The I-V Measurement System for Solar Cells Based on MCU

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Abstract. In this paper, an I-V measurement system for solar cells based on Single-chip Microcomputer (MCU) is presented. According to the test principles of solar cells, this measurement system mainly comprises of two parts—data collecting, data processing and displaying. The MCU mainly used as to acquire data, then the collecting results is sent to the computer by serial port. The I-V measurement results of our test system are shown in the human-computer interaction interface based on our hardware circuit. By comparing the test results of our I-V tester and the results of other commercial I-V tester, we found errors for most parameters are less than 5%, which shows our I-V test result is reliable. Because the MCU can be applied in many fields, this I-V measurement system offers a simple prototype for portable I-V tester for solar cells.

1. Introduction
Booming world economy’s increases the demand for energy, with the traditional fossil energy sources dwindling, while the use of fossil energy has also caused serious environmental pollution [1]. In order to solve the resulting energy crisis and environmental problems, more attention orientates to renewable energy, in which development and utilization of solar energy is a viable option. Now solar photovoltaic technology is the highly regarded, and the PV as the core components of solar technology has become the focus of many researchers. In solar cell research and industrial production process, it is necessary to test the performance of solar cells and sort solar cells.

In this paper, a new solar cell I-V tester based on MCU is presented. This measurement system mainly comprises of two parts— data gathering, data processing and displaying. After the development is finished, this system was used to test solar cells. Comparing our results and the test result from other tester, we find the test results coincide with each other, which shows the reliability of our test system.

2. Design of Data Collecting
The optical and electrical properties of solar cells are mainly calibrated by its I-V curve. Because the standard measurement condition is under spectrum AM1.5, the irradiance is 100mW/cm² and the temperature is fixed at 25 degree. Both the variation of temperature, spectrum and irradiance will affect the results of the I-V curve, so the goals of data collecting are to gather the information of temperature, irradiance condition, current and voltage, then send these information to the computer. The computer was used to deal with the above data, and convert the data gathered from non-standard condition to the data under standard test condition.

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In our system, DS18B20 was used to acquire the temperature information, for this sensor can directly output the binary data. The gathering of irradiance information relies on the principles that the short-circuit current is always proportional to the irradiance. So a very small standard solar cell was used as an irradiance detector. By measuring the voltage upon a known resistance, we can deduce the irradiance. The current and voltage measurement depends on the adjustable resistance linked to the detected solar cell. MCU can control the stepping motor to change the adjustable resistance to one fixed value, then measure the voltage and current at that time. This process was repeated many times, and then current and voltage in the loop were collected. The schematic of current and voltage collecting was shown in figure 1 [2]:

![Figure 1: The current and voltage collecting principle diagram.](image)

In figure 1, \( R_0 \) is the load resistance, \( R_{std} \) is the standard resistance, \( V_{ref} \) is the reference voltage source. The switch \( K_1, K_2 \) and \( K_3 \) all are solid state relay. It is the MCU who control the conduction and interrupt of the solid state relay, and then different loops were formed to gather the current and voltage signal. Through the following procedures, we can acquire the voltage and current values of solar cell under different load conditions.

1) The irradiance is fixed, then the load resistance was tuned to a unique value, \( K_3 \) is close. \( K_1 \) links to \( K_{11} \), \( K_2 \) connects to \( K_{21} \). The voltage between \( R_0 \) is

\[
V = \frac{R_0}{R_0 + R_{std}} V_{ref}
\]

From the Eq.(1), the expression of resistance \( R_0 \) is:

\[
R_0 = \frac{V}{V_{ref} - V} R_{std}
\]  

2) Keep the irradiance and \( R_0 \) unchangeable, the switch \( K_3 \) is close, \( K_1 \) connects to \( K_{12} \), \( K_2 \) connects to \( K_{22} \). Then this electric circuit only contains solar cell and \( R_0 \). At this time the port voltage is named as \( V_c \). Through the procedure 1, the value of \( R_0 \) is deduced, then the current in the loop is:

\[
I_c = \frac{V}{R_0} = \frac{V_{ref} - V}{V} \frac{V_c}{R_{std}}
\]

3) In this step, the MCU is used to control the stepper motor driver and the rotate of the stepping motor, then the value of \( R_0 \) is changed. Repeat the procedure 1 and 2, the current and voltage under different load resistance can be obtained.

4) Change the \( R_0 \) to the minimum as possible, so the resistance of load is much smaller than the inner resistance of solar cell. According to the procedure 1 and 2, the short-circuit current \( I_{sc} \) is obtained.

5) The switch \( K_3 \) is off, \( K_1 \) connects to \( K_{12} \), \( K_2 \) connects to \( K_{22} \). Under these conditions, the loop which contains the solar cell and load resistance is open, so the voltage at this time is the open-
circuit voltage $V_{oc}$ of the solar cell. The hardware diagram of data sampling circuit is shown in figure 2.

Firstly the collecting data was saved in the memory of MCU. After the sampling process ends, the LED lights and informs the user that the data collecting process is finished. Then the data was send to the PC by the serial port. All the follow-up data processing was completed by computer.

3. Design of data processing and result displaying
The work mode adopted in our system is upper computer and lower computer mode. PC is the upper computer, MCU is the lower computer. The data sending, receiving and control communication between two computers are through the RS-232 serial port. The human-computer interface is developed by VC++6.0 software [3]. Any operator can monitor the process of data collecting through the human-computer interface and acquire the I-V curve and the related parameters of the detected solar cell.

![Figure 3](image3.png)

**Figure 3** Human-computer interaction interface.

The finished human-computer interaction interface is shown in figure 3. The interface comprises of three push buttons, namely “Open”, “Close” and “Compute”, respectively. When the user received the signal which shows the collecting process was finished, clicks “Open”, the serial port of computer began to receive the information from the lower computer. After the data transmission is over, the dialog box as shown in figure 4 will pop, which informs the user the data receiving process is over. At that time the area of the detected solar cell should be input. Operator inputs the area of solar cell to the “Area”, click “Compute ” button, then the I-V curve and all related parameters will display in the

![Figure 4](image4.png)

**Figure 4** The dialog box after data transmission is over.
4. The experimental results

After the test system is developed, three solar cells connected by series connection with area 7.5*7.5cm² were tested by this system and the test result is shown in figure 5.

![I-V test results](image)

Figure 5 I-V test results.

It can be seen from figure 5 that both the I-V curve and the related parameters shown in the interface are very straightforward. The same solar cell test in Jiawei Solar Cell (Wuhan) Cor. reports the results that the Voc is 1.797V, the maximum power is 1.349W, the work current is 1.008A and the conversion efficiency is 7.98%. By comparing two test results, we find the errors of most parameters are less than 5%, which shows the development of our system is successful.

5. Conclusions

In this paper, an I-V tester based on MCU is introduced. It can be seen from the experimental results that the operation of this measurement system is simple and the related characteristic of solar cell can be displayed in human-computer interface by graphical and numerical methods. Under the condition that the spectrum derivation was not included, most parameters error for solar cell were less than 5%, which shows the experimental results for our test system is reliable. For MCU is small bulk, this tester can be applied to portal I-V tester, which is helpful to diagnose the large-scale PV array.

References

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