Design of a High-precision 5V/10V DC Voltage Reference Source

Yubo Yang\textsuperscript{1a*}, Jing Meng\textsuperscript{1b}, Wenbo Yao\textsuperscript{2c}

\textsuperscript{1}China Electric Power Research Institute, Beijing 100192, China
\textsuperscript{2}State Grid Chongqing Electric Power Research Institute, Chongqing 401123, China
\textsuperscript{a}yangb3333@163.com, \textsuperscript{b}370470928@qq.com, \textsuperscript{c}1346905937@qq.com

Abstract—This paper introduces a self-developed DC voltage source, which uses the Zener reference LTZ1000 as the voltage reference element. Selecting high precise resistors and using appropriate measures to insulate and isolate, the short—time relative stability of 7V output voltage provided by LTZ1000 is 1.5×10\textsuperscript{-8}. The voltage of 10V is increased up by a network, composed by high precise resistors with the same temperature coefficient, and its short—time relative stability is 2.2×10\textsuperscript{-8}. The voltage of 5V is divided by a network, composed by high precise resistors with the same temperature coefficient, and its short—time relative stability is 3.6×10\textsuperscript{-7}. The circuit is suitable for signal acquisition, voltage calibration and other applications.

1. Introduction

As an important part of digital and analog circuits, reference voltage is an essential basic circuit module in various electronic circuit systems\textsuperscript{[1]}. However, most of the devices that can provide high-precision and stable reference voltage in the market are constant voltage output, which can not meet the needs of multiple voltages of 5V and 10V\textsuperscript{[2]}.

In view of the above requirements, this paper proposes a high stable DC voltage source based on the main circuit of Zener reference LTZ1000 and combined with resistance voltage dividing network technology to realize 10V and 5V adjustable output. Its main technical features are as follows:

(1) The circuit can adjust the output of 10V, 7V and 5V.

(2) The short-time (1h) relative standard deviation of 7V voltage output by the reference circuit and 10V and 5V voltage output by the resistance network reach the order of 10\textsuperscript{-7}.

2. Design Principle and Design Scheme

2.1. Basic circuit

The schematic diagram of 7V reference voltage circuit is shown in Fig.1. A heating resistor in the dotted line box in the lower left corner and a zener diode in the dotted line box in the middle are integrated with two transistors \textit{Q}_1 and \textit{Q}_2 in the LTZ1000 chip\textsuperscript{[3]}, which is the core part of the whole reference voltage circuit\textsuperscript{[4]}. After the circuit is powered on, the LTZ1000 element can produce a reference voltage with high stability and very low noise of about 7V with the corresponding peripheral circuit.
7V voltage stabilizing circuit consists of $R_1$, $R_7$, $A_1$, $Q_1$ and voltage stabilizing tube. The temperature control circuit in the large dotted box on the left consists of $R_3$, $R_4$, $R_6$, $A_2$, $Q_2$ and heating resistance. Among them, transistor $Q_1$ and operational amplifier $A_1$ are used as temperature compensation control, while transistor $Q_2$ and operational amplifier $A_2$ are used as temperature heating control. Transistors $Q_1$ and $Q_2$ work in the critical state of $V_{CB} = 0V$, and both use the temperature sensitivity of transistor PN junction to control the operational amplifier.

In the temperature control circuit, the temperature detection circuit is composed of transistor $Q_2$, amplifier $A_2$ and resistors $R_3$, $R_4$ and $R_6$. The temperature is controlled by controlling the power of the heating resistor. The $Q_2$ emitter junction has a positive temperature coefficient, when the temperature remains unchanged, $R_3$ and $R_4$ constitute a voltage dividing circuit to keep the voltage of the transistor $Q_2$ emitter junction unchanging. When the temperature rises, it will cause the emission junction voltage of transistor $Q_2$ to rise, and the current flowing through $R_6$ will increase. At the same time, the collector voltage of $Q_2$ will decrease, and the output voltage of amplifier $A_2$ will decrease, to reduce the current flowing through the heating resistance and reduce the temperature. When the temperature decreases, the adjustment process is opposite, so as to control the temperature stability inside the LTZ1000.

The most critical resistors in the circuit are $R_3$ and $R_4$. For the voltage divider composed of $R_3$ and $R_4$, the output voltage will also change by 1ppm for every 100ppm change in the partial voltage ratio at the voltage dividing point. The secondary key resistors are $R_1$ and $R_6$. $R_1$ is the sampling resistance, which is generally in a non constant temperature environment. Therefore, when the temperature changes, the resistance value of $R_1$ will also change with the temperature, which will affect the output voltage. If the value of $R_1$ changes by 100ppm, the impact on the output is 0.0263ppm. For every 100ppm change in the resistance value of $R_6$, the impact on the output is 0.2ppm. The design is based on the ultra high precision metal foil resistors VHP100 and RNC90Y produced by Vishay, the accuracy is 0.005% and the temperature drift is less than 10ppm/°C.

### 2.2. Boost circuit

After obtaining the constant voltage reference, a resistor boosting network is required to raise it to 10V\(^6\). Therefore, a resistor network composed of the same type, the same batch, and the high-precision resistor with the same temperature coefficient and resistance value can be realized. The advantage is that the change of resistance stability will not lead to the change of its proportion in the whole network. The principle diagram of the boosting network is shown in Fig.2. $R_1$-$R_{10}$ are high-precision resistors with the same resistance value and temperature coefficient, $R_i$ is the input of 7V reference voltage, $R_{10}$ is the output of 10V voltage, and $R_{11}$ is the trimming resistor to adjust the deviation of 10V output voltage.
2.3. Voltage dividing circuit
High precision network resistor is used to divide the output voltage, as shown in Figure 3. The voltage dividing circuit has high requirements for the resistance ratio of the resistance, but does not have high requirements for the resistance of a single resistance. Therefore, this paper selects the resistance with the same temperature coefficient as the partial voltage proportional resistance to offset the influence of temperature change. LT5400 (four matched resistors) produced by Linear Technology is preferred in this paper, the voltage of 5V can be obtained by matching the voltage divider of the 7V reference voltage.

3. Test scheme and results
The reference voltage circuit is designed and manufactured, as shown in Fig. 4.
In order to check the output characteristics of the system more reasonably and prevent the interference of human factors, the automatic acquisition method of Agilent 3458A 8-bit semi digital voltmeter controlled by LabVIEW program is adopted. The measurement results are directly displayed and recorded by computer.

The output voltages of 5V, 7V and 10V are measured and recorded, where 7 V is the reference voltage output by the DC constant voltage reference circuit, 10 V is the voltage output through the boost network, 5 V is the voltage output by the voltage dividing circuit. The measurement results are shown in Fig. 5-Fig. 7, and the average value and Relative Standard Deviation of the test results are shown in Table 1.
Fig. 6 10V Voltage output curve

Fig. 7 5V Voltage output curve

Table 1. Average Value and Relative Standard Deviation of measured voltage

| Voltage/V | Average voltage/V   | Relative Standard Deviation |
|-----------|---------------------|-----------------------------|
| 7         | 7.11004562         | 1.5×10⁻⁸                    |
| 10        | 10.0000947         | 2.2×10⁻⁸                    |
| 5         | 5.00621414         | 3.6×10⁻⁷                    |

4. Conclusion

By optimizing peripheral devices with outstanding performance and adopting reasonable circuit structure, the short-time stability of 7V voltage output by DC constant voltage reference circuit is
The short-time stability of 10V voltage obtained by boost network is $2.2 \times 10^{-8}$. The short-time stability of 5V voltage obtained by voltage dividing network is $3.6 \times 10^{-7}$, which meet the requirements of design indicators.

In the follow-up research, the temperature control circuit is designed to improve the stability of the circuit output.

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