Design of high stable Numerically Controlled Constant-current Source

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***Abstract*—A Numerically Controlled constant-current source is designed. A negative feedback of closed-loop is used in the source based on Single Chip Microcomputer. The system has a small ripple current and reliable step-adjustable function. The setting and the output are precise. The output of the constant-current source is stable when the load is changed. The errors can reach the level of 0.1%.**

Keywords-SCM; Constant-current source; Closed-loop; High Stability

I. INTRODUCTION

In the field of testing semiconductor devices, sensors and medical diagnostic instruments, constant-current source is an integral part. The quality of stability and accuracy plays a vital role. The common constant-current sources in general only have a single current value, or a limited number of current values. The versatility is limited, and the stability and reliability are low.

With the development of the computer technology and electronic technology, the constant-current source controlled by the SCM has great performances in the stability and reliability nowadays. The constant-current source described by this paper is a Digital Controlled DC (direct current) constant-current source with high stability and low power. When the load or the ambient temperature changes, the output-current is stable. In addition, the output current is high in precision and adjustable.

II. SYSTEM COMPONENTS

This system is mainly composed of a constant-current source circuit, a microcomputer control unit, A/D and D/A converter circuit as well as the power supply component. Its system block diagram is shown in Fig. 1. SCM is the core control unit. The current value is set through the keyboard. Control signal is output after the processing of SCM. The D/A converter convert it to analog signal. The analog signal is magnified and level-converted so that it can be input into voltage-controlled constant-current source circuit to generate current signal.

In order to improve the output precision and stability of this system, the precision resistor is used to convert the actual output current into voltage signal. The voltage signal is input into the A/D converter after sampling. The output of the A/D is compared with the value which is pre-set. The output current bias is adjusted real time. It is a closed-loop regulation system so that the output current can be locked.

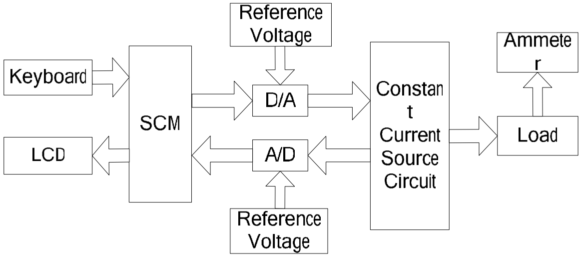

Figure 1. System Diagram

III. CONSTANT-CURRENT SOURCE CIRCUIT

A. Principle of operation

Constant-current source circuit is a DC negative feedback automatically adjusting system which is composed of reference voltage, sampling, amplifier comparison and adjustment. The program of Tandem Current Stabilizer is used in this design, as shown in Fig. 1.

Tandem Current Stabilizer is composed of reference voltage, adjustment, amplifier, sampling resistor and load resistor. The current signal is converted into voltage signal by sampling resistor. The voltage is compared with reference voltage. The output signal of the amplifier comparator drives regulating device to output current. In the end, the current is constant.

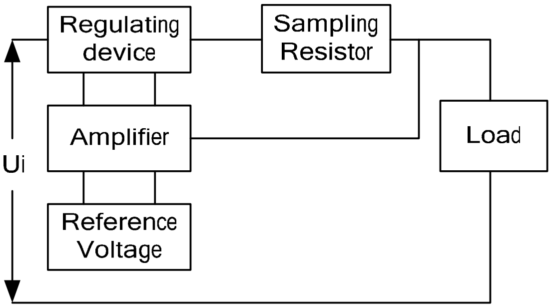

Figure 2. Functional Block Diagram of Tandem Current Stabilizer

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B. Circuit Design

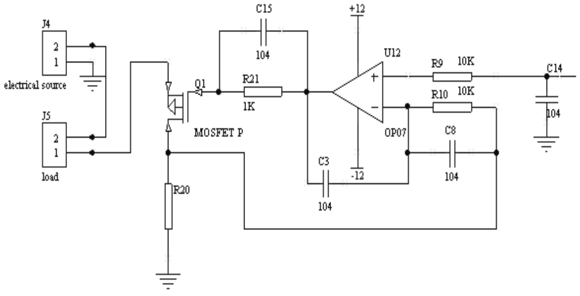

Figure 3. Constant-current Source Circuit

In order to obtain a high stability and precision, constant-current source circuit uses precision operational amplifier OP07, 11N06 which is used for driving the load 11N06 and the precision power resistor of 1 Ω as a sampling resistor. As is shown in Fig. 3, R_{20} is a Sampling Resistor, U_+ and U_- are the inputs of OP07 and U_0 is the output of OP07.

When the circuit runs, the feedback signal of Sampling Resistor R_{20} is input into the reverse input end of OP07 through R_{10} .The control signal of D/A is input into the cocurrent end of OP07. OP07 compares the two signals. If $U_+ > U_-$, the output of OP07 is positive and 11N06 is tend to be conductive. Collector current I_c increases. Then the feedback signal is compared with reference voltage. If $U_+ < U_-$, the output of OP07 is negative and 11N06 is tend to cut off. Collector current I_c reduces. The process of negative feedback can adjust automatically to make sure that I_c is constant.

According to the basic principles of OP, we can obtain:

$$(U_+ - U_-)A_D = U_0 . \tag{1}$$

So:

$$U_+ - U_- = U_0 / A_D . \tag{2}$$

A_{D} is the Open-loop gain of OP and its value can be more than 10^6.

According to the basic principles of virtual short circuit, we can obtain:

$$U_+ - U_- = 0 . \tag{3}$$

So:

$$U_+ = U_- \ . \tag{4}$$

We can obtain the following formula which describes the relationship between the current value, the sampling resistor, and the reference voltage.

$$I_0 = \frac{U_+}{R_{20}} \tag{5}$$

For the value of the sampling resistance is 1Ω, there is a direct relationship between the values of constant current and the reference voltage. In other words, $1\,mV$ of reference voltage corresponds to $1\,mA$ of current value.

C. Cooling Protection

The electric current flowing through 11N06 is up to $2\,\mathrm{A}$. The less the load resistance becomes, the greater heat 11N06 devices consumes. If the cooling process is not properly, 11N06 may also be damaged. Furthermore, when the constant current value is $2\,\mathrm{A}$, the power of $1\,\Omega$ base resistance is up to $2\,\mathrm{W}$. Although we choose metal shell precision resistor of $25\,\mathrm{W}$, install heat sinks, and smear the Thermal Grease, the base resistance temperature is still high in practical experiments. The rise of temperature will lead to the change of base resistance, impact on the sampling precision and then affect the accuracy of the constant current source. To solve these problems, we adopt the "hair dryer-style" cooling fans to cool the base resistance and 11N06 heat sinks forcibly. This method reduces the temperature rise of base resistance effectively and alleviates the heat dissipation of 11N06.

IV. NUMERICAL CONTROL CIRCUIT

The Numerical Control Circuit is composed of the microcontroller, D/A converter, A/D converter, LCD and the keyboard. We set the value of output current via the keyboard. The current is converted to the corresponding control signal and sent to the D/A which is used to control the circuit of constant-current source. The actual output value sent to the MCU by the A/D chip will compare with the settings to adjust the output accuracy. The settings of output value, as well as the output are displayed by the LCD. The Basic Diagram is shown in Fig. 1.

A. SCM Controller

SCM is the core of the numerical part, whose main function is to make the current settings to be converted to the constant-current source control signal, get the adjustment of the output accuracy and the visualization of the process of operation, and output results. The system chooses the AT89C52 manufactured by ATMEL Company. This kind of SCM is a low-voltage, high-performance CMOS 8-bit microcontroller, one chip includes 8k bytes of Flash read-only program memory that can be repeatedly rewritten and erased, and also includes 256 bytes of random access data memory (RAM). It is compatible with the standard MCS-51 instruction system. The chip includes general-purpose 8-bit CPU, and flash memory cell.AT89C52 is one of the 51 series microcontrollers which are widely used.

B. D/A converter and A/D converter

In order to realize the stepping control of the current source whose output range is 20-1000 mA and resolution is 1,the system uses converter called TLV5618 which has 12 bits.TLV5618 is the D/A converter which is two-channel ,12 bits voltage output. In order to guarantee the stability and the accuracy of the output voltage, its reference voltage circuit uses $1.2\,\mathrm{V}$ precise voltage datum IC of LM336-1.2. Besides, a 3296 multiple cycle potentiometer is used to make the voltage to be adjusted to 1.024 V . In order to measure the current value between 20 mA and 1000 mA , we use the voltage drop on the sampling resistor as the sampling signal of the output current. According to the calculated results, the 8 bits and 10 bits A/D converter cannot meet the of guaranteeing the measuring accuracy in 0.1%, so the ADS7816 is chosen, which has 12 bits. The voltage value of the sampling resistance is 0-2000 mV , so we choose the precise voltage datum IC of LM336-2.5 as the reference voltage to meet the requirements of measurement.

C. LCD and Keyboard

LCD can display the settings and output of the current. Its interface circuit is simple and easy to control. LCD chooses 128 × 64 dot-matrix 6963 graphics display module with backlight. It can display characters and graphics.

The design adopts the keyboard with six keys and it can meet the demand basically. It not only has ±1 and ±10 precise step, but also ±100 quick step. It is facilitate to adjust the set value greatly .The system set the starting value at 1000 mA through the hardware configuration. The users can select the appropriate steps to achieve the settings fast.

V. SOFTWARE DESIGN

The program is responsible for the communication with each module , receiving information of the keyboard, and controlling the LCD display settings and measured values ,at the same time, through the D/A and A/D to adjust the constant current source circuit section, so that it can control the current accurately.

The program is shown in Fig. 4. After the program runs, the first part is initialized and shown by the keyboard, calculate the control signal values which are sent to the D/A by the setting values. It compares the adjustment module settings and the A/D sample value in the adjust module, and adjusts the control signal values until the required accuracy meets the requirement. Then the A/D sample value is displayed. If there is disturbance, it adjusts automatically. If the key is pressed, the new settings are displayed, and then the implementation of the adjustment process is continued.

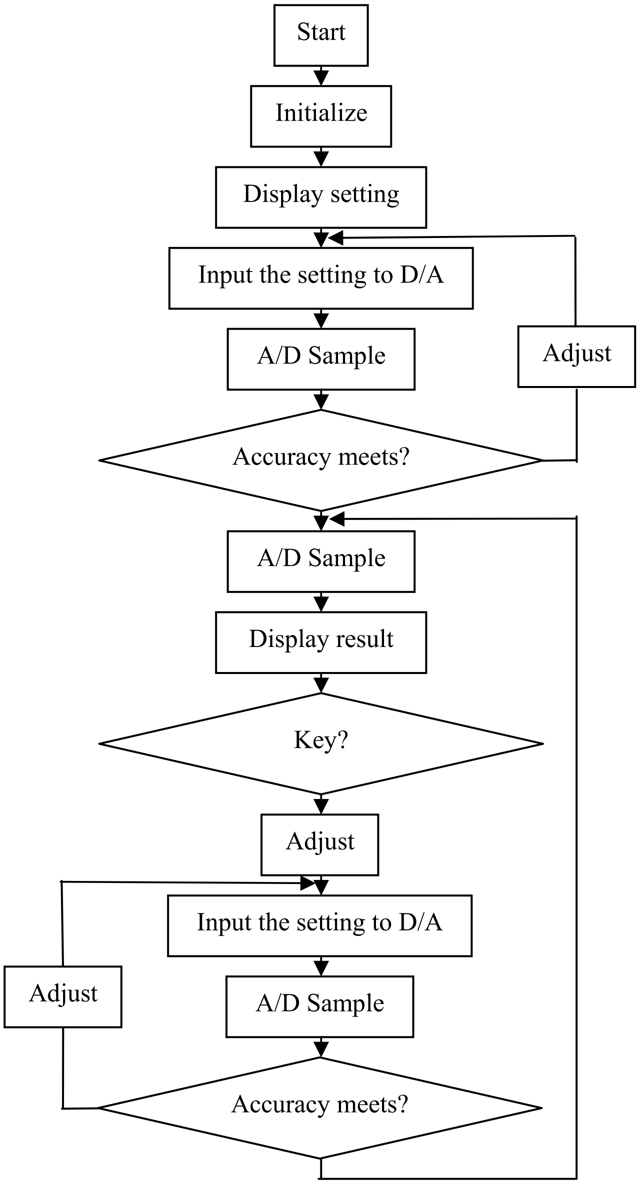

Figure 4. Program flow chart

VI. TEST RESULTS

To compare errors between the measured values and the true value, we select seven values between 20 mA and 1000 mA. The measurement data is shown in Table 1.The formula is followed:

$$\text{Percentage Error}=\frac{|I_1-I_2|}{I_2}\times 100\%$$

TABLE I. TEST DATA

Setting(mA)	I_1(mA)	I_2(mA)	ΔI(mA)	Error
20	20.42	20.287	0.133	0.656%
50	50.212	50.101	0.111	0.22%
100	99.87	99.693	0.093	0.09%
250	249.30	249.56	0.25	0.1%
500	499.43	499.95	0.52	0.1%
1000	1000.51	1000.85	0.34	0.034%

From the data of Table 1, we can know that Percentage Error is superior to 0.1% when the settings are bigger than 50 mA .When the supply voltage changes between AC200 V and 240 V , the output current value changes inconspicuously. Ripple Current is less than 0.1 mA when the current value is 500 mA , 1000 mA and the load value is 5 Ω .

VII. CONCLUSIONS

This paper introduces a high-performance DC constant current source based on SCM. Its output current is set arbitrarily within a certain range and has small changes with the change of load and Temperature. It has strong capacity with a load and the error of the accuracy and stability is less than 0.1%, so it can be used in field which needs the high-stability and low-power DC current source.

This design uses a microcontroller controlled constant-current source circuit which makes the Constant-current source have a greater output range. This design can adjust the output real-time by using the Closed-loop feedback loop which can improve the output accuracy and reinforce the capacity of driving a load. All of the indicators are less than 0.1%. This paper provides a new approach for the design of the high stability constant-current source.

REFERENCES

[1] Yi Xue, “Design of a High Precision Program-controlled Constant-current Source,” Process Automation Instrumentation, vol. 30,Apr.2009,pp. 63-65,doi: CNKI:SUN:ZDYB.0.2009-04-021.

[2] Xi Wang, “Design of precision constant current source used in instruments based on MAX6126,” Electronic Design Engineering, vol.17,Feb.2009,pp.57-58, doi: CNKI:SUN:GWDZ.0.2009-02-025

[3] Hongchuan Zhang, Zhaosheng Teng, Haijun Lin, and He Wen, “Design of precision voltage-controlled constant current source with low power dissipation single-supply,” Chinese Journal of Scientific Instrument, vol. 29, Dec. 2008, pp. 2678-2682, doi: CNKI:SUN:YQXB.0.2008-12-039.

[4] Hongyu Jiang, “Research of a New Type of Constant Current Source with High-precision and High Temperature Stability,” Modern Electronics Technique, vol. 277, 2008, pp. 3-5. doi:CNKI:SUN:XDDJ.0.2008-14-003.

[5] Dongbo Zhao, Rongxing Guo, and Yubin Zhao, “Design and Realization of the Digital Controlled DC Current Source Based on SCM,” Instrumentation Technology, vol. 8, 2008, pp. 58-60. doi:CNKI:SUN:YBJI.0.2008-06-023.

[6] WeiJie Chen, Hong Zhang, “Design of the High Precision Digital DC Current Source Based on Combined Optimal Algorithm,” China Integrated Circuit, vol. 8, Jul. 2008, pp. 3807-3811, doi:CNKI:SUN:KXJS.0.2008-14-025.