Signal Detection and Signal Source Integrated System Design

Wanchang Lai¹, Hengxu Ma¹*, Guangxi Wang¹, Hongjian Lin¹ and Jinchu Huang¹

¹ College of Nuclear Technology and Automation Engineering, Chengdu University of Technology, Chengdu, Sichuan, 610059, China
Email: 17844649567@163.com

Abstract. A signal detection and nuclear signal generator is designed with a 7 and a half high-precision measurement module, high-precision reference source, and digital potentiometer, which integrates the measurement of three signals of bipolar high voltage, micro/high current, and large resistance. And precision adjustable voltage source and current source of microvolt level and picoamp level. Experimental tests show that the system can accurately measure a variety of IVR signals, while providing a stable and precise voltage source and current source, and is easy to operate and easy to carry.

Keywords: Signal detection, nuclear signal generator, stable and precise

1. Introduction
In the application field of nuclear technology, there are many requirements for the measurement of voltage, current, resistance and constant voltage/constant current sources, and the parameters cover a wide range, and some have bipolar requirements. This project is based on STM32 Single-chip microcomputer, high-precision measurement module, reference source chip, with voltage sampling grading circuit and digital potentiometer, can achieve high-precision detection of voltage, large current, micro current, and resistance at the same time, providing 1.0μV~10V and 1.0pA~10mA The high-precision adjustable signal source can be used for data display and selection/setting of corresponding functions through a 4.3-inch TFT LCD screen, which can meet the needs of actual work in the simplest way.

2. Overall System Design
The instrument is composed of signal measurement module, signal source module, STM32 module, human-computer interaction interface (LED display, signal source output setting) and power supply. The structure design is shown in figure 1.

Figure 1. System structure design diagram.
The signal measurement module can automatically perform range switching measurement on the input signal, and display it in the LED module after passing through the STM32 controller. On the LED signal source control interface, you can choose whether the output is a current source or a voltage source. After the setting is completed, the controller controls the resistance of the digital potentiometer module according to a predetermined algorithm, and outputs the required voltage and current after filtering and smoothing signal.

3. System Hardware Design

3.1. Realization of Signal Measurement
Two seven-and-a-half-digit voltage/current meters are used, with a detection range of 0~+10A and 0~±10kV, and the accuracy is better than 1μA and 1μV. The voltage detection module will be pre-connected to a voltage sampling and classification module, using 16-bit bipolar The AD conversion chip samples and calculates the input signal and controls the corresponding relay to attenuate in stages; a fA-level micro-ampere meter (detection range 200fA~2mA); a G ohmmeter (0.1Ω~100GΩ), which will be detected through the RS232 serial port The data is transmitted to the microcontroller and then displayed on the LED screen.

3.2. Realization of Adjustable Signal Source
The signal source module includes a current source of 1.0pA~10mA and a voltage source of 1.0μV~10V. The module circuit adopts four batteries for independent power supply. At the same time, the ground wire is set separately. The circuit board adopts multi-layer all-enclosed multi-layer signal shielding and drying. For dry processing, dedicated shielded wires are used for interfaces.

3.3. Implementation of the Reference Source
The design circuit is shown as in figure 2.

![Figure 2. Reference source design.](image)

The ADR440-10V chip is used to output the standard 10V voltage, and the high input impedance chip is connected at the same time. Because the 1024-bit digital potentiometer is selected, the voltage is slightly amplified, and the same direction proportional operation amplification formula (1):
Vout = Vin × \left(1 + \frac{R6+R7}{R4+R5}\right) \quad (1)

In the test, R7 and R4 are compensation resistors. Due to the small amplification ratio, this compensation bit is set in addition to high-precision chip resistors to ensure accurate output of the preset voltage. Set the voltage output Vout to 10.24V, use the 0 to 999 digits in the algorithm, and use 10 digits as a group to control the unit voltage as 0.1V, corresponding to the output 0.1V to 10V, to solve the voltage over the potentiometer after the output voltage and control output. The value does not match.

3.4. Realization of Signal Shielding
In view of the problem that weak signals are easily affected by external electromagnetic interference, in addition to the use of multi-layer shielding covers to shield the overall circuit, the circuit also introduces a current protection ring to perform secondary independent shielding of each segment of the micro signal, around the pins. Set the copper to completely surround it and connect it to the ground. Set multiple through holes to completely separate the chip pins from the circuit. At the same time, remove the solder assembly layer to ensure that all guard rings are in electrical contact with all surface leakage current paths [1].

3.5. Realization of Current Source
The current source adopts two segmented output forms, the first segment output current is 0.1mA–10mA, the circuit is shown in Figure 3. From the relationship between the formula (2) and the output current plus a high-precision knob potentiometer with R1 set to 20KΩ [2], the constant current source circuit composed of the LM317 chip is output controlled;

\[ I_o = \frac{V_{ref}}{R_1} + I_{adj} = \frac{1.25V}{R_1} \quad (2) \]

The second segment uses four groups of high-precision large resistors (100G, 1G, 10M, 100K) with two dual-channel extremely low bias selectors TMUX6121 to achieve high-precision current output, and each segment is set to two Range [3], set the compensation resistance bit at the same time to reduce the influence of resistance on the output signal [4].

3.6. Realization of Voltage Source
Aiming at the problem that the output voltage of the signal source is small, a multi-level voltage divider circuit is designed, and two digital potentiometers are connected in series on the basis of the reference source module. In addition to the continuous use of the voltage micro-amplifier circuit, a low bias voltage operation is added. The amplifier acts as a voltage follower to increase its transmission capacity. The block diagram is shown in Figure 4.
Since the potentiometer can control the voltage output in three levels, two algorithms are designed to control the potentiometer. When the output voltage is above 0.01V, only the first digital potentiometer is used to control the output of the voltage signal. When the voltage is less than 0.1V, control the 1/2/3 digital potentiometer through the controller, starting from the lowest third.

4. Circuit Test Results and Analysis

4.1. Large Voltage Sampling and Classification Circuit

High-voltage instruments commonly used in laboratories generate several 0-5KV voltages into the circuit. By detecting the on-off of the relay of the attenuation circuit, it is judged whether the voltage can be adjusted to the appropriate attenuation gear correctly. The experimental results are shown in Table 1. The test results show that the designed circuit can be accurately classified according to its voltage value, so that the voltage detected by the voltmeter can reach the most accurate value.

Table 1. Comparison circuit conduction multiple selection results.

| Input voltage(±V) | Attenuation factor selection |
|-------------------|-------------------------------|
| 5                 | 1:1                           |
| 50                | 10:1                          |
| 500               | 100:1                         |
| 5000              | 1000:1                        |

4.2. Constant Current Source/Constant Voltage Source

Use the three IVR measurement modules that come with the instrument for testing. During the test, the corresponding micro current/voltage value is obtained by setting the gear position and the resistance value of the sliding rheostat [5], and then accurately measuring it, and calculating the values in Table 2 and Table 3. The test results show that the pA-level constant current source designed in this project can achieve the expected goal. When the micro current is in the range of 1pA–1nA, the error is controlled within 2%, and when the micro current is 1nA and above, the error can be controlled within 0.3%; μV
level constant voltage source error can be controlled within 0.01%

| Num | Set value | Measured value | Num | Set value | Measured value | Num | Set value | Measured value |
|-----|-----------|----------------|-----|-----------|----------------|-----|-----------|----------------|
| 1   | 1pA       | 1.02pA         | 4   | 1nA       | 1.001nA        | 7   | 1μA       | 1.000μA        |
| 2   | 10pA      | 10.10pA        | 5   | 10nA      | 10.040nA       | 8   | 10μA      | 9.999μA        |
| 3   | 100pA     | 100.4pA        | 6   | 100nA     | 99.997nA       | 9   | 100μA     | 100.010μA      |

| Num | Set value | Measured value | Error /%FS |
|-----|-----------|----------------|-------------|
| 1   | 1.0μV     | 1.01μV         | 0.01        |
| 2   | 50.0μV    | 50.00μV        | 0           |
| 3   | 1.0mV     | 1.00mV         | 0           |
| 4   | 50.0mV    | 50.01mV        | 0.01        |
| 5   | 1.0V      | 1.00V          | 0           |
| 6   | 5.0V      | 5.00V          | 0           |

5. Conclusion
The signal detection and signal source integrated system designed in this subject can perform high-precision measurement for the measured value. The output signal generated by the signal source module is smooth and stable, which can meet most of the needs of hardware technology applications. At the same time, the miniaturization and multiplicity of the instrument the function also reduces the cost of use and is convenient for scientific researchers to conduct experiments.

Acknowledgments
The authors than to The College of Nuclear Technology and Automation Engineering, Chengdu University of Technology, Contract 2017YFC0602105 for the financial support of this study.

References
[1] Xiong N 2017 Application research of electromagnetic compatibility technology in PCB design Henan Science and Technology (5): 132-133.
[2] Wu M C 2011 High-precision wide-range constant current source design Electrical Measurement and Instrumentation 48(1): 64-66.
[3] Lei S J, Wei Z Y, Fang M H, etc. 2013 Development of a weak current source with a range of 100pA~1μA Acta Metrology (3): 270-277
[4] Willenberg G D, Tauscher H N 2009 Novel digital voltage ramp generator to use in precision current sources in the pico-ampere range IEEE T. Instrumentation and Measurement 58(4): 756-760.
[5] Chen Z X, Wei W, Nong G Y 2013 Research on calibration method of pA micro-current meter Nuclear Electronics and Detection Technology (8): 185-190