Tech (/category/2/tech)

/ A Design Flaw and Current Cancellation Circuits of Fluke 732B (/topic/300.rss)

L (/user/lymex)**lymex (/user/lymex)** Sep 15, 2019, 6:08 AM (/post/1370)Sep 15, 2019, 6:08 AM (/post/1370)

Fluke 732B is a solid-state benchmark in production and almost the only one used in high-level metrology departments. It is mainly used to directly receive the transmission of JVS, and is responsible for performing the benchmark, downward calibration, and comparison of external transmission when JVS is not turned on.

732B is an improvement from 732A, and the predecessor of 732A is 731B.

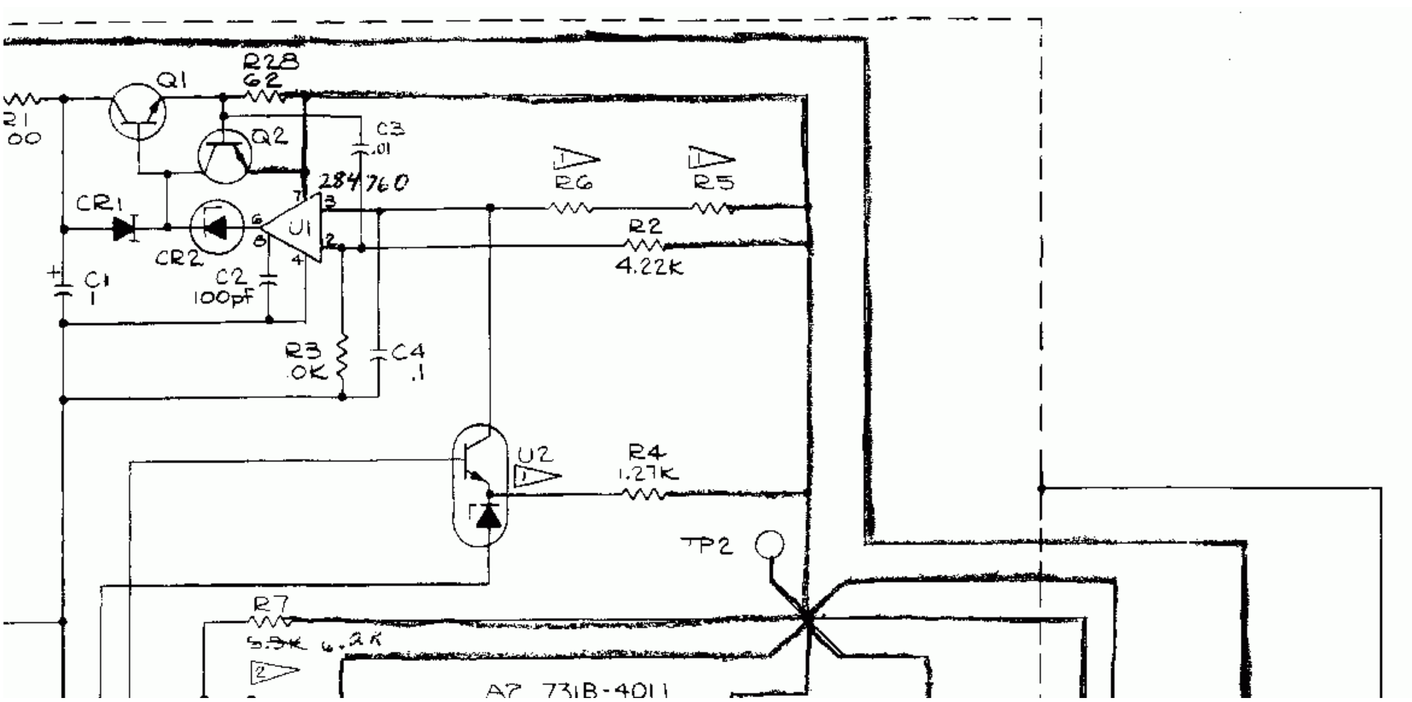
732B's design flaws are poor output overload characteristics and excessive short-circuit current.

The measured short-circuit current of 731B is 11.9mA, the short-circuit current of 732A is 27.5mA, and the short-circuit current of 732B reaches 49mA.

The benchmark is no better than the power supply. What does it take for such a large short-circuit current? On the one hand, the interior is easily overheated and damaged, and it is not good for external circuits. The maximum output of the indicator is 12mA. If it exceeds a certain value, the voltage should be reduced instead of sticking to the output.

From the perspective of the short-circuit current-limiting circuit, the methods of these three benchmarks are exactly the same.

The figure below is for 731B. The 62-ohm R28 and Q2 jointly achieve current limiting. The output current almost completely flows through R28. When the voltage of this resistor reaches about 0.6V due to the increased output current, Q2 starts to conduct. The base drive current of the output tube Q1 is shunted to achieve the current limiting purpose. At this time, the output current is about 0.65V / 62 = 10.5mA. In addition, there is a current path CR1, which is about 1mA. When there is a short circuit, because the op amp is not powered, the regulator CR2 has no current.



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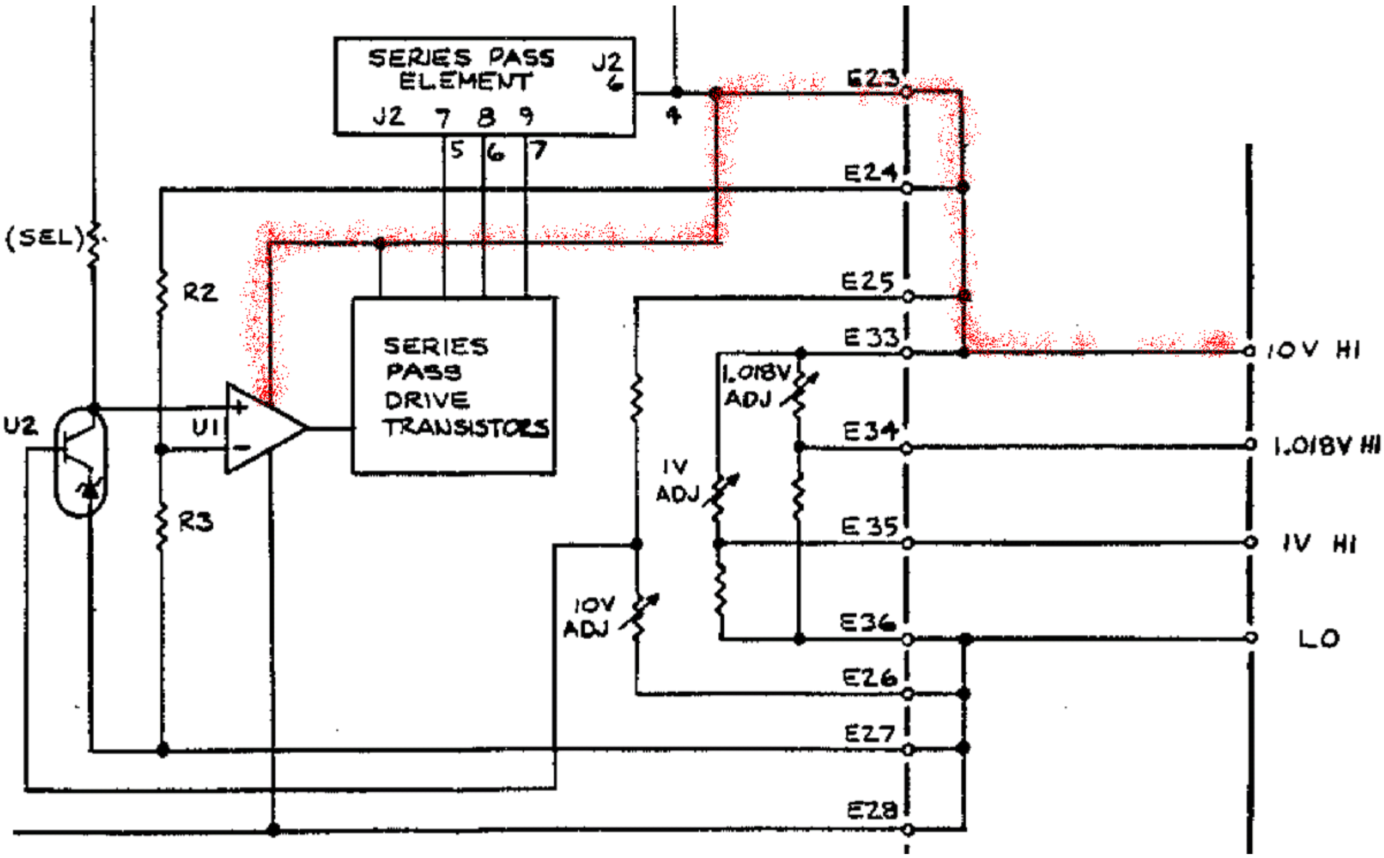
The circuit diagram of 732A is not a whole and it is difficult to use. Although some people have included me, I have drawn a complete circuit diagram. Here I just refer to the block diagram. To illustrate: the power supply of the op amp is still from the 10V output:



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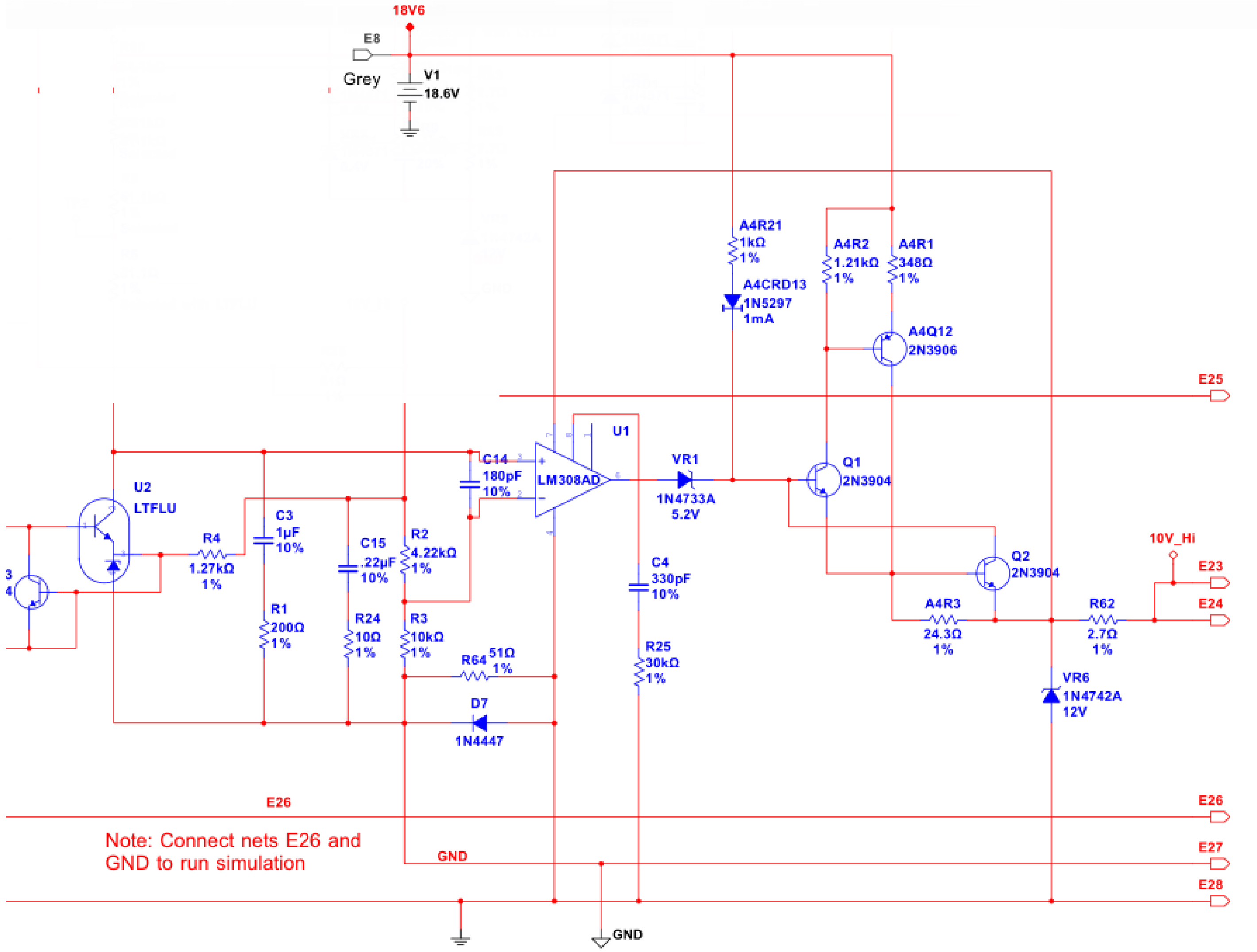
Or post a 732A circuit diagram (local) compiled by a foreign enthusiast. After the short circuit, the main current comes from the R3 and Q2 current limit, which is about 0.65V / 24.3R = 26.7mA, plus the 1mA current of CRD13, which is consistent with the test value.



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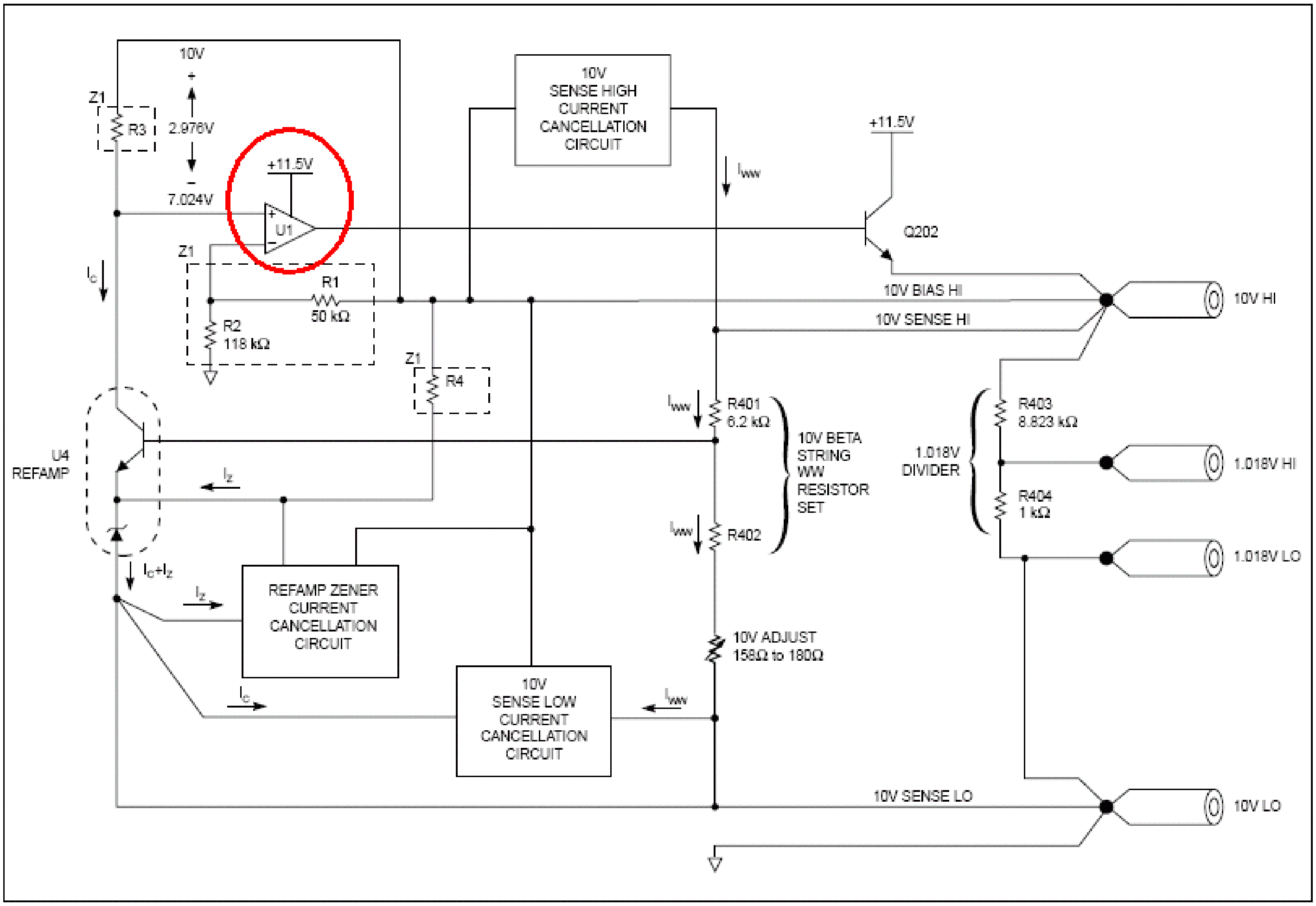
However, the 732B has been improved and the op amp power supply has been changed to supply directly from the 11.5V power supply:



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What's so bad about powering the op amp from 10V? Stable and reliable. It is necessary to "improve" to directly supply power from the power supply, and no corresponding measures have been taken.

Why does 732B change to direct power supply?
May be to be independent, not involving 10V, so as not to affect everyone on their own failure. In fact, this reason cannot be explained.
Or maybe you are afraid of putting too much load on 10V? That's not right, OP97F consumes only 0.4mA.
Design specifications? Specifications should be based on good performance, and performance compliance requirements (including potential requirements) are the most reasonable specifications. Moreover, there are many places where 732B does not meet the "standard".

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L (/user/lymex)**lymex (/user/lymex)** Sep 15, 2019, 6:19 AM (/post/1371)Sep 15, 2019, 6:19 AM (/post/1371)

Look at the specific circuit of 732B

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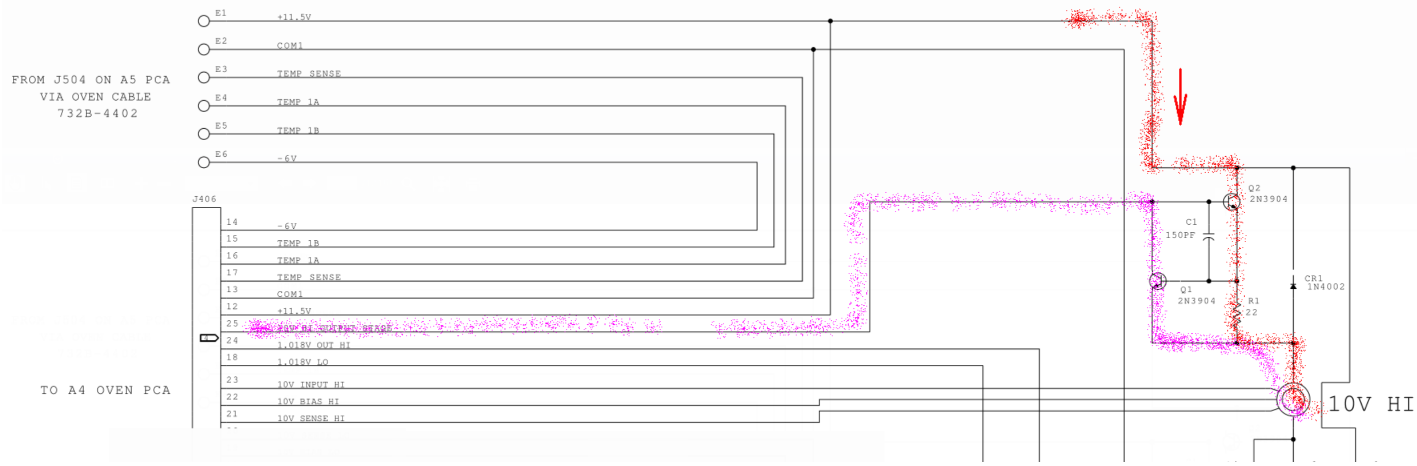
After the output is short-circuited, the red path provides nearly 30mA (0.65V / 22R), and the other 30mA is provided by the purple path.



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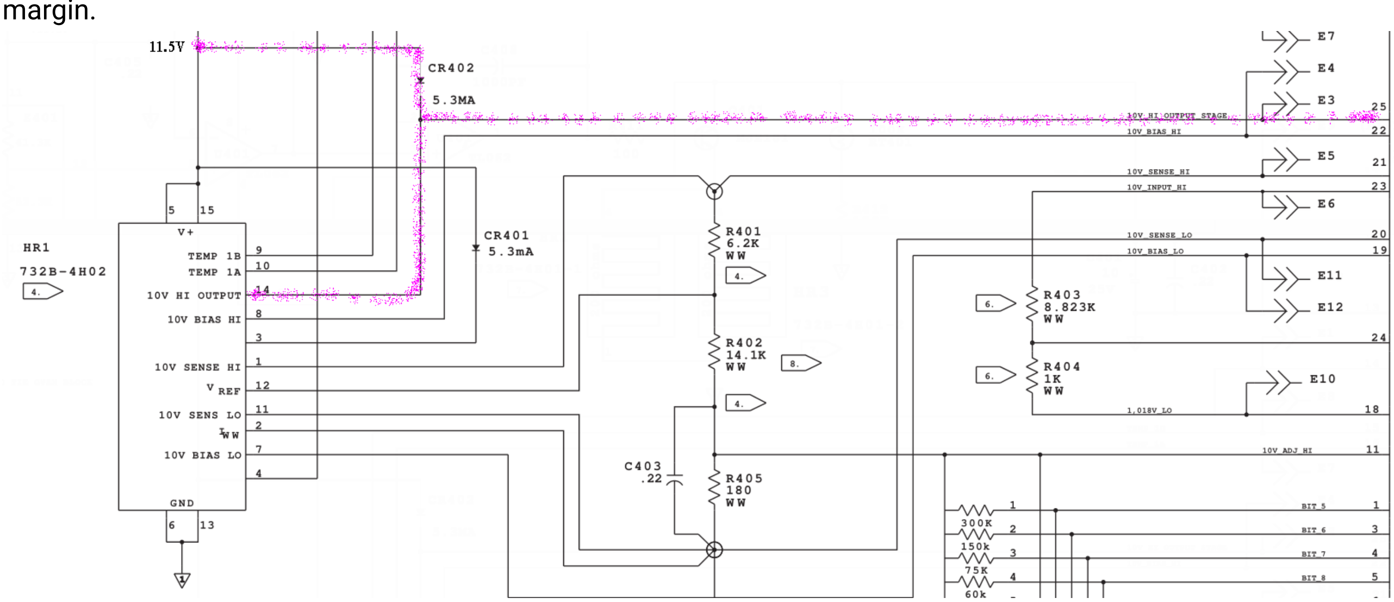
The purple part is divided into two parts, one is a 5.3mA constant current tube, and the other is a mysterious black box HR1 with no specific circuit diagram, 14 feet.

It is not known why Fluke increased the constant current tube from 1mA to 5.3mA. In fact, the magnification of the output tube 2N3904 is sufficiently large. The maximum Ib <0.1mA is guaranteed at 10mA, and 1mA is 10 times the margin.



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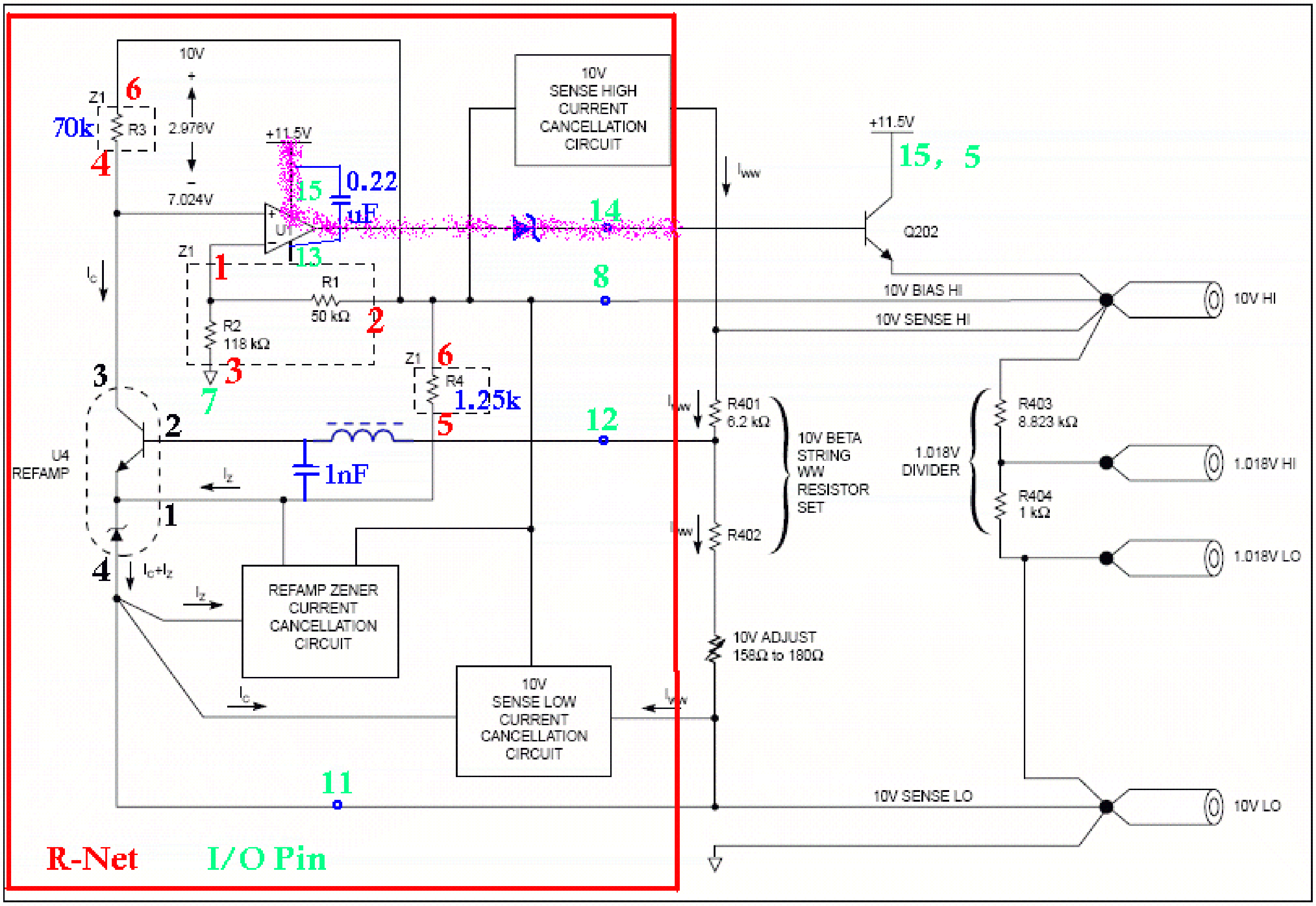
This black box has no specific circuit diagram, but there is a block diagram, which is in the red box below. I have marked and added the necessary components that actually exist such as the blue voltage regulator tube (note: the red area is not the thermostatic bath area. Constant temperature The slot is larger than this range, including resistor strings R401, R402, etc.)



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Obviously, because the op amp is connected to a 11.5V power supply, the op amp is always powered when the output is shorted, but the voltage of the green 12 pin is very low, causing the op amp + input to be much larger than the-input, and the output of the op amp is very high. The voltage tube provides current to the green 14 pin. This current is actually the current limit of the op amp. Therefore, the op amp works in the limit state. Although it will not be damaged, it will generate heat. It is about 11.5V × 20mA = 230mW, so it will recover after a short circuit. All become problems.

The earliest 731A was the direct output of the op amp. There was a problem with the current limit of the op amp after the output was shorted. 731B has been improved, but 732B was changed back and became a design flaw.

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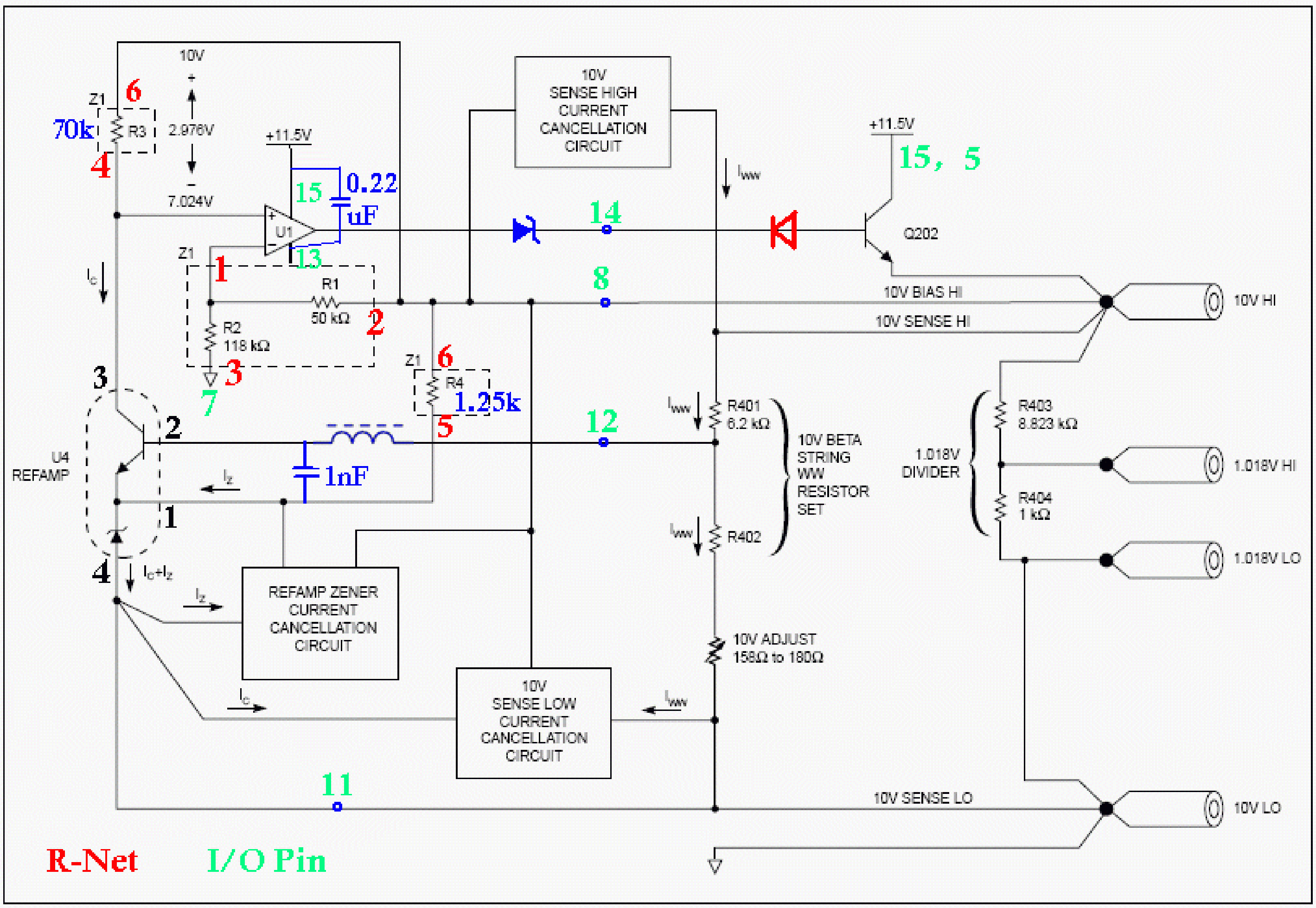
L (/user/lymex)**lymex (/user/lymex)** Sep 15, 2019, 6:34 AM (/post/1372)Sep 15, 2019, 6:34 AM (/post/1372)

The simplest improvement is to add a red diode as shown below



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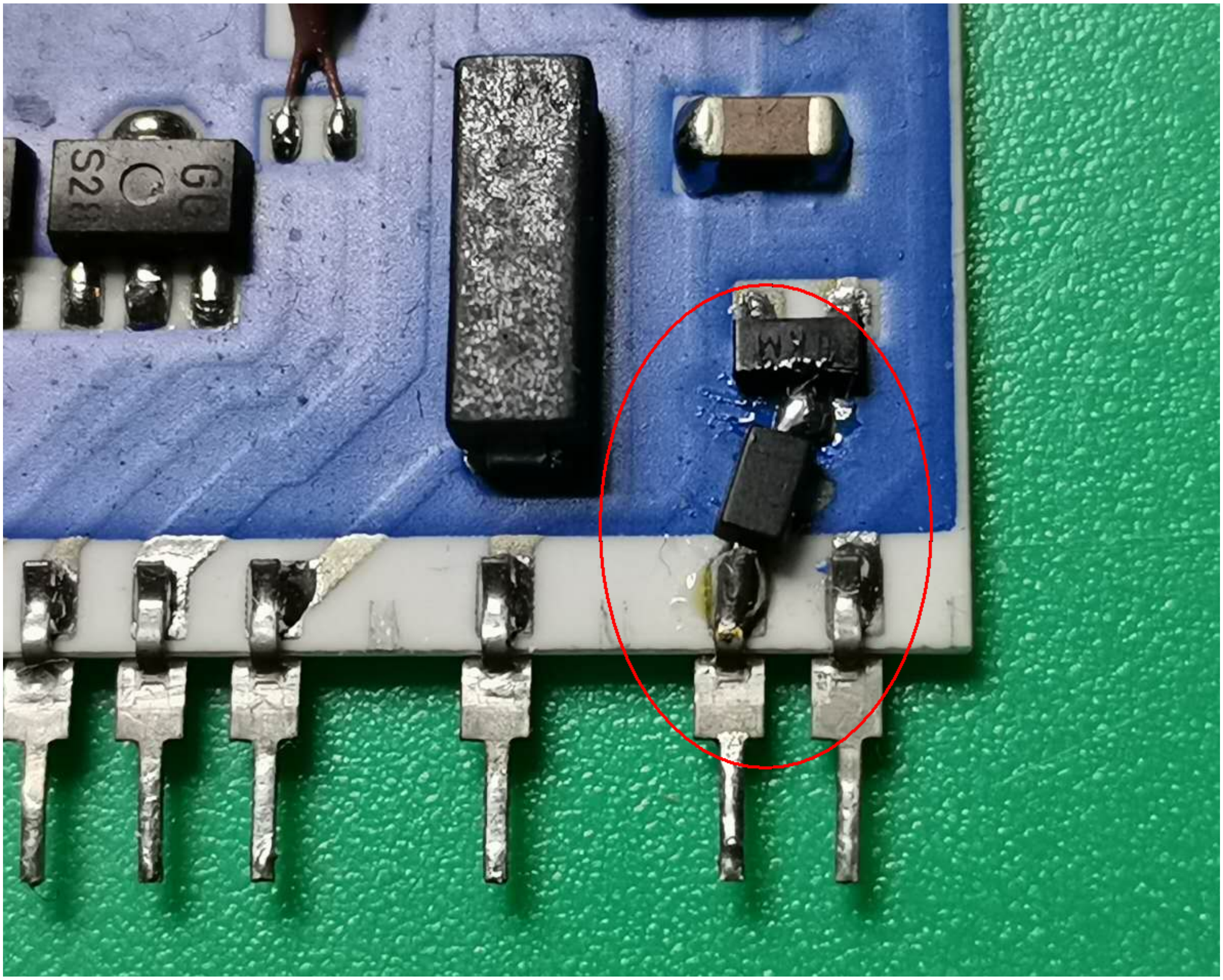
This diode is forward-biased during normal operation. There is no relationship with a voltage drop of 0.65V. Anyway, this voltage drop is mainly in the voltage regulator tube. Fluke is a constant current diode that sinks current to the op amp during normal operation. .

Once short-circuited, the output of the op amp is saturated, and the right end of the diode is low, so the diode is reverse biased, there is no current, and the op amp has no output current, which is truly protected.

The photo of the circuit board with a diode added is as follows:



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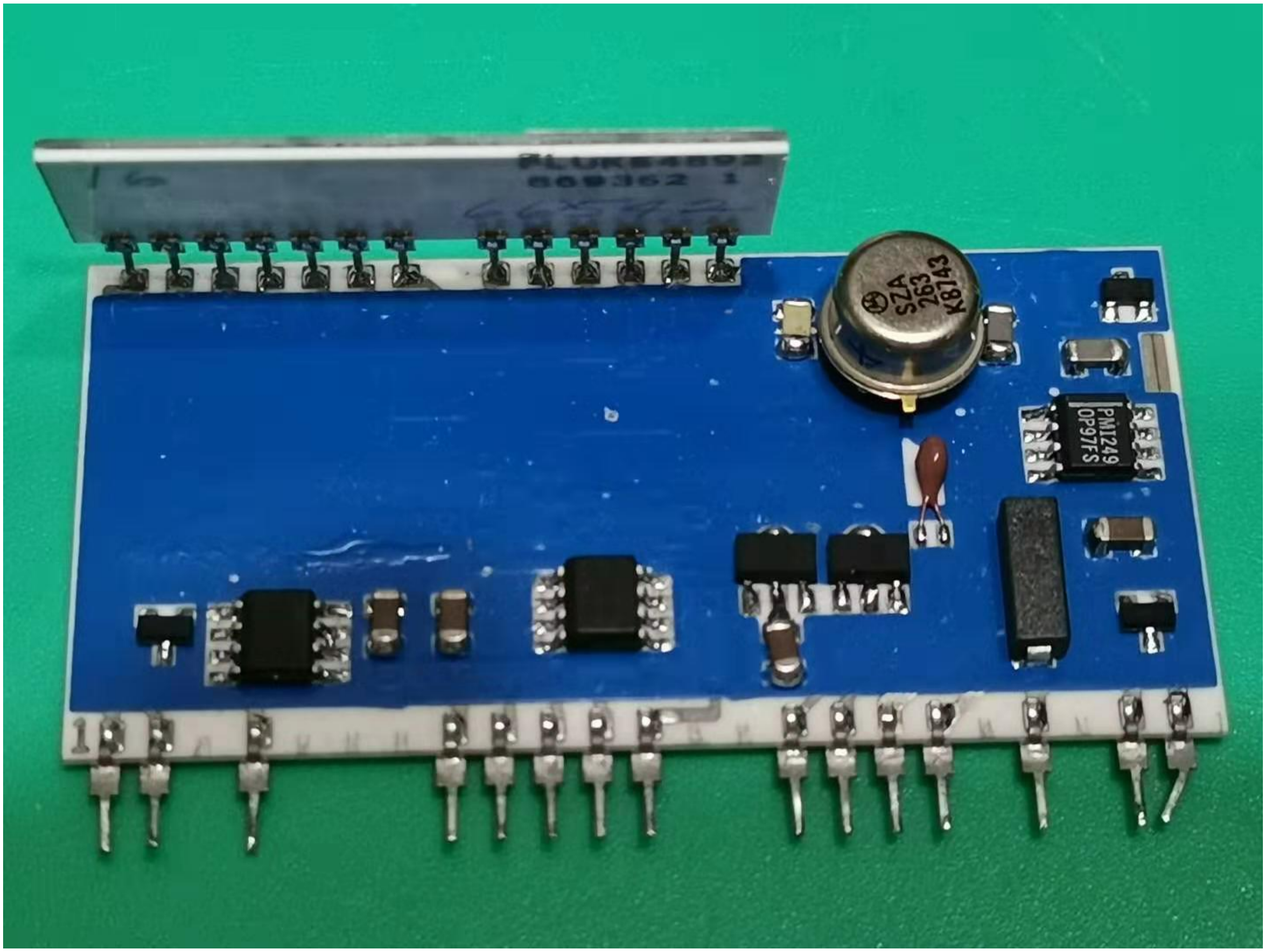
L (/user/lymex)**lymex (/user/lymex)** Sep 15, 2019, 7:10 AM (/post/1373)Sep 15, 2019, 7:10 AM (/post/1373)

Note 1

The necessity and method of Fluke's three CANCELATION circuits

Fluke's most mysterious circuit board made me take it apart, but it was single-sided, multi-layered, and it was almost impossible to detect the internal structure, even if it was destroyed, so drawing a complete current became an impossible task.



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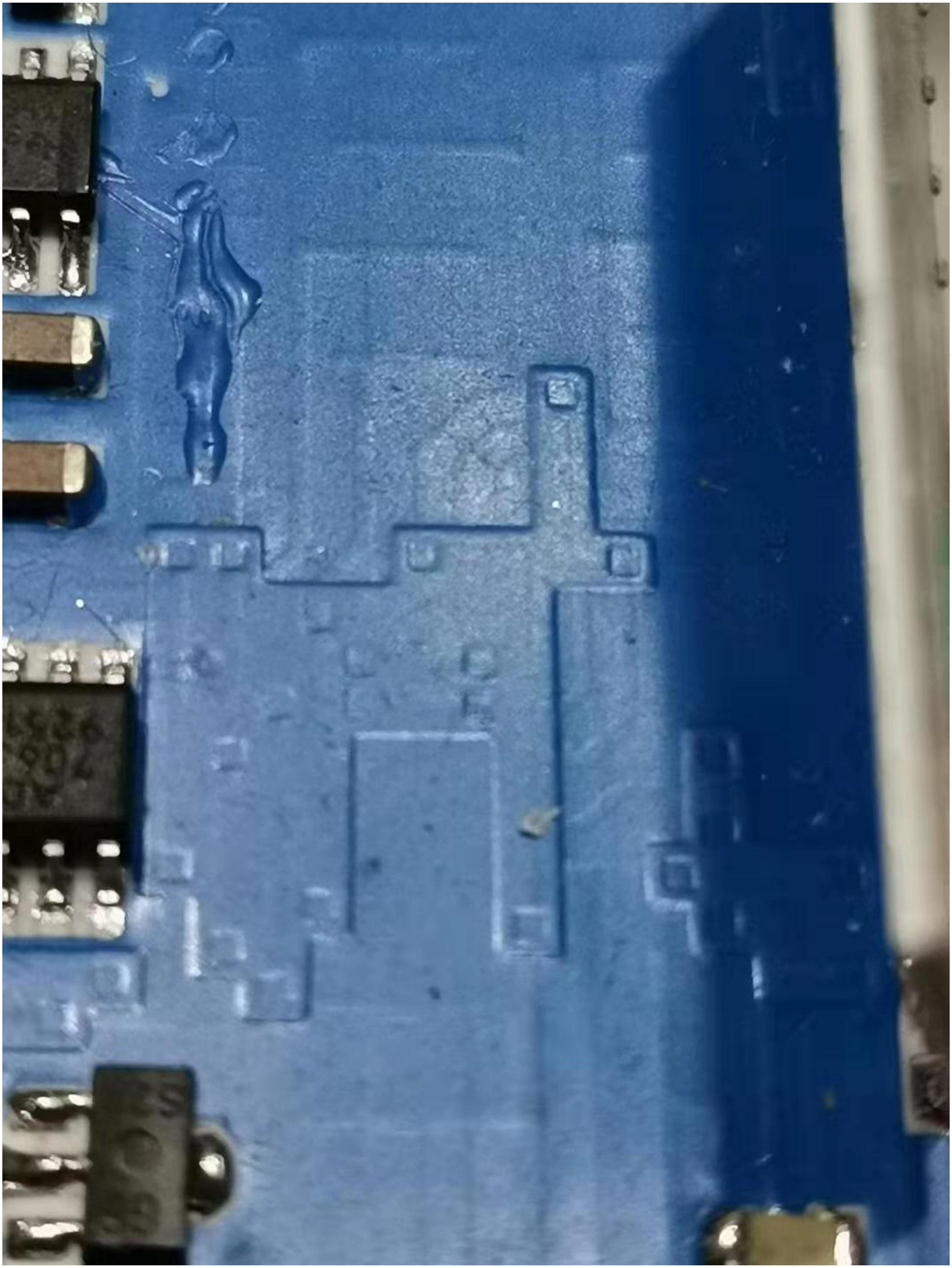

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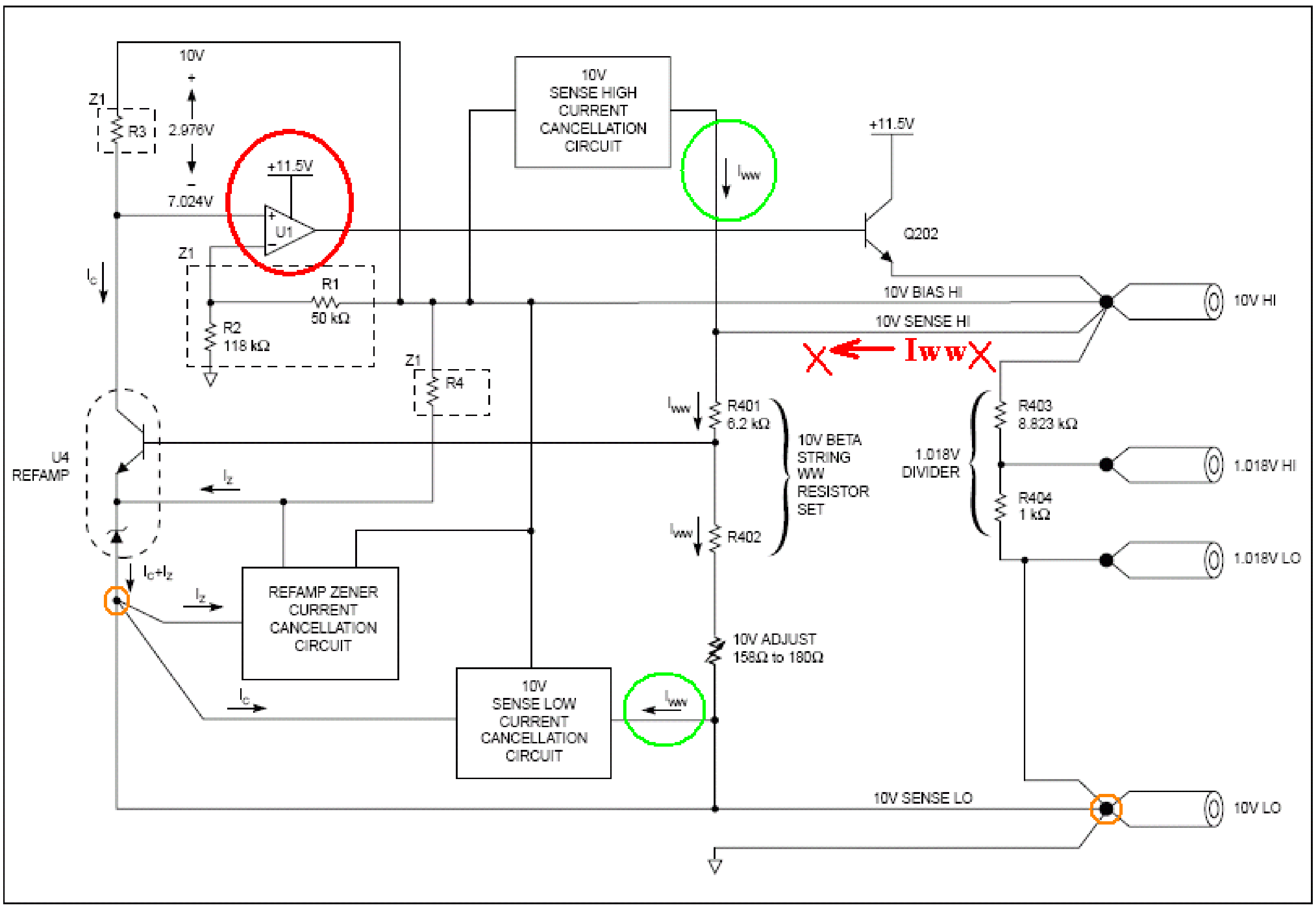
There are three compensation circuits. It is easy to read in lower case:
10V sense high current cancellation circuit
10V sense low current cancellation circuit
RefAmp Zener current cancellation circuit

In translation, there are three current compensation / cancellation circuits: 10V high detection, 10V low detection, and reference ground.

The upper end of the 6.2k voltage-dividing resistor (sense Hi) is ideally connected directly to the terminal post. Actually, because it is placed in a constant temperature box, the wiring is very long, and because it is not as stable as possible due to heat, a flexible board is used. Line, so the internal resistance is relatively large, temperature drift and uncertain factors have an impact. This is a sense wire. Ideally, no current flows. Actually, about 0.5mA flows, and the actual measurement of the line resistance reaches 0.25R. In this way, the voltage drop is 150uV. If calculated according to the 4% change (copper resistance temperature) 10 degree change), the impact is 10uV = 1ppm, which is very large, so a cancellation circuit is added to cancel it. Similarly, the grounding voltage-dividing resistor is also grounded using offset compensation.



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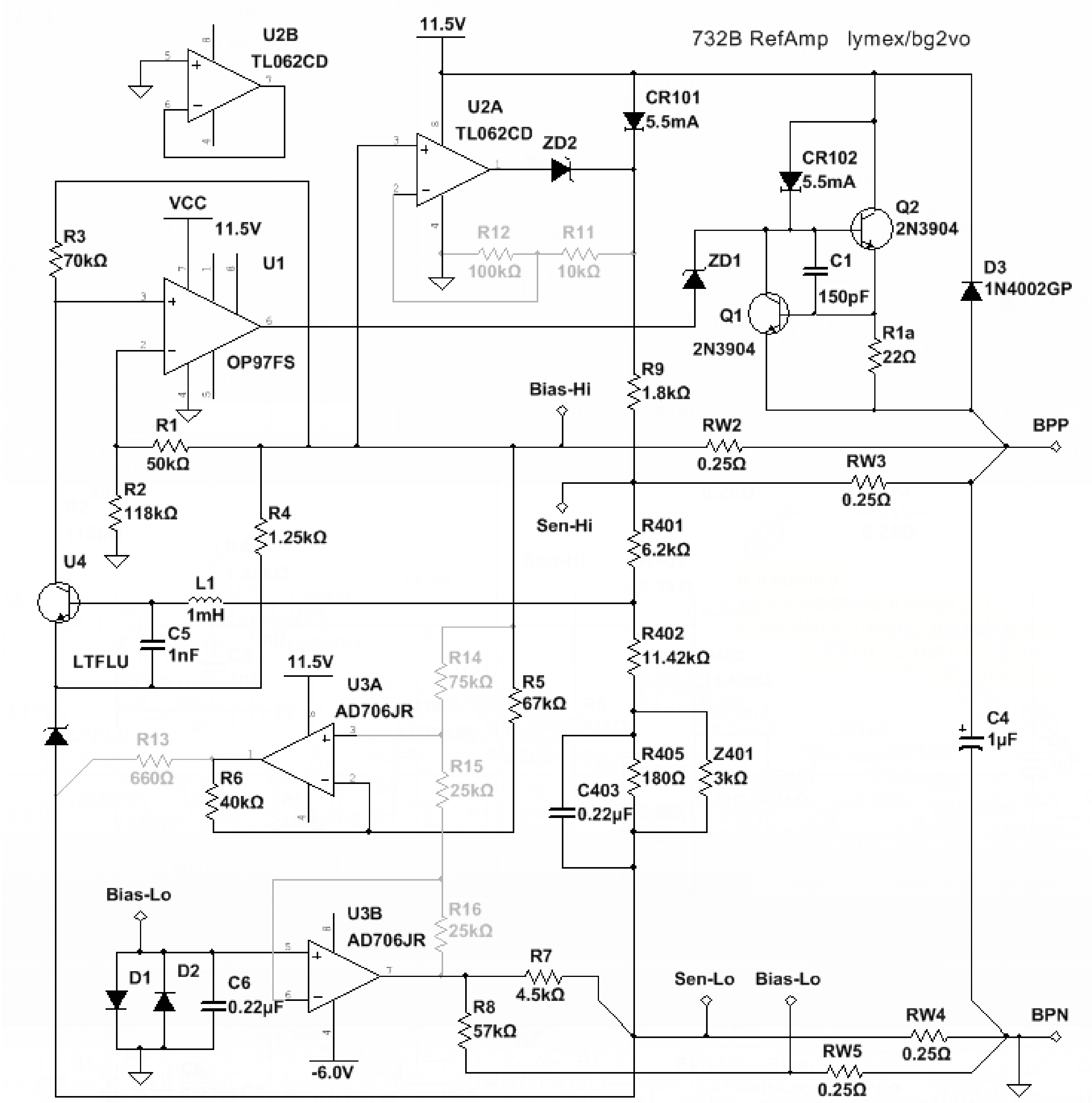
There are generally three methods of current compensation:
1. Passive component method, which is to connect a resistor under a stable voltage;
2. Open loop current source method requires an op amp, voltage reference, and several resistors. Holland circuits are commonly used. The principle can refer to TI 's AN-1515 http://www.ti.com/lit/an/snoa474a/snoa474a.pdf (http://www.ti.com/lit/an/snoa474a/snoa474a.pdf)
3. The active closed-loop method is to detect the voltage of the two orange circles and adjust the absorbed Iz to be 0. This last method I used in the 7 to circuit post

Although the specific compensation circuit of 732B is unknown, according to the compensation principle and part of the drawn circuit, a complete one is put together:



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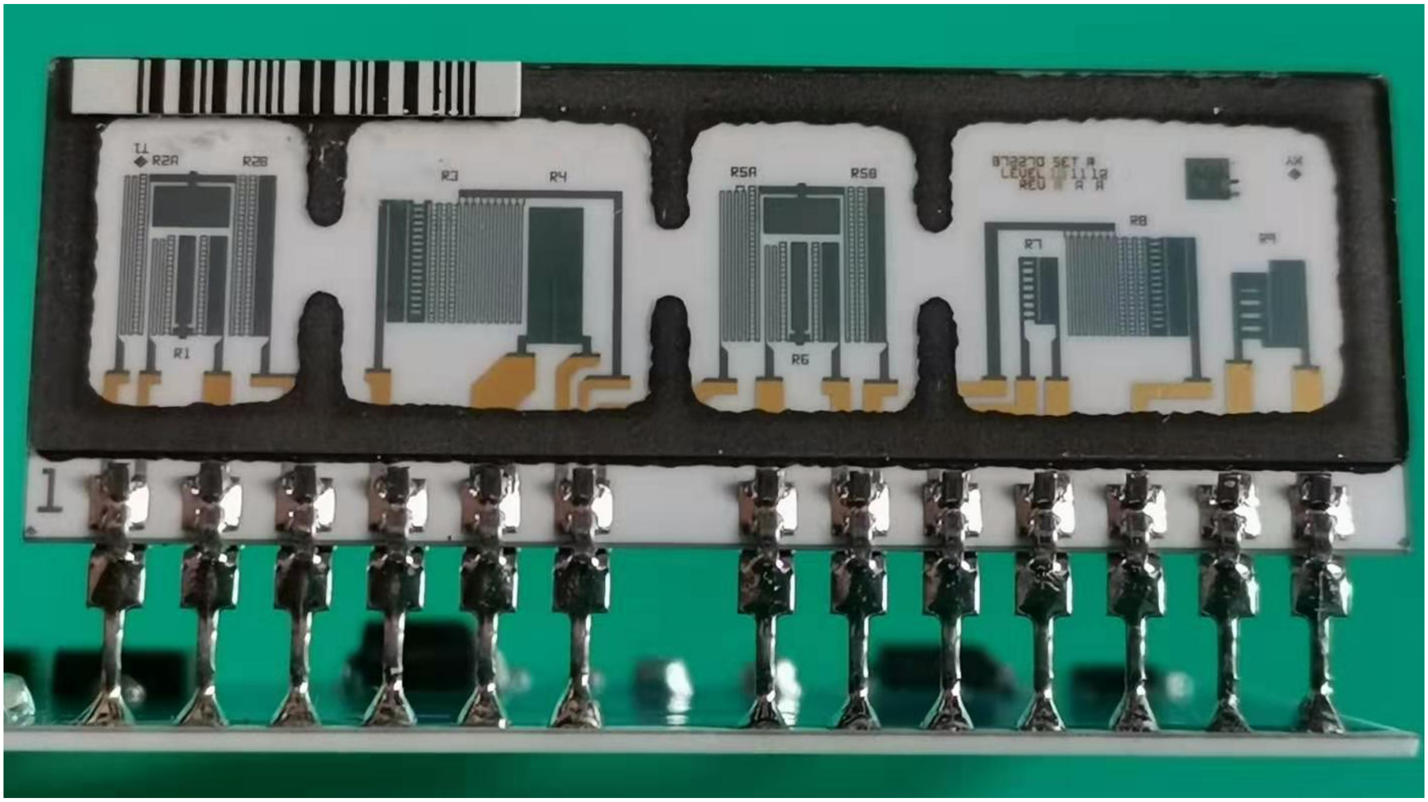
Among them, R1 to R9 are ceramic glass packaged resistor plates, which are labeled on the ceramic substrate, and there is basically no problem with this resistance value and position;



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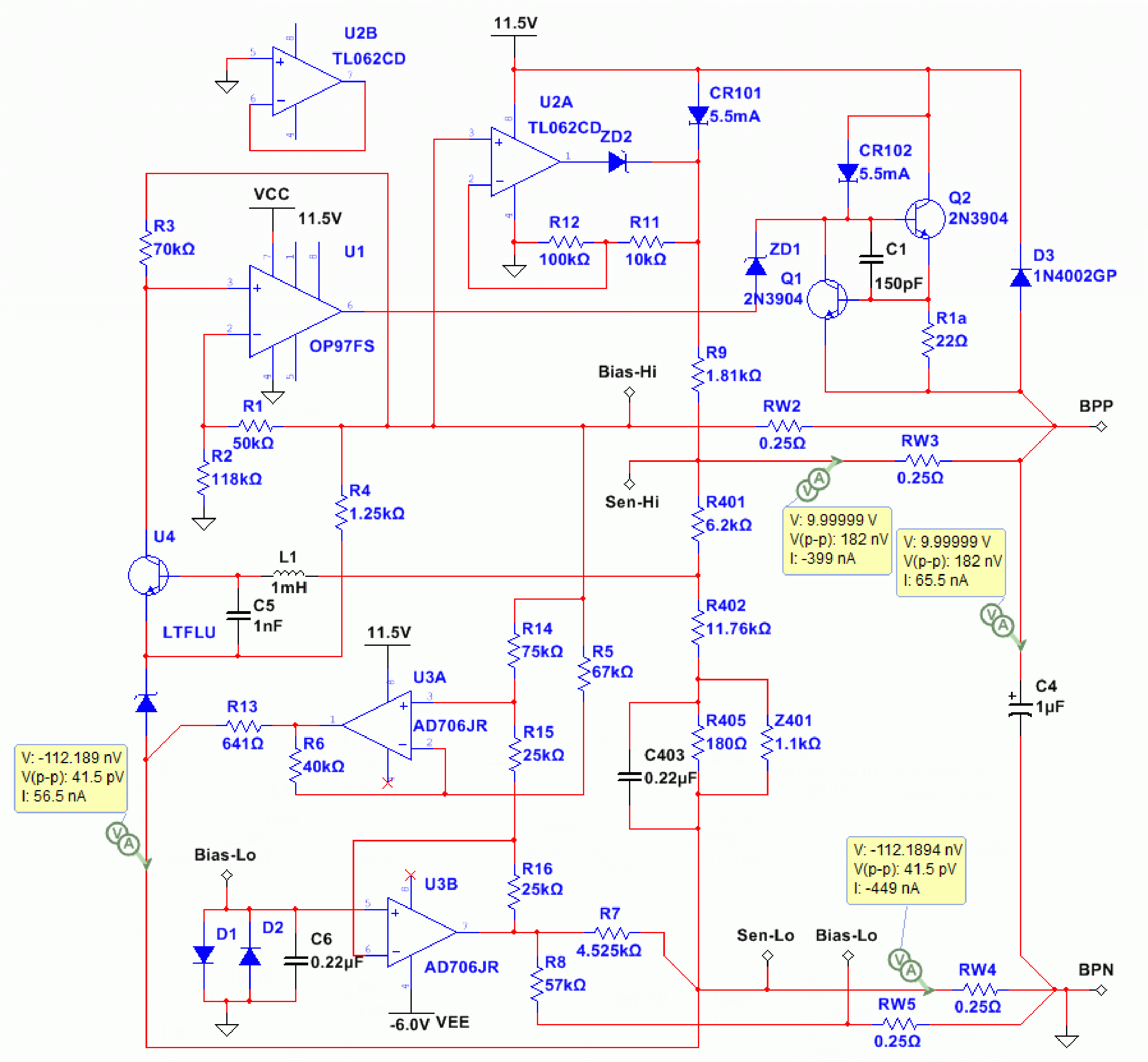
R11 to R16 are guessed. They are shown in gray. The resistor is hidden inside the tile.

This circuit has passed simulation, and the compensated currents are all below 0.5uA (less than 0.1%).



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For detection compensation, the compensation current needs to be 10 / 17.87 = 0.56mA. There is already a 1.8k compensation resistor, so a voltage of 1.0V is required. This is easy. R11 and R12 can be divided.

Under test compensation, R7 = 4.5k is required, and the voltage is -0.56 * 4.5 = -2.5V. This is also very easy. R14 to R15 can be divided from 10V.

The ground current compensation of the voltage regulator is more difficult. Only the voltage division of R5 and R6 is known. In addition, the voltage regulator current = 3mA is also known. Finally, the reference voltage is + 2.5V and the output is 2.0V / 1.98V. It is obtained through the partial pressure of R14 and R15, while R13 = 1.98 / 3 = 660 ohms.

In actual simulation, because the voltage regulator used is not the same as the LTFLU, the current is different, so several resistors have been fine-tuned to verify that the current can be small after compensation.

L (/user/lymex)**lymex (/user/lymex)** Sep 15, 2019, 7:10 AM (/post/1374)Sep 15, 2019, 7:10 AM (/post/1374)

Note 2Analysis
of other people's circuits, trying to find faults, is a method of self-learning

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T (/user/thy888)**THY888 (/user/thy888)** Sep 15, 2019, 6:48 PM (/post/1376)Sep 15, 2019, 6:48 PM (/post/1376)

Well analyzed. Those three compensation circuits, high-side compensation and low-side compensation, Zener current compensation (actually absorption), it is estimated that similar circuits can be found in the 5700. The 5700 reference board has the shadow of these circuits

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M (/user/mytek)**mytek (/user/mytek)** Sep 17, 2019, 6:32 PM (/post/1387)Sep 17, 2019, 6:32 PM (/post/1387)

- The reference voltage regulator tube + sampling resistor + current drive protection + four wires can obtain a complete voltage reference circuit, but it is purely theoretical. For a conceptual circuit, the idealization of key components will be required, that is: the current consumption of the reference voltage regulator tube is 0; the current consumption of the sampling resistor is 0; the resistance on the loop line is 0.
- As for the actual circuit, it does not meet the ideal requirements. Take FLUKE 732B as an example: the reference voltage regulator current is 3mA; the sampling resistor current is 0.56mA; the sampling loop line resistance is 0.25 ohms. According to lymex analysis, the upper detection compensation and the lower detection compensation are for the sampling resistor current cannot be 0; the voltage regulator ground current compensation is for the reference voltage regulator current. The introduction of compensation current makes the loop resistance on the physical structure even if it is not 0, which can offset most of the additional errors.

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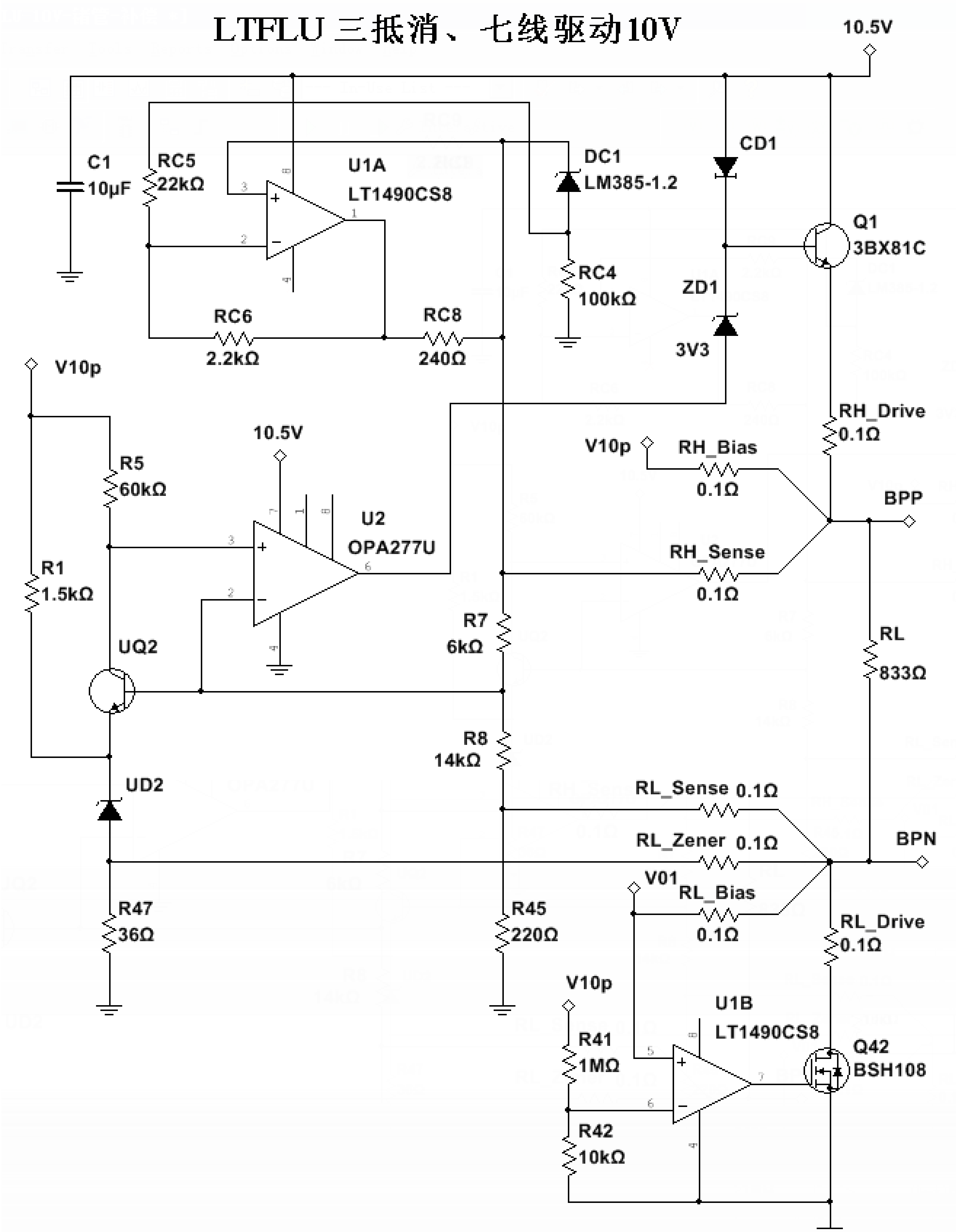
L (/user/lymex)**lymex (/user/lymex)** Oct 2, 2019, 5:50 PM (/post/1474)

LTFLU three-compensation, 7-wire drive circuit Load current path: 10.5V power supply, Q1, RH_Drive, BPP, RL, BPN, RL_Drive, Q42, ground. Ideally, this current does not flow through the other parts at all, so it has no effect on the internal circuit.



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The L_Zener lead is connected to the ground of the negative output terminal and the Zener tube. Because there is compensation, there is no current on this line, and the voltage at both ends is equal.

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Due to the low-end resistance ground compensation, the L_Sense line has no current, and the b current and U2-current of the FLU can be ignored, so the voltage of the FLU is equal to the voltage of the main lower resistor R8.

Also because there is high-end compensation of high detection resistance, there is no current in the H_Sense line, so the output voltage is perfectly divided by R7 and R8, and the output = Vz * (1 + R7 / R8).

H-Bias and L_Bias are used internally and must be independently led from the terminal.

U1A and peripheral circuits are high-end resistor string compensations. DC1 and RC4 provide a 1.25V reference, and RC5 and RC6 are the reference voltage dividers. If the voltage is not divided, the output of U1A is insufficient and RC8 is the compensation resistor.

U1B and peripheral circuits are negatively driven, and also provide a -stable 0.1V voltage V01 for two ground compensation and other internal units (Null Meter).

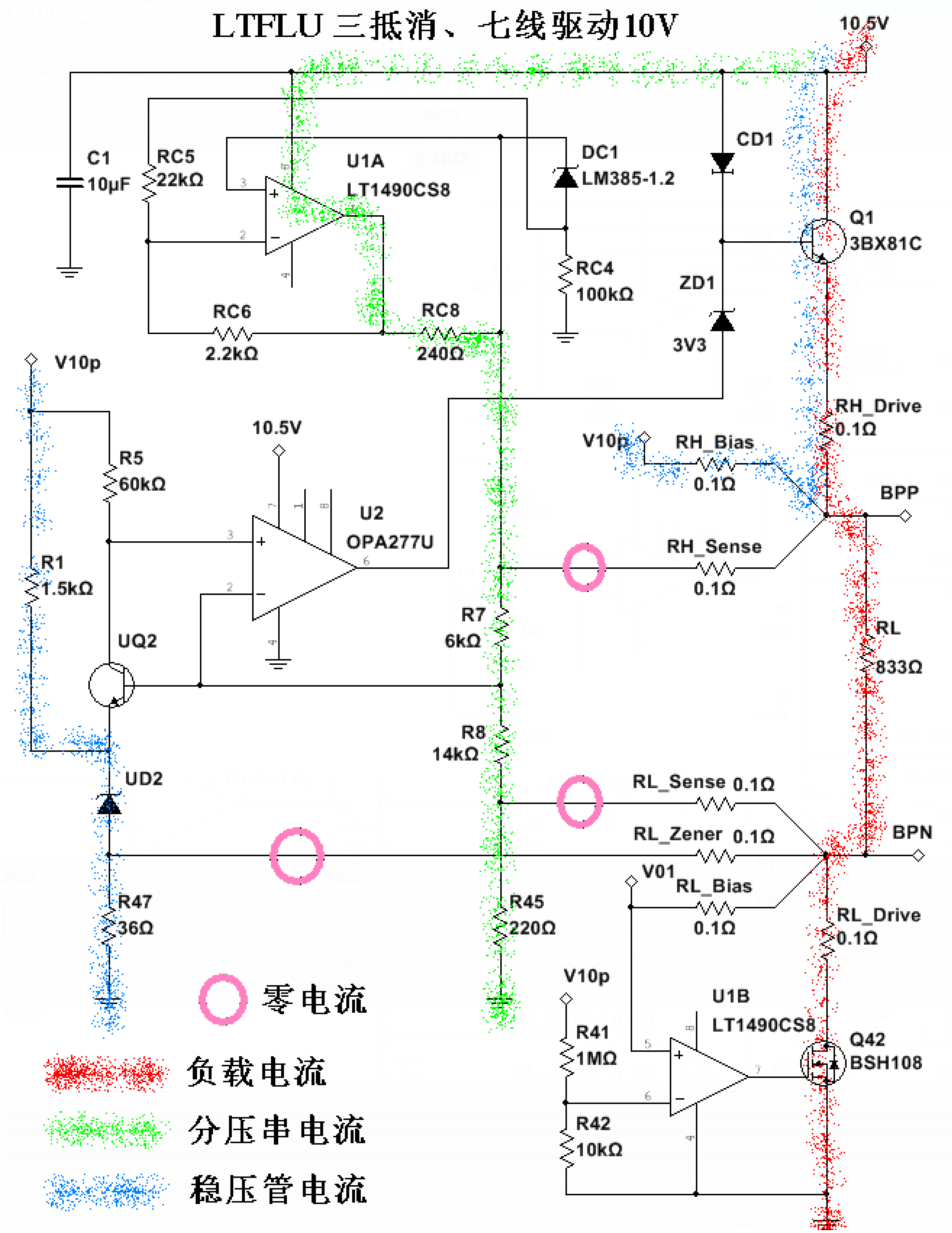
DC output internal resistance calculation
Part of the internal resistance of the positive and negative terminals to the internal welding point, copper terminal is about 0.05mR.
The other part is caused by the Av of the op amp. The output of the 0-10mA op amp changes by about 1V. The gain of 10V / uV will make the input of the op amp differ by 0.1uV, affecting 0.014ppm. = 0.014mR

Note: In order to explain the principle, this circuit has removed the protection part and stable anti-vibration part.

Attachment:
FLU current path: 10.5V, Q1, RH_Drive, RH_Bias, R1, UD2, R47, and ground.

Current path of voltage divider resistor string: 10.5V, U1A, 8 feet, 1 foot, RC8, R7, R8, R45, and ground.

In a word: for any precise voltage source, the current must have its own path, and the two voltage detection lines have no current.



(/assets/uploads/files/1570160270700-4382a244-c6fb-4d6a-8d0c-21ae00610560-image.png)

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T (/user/thy888)THY888 (/user/thy888) Feb 9, 2020, 6:45 PM (/post/1796)

10 out of 10

@lymex said (http://bbs.1ppm.cn:4567/uid/8) in a Design Flaw and Current Cancellation Circuits of Fluke 732B of Fluke 732B (/post/1474) :

> Attached:

Ask the boss, 7-line drive 10V high-side current compensation, why do we need a dedicated 1.25V reference to do it. No need to zoom in by 1.125 times for 10V to compensate

└ 1 Reply ›

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└ (/user/lymex)**lymex (/user/lymex)** Feb 13, 2020, 10:09 PM (/post/1797)

@ THY888 said (http://bbs.1ppm.cn:4567/uid/25) in a Design Flaw and Current Cancellation Circuits of Fluke 732B of Fluke 732B (/post/1796) :

> @lymex said (http://bbs.1ppm.cn:4567/uid/8) in a Design Flaw and Current Cancellation Circuits of Fluke 732B of Fluke 732B (/post/1474) :
>
> Ask the boss, 7-line drive 10V high-side current compensation, why do we need a dedicated 1.25V reference to do it. No need to zoom in by 1.125 times for 10V to compensate

It is also possible to use 1.25V based on 10V, but the circuit is probably more complicated.
To generate 1.25V with a dedicated reference, only one resistor and one zener are needed.

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