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Version Information

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2018-09-15	*HCJ*	*V1.0*: external release version.
2019-12-27	*HCJ*	*V1.1*: Revision of errata

BL0939 Application Guide

Catalog

BL0939 is a special chip developed by Shanghai Beiling Co., Ltd. for power measurement in the smart home field. It supports two measurement channels and can simultaneously perform metering and leakage fault detection, with settable leakage detection current, fast response time, small size, simple peripheral circuit, and low cost.

Chip function features.

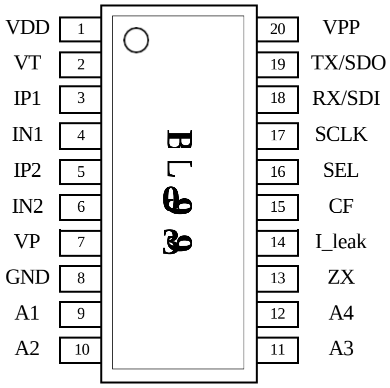
- Three independent Sigma-Delta ADCs for measuring two currents and one voltage.
- Current RMS range (10mA~35A) @1mohm
- Active power (1w~7700w)@1mohm
- Can output current, voltage RMS, fast current RMS, active power, current and voltage waveform phase angle
- Batch factory gain error less than 1%, peripheral components to meet certain conditions can be free of calibration
- Both current channels are equipped with leakage/overcurrent monitoring function, monitoring threshold and response time can be set
- Voltage over zero signal output
- Built-in waveform register for outputting waveform data for load type analysis
- Integrated temperature sensor to meet the product itself over-temperature monitoring, high current node preset temperature alarm, ambient temperature measurement and other needs

- Integrated SPI (fastest rate supports 900KHz) and UART (4800Bps) communication interface, UART communication method supports multi-chip communication (SSOP20L package only)
- Power down monitoring, chip reset when below 2.7V
- Built-in 1.218V reference voltage source
- Built-in oscillation circuit, clock approximately 4MHz
- Chip single operating power supply 3.3V, low power consumption 10mW (typical)

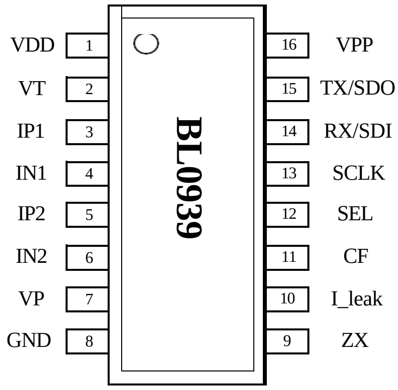
- SSOP20/SOP16 package

Chip pin description.

BL0939 is available in two packages.



SSOP20L



SOP16

Pin Description (SSOP20L)

Pin No.	Symbols	Description
1	VDD	Power supply (+3.3V)
2	VT	External temperature sensor signal input
3, 4	IP1, IN1	Analog input for current A channel, maximum differential voltage of pin ±50mV(35mV rms)
5, 6	IP2, IN2	Analog input for current B channel, maximum differential voltage of pin ±50mV(35mV rms)
7	VP	Voltage signal positive input, maximum differential voltage ±100mV (70mV rms)
8	GND	Chip Land
9	A1	UART multi-chip communication mode, used to set the address of the chip, A4/A3/A2/A1 binary code (0000~1111) can set the address 0~15; there is a pull-down resistor inside the pin, hanging is 0 level, the pin is directly connected to VDD is high level. Matching with the device address in UART communication protocol
10	A2	
11	A3	
12	A4	
13	ZX	Voltage over zero indication
14	I_leak	Current 2-channel leakage/overcurrent alarm output
15	CF	Electrical energy pulse output, multiplexing function see MODE register description

16	SEL	UART/SPI communication mode selection (0: UART 1: SPI) with internal pull-down resistor 0 level (UART) overhung, high level (SPI) if the pin is connected directly to VDD
17	SCLK	SPI mode clock input; in UART communication mode, just dangle
18	RX/SDI	UART/SPI multiplexed pins, UART RX/SPI DIN
19	TX/SDO	UART/SPI multiplexing pin, UART TX/SPI DOUT, external pull-up resistor required
20	VPP	Retain, just suspend

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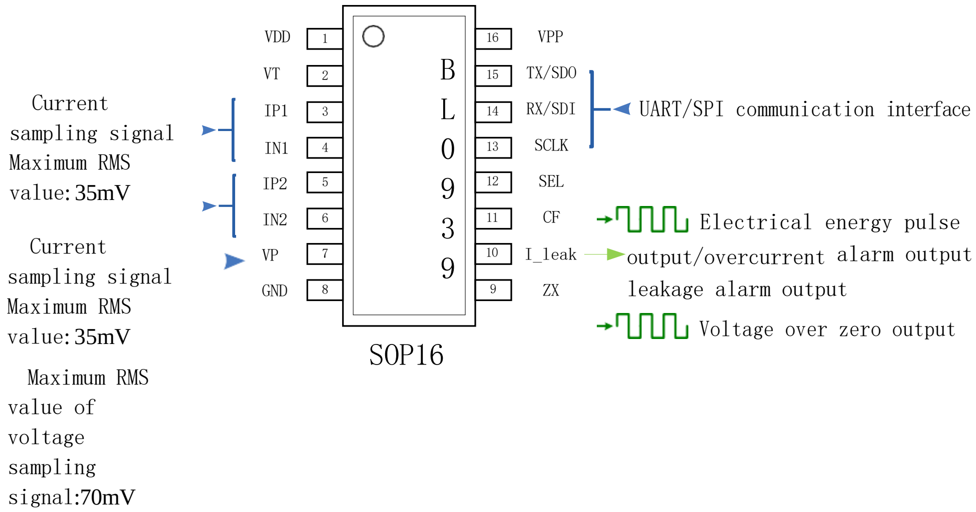
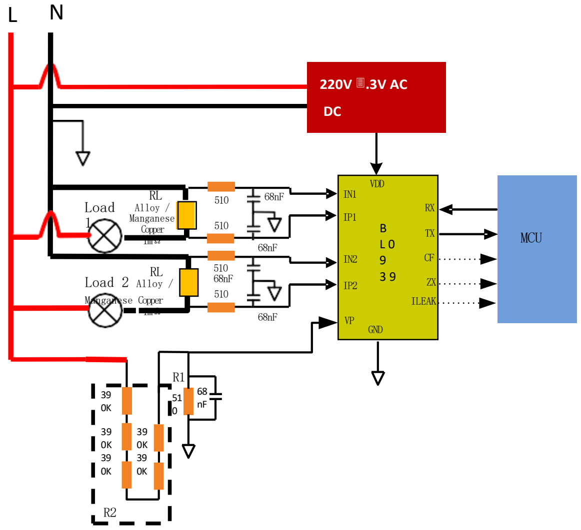
5, 6	IP2, IN2	Analog input for current B channel, maximum differential voltage of pin ±50(35mV rms)
7	VP	Voltage signal positive input, maximum differential voltage ±200mV (70mV rms)
8	GND	Chip Land
9	ZX	Voltage over zero indication
10	I_leak	Current 2-channel leakage/overcurrent alarm output
11	CF	Electrical energy pulse output, multiplexing function see MODE register description
12	SEL	UART/SPI communication mode selection (0: UART 1: SPI) with internal pull-down resistor 0 level (UART) overhung, high level (SPI) if the pin is connected directly to VDD
13	SCLK	SPI clock input, UART communication mode, dangling
14	RX/SDI	UART/SPI multiplexed pins, UART RX/SPI DIN
15	TX/SDO	UART/SPI multiplexing pin, UART TX/SPI DOUT, external pull-up resistor required
16	VPP	Retain, just suspend

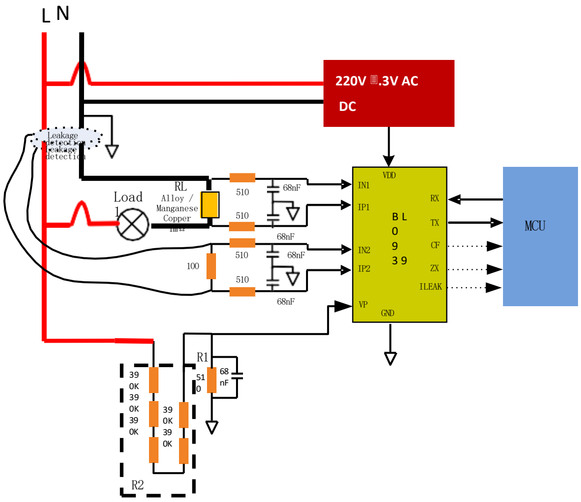
SOP16 package as an example



Two-way metering application circuit diagram.
The Uart communication method and the resistance sampling method are used as examples, and the sampling can also be done by the mutual sensor method.



One way metering and one way leakage detection application circuit diagram



Caution.

1) CF pin can be configured as an over-current alarm output; ZX is used to output a voltage over-zero signal; if only the electrical parameter detection function is required, these two pins can be left out of the MCU.

2) The rate of the UART interface, the communication protocol is described in "BL0939 datasheet v1.1.pdf".

3) The BL0939 is factory corrected for gain, and the peripheral devices are guaranteed to be accurate to within 1% if calibration is to be waived.

4) The TX pin requires an external pull-up resistor.

5) Zero-sequence current transformer is used for leakage detection, and the leakage threshold and response time can be set through registers at the same time through L and N wires

6) SPI communication method, described in the "BL0939 datasheet v1.1.pdf".

Considering that the maximum current of smart home products generally does not exceed 16A, the current is sampled using an alloy resistor of 1 milliohm, and the voltage sampling channel uses a resistive voltage divider to reduce the 220V voltage to 57.52mV rms by the VP pin of the chip.

The connection circuit between BL0939 and MCU is very simple, only TX,RX need to be connected if the system level is the same, UART Communication method 4800bps, N, 8, 1.5. MCU obtains active power, voltage, current, active energy pulse through communication frame

Punch count.

About electrical parameter conversion

BL0939 In defining the product, considering that manufacturers of smart home products are not professional manufacturers of measuring instruments, there is no professional

The calibration device, which also requires relatively low accuracy for power metering, only provides power consumption reference information and is not used as a billing standard. The smart device only needs to read active power, voltage and current, and calculate the power consumption according to the active power pulse count, so the BL0939 circuit is shipped with the guarantee that the gain deviation of the chip itself is less than 1%.

If the customer's peripheral devices are 1% accurate, the accuracy of the whole machine can be within 2% without calibration.

As an example of the parameters in the application circuit diagram.

The current sampling resistor RL is 1 milliohm, and the voltage channel is divided by R2 (390K*5) + R1 (0.51K) resistors to step down the AC 220V voltage to the mV level signal to the VP pin; the MCU gets the register data of BL0939 through the Uart interface.

Actual current value $= \frac{\text{Current RMS register value} * Vref}{324004 * RL}$ Amps

Actual voltage value $= \frac{\text{Voltage RMS register value} * Vref * (R2+R1)}{79931 * R1 * 1000}$ volts

Actual active power value $= \frac{\text{active power register value} * Vref2 * (R2+R1)}{4046 * RL * R1 * 1000}$ watts

The CFA_CNT register holds the number of electrical energy pulses.

Power corresponding to each electrical energy pulse degree $= \frac{1638.4 * 256 * Vref2 * (R2+R1)}{3600000 * 4046 * RL * R1 * 1000}$

RL in milliohms, R2,R1 in K ohms; Vref=1.218 volts.

Example: IA_RMS register value is 266013,V_RMS register value is 3774945,A_WATT register value is 156906, CFA_CNT register value is 1200; converted according to the formula.

Actual current value $= \frac{266013 * 1.218}{324004 * 1} \approx 1A$

Actual voltage value $= \frac{3774945 * 1.218 * (390*5+0.51)}{79931 * 0.51 * 1000} \approx 219.999$ volts

Actual active power $= \frac{156906 * 1.218 * 1.218 * (390*5+0.51)}{4046 * 1 * 0.51 * 1000} \approx 220.032$ watts

After powering up BL0940, the accumulated power $= \frac{1638.4 * 256 * 1.218 * 1.218 * (390 * 5 + 0.51)}{3600000 * 4046 * 1 * 0.51 * 1000} * 1200 \approx 0.196$ kWh

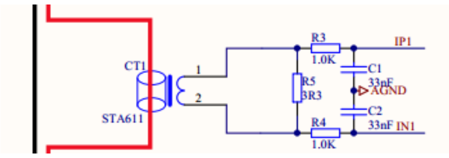
Caution.

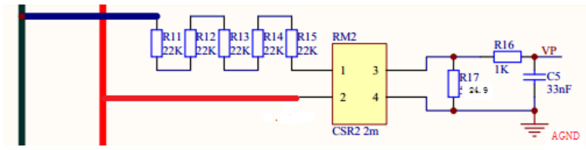
1) A_WATT, B_WATT registers are in complementary mode and need to be converted if they are negative power.

2) If the A_WATT register is negative power, the active power pulse count (CFA_CNT) register is decreasing, i.e. 0x000000->0xFFFFFF->0xFFFFFE->...->0x000001, which requires attention when accumulating electrical energy for processing.

3) BL0939 Unable to power down and save data.

If a current transformer (CT) and a voltage transformer (PT) are used for sampling, a typical circuit for the front end is as follows.





Assume that the current transformer CT1 has a ratio of Rt = 2000:1 and a load resistance of R5 (3.3 ohms); the voltage transformer (RM2) is a 1:1 current type voltage transformer; the load resistance R17 = 24.9 ohms

$$\text{Actual current value} = \frac{\text{Current RMS register value} * Vref}{324004*(R5*1000)/Rt} = \frac{\text{Current RMS register value} * 1.218}{324004*(3.3*1000)/2000} \text{ Amps}$$

$$\text{Actual voltage value} = \frac{\text{Voltage rms register value} * Vref*(R11+R12+R13+R14+R15)}{79931*R17*1000} = \frac{\text{Voltage rms register value}*1.218*(22*5)}{79931*0.0249*1000} \text{ Volt}$$

Actual active power value

$$= \frac{\text{active power register value}*Vref^2*(R11+R12+R13+R14+R15)}{4046*\left(\frac{R5*1000}{Rt}\right)*R17*1000} = \frac{\text{active power register value}*1.218^2*(22*5)}{4046*\left(\frac{3.3*1000}{2000}\right)*0.0249*1000} \text{ watts}$$

The CFA_CNT register holds the number of electrical energy pulses; each electrical energy pulse corresponds to the amount of electricity

$$= \frac{1638.4*256*Vref^2*(R11+R12+R13+R14+R15)}{3600000*4046*\left(\frac{R5*1000}{Rt}\right)*R17*1000} = \frac{1638.4*256*1.218^2*(22*5)}{3600000*4046*\left(\frac{3.3*1000}{2000}\right)*0.0249*1000} \text{ degree}$$

R5 in ohms, R11, R12, R13, R14, R15, R17 in K ohms; Vref = 1.218 volts.

About active power anti-submarine threshold setting

Usually there is a possibility of noise signals due to the PCB routing or external electromagnetic interference when there is no load during PCB routing impact, the chip detects noise power, resulting in a possible positive or negative power in the active power register.

The BL0939 has a patented power anti-submarine function to ensure that the board-level noise power will not accumulate power when there is no current input. The active anti-submarine threshold register (WA_CREEP) is an 8bit unsigned number, default is 0BH. The value is the same as the active The power register values correspond to the following equation. When the absolute value of the input active power signal is less than this value, the output active power is set to zero. This allows the value of the output active power register to be zero in the absence of load, even if there is a small noise signal.

Address	Name	External	Internal	Bit width	Default Value	Description
		Read/write	Read/write			
0x17	WA_CREEP	R/W	R	8	0x0B	Active power anti-submarine register

You can set WA_CREEP according to the value of power register A_WATT/B_WATT, their correspondence $WA\_CREEP = \frac{WATT}{3.0517578125*8}$

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

WA_CREEP default value is 0x0B; corresponding WATT active power register value

= 11*8*3.0517578125≈268; if 1milliohm sampling resistor is used, the voltage is divided by resistance 390K*5+0.51K; corresponding actual power
= 268/713.1 = 0.376 watts.
In practice, the active anti-submarine threshold register setting can be increased according to the application requirements, for example, metering is not required below 1 Watt. Threshold setting of 1W Corresponding parameter: =713.1/(3.0517578125*8) ≈ 29, WA_CREEP=0x1D.

About leakage/overcurrent detection threshold setting

BL0939 If zero-sequence current transformers are used for leakage detection, the leakage threshold setting needs to be set according to the zero-sequence current
The parameters of the transformer are calculated

地址	名称	外部 读/写	内部 读/写	位宽	默认值	描述
0x10	IA_FAST_RMS_CTRL	R/W	R	16	0xFFFF	A 通道快速有效值控制寄存器
0x1E	IB_FAST_RMS_CTRL	R/W	R	16	0xFFFF	B 通道快速有效值控制寄存器

通过 IA_FAST_RMS_CTRL 和 IB_FAST_RMS_CTRL 两个快速有效值控制寄存器，可选择刷新时间为半周波或周波，并设定快速有效值阈值（即漏电或过流阈值）。

Suppose the ratio of zero-sequence current transformer is 600:1 and the load resistance is 100 ohms; if a 30mA leakage alarm is required, then the fast RMS control register setting value of the corresponding channel

$$= \frac{30mA*\text{load resistance value}*324004}{\text{Variable ratio}*1.218} * \frac{0.72}{512} = \frac{30*100*324004}{600*1.218} * \frac{0.72}{512} =$$

Since the fast RMS register only detects half-period or period RMS values, there may be data jumps in comparison

In large cases, there may be at least a 5% jump, so be careful to consider the detection margin when setting the threshold register.

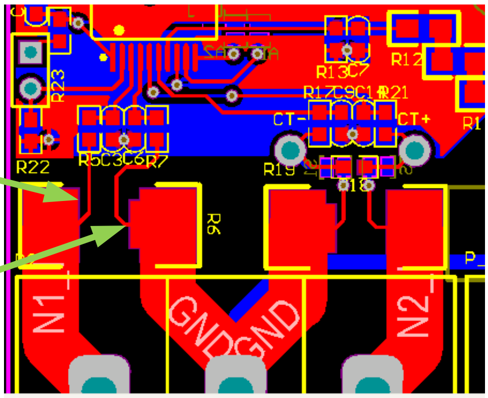
Ix_FAST_RMS_CTRL=1870*0.95=1776.

PCB Design Considerations

When PCB wiring requires attention to.

1) Current sampling resistors, capacitors as close as possible to the BL0939 pin, to prevent the lead is too long, the PCB board of other signal lines of interference; (current sampling signal about 5uV ~ 16mV)
2) In order to reduce the interference of the current sampling signal, the ground of the sampling resistor and the power supply ground are separately aligned; the current channel is differential sampling, IP, IN signal alignments are parallel and close to each other, and the PCB board alignments are as short as possible.
3) The external circuit parameters of the current sampling IP, IN should be balanced as much as possible and the alignments should be kept parallel and as short as possible.
4) Since the load current is flowing through the alloy resistor, it is important to note that the load current may be up to 16A at the PCB

   The alignment of the board to the alloy sampling resistor is as thick as possible (high current alignment)



Current sampling differential alignment out of the inside of the sampling resistor

Sampling resistor and GND connection pads are separately wired, separate from

5) Voltage sampling resistance voltage divider network as the AC 220V voltage is reduced to about 57.52mV, pay attention to the voltage withstand resistance to meet the requirements, while considering the creepage distance; and current sampling line separation distance to prevent signal crosstalk

6) Decoupling capacitor C12 for the 3.3V power supply of the BL0939 as close as possible to the VDD pin of the chip.

Reference: BL0939_Datasheet_V1.1.pdf

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