Data Acquisition and Analysis of Photocell Characteristics and Its Application in Switch Circuit Control

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Abstract. Photocells which produce a voltage and supply an electric current when illuminated have been widely used. The basic characteristics of the photocell were tested and analysed through experiments by an optical control experimental platform, such as short circuit current, open circuit voltage, illumination characteristic, volt ampere characteristic, load characteristic, and spectral characteristic. The experimental results are in agreement with the theoretical analysis. The light control switch circuit was realized by using photocell. In this way, the principles and operation of photocell can be well comprehended.

1. Introduction
The photocell is a PN junction photoelectric device which can convert light energy directly into electric energy without an additional bias voltage. According to the use of photocells they can be divided into two categories: solar photocells and measuring photocell. Solar photocells are mainly used as power supply, and its requirements are high efficiency and low cost. With the advantages of simple structure, small volume, light weight, high reliability, long service life, and the directly conversion of solar energy into electrical energy characteristics in space, it has not only become an important power of the aerospace industry, but also widely used in the places where power supply is difficult. The main function of measuring photocell is photoelectric detection, can convert light signals into electrical signals under the condition of no bias voltage, the demand for it is of wide linear range, high sensitivity, spectral response, appropriate good stability and long service life, so it is widely used in precision measurement.

Using silicon photocell experimental apparatus, basic characteristics of photocell can be achieved by data Acquisition and analysis; and an optical control switch circuit with photocell has been developed in this experiment.

2. Experimental Apparatus
Silicon photocell experimental apparatus can help us to understand and familiar with silicon photocell. The basic characteristics of silicon photovoltaic cells are mainly studied, such as short-circuit current, photoelectric characteristics, spectral characteristics, volt ampere characteristics, time response characteristics and so on, and the application of silicon photocell can be realised.

The PCB board and the optical path component of the experimental apparatus are partly placed in the box. In the PCB part of the circuit, the modular design is equipped with independent voltmeters, ammeters and independent illuminance meters. All the display units and various regulating units are placed on the panel. When doing experiments, it is easy to connect, adjust, observe and record.
3. Data Acquisition and Analysis of Photocell Characteristics

3.1. Work Principle and Basic Characteristics of Photocell
Photodetectors, also called photosensors, are sensors of light or other electromagnetic radiation which are widely used in the digital camera, optical communication, solar cells and other fields, the photocell is a basic unit of semiconductor photoelectric detector. Deep comprehension of the working principle and characteristic of the silicon photocell can help further understanding principle of semiconductor PN junction, photoelectric effect theory and photocell generation mechanism.

- **Short circuit current**
  As shown in Fig 1, the different values of the current are displayed under different illumination. This is short circuit current characteristics of silicon photocell.

- **Open circuit voltage**
  As shown in Fig 2, under different illumination, the voltmeter displays different voltage values. This is Open circuit voltage characteristics of silicon photocell.

- **Illumination characteristics**
  The photocurrent and photo electromotive force of photovoltaic cells are different under different light intensities, and the relationship between them is the light characteristics.

- **Volt ampere characteristics**
  When the input light intensity of silicon photocell is constant, the relationship between the output voltage and current of the photocell along with the change of load resistance is called the volt ampere characteristic.

- **Load characteristics**
  The photocell is used as a battery, as shown in figure 3. Under the influence of internal electric field, the incident photon will excite the bound electrons in the dielectric band to the conduction band due to the internal photoelectric effect, resulting in the photovoltaic voltage, and the current flow will be generated when a load is added at both ends of the photocell. The load characteristic of silicon photocell can be measured by changing the value of load resistance $R_L$ in experiment.

- **Spectral characteristics**
  The spectral response characteristics of a general photocell indicate the relationship between the short circuit current and the incident light wavelength under the condition that the incident energy is kept constant.
3.2. Module of Characteristics Test.
Test module. Electronic circuit structure, a voltmeter: independent voltmeters, three switches, 200 mV, 2 V, 20 V, by dialling switch to regulate. "+" "-" correspond to the "positive", "negative" polarity of voltmeter.

An ammeter: independent ammeter, three switches 200 μA, 2 mA, 20 mA, 200 mA. Dialling switch to regulate. "+" "-" correspond to the "positive", "negative" polarity of voltmeter.

Fixed resistance value: RL1=1 KΩ, RL2=2 KΩ, RL3=5 KΩ, RL4=10 KΩ, RL5=20 KΩ, RL6=50 KΩ, RL7=100 KΩ, RL8=200 KΩ, RL9=500 KΩ, RL10=1 MΩ, RL11=2 MΩ, RL12=5 MΩ. DC power supply: ~12 V adjustable "~12 V" as the positive pole of the power supply and the other end as negative.

3.3. Data Acquisition and Analysis

3.3.1. Short Circuit Current Characteristic Test of Silicon Photocell. Under the condition of the Fig1 circuit, the illuminance on photocell is controlled by illumination meter. Adjust illumination to the minimum, connected to the illumination meter, DC power to the minimum, open the illumination meter, at this time the illumination meter readings should be 0. Turn on the power supply and adjust the illumination control knob clockwise, so that the illumination value is in the following table 1.

| Illumination (lx) | 0  | 100 | 200 | 300 | 400 | 500 | 600 |
|------------------|----|-----|-----|-----|-----|-----|-----|
| Photo current (mA) | 0  | 7.3 | 14.6 | 22  | 29.6 | 37.1 | 45  |

3.3.2. Open Circuit Voltage Characteristic Test of Silicon Photocell. Under the condition of the Fig2 circuit, the illuminance on photocell is controlled by illumination meter. Adjust illumination to the minimum, connected to the illumination meter, DC power to the minimum, open the illumination meter, at this time the meter readings should be 0. Open the power supply, adjust the illumination adjustment knob clockwise, make the illumination value in turn as the light value in the lower table, read out the voltmeter reading, and fill in table 2.

| Illumination (lx) | 0  | 10 | 20 | 30 | 40 | 50 | 100 | 200 | 300 | 400 | 500 | 600 |
|------------------|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|
| Photovoltage (mV) | 0  | 225 | 255 | 270 | 282 | 291 | 321 | 346 | 361 | 371 | 379 | 385 |

According to table 1 and table 2, the illumination characteristic curve can be drawn by software as shown in Figure 4. The short-circuit current is proportional to the illumination according to Figure 4.
3.3.3. Volt Ampere Characteristic Test of Silicon Photocell. Adjust illumination to the minimum, connected to the illumination meter, DC power to the minimum, open the illumination meter, at this time the illumination meter readings should be 0. The voltage meter is adjusted to 2V, and the current meter is adjusted to 200uA. The light intensity adjustment knob is adjusted counter clockwise to the minimum position. The photocell is connected with the resistance R and the ammeter, while the voltmeter is used to measure the voltage across the photocell. The value of R is 200 ohms, the power supply is adjusted clockwise, the illumination regulation knob is increased, and the illuminance value is increased to 500lx. Record the readings of the voltmeter and ammeter at this time and fill in the table 3 below; The R is replaced by the resistance value in the table 3, and the steps are repeated. The readings of the ammeter and voltmeter are recorded, and the lower table is filled. Data analysis: According to table 3, Figure 5 can be drawn, it is shown that when the resistance of the load is the same and the illuminance is constant, the current is linearly related to the voltage, and the higher the voltage, the higher the current. The same illumination, under the same voltage, the load is different, the current is also different.

| Resistance(Ω) | 200 | 2K | 5.1K | 7.5K | 10K | 15K | 20K | 25K | 51K | 200K |
|---------------|-----|----|------|------|-----|-----|-----|-----|-----|------|
| Current(uA)   | 51  | 50.9 | 45.6 | 36.2 | 29.3 | 21.3 | 16.4 | 13.4 | 6.7  | 1.8  |
| Voltage(mV)   | 61  | 153.4 | 277 | 313 | 327 | 341 | 347 | 351 | 358 | 363 |

Under condition: Illumination 100lx:

| Resistance(Ω) | 200 | 2K | 5.1K | 7.5K | 10K | 15K | 20K | 25K | 51K | 200K |
|---------------|-----|----|------|------|-----|-----|-----|-----|-----|------|
| Current(uA)   | 10.1 | 10.1 | 10.1 | 10.1 | 10.0 | 9.7  | 9.0  | 5.4  | 1.5  |
| Voltage(mV)   | 12  | 30 | 61 | 87 | 110 | 160 | 205 | 235 | 287 | 307 |

Under condition: Illumination 300lx

| Resistance(Ω) | 200 | 2K | 5.1K | 7.5K | 10K | 15K | 20K | 25K | 51K | 200K |
|---------------|-----|----|------|------|-----|-----|-----|-----|-----|------|
| Current(uA)   | 30.5 | 30.4 | 30.2 | 28.6 | 25.6 | 19.3 | 15.2 | 12.5 | 6.4  | 1.7  |
| Voltage(mV)   | 36  | 91 | 183 | 243 | 281 | 310 | 319 | 328 | 339 | 346 |

3.3.4. Load Characteristic Test of Silicon Photocell. Adjust illumination to the minimum, connected to the illumination meter, DC power to the minimum, open the illumination meter, at this time the illumination meter readings should be 0. The voltage meter is adjusted to 2V, and the current meter is adjusted to 200uA. The light intensity adjustment knob is adjusted counterclockwise to the minimum position. The circuit is connected to the circuit shown in Fig. 3, and the value of R set firstly 1K euro.
Open the power supply, adjust the "light regulation" knob clockwise, gradually increase the illuminance to 0Lx, 100Lx, 200Lx, 300Lx, 400Lx, 500Lx, 600lx, respectively record ammeter and voltmeter readings, fill in the table below. And secondly R is set to 5.1K, repeat the operation just now, and finally R is used 10K. Data analysis: According to table4 filled, Figure 6 can be drawn by software, it is shown that under the same load conditions, the current increased with the increase of light intensity, current is increased; the actual use are connected to the load resistor $R_L$, output current with illumination (flux) and nonlinear increase slowly increased with increasing load and linear range of $R_L$ is more and more small. Therefore, when the output current is need to linearly related to the illuminance, the load resistance is smaller as the condition permits, and is limited to use within the illumination range.

**Table 4.**

| R=1K | Illumination(Lx) | 0 | 100 | 200 | 300 | 400 | 500 | 600 |
|------|------------------|----|-----|-----|-----|-----|-----|-----|
|      | Current(uA)      | 0  | 10.7| 21.6| 32.5| 43.5| 54.5| 65.1|
|      | Voltage(mV)      | 0  | 21  | 43  | 64  | 87  | 108.9| 130 |

| R=5.1K | Illumination(Lx) | 0  | 100 | 200 | 300 | 400 | 500 | 600 |
|--------|------------------|----|-----|-----|-----|-----|-----|-----|
|        | Current(uA)      | 0  | 10.7| 21.4| 31.8| 41.1| 47.2| 51.4|
|        | Voltage(mV)      | 0  | 65  | 130 | 193 | 250 | 287 | 312 |

| R=10K  | Illumination(Lx) | 0  | 100 | 200 | 300 | 400 | 500 | 600 |
|--------|------------------|----|-----|-----|-----|-----|-----|-----|
|        | Current(uA)      | 0  | 10.9| 20.4| 26.3| 28.9| 30.3| 31.5|
|        | Voltage(mV)      | 0  | 120 | 228 | 293 | 322 | 338 | 352|

**Figure 6.** Load characteristics of silicon photocell

3.3.5. Experiment for Measuring the Illumination Characteristics of Silicon Photocell. Slowly adjust the light intensity adjustment potentiometer to the maximum, S2, S3, S4, S5, S6, S7 (different S switch stand for different wavelength) up and down in turn, record a minimum value E as a reference; slowly adjust the potentiometer until the illuminometer displays as E, use multi-meter to record the output data and filling the following form. That is testing out resistance under orange, yellow, green, blue, violet light respectively when the illuminance E. Data in Table 5 corresponds to different wavelengths, sensitivity of the photocell is different.
Table 5.

| Wavelength (nm) | Red (630) | Orange (605) | Yellow (585) | Green (520) | Blue (460) | Violet (400) |
|-----------------|-----------|--------------|--------------|-------------|-----------|-------------|
| Base responsibility | 0.63 | 0.61 | 0.56 | 0.42 | 0.25 | 0.06 |
| Voltage (mV)    | 275  | 266  | 257  | 252  | 274  | 299  |
| Responsibility  | 178.75 | 162.26 | 143.92 | 105.84 | 68.5  | 17.94 |

4. Application Circuit and Its Analysis

By changing light intensity on the photocell, we can control the intensity of the LED. Figure 7 is a light control circuit.

Figure 7. Silicon photocell optical control switch circuit

Open the power switch, slow adjust the illumination, adjust the potentiometer, when the illuminance increases to a certain value, the light-emitting diode will be extinguished. On the contrary, when the intensity of the light on the silicon photocell is changed from strong to weak, when the illumiance reaches a certain value, the light-emitting diode will emit light, thus the design of the light controlled switch circuit based on the silicon photocell is realized.

5. Summary

Using photocell experimental apparatus for data collection and analysis, then handling data by software, you can analyse characteristics of photocell; test results are consistent with the theory. After knowing the characteristics of the photocell, we can build an optical control circuit using photocell. This experiment system has been used for our college students. This platform can be used for the experiment and practice, emphasizing modular design with detecting and designing system. In this way, students can understand the principles and operation of photocell well.

6. References

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