BL0940 Application Note

目录

Overview

The BL0940 is a high accuracy electrical energy measurement IC intended for single-phase application. It measures line voltage and current and calculates active energy and instantaneous rms voltage and current. The devices are suitable for multifunction smart electricity meters, power distribution units for corporate data centers, the Internet of Things, and in-home energy monitors for consumers.

The document describes system application issued when using the BL0940 to design single-phase energy meters. Generally, a single-phase smart meter consists of a single-phase energy metering IC, an MCU processor and its peripheral components. MCU reads and writes data of metering IC through the SPI/Uart interface. When using shunt sampling neutral current, MCU can be isolated from the metering IC by optocoupler. If the end user does not touch the internal components of the energy meter, ground of the MCU can also be connected to the neutral line and MCU connects to the metering IC directly

BL0940 Features：

- Two independent Sigma-Delta ADCs
- The Range of Current is （10mA~35A）@1mohm
- Measure RMS Voltage and Current, Fast RMS Current, Active Power, Active Energy
- The Gain error is less than 1%
- Voltage Zero-Crossing Logic Output
- Provide a Uart/SPI Communication Interface
- On-chip Power Supply Monitor
- On-chip voltage reference of 1.218V
- On-chip oscillator circuit, clock frequency 4MHz
- Power Supply 3.3V, Low Power Consumption 10mW (Typical)

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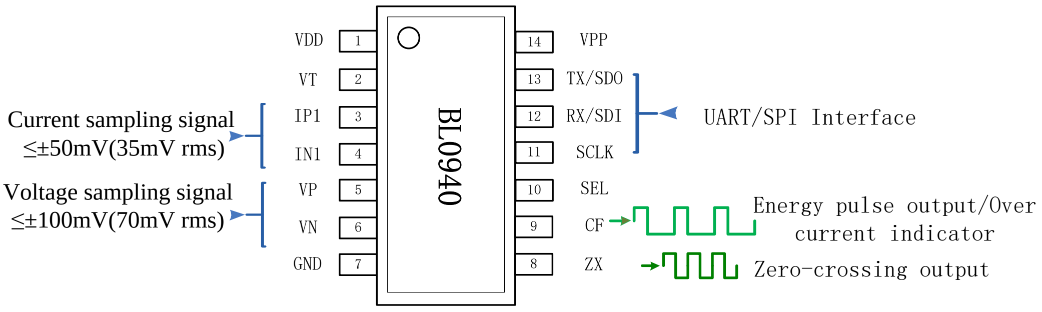
Pin Description:



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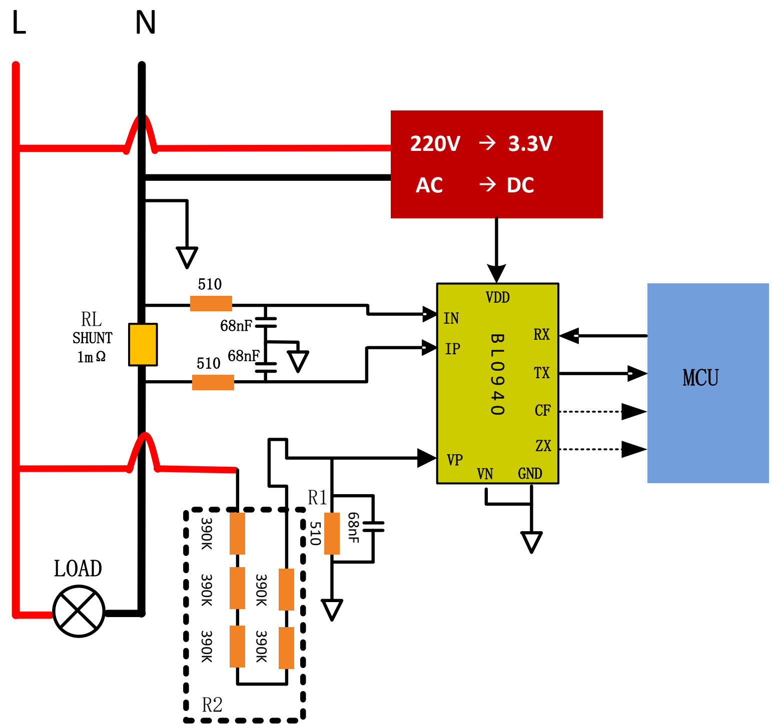
Pin	Symbol	Descriptions
1	VDD	Power supply(+3.3V)
2	VT	External temperature sensor (NTC) signal input
3，4	IP1，IN1	Analog input for current channel, this differential input has a maximum input range of ±50mV (35mV rms)
5，6	VP，VN	Analog input for voltage channel, this differential input has a maximum input range of ±100mV (70mV rms)
7	GND	Ground reference.
8	ZX	Voltage channel zero-crossing output pin
9	CF	Energy pulse output. See the MODE Register Description
10	SEL	Interface Select Pin (0: UART 1: SPI), internal pull-down resistor, so disconnect is low level(Uart), connected to VDD is high level(SPI)
11	SCLK	Serial clock input for SPI interface. If using Uart interface, the pin doesn' t need be connected.
12	RX/SDI	Data input for SPI interface/Receive line for Uart interface
13	TX/SDO	Data output for SPI interface/Transmit line for Uart interface, this PIN require external pull-up resistor
14	VPP	Reserved

Typical Application Circuit Diagram：

Resistor sampling and Uart communication is taken as an example, and transformer sampling can also be used.



Note:

1）the CF Pin can be configured as over-current alarm output, ZX Pin can be used by MCU to operate relay

2）the configuration of SPI/UART interface, and the communication protocol is described in BL0940 datasheet.

3）the gain error of BL0940 has been calibrated to be within 1% at the factory. The accuracy of peripheral components should be within 1% for calibration-free.

4）the TX Pin need be connected with a pull-up resistor.

The shunt size(1mΩ) is selected to maximize the use of the dynamic range on current channel. However, there are some import considerations when selecting a shunt for an energy metering application. First, minimize the power dissipation in the shunt. the maximum rated current can be 35A,therefore the maximum power dissipated in the shunt is $(35A)^2 \times 1m\Omega=1.225W$. Secondly, the higher power dissipation may make it difficult to manage the thermal issues. High temperatures may cause significant error at heavy loads. So, the maximum rated current@ (1mΩ shunt) should be limited to 16A.

The voltage attenuation is carried out by a simple resistor divider. In this design the line voltage is attenuated down to $(220V \times 0.51K\Omega)/(390K\Omega \times 5+0.51K\Omega)=57.52mV$ rms.

Electrical parameter conversion

The manufacturer of smart device is not a professional measuring instrument manufacturer, has not professional calibration equipment. So, the gain error of BL0940 is calibrated within 1% in IC factory. If the accuracy of peripheral components is within 1%, the accuracy of the whole device in basic current can be within 2% without calibration.

Electrical parameters conversion formula as follow:

The current sampling shunt resistor(RL) is 1mΩ, the voltage attenuation is carried out by R2（390K*5）+R1（0.51K） to VP PIN. MCU get the register data of BL0940 through Uart/SPI interface.

$$\text{Current}=\frac{I\_RMS\_Reg*Vref}{324004*RL} \quad \text{A}$$

$$\text{Voltage}=\frac{V\_RMS\_Reg*Vref*（R2+R1）}{79931*R1*1000} \quad \text{V}$$

$$\text{Active Power}=\frac{WATT\_Reg*Vref^2*（R2+R1）}{4046*RL*R1*1000} \quad \text{W}$$

CF_CNT register stores the count of active energy pulses.

The active energy per pulse:

$$\text{The active energy/CF}=\frac{1638.4*256*Vref^2*（R2+R1）}{3600000*4046*RL*R1*1000} \quad \text{kWh}$$

The unit of RL is mΩ， the unit of R2,R1 is KΩ; Vref=1.218 伏;

Example : the value of I_RMS register= 266013， the value of V_RMS register=3774945， the value of WATT register =156906， the value of CF_CNT register=1200. Conversion through the formula:

$$\text{Current }=\frac{266013*1.218}{324004*1} \approx 1A$$

$$\text{Voltage }=\frac{3774945*1.218*（390*5+0.51）}{79931*0.51*1000} \approx 219.999V$$

$$\text{Active power}=\frac{156906*1.218*1.218*（390*5+0.51）}{4046*1*0.51*1000} \approx 220.032W$$

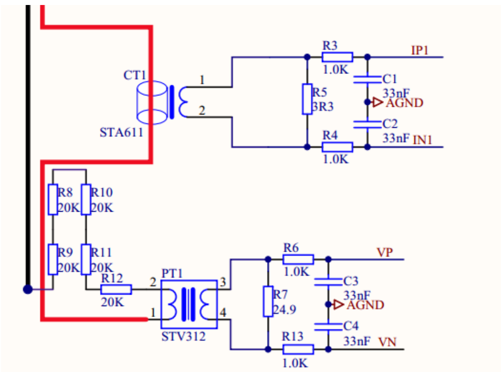
$$\text{Active energy}=\frac{1638.4*256*1.218*1.218*（390*5+0.51)}{3600000*4046*1*0.51*1000} * 1200 \approx 0.196\text{ kWh}$$

Note:

1） WATT register is a complement. MSB is the sign bit.

2） If the MSB of WATT register is 1, that means negative active power, the active energy pulse count of CFA_CNT is decreasing, 0x000000->0xFFFFFF->0xFFFFFE->...->0x000001

If use current transformer(CT), voltage transformer(PT) as sampling components, the typical circuit is:



Assume that the ratio of current transformer (CT1) is Rt=2000(2000:1), and the load resistor is R5(3.3Ω). the voltage transformer (PT1) is a 1:1 current type voltage transformer., and the load resistor is R7(24.9Ω).

$$Current = \frac{I\_RMS\_Reg*Vref}{324004*(R5*1000)/Rt} = \frac{IA\_RMS\_Reg*1.218}{324004*(3.3*1000)/2000} \quad A$$

$$Voltage = \frac{V\_RMS\_Reg*Vref*(R8+R9+R10+R11+R12)}{79931*R7*1000} = \frac{V\_RMS\_Reg*1.218*(20*5)}{79931*0.0249*1000} \quad V$$

$$Active\ power = \frac{WATT\_Reg*Vref^2*(R8+R9+R10+R11+R12)}{4046*(\frac{R5*1000}{Rt})*R7*1000} = \frac{WATT\_Reg*1.218^2*(20*5)}{4046*(\frac{3.3*1000}{2000})*0.0249*1000} \quad W$$

CFA_CNT register stores the count of active energy pulses.

The active energy per pulse

$$= \frac{1638.4*256*Vref^2*(R8+R9+R10+R11+R12)}{3600000*4046*(\frac{R5*1000}{Rt})*R7*1000} = \frac{1638.4*256*1.218^2*(20*5)}{3600000*4046*(\frac{3.3*1000}{2000})*0.0249*1000} \quad kWh$$

The unit of R5 is Ω, the unit of R7, R8, R9, R10, R11, R12 is KΩ; Vref=1.218V;

No load threshold

The BL0940 includes a no-load threshold and start-up current feature that eliminates any creep effects in the meter. BL0940 stops energy accumulation if the energy falls below a programmable threshold. The no-load feature is enabled by default.

Active power anti-creep threshold register (WA_CREEP) is 8bits unsigned value, the default value is 0x0B.when the absolute value of active power is less than WA_CREEP*3.0517578125*8, the active power register(A_WATT) is set to zero,

Addr	Name	External R/W	Internal R/W	Bits	Default	Description
0x17	WA_CREEP	R/W	R	8	0x0B	Active power no-load threshold

The corresponding relationship between WA_CREEP and WATT register is shown in following:

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

When the BL0940 is in anti-creep state, the I_RMS register is also set to zero.

The default value of WA_CREEP register is 0x0B, the corresponding value of WATT register is 11*8*3.0517578125≈268;

In the typical application , the current sampling resistor is 1mΩ, the voltage divider is 390K*5+0.51K; the anti-creep active power is =268/713.1=0.376W

In customer application, the value of WA_CREEP register can be set according to the application requirements. For example, the anti-creep active power is required within 1W. the threshold value =713.1/(3.0517578125*8)≈29. WA_CREEP=0x1D.

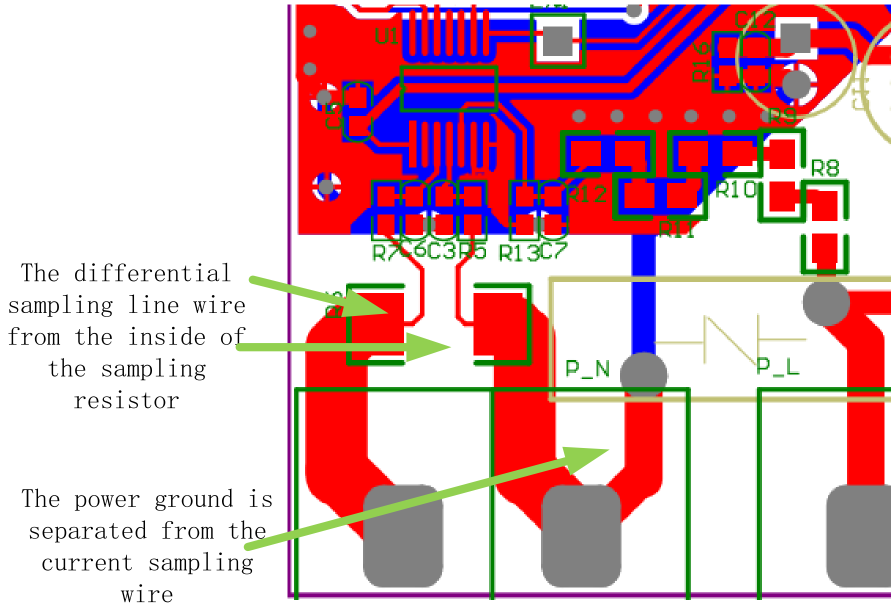
PCB Layout Considerations

1) The resistors and capacitors of the current sampling should be close to the IP1, IN1 PIN of the BL0940 to prevent crosstalk from the other signal on the PCB board. (current sampling signal maybe 5uV～16mV)

2) If the SMT shunt resistor is used for current sampling, in order to reduce the crosstalk to the current differential sampling signal, the ground wire of sampling resistor is

separated from the power supply ground. The PCB wire of current sampling IP and IN should be balanced as far as possible, and the wire should be kept parallel and as short as possible.

3） The load current is flowing through the shunt resistor, the heavy load current maybe exceeds 16A, so, keep the current wire as wide as possible.



4） The decoupling capacitor C5 of the power supply of BL0940 is close to VDD PIN.

Reference: BL0940 Datasheet