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# Micro Resistance Tester based on AC Constant Current Excitation

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**Abstract.** The traditional four-probe method to extract the response signal of the micro-resistance under test can improve the accuracy of the lead resistance and the contact resistance on the measurement result, but not effectively eliminate the internal noise of the operational amplifier and the external electromagnetic interference. In this paper, a sinusoidal constant current source excited by a fixed frequency is used to inject a response signal from a low-noise, high-impedance operational amplifier. After the phase-locked amplification and filter circuits are combined to form an adjustment circuit, the fixed frequency signal is shaped and dynamically phase-shifted, Into the lock-in amplifier as a reference signal. The developed prototype (0-1Ω) and a dedicated impedance tester were tested, the test results show that the prototype work is stable, with higher measurement accuracy.

## Introduction

It is often necessary to determine the resistivity of some highly conductive materials. In scientific research, resistivity measurements are often used as a means of monitoring material structure and material morphological changes in engineering practice. For example, the battery is widely used in military, industrial and civil applications [1][2].Its internal resistance is an important parameter that reflects whether it can normally provide current output. After a new battery is put into use, the internal resistance will gradually become larger over time, so that it can not be normally powered. Battery internal resistance is generally milliohms, such as substation common 200Ah VRLA battery resistance is only about 1 mΩ.

The use of constant current source to be tested micro-resistance, the response signal amplified by high-impedance low-noise preamplifier, conditioning circuit using integrated lock-in amplification technology[3]. MSP430 microcontroller is selected as the main controller to conduct on-line measurement of the micro-resistance. The prototype and the special resistance tester developed by the MSP430 are compared and the results show that the tester has high stability and test accuracy. This article will work on it and some of the main module design in more detail.

## The Composition of the Micro-Resistance Tester

Tester system block diagram shown in Fig.1. It is composed of MSP430 microcontroller system to achieve data acquisition, processing and display, and assume the sine wave signal generator, shaping and dynamic phase shift function 0-180 degrees.

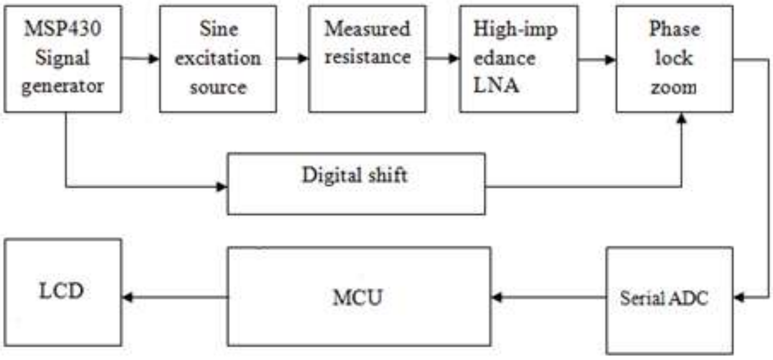


Figure 1. System block diagram

**Micro-Resistance Measurement Method.** Bridge method can be more accurate measurement, but its cumbersome measurement operations and not be measured online. Direct measurement method is simple and fast, but not overcome the lead resistance and contact resistance on the measurement results, should not be used in the measurement of small resistance occasions. Connecting a constant current excitation source to the resistance to be tested in series with the excitation probe means that the excitation effect is independent of the probe lead resistance and the contact resistance. Preamplifier use low-noise high-impedance amplifier, high resistance means that the lead resistance can be ignored. If it is noticed that the test probe and the two terminals of the resistor to be tested are in reliable contact, the influence of the contact resistance on the output response voltage can be improved and the true voltage across the resistor under test can be obtained. The voltage divided by the known excitation source current is the measured resistance. Test principle shown in Fig.2.

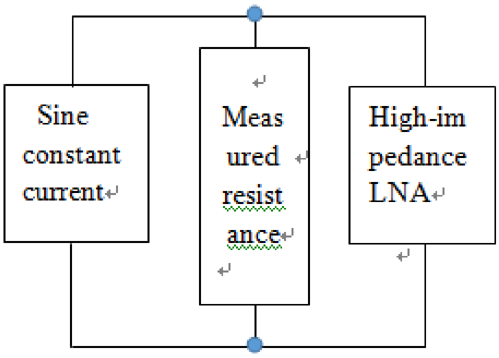


Figure 2. Measurement of micro-resistance method

**Communicate the Role of a Constant Stimulus.** Micro-resistance measurement is a small signal measurement, and in the measurement of the small signal pre-amplifier and conditioning circuit must take into account what steps should be taken to overcome the internal op amp noise and external electromagnetic interference. In this paper, a fixed-frequency sinusoidal constant-current source excitation, the response signal amplified by a high-impedance low-noise preamplifier, conditioning circuit using integrated lock-in amplification technology, the fixed-frequency signal phase-shifted by the lock-in amplification reference signal, so the design can effectively inhibit the noise and external interference effects.

The sinusoidal excitation current source is injected into the micro-resistor to generate the AC response voltage signal. After pre-amplification, it is sent to the integrated lock-in amplifier to be phase-locked and amplified. The second-order active low-pass filter filters out the AC component into the DC voltage output. The voltage is A / D converted under the control of the single-chip microcomputer to obtain the response DC voltage value of the micro-resistor.

## The Main Module Circuit

**Signal Generator and Digital Phase Shifter.** The frequency of the signal generator should consider the signal detection error caused by the electromagnetic interference away from the power system power frequency. At the same time, considering the tester can also be used to measure the internal resistance of the battery because the impedance of the battery has the smallest change of high frequency Zone 0.1 ~ 10 kHz impedance real part as the battery internal resistance, the concentration polarization interference is relatively small, the test using 1kHz AC current as the injection current.

Use MSP430 microcontroller programming to achieve stable frequency 1kHz sinusoidal signal, and after shaping the scan 0-180 degrees phase shift function, as the reference signal for the lock-in amplifier input, while input sinusoidal excitation constant current source.

**Sine (AC) Excitation Constant Current Source.** Constant current power amplifier circuit using Class B complementary push-pull circuit to form a closed-loop current control loop feedback system, we can adjust the circuit parameters through simulation design. Excitation source circuit shown in Fig.3.

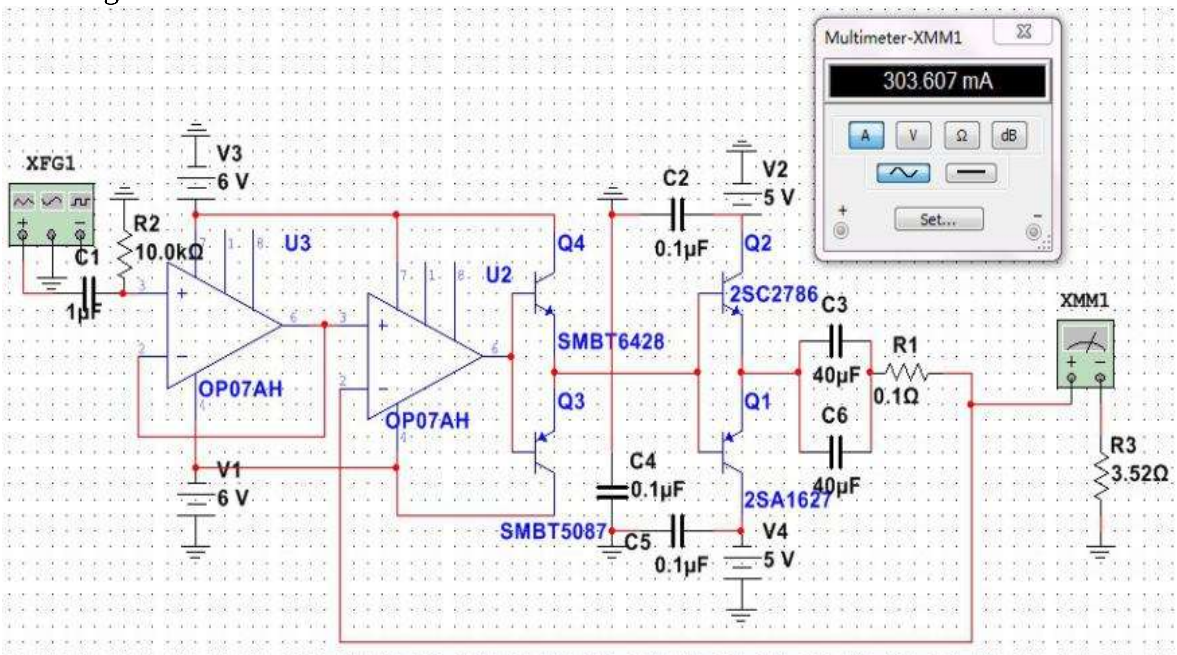


Figure 3. AC excitation source circuit

The initial value of the design parameters of the excitation constant current source and the amplifying circuit is estimated as follows. A zoom, composite drive, ±9V constant current source, R3 = 4 unchanged, I = 0.1 A; 0.1 V at maximum 1 μΩ, differential amplifier A = 20, output 2 V (if A = 50, output = 5 V related to AD reference voltage); If the minimum resistance measured = 0.001 Europe, the voltage = 0.1 milliamperes, when A = 20, U0 = 2 milliamperes.If we choose 12 AD, the reference voltage = 2V, the quantization value of 0.5mV, R3 can be measured directly to calculate the voltage value of the current, then should first measure the bridge R3, for example, the sampling resistor can choose 5mΩ.

**Phase-locked Amplifier Circuit and Conditioning.** Phase-locked amplifier circuit by the digital phase shifter and integrated lock-in amplifier circuit, as shown in Fig.4. In the picture, the digital phase shifter adopts MSP430 one-chip computer to realize the dynamic scanning signal of 0-180 degrees of phase place as the reference signal of AD630. AD620 the first level differential amplification voltage signal, the second stage balanced modulation and demodulation chip AD630 phase lock amplification. Get the same frequency with the excitation source signal component, that is, to remove the noise voltage response signal, the signal through a second-order low-pass filter, filter out the AC component into the A / D converter.

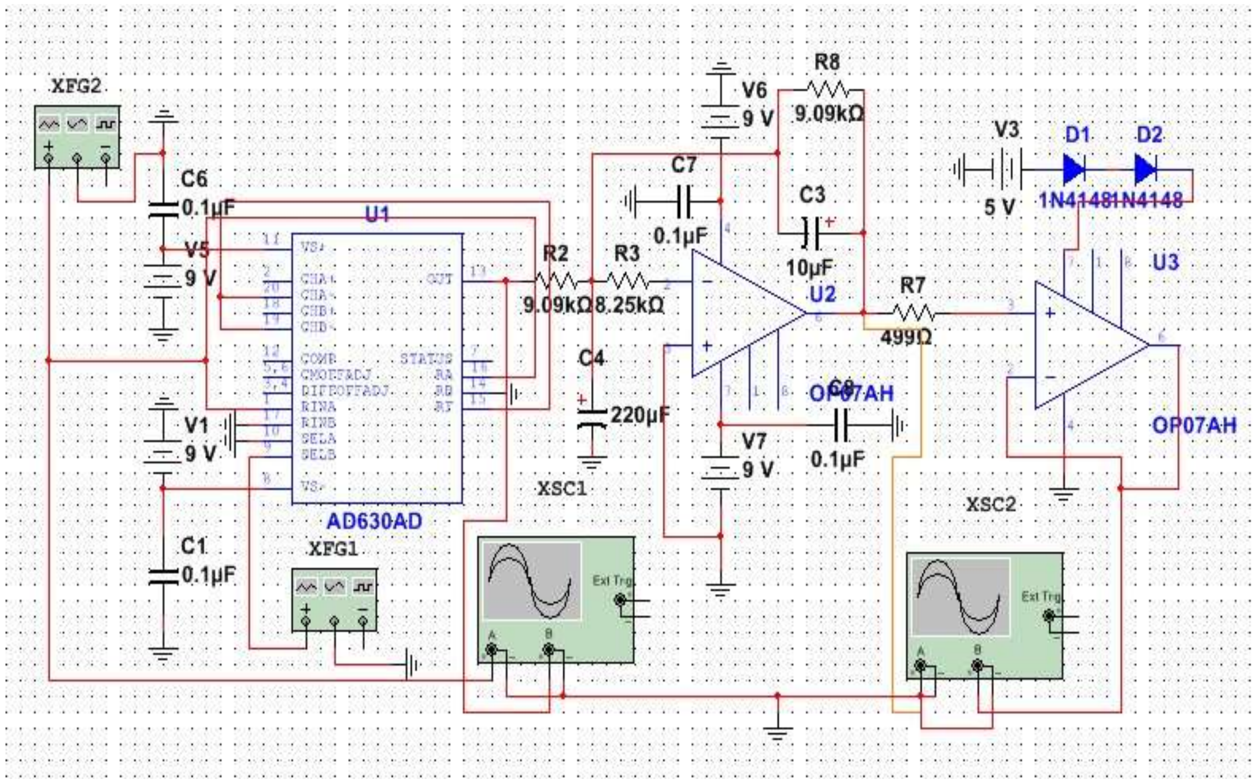


Figure 4. AD630 phase lock and filter schematic

**MSP430 Master System.** MSP430 system includes keyboard display dialogue interface, 240 * 160 LCD, data channel acquisition. The main program shown in Figure 5, the man-machine interface shown in Figure 6, CA0, CA1 two data channels collected and written in C language program. In the data processing of 60,000 samples were collected in batches and two levels of correction, and the results displayed in real time on the LCD.

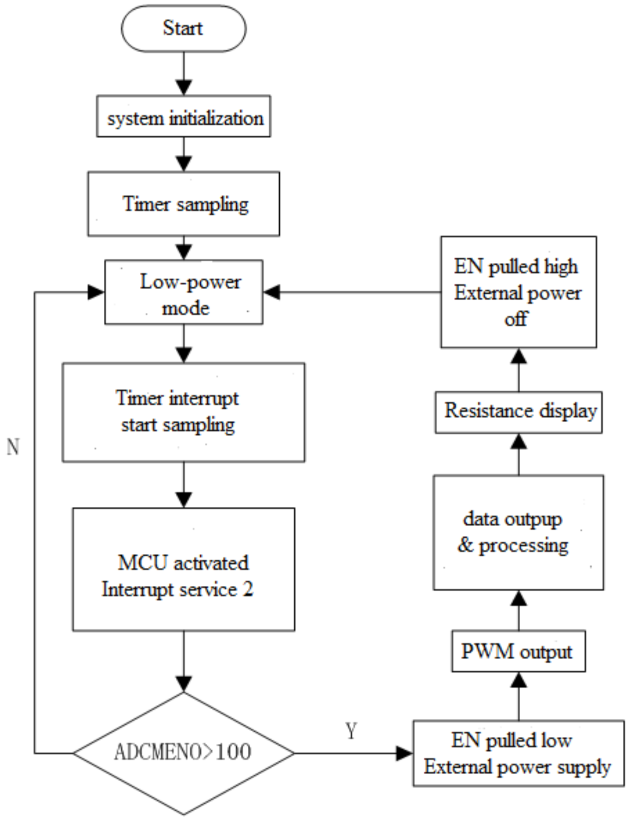


Figure 5. Main program flow chart

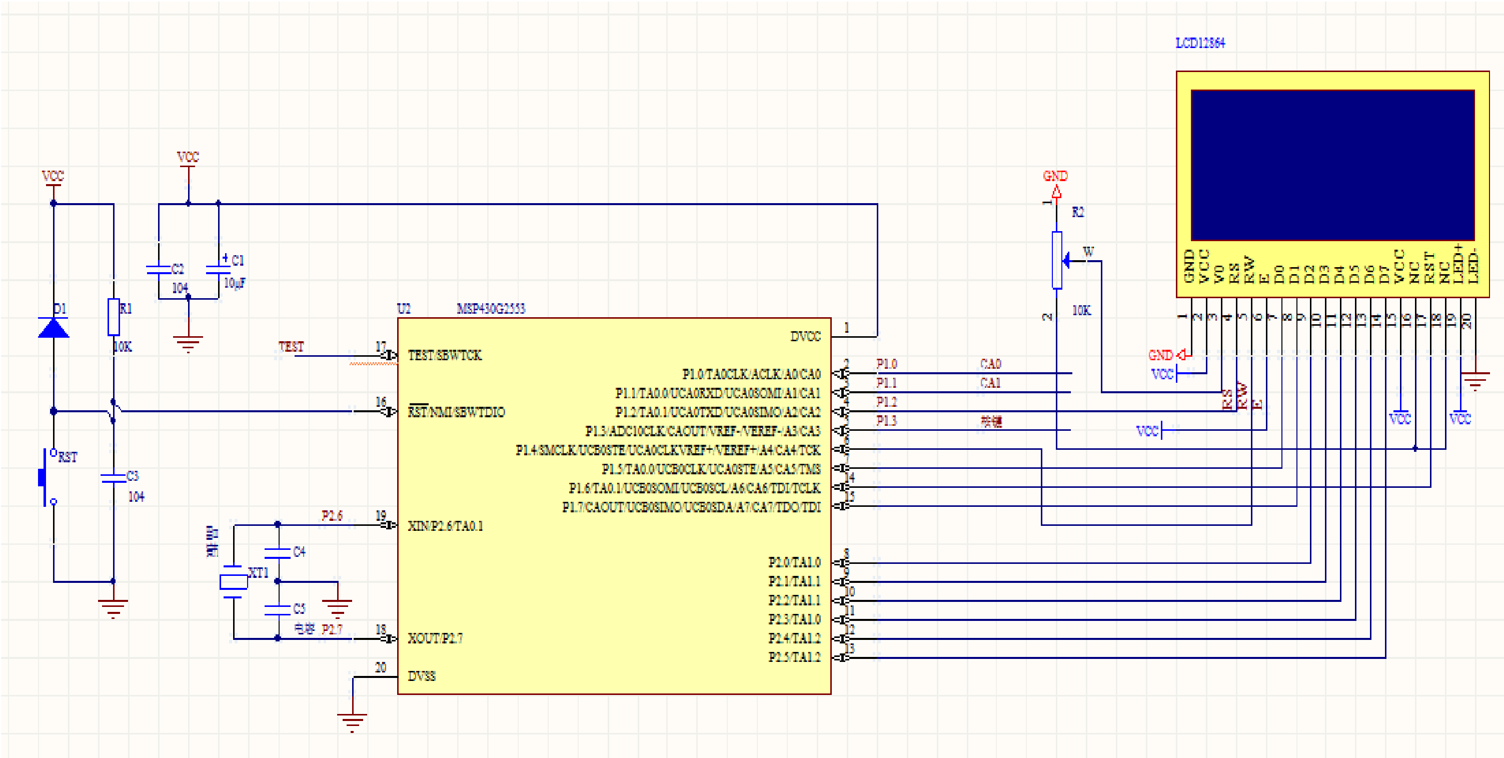


Figure 6.  MCU measurement and control system

In addition, the ADC12 core is a 12-bit A / D converter and stores the result in the ADCMEN. The core uses two programmable reference voltages and can define the maximum and minimum conversion voltage. The ADC outputs a full scale value of 0FFFH when the input analog voltage is equal to or higher than the internal reference voltage of 2.5V and is between 0000H and 0FFFH when the input analog voltage is equal to or less than the internal reference voltage of 2.5V. The final conversion results satisfy the formula: $N_{ADC} = 4095 \times (\text{Vin-V}_{R-}) / (V_{R+} - V_{R-})$.

## Test and Result Analysis

Test equipment: Use the Agilent 4338B-ATO-28 low resistance tester and the tester, where the test value of the Agilent 4338B-ATO-28 low resistance tester is considered the standard value, the tester's test value is the measured value.
Test Method: The same test source for the comparison test, with reference to test technology in the relevant provisions derived from the tester test level.
Test objects: The newly purchased 6V / 4A batteries and the resistance range of 10 mΩ-100 mΩ resistance wire were selected.
Test results: See Table 1 and Table 2.

**Table 1  Battery internal resistance test results**

| number of times | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| standard value [mΩ] | 21.88 | 22.05 | 19.91 | 22.6 | 21.28 | 20.12 | 20.19 |
| measurements [mΩ] | 22.01 | 22.10 | 20.11 | 20.9 | 21.18 | 20.19 | 20.11 |
| Absolute error [mΩ] | 0.13 | 0.05 | 0.10 | 0.17 | -0.10 | 0.17 | -0.07 |

**Table 2 Resistance wire test results**

| number of times | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| standard value [mΩ] | 10.11 | 13.45 | 18.31 | 20.29 | 24.65 | 28.05 |
| measurements [mΩ] | 10.19 | 13.32 | 18.37 | 20.18 | 24.55 | 28.18 |
| Absolute error [mΩ] | 0.07 | -0.13 | 0.06 | -0.11 | -0.10 | 0.13 |

The maximum battery test error occurs at 20.12mΩ, 0.17mΩ; resistance wire test maximum error occurs at the standard value of 38.76mΩ at 0.19mΩ. According to the formula of the maximum reference error, the maximum reference error is better than 0.2%; the accuracy grade is 0.02.

## Conclusion

The four-probe method has the characteristics of directly overcoming the contact resistance and the lead resistance, and is suitable for the low-resistance measurement. The design of the micro-resistance tester which is selected to inject the sinusoidal constant-current excitation source has the characteristics of simplifying the test system design and more What matters is that it effectively suppresses noise and external disturbances. It is not hard to see that this method of injecting stimuli into AC can test the internal resistance of DC power supply through capacitive coupling. In this paper, the tester based on the above principle, respectively, resistance wire and the newly purchased battery resistance comparison test results show that the tester has a high stability, resistance accuracy of mΩ grade better than 0.2%, this measurement method Certain practical value.

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