((0x5,{A4,A3,A2,A1})+ADDR+Data_L+Data_M+Data_H) & 0xFF) and then reversed bit by bit;

Timing description

	illustrate	Min	type	Max	unit
t1	Interval time between MCU sending bytes	0		20	M
t2	Interval time from the end of MCU sending register address to BL0939 sending byte during read operation		72		u

t3	Interframe time	0.5			u
t4	Interval time between bytes sent by BL0939		116		u

3.2.6packet sending mode

Through the command " (0x5,{A4,A3,A2,A1}) + 0xAA ", BL0939 will return a full power parameter packet. A total of 35 packets were returned

bytes, 4800bps time cost 77ms. The specific format is: Baotou（ 1byte head）→♍◆❒❒♏■♦ _A Fast RMS（ 3byte IA_FAST_RMS）

→ Current A RMS value （ 3byte IA_RMS） → Current B RMS value （ 3byte IB_RMS） → Voltage RMS value （ 3byte V_RMS） →

electric current B Fast RMS（ 3byte IB_FAST_RMS）→ A Channel power value（ 3byte A_WATT）→ B Channel power value（ 3byte B_WATT） __

→✌ ♍♒♋■■♏● □◆●♦♏ count value （ 3byte CFA_CNT）?B channel pulse count value （ 3byte CFB_CNT）→✋■♦♏❒■♋● temperature measurement value（ 🗎♌🖂♦♏ TPS1 + 1byte 0）

?External temperature sensor measurement value（ 🗎♌🖂♦♏ TPS2 + 1byte 0）

→☝♒♏♍&♦◆❍ value （ 1byte CHECKSUM）.

Full electric parameter package format:

name	byte order No	content	name	byte order No	content
Baotou	0	Head（ 0x55）	B_WATT	19	B_WATT_l
IA_FAST_RMS	1	IA_FAST_RMS_l		20	B_WATT_m
	2	IA_FAST_RMS_m		twenty one	B_WATT_h
	3	IA_FAST_RMS_h	CFA_CNT	twenty two	CFA_CNT_l
IA_RMS	4	IA_RMS_l		23	CFA_CNT_m
	5	IA_RMS_m		24	CFA_CNT_h
	6	IA_RMS_h	CFB_CNT	25	CFB_CNT_l
IB_RMS	7	IB_RMS_l		26	CFB_CNT_m
	8	IB_RMS_m		27	CFB_CNT_h
	9	IB_RMS_h	TPS1	28	TPS1_l
V_RMS	10	V_RMS_l		29	TPS1_m
	11	V_RMS_m		30	0x00
	12	V_RMS_h	TPS2	31	TPS2_l
IB_FAST_RMS	13	IB_FAST_RMS_l		32	TPS2_m
	14	IB_FAST_RMS_m		33	0x00
	15	IB_FAST_RMS_h	checksum	34	checksum
	16	A_WATT_l			

A_WATT	17	A_WATT_m
	18	A_WATT_h

checksum=（（ (0x5,{A4,A3,A2,A1}) + 0x55 + data1_l + data1_m + data1_h +……. ） & 0xff） and invert

3.2.7 UART Interface Protection Mechanism

The UART communication of BL0939 provides a timeout protection mechanism. If the interval between bytes exceeds 18.5mS, the UART
The interface resets automatically.

If the frame identification byte is wrong or the CHECKSUM byte is wrong, the frame data is discarded.

UART module reset: RX pin is pulled high after the low level exceeds 6.65mS, and the UART module is reset.

4 order information

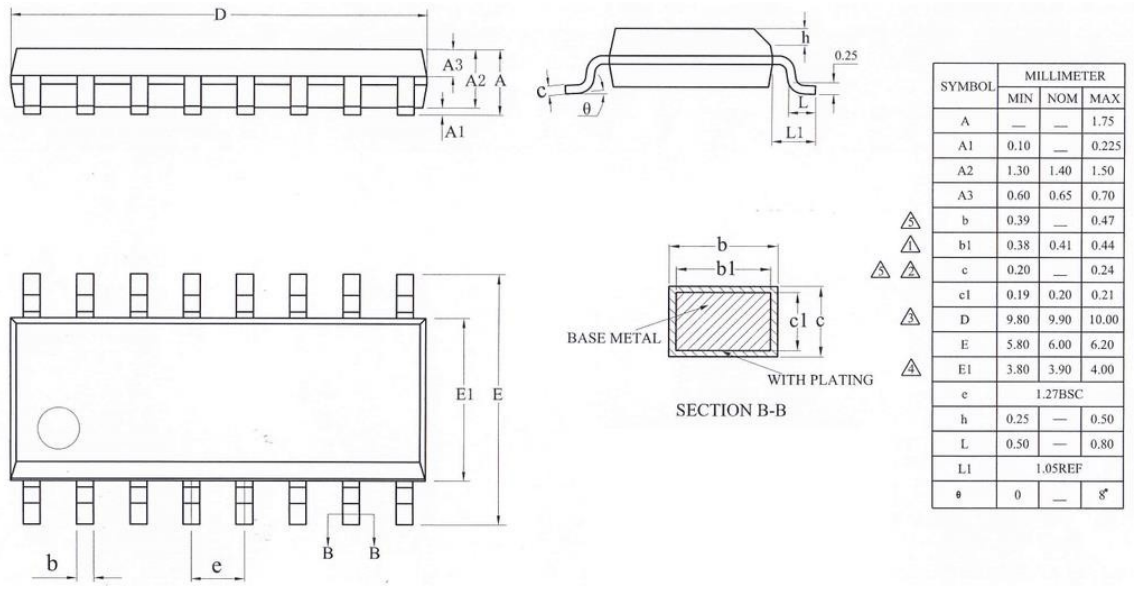
BL0939-X X=SOP16L: SOP16L encapsulation

X=SSOP20L: SSOP20L package

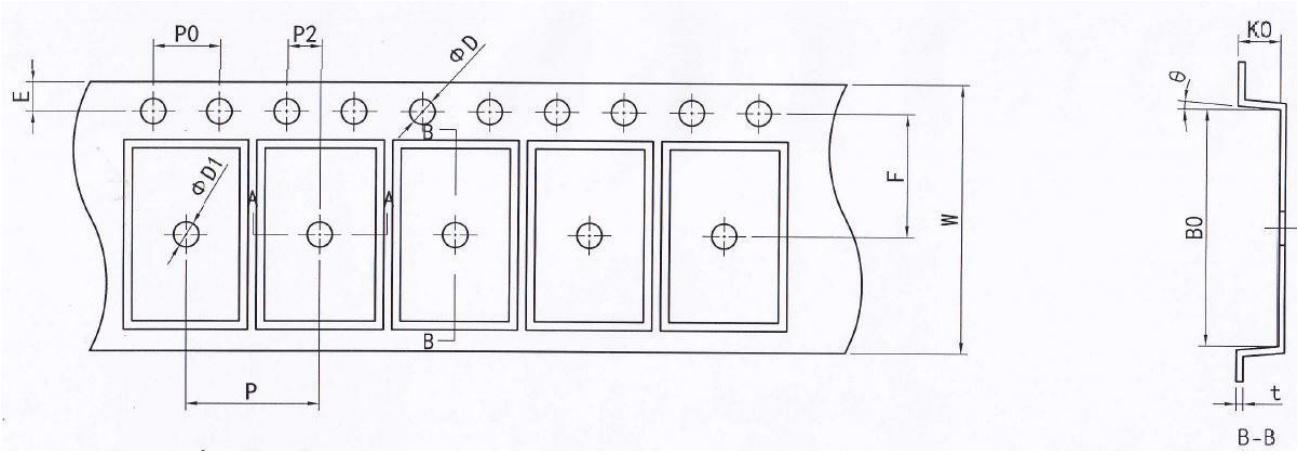
5 encapsulation

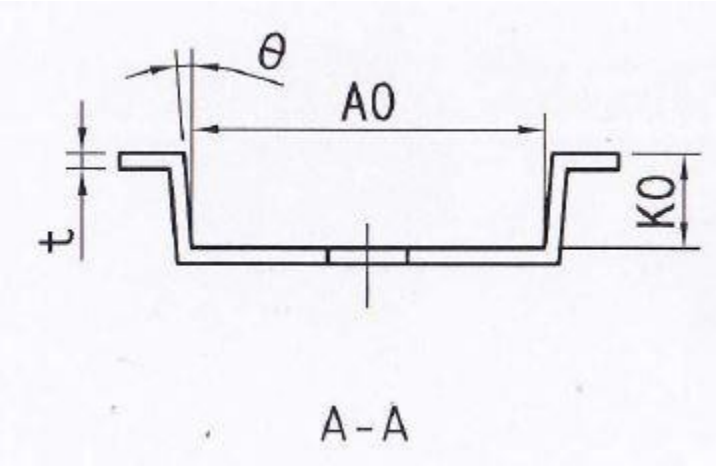
Moisture Sensitivity Level MSL 3
Warranty Period Two Years
Packing method Taping
packing Minimum packing 2500

5.1 SOP16L



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	—	—	1.75
A1	0.10	—	0.225
A2	1.30	1.40	1.50
A3	0.60	0.65	0.70
b	0.39	—	0.47
b1	0.38	0.41	0.44
c	0.20	—	0.24
c1	0.19	0.20	0.21
D	9.80	9.90	10.00
E	5.80	6.00	6.20
E1	3.80	3.90	4.00
e	1.27BSC		
h	0.25	—	0.50
L	0.50	—	0.80
L1	1.05REF		
θ	0	—	8°





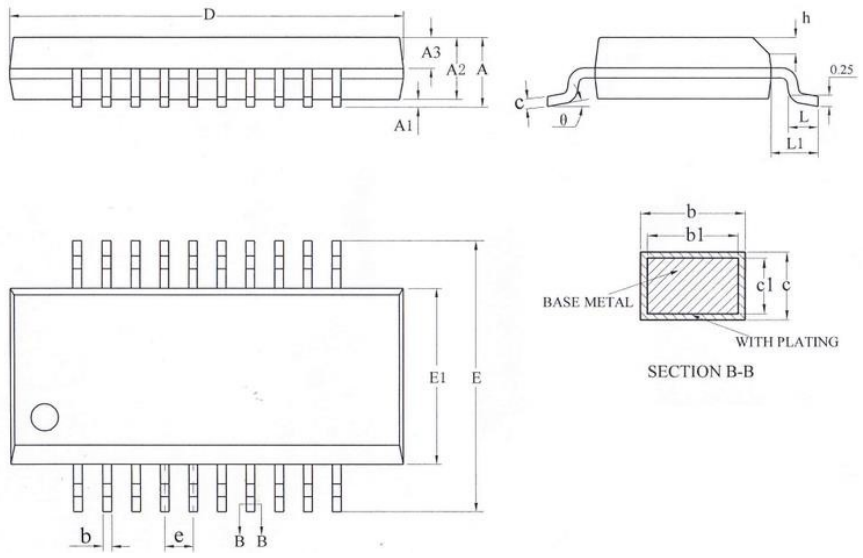
共同尺寸

	外 观	尺 寸(mm)
	E	1.75±0.10
	F	7.50±0.05
⚠1	P2	2.00±0.10
⚠2	D	1.55±0.05
	D1	$1.50^{+0.25}_{-0}$
	P0	4.00±0.10
	10P0	40.0±0.20

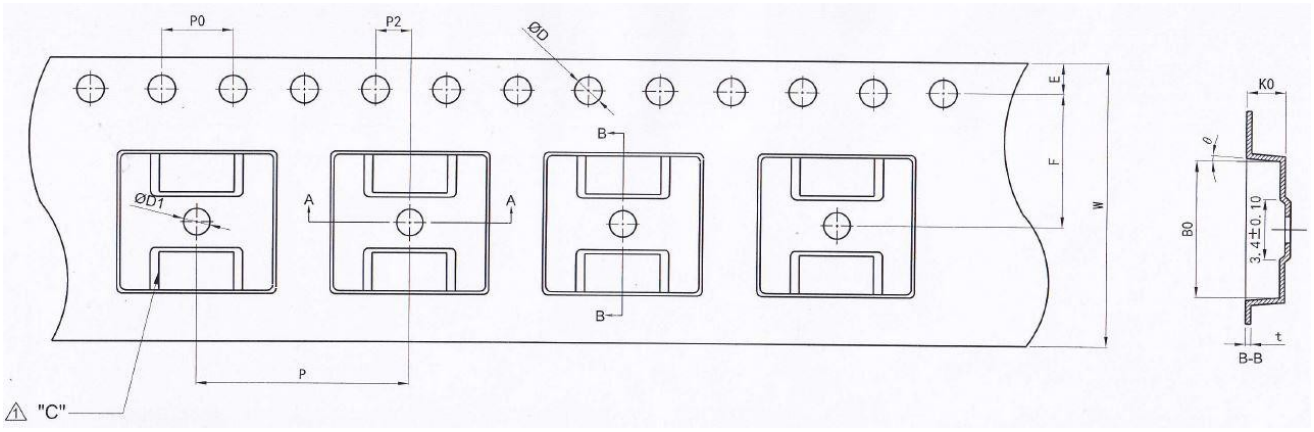
口袋尺寸

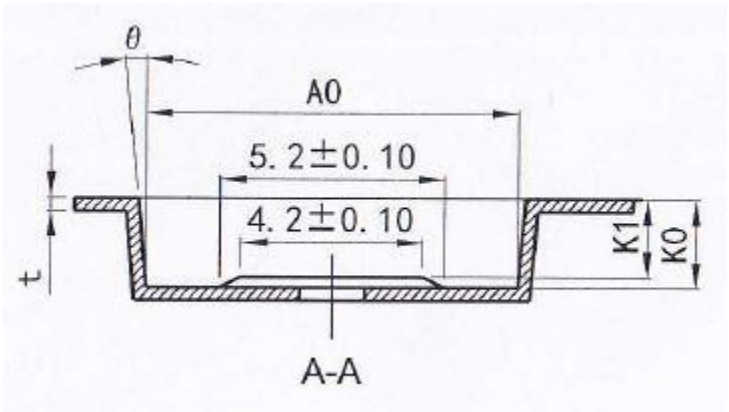
外 观	尺 寸(mm)
W	16.00±0.30
P	8.00±0.10
A0	6.70±0.10
B0	10.40±0.10
K0	2.10±0.10
t	0.30±0.05
θ	5° TYP

5.2 SSOP20L



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	—	—	1.75
A1	0.10	0.15	0.25
A2	1.30	1.40	1.50
A3	0.60	0.65	0.70
b	0.23	—	0.31
b1	0.22	0.25	0.28
c	0.20	—	0.24
c1	0.19	0.20	0.21
D	8.55	8.65	8.75
E	5.80	6.00	6.20
E1	3.80	3.90	4.00
e	0.635BSC		
h	0.30	—	0.50
L	0.50	—	0.80
L1	1.05REF		
θ	0	—	8°





共同尺寸

外 观	尺 寸(mm)
E	1.75±0.10
F	7.50±0.10
P2	2.00±0.10
D	1.55±0.05
D1	$1.5^{+0.25}_{0}$
P0	4.00±0.10
10P0	40.00±0.20

口袋尺寸

外 观	尺 寸(mm)	
W	16.00±0.20	②△
P	12.00±0.10	
A0	8.40±0.10	③△
B0	7.75±0.10	③△
K0	2.50±0.10	③△
t	0.30±0.05	
θ	3~5° TYP	
K1	2.10±0.10	③△