Design and Fabrication of a High Precision Constant Current Source Current Generator

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Abstract: A high precision constant current generator with current sources is designed. It adopts precise operational amplifier circuits, high precision constant current sources and FPGA chips. It can generate sine waves, triangle waves and square waves (the duty cycle is adjustable) with adjustable frequency and high precision. The output current ranges from 0 to 4000mA, which can be set as required. It has digital display and strong anti-interference ability, which can provide the current with 0.05% precision. In this paper, the working principle and design idea of the circuit are analyzed. The whole program is compiled under the environment of LabVIEW, and the assembly, welding and debugging of the circuit are completed.

1. Introduction
At present, considering economic benefits, most generators sold in the market are designed to use overload current simulation to test electrical products because most of these products are of high automation, large volume, heavy weight and high cost; or they directly use visual inspection method by increasing load, but the load is not controllable and adjustable during the inspection, which makes it hard to get the required current value quickly and accurately. In short, it is difficult to widely use this kind of current generator in the field. The current generator with constant current source introduced in this paper mainly has the advantages of high precision, low cost, small volume, light weight, easy to operate, and the equipment has a hanging hole, which can be hung at the nearby site through the hanging rope, etc. The operation of setting the required current is simple, and the output current value is displayed in real time by using the digital tube.

This current generator with constant current source can be widely used in a variety of occasions: the test and verification of standard power frequency current transformer, the calibration and setting of electrical equipment in civil building site, the field debugging and setting of electrical fire monitoring system, and the adjustment of development, production, testing and maintenance of various electrical equipment in workshops and laboratories. It is easy to carry and low in price, but it can accurately, safely and quickly acquire current ranging in 0-4000mA, which has high practical value.

2. Design scheme
Through the analysis of its working principle, further analysis of the main parameter design, determine the design scheme.

2.1 Analysis of design principle
It adopts the design of precise operational amplifier circuit, high-precision constant current source, charging voltage of 7.5V and keyboard input of $4 \times 4$ matrix. The main control chip uses...
FPGA-XC3S1200E to generate high-precision sine wave. The frequency and phase are adjusted by software programming and sent to the digital to analog converter (DAC). The data is converted by DA and filtered by first-order high-pass filter and second-order active low-pass filter. The sine wave amplitude is adjusted by voltage to obtain the required current value which is displayed in real time by digital tube. The RS232 serial port of the computer completes the communication functions such as waveform signal type selection, output current range selection, etc. The functional block diagram is shown in Figure 1.

![Functional Block Diagram](image)

Figure 1. The functional block diagram of current generator with constant current source

### 2.2 Design of main parameters

The generator uses lithium battery pack as power supply, with charging voltage of 7.5V; it uses FPGA chip to generate frequency-adjustable and high-precision sine wave, triangle wave and square wave (duty cycle adjustable), with output current of 0-4000mA and step size of 0.01mA for setting; it can provide current of 0.05% accuracy, with single output time of 5-300 seconds and step size of 1 second for setting; its output circuit impedance is less than 0.5Ω. See Table 1 for main indexes of design technology.

| Name              | Parameter                   |
|-------------------|-----------------------------|
| Output current    | 0-4000mA, step size 0.01mA can be set |
| Output accuracy   | 0.05%                       |
| Output loop impedance | <0.5Ω                    |
| Single output time| 5-300 seconds, step size 1 second can be set |
| Charging voltage  | DC ±7.5V                    |

### 3. Circuit design

From the power supply circuit, keyboard input circuit, current shaping amplification, data DA conversion to digital display to describe the design ideas.

#### 3.1 Design of voltage stabilizing circuit for power supply

The product is portable, with large capacity lithium battery pack as power supply, which has long working life. The power supply is connected in parallel with IM7805 and IM7905 to obtain stable voltage, which can provide current ≤ 4A. The circuit diagram is shown in Figure 2.
3.2 Design of keyboard input circuit
The keyboard is input in 4 × 4 matrix mode, with simple operation. Press the key to input the current value and output duration required, which can be output after the confirmation by one key. The circuit diagram of the keyboard input is shown in Figure 3.

3.3 Design of DA conversion circuit
There is serial communication between chip FPGA SPI and the communication interfaces of DA converter and chip LTC2624. The gain of each amplifier is set to 8-bit command word, which is composed of two 4-bit parts, and the highest B3 is sent first. The amplifier output AMP_DOUT responds to the original gain setting. When the DAC_CS of FPGA is set to low, the SPI bus starts to transmit data. The amplifier collects the output serial data AMP_DOUT at the falling edge of the clock signal SPI_SCK. The voltage output formula $V_{OUT} \times V_{REFERENCE}$ is configured as 5V here, as shown in Figure 4.
3.4 The circuit of current amplification and filtering

The main control chip FPGA-XC3S1200E generates high-precision sine wave. The frequency and phase are adjusted by software programming, and sent to the digital to analog converter (DAC) of SPI interface. The data is converted by DA and filtered by first-order high-pass filter and second-order active low-pass filter. The signal generation mode is selected and the output current is adjusted to obtain the required current value. Combined with precise operational amplifier circuit and high-precision constant current source, the current required for output is guaranteed.

The large current power operational amplifier OPA548 is powered by 30V dual-power supply, and the gain is determined by negative feedback resistance. Taking $R_1 = 51K$ and $R_4 = 10K$, the system can reach the accuracy index of 0.01, and can change the value of load voltage to make the change range of output current meet the requirements of $\leq Q1\% + 1mA$. 

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(a) SPI Communication Protocol to LTC2642 DAC

(b) Schematic diagram of data DA conversion

Figure 4. DA conversion circuit
Figure 5. The circuit of current amplification and filtering

3.5 Serial communication RS232
There is a serial port communication function of computer RS232, the circuit design of waveform signal form selection, output current range control, etc. of which is completed, as shown in Figure 6.
3.6 Design of digital display circuit

The programmable high-precision sine wave generator is generated by the chip FPGA, and the frequency and phase are adjusted by software programming. Here, it is set as 50Hz and sent to the digital to analog converter (DAC) of SPI interface. The required current value is obtained by adjusting the amplitude. The output current value is displayed in real time by five-digit digital tube, and the minimum display accuracy can be set to 0.01mA. The circuit diagram is shown in Figure 7.

4. Program block diagram

The whole program is completed in the Lab VIEW environment. Figure 8 is part of the program block diagram, including sine wave generator, DA data conversion output, digital display and other programs.
5. Manufacture and debugging
After the completion of the circuit design, the simulation debugging is carried out. The circuit board is made according to the schematic diagram designed, and then the corresponding electronic components and chips are purchased according to the circuit diagram to assemble and weld the circuit board. The main control chip FPGA-XC3S1200E is used to complete the welding of circuit board with the peripheral circuits of voltage stabilizing circuit for power supply, keyboard input circuit, digital display circuit, filtering and current amplification circuit. After checking, download the program. After the joint debugging of software and hardware, carry out data test. The measurement diagram of 50Hz and 2000mA voltage signal output is shown in Figure 9. It can connect with computer through RS232 communication serial port, select signal generation mode and adjust output current, and download to flash for operation, or operate independently through keyboard, as shown in Figure 10.

Figure 8. Partial program block diagram of FPGA of current generator with constant current source

Figure 9. The measurement diagram of 50Hz and 2000mA voltage signal output

(a) Sine wave  (b) Triangular wave  (c) Square wave

Figure 10. Waveform signal selection and output diagram
6. Conclusion
This paper introduces the design process and manufacture of a high-precision current generator with constant current source. The whole program is completed in the Lab VIEW environment. The output current can be set according to the needs. With digital display, convenient operation, high stability, it can meet the requirements of a variety of constant current source circuits. Through the test, the feasibility of it has been verified. Now it has been mass produced and used in many occasions. The product design is a breakthrough and improvement of conventional products, with high cost performance and good application prospects.

Reference
[1] Li, Z.P., Wang, S.K., Zhang, N., Zhao, Q. (2017) Design and experiment of current source based on single chip microcomputer. Research and exploration in laboratory, 36 (1): 49-53.
[2] Shao, W.H., Gu, A., Sui, J.J. (2015) Design and implementation of STM32-based portable constant current source. Automation & Instrumentation, 30 (12): 29-32.
[3] Xie, Z.Y., Gong, Z.G., Yang, X., Wu, X.Y. (2013) The design of a high stable and digitally controlled alternating constant-current source. Electrical measurement & instrumentation, 50 (567): 102-106.
[4] Mi, W.W., Yang, F., Xu, L.L. (2012) Design and Manufacture of High Precision Constant Current Source. Electronic test, 2012 (12): 65-71.
[5] Miao, X.F. (2011) Digital Constant Current Source Based on the Adjustable Voltage Regulator. Electronic measurement technology, 34 (7): 13-15.
[6] Yang, Y.H., Yan, X.C., Guo H. (2009) The design of AC high precision constant current source. Electrical measurement & Instrumentation, 46 (10): 72-75.
[7] Jiang, H.Y. (2008) Research of a new type of constant current source with high-precision and high temperature stability. Integrated circuit and materials, 277 (14): 3-6.
[8] Tao, L.W., Wang, Y.M., Lei, K.Z. (2007) Precision numerical control constant current source based on microprocessor. Application of electronic technique, (7): 138-140.
[9] Zhai, Y.W., Ai X.Z., Yang, X. (2002) Design of practical constant current source circuit. Electronic measurement technology, 26 (5): 25-26.
[10] Xu, Y.X., Hou, G.L., Zhang, J.H. (1999) Design of high loaded constant current circuit. Modern electric power, 16 (8): 71-72.
[11] Zheng, Q.X. (2010) Xilinx Fpga Digital Circuit Design. Science Press, Beijing.
[12] Lin, J., Lin, Z.Y., Zheng, F.R. (2010) Lab VIEW Virtual Instrument Programming. People post and Telecommunications Publishing House, Beijing.
[13] Tian, G., Xu, W.B. (2008) Xilinx FPGA Development Practical Guid. Tsinghua University Press, Beijing.