BL0932 Application Note

PIN ASSIGNMENT

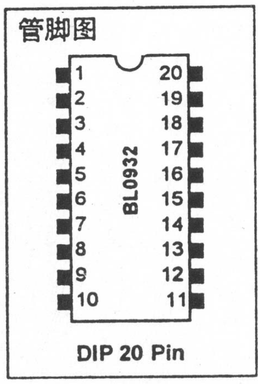

图 6 管脚图

DESCRIPTION

BL0932 IC is the main chip widely used for single-phase anti-steal electronic watt-hour meters. BL0932 is the modified version of BL0931. It keeps the main features of BL0931, such as better linearity, wide range of dynamic measurement, against potential shift, as well as provides real anti-steal of electricity power. The watt-hour meters made of BL0932 have better reliability.
BL0932 is a special large integrated circuit used for static electronic watt-hour meter. It uses silicone barrier BICMOS process with advanced circuitry, dual measurement of wattage, excellent performance, safe & reliable. The circuit is plastic/ceramic packaged dual in line with 20 pins.

FEATURES

- Have real function of anti-steal of electricity, precisely measure both positive and negative wattful power and integrate the electrical energy at the same direction.
- Good linearity, wide dynamic operating range.
- Prevent from potential shift
- Fast pulse output for computer data processing, slow pulse output will directly drive the pulse motor
- For used both as single-phase and three-phase watt-hour meter
- Compatible with BL0931 for outline and pin signal
- Good reliability with more than 20 years life of time.

PIN DESCRIPTION

Table 1. PIN DESCRIPTION

Pin number	Symbol	Explanation
1,2	V_{i1},V_{i2}	Current sample signal input
4	V_V	Voltage sample signal input
4,5		Internal mutual connection
6,7	V_{r6} , V_{r7}	Voltage reference outside adjusting terminal
8	P_8	Watt power pile-up pulse
9	S_Q	Negative watt power indicator signal
10	T_C	Testing control terminal
11	V_{SS}	Negative supply
3,12	GND_A, GND_D	Analog to ground, digital to ground
13,14	M_O	Pulse electrical machinery drive output
15,16	O_{SC}	Crystal oscillation
17	V_{DD}	Positive supply(+5v)
18,19	C_1	Integral capacitance
19,20	C_2	Integral capacitance

CIRCUIT PRINCIPLE

Fig. 1 shows the diagram of BL0932. It can be roughly divided into four parts as for the measurement functions: multiplier, current-frequency converter(IFC), frequency-division logic(add/deduct counter), display and logic. Traditional single-phase inductive watt-hour meter and single-phase electronic watt-hour meter can only measure the positive wattful power in the same direction of the current and voltage, but can not measure negative wattful power in the counter direction of the current and voltage. It would even reverse and could not prevent from stealing electricity or somewhat better to stop reversing display the stealing action, such as BL0931. BL0932 electronic watt-hour meter has overcome the above-mentioned disadvantages. It adds the function of measuring the negative wattful power on the base of BL0931. It can convert either the positive wattful power into pulse output or the negative wattful power into pulse output with the same direction of the positive power. There is a higher frequency pulse output at Pin8 for calculation or computer process while a lower frequency pulse output at Pin13 & Pin14 for driving the pulse motor so that making mechanical counter move to integrate the power for recording power consumption. Thus we can make a real anti-steal electronic watt-hour meter which integrate both positive and negative wattful power in the same direction to accumulate the total power consumption. It warmly welcomed by the end-users. I once wrote an article named BL0931 Static Single-phase Electronic Watt-hour Meter IC, in which some applicable technologies were not introduced. Here I will add these for your reference.

1. Current ratio multiplier with chopper balanced input

   The multiplier in BL0932 is a current ratio analog multiplier. The two inputs of the multiplier are from voltage sample signal Vv of Pin4 & Pin3 and current sample signal VI of Pin1 & Pin2. Operation Amplifier OP2 is a close-loop amplifier with close-loop gain=47. OP2 is a dual-input operational amplifier. Because of the earth effect, the input impedance of OP2 is about 1KΩ at Pin2 while a higher input impedance at Pin1. The signal to the multiplier is about 48 VI . If a resister is connected to Pin1, it will not effect the gain of the OP and not change the accuracy of the meter. But if add a resister at Pin2, it will effect the close-loop gain of the OP and further to change the accuracy (or error) of the whole meter.

   Voltage sample signal Vv is put to the buffer end of MOS field effective transistor after chopper switched by a group of electronic switches through Pin4(Pin5) and Pin3. The impedance at the input terminal of MOS FET is very high so it is regarded as open as to the divider net.

   The control signal W of the electronic switch is a square wave of 32Hz with the function of making Pin4 & Pin3 alternatively turn on the buffer of the FET every 1/64 seconds so that the phase direction from the voltage sample signal to the current ratio multiplier reverses every 1/64 seconds. As the phase direction from current sample signal to the multiplier will no change, in one 1/64 seconds the input phase directions of the voltage and current are same, in another 1/64 seconds are different. This chopper-balanced inputs make the inputs at multiplier only related to Vv & VI, but nothing with phase direction. This is better for identifying positive and negative wattful power.

2. Current to frequency converter (IFC)

   The current to frequency converter consists of current integrator (OP3), comparator, clock-timed single regulator and constant power supply. The integrating capacitance of the current integrator is also controlled by W pulse signal through two groups of electronic switches and changes the direction to connect to OP3 every 1/64 seconds. This arrangement makes the integrating capacitance C in the alternatively to-and-fro integrating conditions to improve the non-linearity. Its scale characteristics and resolution are much better than general VFC. When the output triangle wave reaches Vref, the converter outputs a high level and later single regulator outputs a delayed PS1 pulse controlled by the timer to turn on the constant power supply to force the integrator drop down to the start point. So the integrating will cycle without end. The slop of the output triangle wave of OP3 will be changing with the output of the multiplier, i.e., the PS1 frequency will be changing with the output varied.

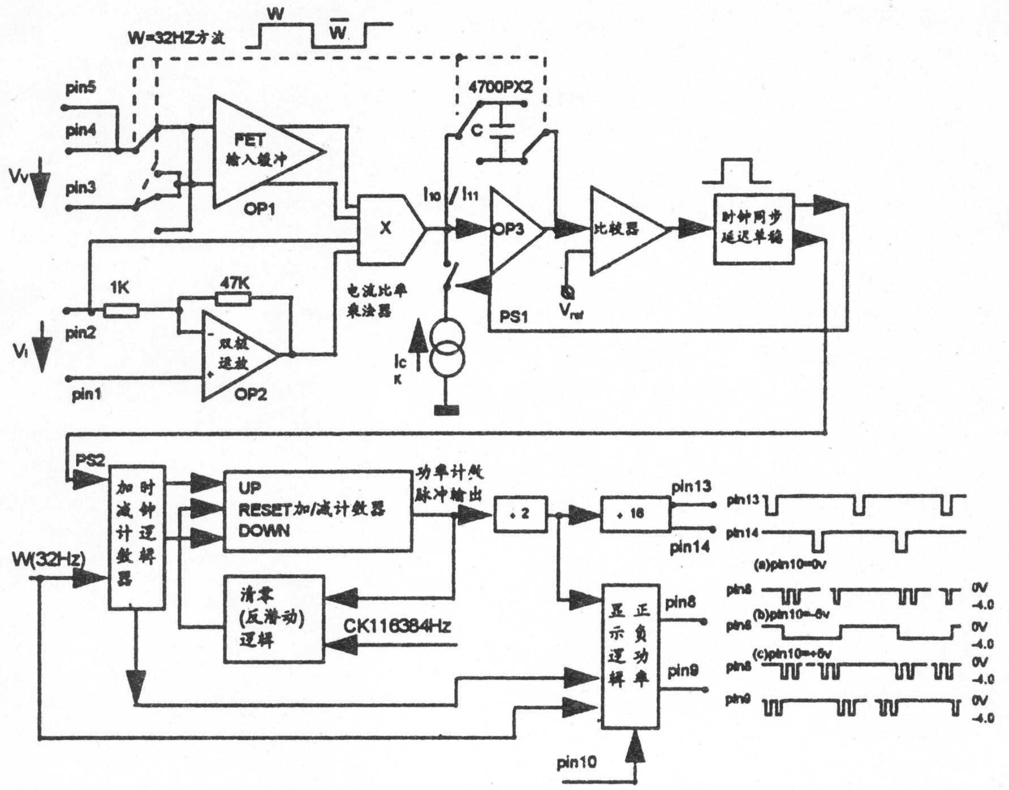

图 2 BL0932 原理图

Fig. 1 block diagram of BL0932

3. Frequency-division circuitry

Frequency-division circuitry is mainly a multi-stage reversible counter to perform add/deduct functions. It also includes set-to-zero (against potential shift) logic and counting timer logic. The input signal of timer logic includes W(32Hz square wave), PS2 pulse(same frequency as PS1, but width).

The function of the frequency-division circuit is firstly to detect the fast pulse signal only related to the product of Vv*VI and proportional to wattful power. It can detect not only the positive wattful power pulse but also the negative wattful power pulse. At the measurement principle, it ensures the same accuracy of pulse detection, i.e., the accuracy of positive wattful power measurement is the same as negative. Secondly, it divides the higher frequencies to produce a pulse signal with lower frequency reflecting the average wattful power in a certain period of time. This frequency of the pulse signal is still proportional to the wattful power which is related to the product of Vv*VI. We call the pulse signal power counting pulse.

BL0932 (or 0931) takes two measurements to overcome the potential shift. First, the multiplier uses chopper-balanced input to make it output a constant DC current (or slowly shifting DC change) which will not cause the change of the final output pulse (power counting pulse) from the frequency divider. Secondly, BL0932/31 has build in anti potential shift in its internal logic. When the external line use electricity and Pin10=-5V, the duration of producing every pulse by the frequency division circuit is much less than 256 seconds. Each power counting pulse, after reset logic to zero, will produce reset signal for the reversible counter to make the reversible counter reset to zero. Fig.4 shows that the power counting pulse is output at Pin8 through the second frequency divider and then output alternatively at Pin13 & Pin14 through 16 frequency division. Thus the output pulse frequency between Pin13 & Pin14 is 1/8 of the frequency at Pin8. When the load current is zero or very small, the duration of the counting pulse is longer than the operation duration of the anti potential shift logic: 256 seconds. The anti potential shift logic outputs a reset signal every 256 seconds to reset the above add/deduct counter to zero which prevent from forming overflow pulse (power counting pulse). This make Pin8, Pin13 and Pin14 output no pulses to reach the goal of anti potential shift.

Now let us observe, using the anti potential shift logic, the start current of some meters and the effectiveness produced by the meter accuracy to the start current.

Example 1: A single-phase electronic watt-hour meter has the constant: 5V, 1600P/Kwh, see its output at Pin8 in following three conditions:

(A). The measured power is 1kW, then the counting pulse will be 1600*2=3200 (each), the pulse duration is 3600/3200=1.125 seconds, much less than 256 seconds. So there is pulse output at Pin8 with the duration equals to 1.125*2=2.250 seconds.

(B). The measured power is 4.4W(220V, 20mA), and the meter has no error, then BL0932 will produce the following number of power counting pulse within one hour:

1600*2*4.4/1000=14.08 (each)

The duration of power counting pulse is 3600(sec)/14.08=255.68(sec) which is little bitter less than 256 seconds. So it can produce power counting pulse and output at Pin8 after 2 frequency division with pulse duration 511.36 seconds.

(C). The measured power is 4.4W(220V, 20mA) and the meter error is －0.124%, then the duration of power counting pulse is:

3600(sec)/(1600*0.99876*2*4.4/1000)
=255.999(sec)

So |-0.124%| is the critical value of error for a meter of 5A, 1600 pulses/kWh. If the error is larger than |-0.124%|, 20mA(0.4%Ib) can not start; less than |-0.124%|, can start.

Here we resume the crystal frequency of the meters in the above examples is correct as 32768Hz.

Example 2: A single-phase electronic watt-hour meter has the constant of 5A,3200 pulses/kWh and no error, please calculate its start current. The critical start duration of power counting pulse in the BL0932 is 256 seconds. The duration is responsible to 14.0625 pulses per hour, 7.0313 pulses at Pin8. These pulses response to the wattage 7.0313/3200=0.0021972 (kWh). Thus the power is 192W. The load current is I=2.1972(W)/220V=9.987(ma). And 0.2%Ib = 10ma, so the meter of 5A, 3200P/kWh can be started at 0.2%Ib.

Using the same calculation we can get the critical start current for 10A, 1600P/kWh and 20A, 800P/kWh meters respectively 19.975ma and 39.95ma. These two meters can both start at 0.2%Ib. In order to give more rooms, the load error should be more than or equal to zero.

4. Output drive logic

Positive or negative power counting pulses are first 2-frequency division and then 16-frequency division. The 2-frequency divided pulse signal is sent to display logic while 16-frequency divided signal is output alternatively at Pin13 & Pin14. The width of each output pulse is 250 ms and at the middle of other partner's cycle time. So the average frequency of the output signal at Pin13 & Pin14 is 1/8 of that at Pin8.

There three input level at Pin10: 0V, -5V, +5V. These three levels control Pin8 & Pin9 to output three different types of pulse signals proportional to measured power. Table 2 shows the relationship between the level at Pin10 and measured power (Vv*Vi), Pin8, Pin9, Pin13 & Pin14.

Table 2

Input		Output			
Pin10	Measured Power	Pin8	Pin9	Pin13	Pin14
GND	Positive-going Active Power	Negative-going Power Pulse Signal Modulated by Pulse 8192 Hz (0~-4V). See diagram II(a)	0V(DC)	Negative Pulse at the Width of 250ms, 1/16 of the Frequency at Pin8 (0~-4V)	Negative Pulse at the Width of 250ms,1/16 of the Frequency at Pin8(0~-4V)
	Negative-going Active Power	The Same as the Upper Situation	-5V(DC) (Note1)	The Same as the Upper Situation (Note3)	The Same as the Upper Situation (Note3)
-5V	Positive-going Active Power	Power Pulse Square Wave (0~-4V). See diagram II(b)	0V(DC)	The Same as the Upper situation	The Same as the Upper Situation
	Negative-going Active Power	Power Pulse Square Wave (0~-4V). See diagram II(b) (Note3)	Same wave form as Pin8	The Same as the Upper Condition (Note3)	The Same as the Upper Situation (Note3)
+5V	Positive (or Negative)-going Active Power	IFC output Pulse Series Are Exported alternately at Pin8 and Pin9 at the Time Intervals of 1/64s.The Difference between the Output Pulse Series of Pin8 and Pin9 at Two Adjacent 1/64s Time Intervals is Directly Proportional to the Measured Power.Note2		No Output OV(DC)	No Output 0V(DC)

Note1: In this case, even if the measured power is turned from negative-going to positive-going, the level still maintains at –5V until the voltage 220V disappears. If recharged, the –5V level at Pin9 can just return to 0V.

Note2: There are few pulse difference at Pin8 and Pin9 at two adjacent 1/64s time intervals, so the accuracy is low. High accuracy can be achieved if we get the pulse difference in Pin8 and Pin9 at a series of 1/64s time intervals. In this case, the pulse series exported at Pin8 and Pin9 are not modulated by the constant frequency pulse of 8192Hz.

Note3: No pulse is exported at Pin13,Pin14 if BL0931 is in this case.

APPLICATION

Using BL0932 to form a single-phase anti-stealing watt-hour meter

1. Circuitry (Fig. 2)

BL0932 single-phase watt-hour meter (Ii = 10A, C = 1600P/Kwh)

2. Circuitry description

BL0932 can measure both positive and negative wattful power with the same measuring accurate. And it counts at one direction at the mechanical counter. So Pin9 of BL0932 need not to connect to the green LED indicator, this is good for increasing the reliability of the meter.

Pin12 is the earth of the chip, Pin11 is Vss(-5V), Pin17 is Vdd(+5V). 220V AC is voltage divided through R11(470), C4(0.33µ/630V), C5(0.10µ). AC current at C5 is sent to diode D1 & D2 for semiwave rectification. Zener diode Z1 & Z2 (5.1V) are used for voltage clamping to make Vdd & Vss not exceed ±5.1V. The voltage at R11 ends is 11.5VAC, 219VAC at C4(at 0.33µ), 5.5V at C5. Increasing C4 will improve the stability of Vdd & Vss and the driving ability of the step motor. C6 & C7 (4100 - 4700pF) are the integrating capacitor of the built-in I-F converter. Pin15 & Pin16 are connected to the crystal of 32768Hz which determines the logic metre frequency of the chip and converting speed of I-F.

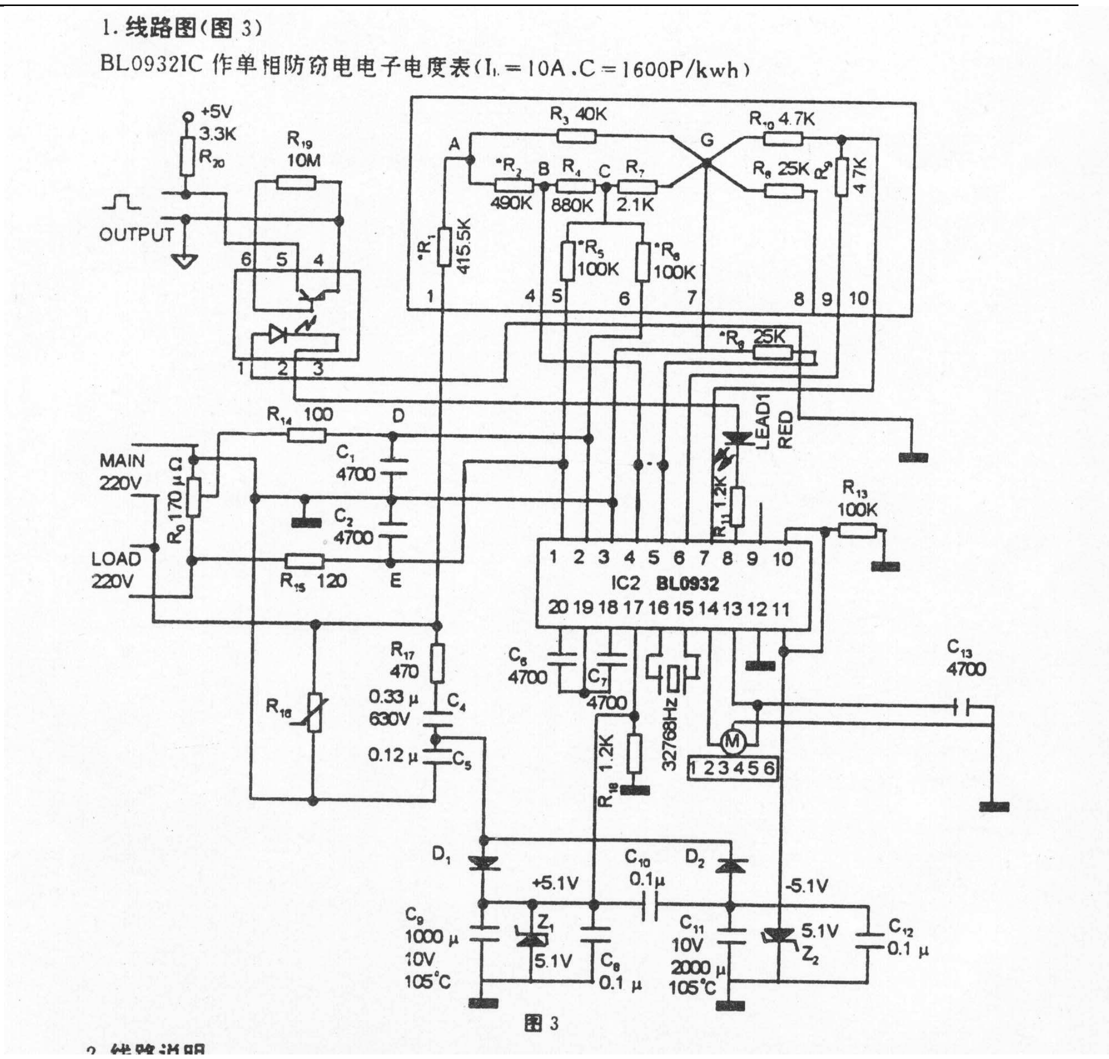

Fig. 2

The sampled signal Vv of BL0932 is obtained through 220V voltage divider formed by R1, R2, R3, R4, R7 and R8, and sent to Pin3 & Pin4 which are buffer input terminals of Vv. Pin3 is also the analog zero of the chip (or signal earth) for measuring reference point. The size of the measured signal is compared with Pin3 rather than other pins. The difference between Pin3 and Pin12 are that Pin3 and related signal earth prevent influence current with no relationship with signal from going through (especially the bigger influence current). The influence current should theoretically be let to Pin12 logic earth end or other related earth line. Pin4 and Pin5 are shorted in the chip shown in dot lines in the diagram. R8(25K) is connected in parallel to Pin3 & Pin5(Pin4) ends, at this time Pin8 of the thick film net should be open.

To calculate the electric potential at A, B, C points at the voltage dividing net of the thick film resistor related to the earth point G. "+" refer to resistors connected in serial, "//" refer to resistors connected in parallel.

UBG is the sampled signal Vv and UCG is the supply voltage with non-linearity compensation at light load. Note here UBG is not considered for adjustment precision. In fact there is difference between thick film resistor net and the nominal figures on the line. But Vv is equal to 0.8V - 0.9V

The input voltage Vi from current sample is produced by the load current flowing through manganin resistor Ro. In the real product, Ro only takes a portion of the resistance of the manganin resistor.

Vi=Ix * Ro

Generally Ro takes a very small value from tens of micro ohms to hundreds of micro ohms, much less than the sampled resistance in the current measurement lines by the multimeter. As BL0932(or0931) is an open-loop device, the precision of Ro is not strictly required, but stability is needed.

The product of Vv*Vi will determine the pulse output frequency of BL0932. The value of Vv is generally at 0.8V to 0.9V. When load current Ix is equal to Ib, suitable value of Vi will increase the precision of the meter and improve the non-linearity error at small signal (light load). Take a right resistance for Ro to let Vi=1.7mv at Ib then adjust the resistance of voltage divider net to make the meter reach the required accuracy at Ib. This kind of meter has good linearity at light load and easy for mass production. Table 3 shows the relationship between the constant of the meter and Ro for user's reference. We recommend the Ro value with "*" in the table.

Table 3 The relationship between meter constant and Ro

Ib / R0 / C	20A	10A	5A
800P/kwh	85μΩ 1.7mV	85μΩ 0.85mV	
1600P/kwh		170μΩ 1.7mV	170μΩ 0.85mV
3200P/kwh			340μΩ 1.7mV

Notes: 1. Vv=0.80-0.90V

2. "*" the values for Ro and Vi are recommended

3. Accuracy adjustment and non-linearity compensation at light load.

It is very convenience to adjust the accuracy of the meter made of BL0932, only two points should be adjusted.

(A) Adjustment of the meter accuracy at Ib point

BL0932 is an open-loop measuring device, the product of Vv*Vi will determine the meter constant, i.e., how many pulse will be output for every kwh wattage. To change the size of Vv By adjusting R8 at Ib point (or other large current point) to adjust the accuracy. You can also change the size of Vi by making a slot on manganin resistor perpendicular to the direction of load current to adjust Ro to reach the purpose of accuracy adjustment. The adjusted accuracy at Ib point will be assured for larger current, because the linear dynamic range is up to 12.5mv. At present, normal electronic meters' Vv is equal to 1.7mv(0.85mv for some meters), far from 12.5mv point, so BL0932 can make meters of times of band,6 times is no problem at linear point of view. But the following factors should be considered: power consumption of manganin resistor, heat-sinking, good connection of current contacts.

(B) Non-linearity compensation at light load

Now foreign and domestic single-phase watt-hour meters with the chip like BL0932 have the non-linearity problem when the load current is smaller, i.e., Vi is smaller and without any compensation (R5, R6 open). Just like that shown in Fig. 3, the ideal chip linearity should not change with the Vi, it should be a horizontal line with linearity as "1". Normal non-linearity has two characteristics: one is going up at small signal(a) while another going down (b). For going up curve, it should be forced down by adding compensation at input ends, for going down curve, it should be forced up by adding compensation at the input ends. These two compensations are different in direction. R7(2.1K), R5(100K), R6(100K), R14(100) and R15(100) in the thick film net are specialized for non-linearity compensation. 100K is the nominal value for R5 and R6, it should be adjusted in application.

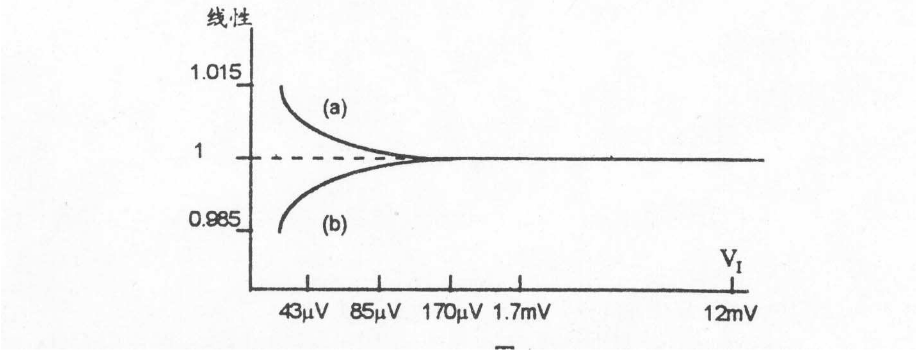

Fig. 3

The non-linearity compensation at light load is actually to just add a very small AC voltage (about 0.2 - 0.5 μv) at the input end of the current sampling amplifier. This voltage will be added to current sampled value from Ro to be as the current sample signal Vi to the multiplier. It effects the output reading of the meter only at light load, because this compensation voltage is very small. Here two types of non-linearity compensation will be introduced.

Fig. 4 is a simplified compensation circuit of BL0932 for Vi at small signal. Point C in the Fig. is the C point of voltage divider net, with about 2.03mVAC. So Uo is the compensation signal source.

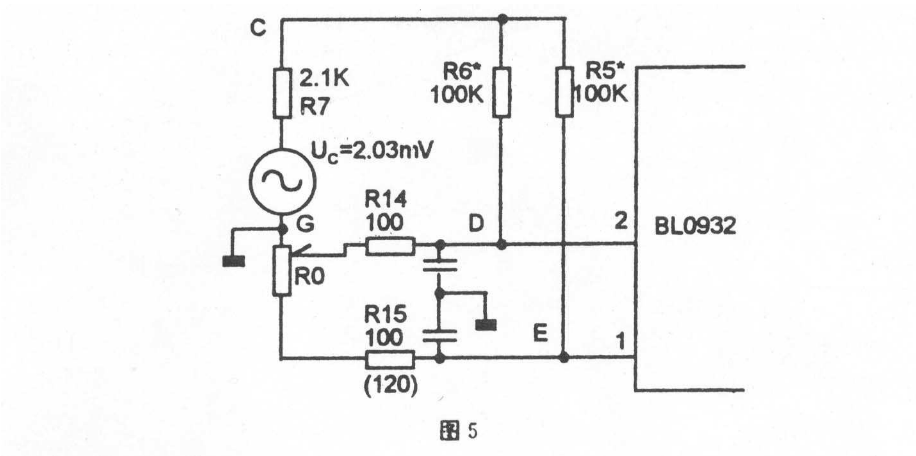

Fig. 4

∵ R14 >> Ro, R15 >> Ro
∴ Ro can be regarded as shortened to R14 and R15.
∵ R6 >> R7 >> R14 >>, R5 >> R7 >> R15
∴ Pin1 & Pin2 are the input ends of buffer amplifier with input resistance much more than (R15+R15).

The compensation source goes through R6 & R5 and makes a difference of voltage drop VDE at R14 and R15.

From the above formula, we can see that VDE has different phase at two different conditions of R6>R5 and R5>R6 (the two phases in reverse), because R14=R15. So two different compensation types should be taken for the above two different non-linearity error.

Type 1: Change R5 & R6

1. For up curve of non-linearity line at small signal (a), increase the resistance of R5 (to Pin1) and decrease R6 (to Pin2).

2. For down curve of non-linearity line at small signal (b), increase the resistance of R6 and decrease R5.

Example 1: A meter uses R5=114KΩ, R6=89KΩ to adjust the up curve of non-linearity error at small signal, resulting with good linearity.

Example 2: A meter uses R5=95KΩ, R6=125KΩ to adjust the down curve of non-linearity at small signal, resulting with good linearity and also fine at small current start as well as anti potential shift. The value of |R5-R6| varies for different chip characteristics, i.e., determined by the degree of non-linearity error at light load. Normally it will not be more than 30KΩ. The value of |R5-R6| should not be too small or the compensation will be insufficient.

Type 2: Change R15 for non-linearity compensation at light load.

R15 is connected to the same input end of current sampling operational amplifier OP2 and it does nothing with the close- loop gain of that OP. Most of BL093(or 0931) has non-linearity curve (b) before compensation, the curve can be easily improved just by increase properly R15 (for instance from 100Ω to 120Ω-130Ω) to the curve level or slightly up. This method is very effective.

The characteristic of non-linearity at light load has close relationship with start characteristic. So it is recommended that the meter reading error when Vi is about 43μV is little bitter larger(+0.3%-0.5%) than that when Vi=1.7mV.

This method can avoid to adjust R5 & R6(generally on thick film resistor net). So I prefer this method to compensate the non-linearity error.

From the above we can see that adjustment of either R1, R2 R4 and R5 will affect Vv to reach the purpose of adjusting the measurement accuracy of the meter. Adjustment of R15 (or R5, R6) will improve linearity at light load. The thick film voltage divider net uses the resistors made of the same material, so the temperature coefficient is the same and the ratio of voltage division will not be effected by the temperature. And also the thick film resistor is very small. But it is very slow and inconvenient to adjust the thick film resistor using laser resistor adjustment instrument. Furthermore, it can only be adjusted to up. Other methods of adjustment of thick film resistor is not reliable. The resistance will change easily if the resistor was treated improperly after adjustment. If there are resistors with the temperature coefficient small enough, for instance, precision metal film resistor of 1% accuracy (the temperature coefficient will reach ±100ppm/C, or even ±50ppm/C) can be used to replace the thick film resistor net. This is easier for accuracy adjustment and linearity adjustment and the accuracy and linearity will be stable after adjustment. But the resistor net is bigger and will occupy more space on the printed circuit board.

4. Printed Circuit Board

In single-phase watt-hour meters, high voltage of 220V and some small signal of μV are located on one small printed circuit board. The influence signal of 0.25μV formed between Pin1 and Pin2 will obviously affect non-linearity errors of the meter. The quality of the PCB, soldering of the board and assembly quality are critical to the success of the product.

(A). The PCB should have good insulation with the insulation resistance more than $10^{11}\Omega$. The pointer will not move obviously when the separated points(lines) are measured by using a meg ohm meter, especially in the environment with higher moisture. Worse base material of the board, bad manufacturing process and bad surface solder mask will lead to a worse insulation which will destroy the measuring accuracy of the meter, especially the accuracy at light load.

Furthermore, no corrosive chemical materials should be left on the board or the printed circuits will be rooted to break and the meter will not reach its certain time of life.

(B). The line pattern on the board should be arranged scientifically. The line for high voltage of 220V should be as short as possible and apart the lines for small signals as far as possible. R17, R16, R4 and R5 are connected to 220V, so they should be located near the edge of the board and turn 220V to low voltage line as fast as possible. Pin1 and Pin2 of the chip are the main input terminals for small signals, they should be close to each other and lined in parallel. they should also be in the same conditions and away from other signal lines. Pin3 is the naught line of analog signals. Try best to prohibit the influence current, especially the large current, which has nothing to do with the measuring signal, to enter this line so that there would be no influence signal voltage produced on this line.

(C). The printed circuit board for the watt-hour meter is a single-side one. Lines are on one side and copper foil on the other side is used as magnetic shield and earth which can lower the earth resistance and minimize the influence signal.