



Department of Electrical Engineering

Laboratory Manual

EE3115

Applied Optoelectronic Devices

Semester B 2023/24

EE 3115 Lab2 Photoresistor Sensor Experiment

Objectives

1. To study the operation of photoresistors (photoconductive cells).
2. To use the photoresistors as controllers of power circuits.

Equipment Required

NORP 12 photoresistor
0.001 μ F, 10 k Ω , 4.7 k Ω , 100 k Ω , 5.6 M Ω
555 IC timer, LM741 IC amplifier
Table Lamp, Signal generator, Solderless breadboard

Suggested Web Reference

1. Sensors/Transducers: (<https://www.tutorialspoint.com/difference-between-sensor-and-transducer>)
2. Photoresistor Basics: (<http://web.mit.edu/rec/www/workshop/photoresistors.html>)
3. Measuring Light Intensity: (<http://education.cnsi.ucsb.edu/inscites/ece-94r/docs/lighting-lab/light-intensity.pdf>)

Background

Photoresistor (also referred to as the photoconductive cell or light-sensitive resistor) is generally made of either cadmium sulphide (CdS) or cadmium selenide (CdSe). The devices are made by the deposition of a layer of the semiconductor material on a substrate of ceramic or silicon. A clear coating of glass or plastic, which forms a lens, can be used to focus the light. In a dark state with zero ambient light level, the semiconductor material has few free electrons; however, when light (or photons) irradiates the cell's surface, the current flow increases and resistivity decreases (Why?).

A dark cell may have a resistance of 1 to 50 M Ω , whereas an illuminated cell's resistance may drop to under 5 k Ω . Dark-to-light resistance ratios of 10,000/1 are not unusual. Accompanying the resistance change is also a change in response time. The cell does not respond instantaneously to the influx of light, i.e. the response time is slow, normally of the order of tens of ms! (What other types of photo-sensitive devices give you a much faster response??)

The cells are sensitive to different wavelengths. The CdS photocell peaks in the region of 500 to 600nm. The CdSe cell peaks in the region of 700 to 750nm. Both peak near the lower (i.e. IR) end of the visible light spectrum.

Photoresistors are also manufactured from selenium, germanium, and silicon. The material that is used determines the sensitivity and response time of the sensor. Geometric patterns in the semiconductor layer can also affect the sensitivity of photoresistors. Zigzag or interleaved patterns provide greater

surface areas but a lower operating voltage. The photoresistor can be used as a potentiometer for the biasing of oscillators or amplifiers.

Figure 1(a) shows the cell as a variable resistor connected in series with a load resistor R_L . As the light increases on the cell, more current will flow through the load resistor R_L .

Figure 1(b) shows the cell being used to change the bias in a transistor amplifier. When the cell is dark, the amplifier will conduct and will go to a cutoff state when the cell is irradiated. If R_1 and the cell are interchanged, the transistor will be switched from an “off” state to an “on” state by the presence of light (work out the mechanism yourself!)

The amplifier can also be used to frequency-modulate an oscillator. The frequency of oscillation is then dependent on the level of light intensity present. Figure 1(c) shows a circuit for an oscillator that uses logic inverters. The frequency depends on the RC time constant. As the light increases on the cell, the effective value of R_1 will decrease; hence the frequency of oscillation will increase. [Note: $f = 1/2\pi RC$]

Photoresistive cells are commonly used in cameras for automatic exposure control, in street lighting, in counting or sensing changes for production control, and in measuring and determining the color density of blood. These components are easy to use and they are small, reliable, and economical.

The NORPI2, at 1000 lux, has a dark-to-light resistance ratio of $1\text{ M}\Omega/400\Omega$, or 2500/1. The cell is made of cadmium sulphide with a peak response at 530nm. The rise time is 18 ms, and the fall time is 120 ms.

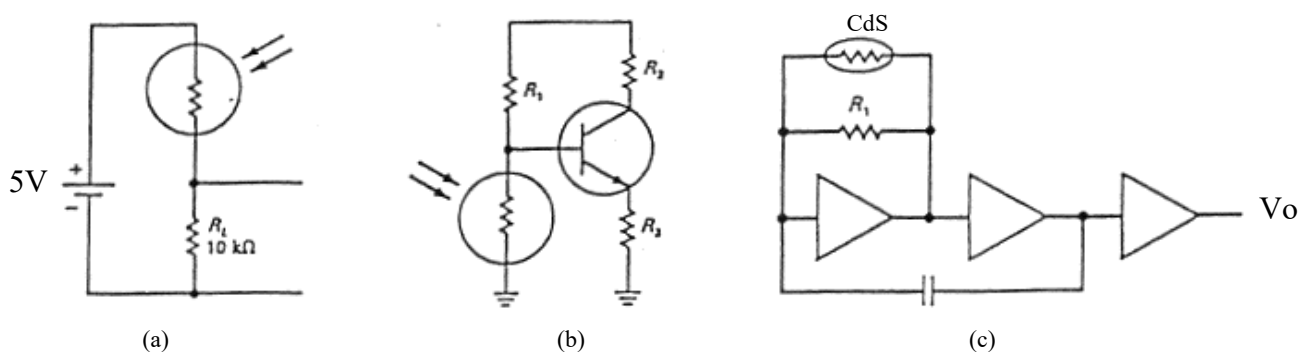


Fig. 1. Applications of CdS photoresistors (a) in series with a load, (b) biasing an amplifier, and (c) photoresistor-controlled oscillator.

SUMMARY

The photoresistor changes its resistance value in proportion to the irradiated light energy present. The resistance of the cell has a dynamic range of over 10,000 to 1. The dark resistance can range from 500 K Ω to 100 M Ω .

Two types of materials are generally used in making photoresistors, namely, CdS and CdSe. The semiconductor material is deposited on a ceramic or silicon base using various geometric patterns.

Photoresistor sensors can be used with amplifiers to record on-off light changes or light variations. Switches can be made to open or close, pinholes in sheet steel can be located, or light reflected from the end of a cassette tape can be made to stop the drive motor.

PRELIMINARY INSTRUCTIONS

This experiment involves testing a photoresistor in several different circuits. The unit will be evaluated by itself, and it will be used to control the frequency of an oscillator. The distance between the lamp and the sensor is recommended to be 6 cm.

Experimental Procedures

1. Photoresistor Evaluation

A table lamp is used as a light source. Construct the circuit shown in Figure 2(a).

- a. Measure the voltage across R_1 when the cell is dark, V_0 (dark).
- b. Measure the voltage across R_1 when the cell is under room light, V_0 (Room light).
- c. Measure the voltage across R_1 when the cell is fully exposed to light, V_0 (light).
- d. Repeat part (b) with different dimmer readings, and plot the graph for the reading with the voltage across R_1 .

2. Amplifier Evaluation/Gain Control

Construct the circuit shown in Figure 2(b). The cell is used in the feedback loop of the amplifier. As light impinges on the cell, its resistance decreases and so does its gain. The gain of the amplifier is determined by $= 1 + R_f/R_2$ or V_o/V_i . Feed the amplifier with a 1-kHz sine wave signal at a $1 V_{pp}$ level (V_i).

- a. Record the output voltage when the cell is dark, V_o (Dark).
- b. Record the output voltage when the cell is under room light, V_o (Room Light).
- c. Record the output voltage when the cell is fully exposed to light, V_o (Light).
- d. Does the light on the sensor cause any change in stage gain? Explain why.
- e. Under the full illumination level and the photoresistor is out of the circuit, record the resistance of the photoresistor. Calculate the dark-to-light resistance ratio.
- f. Repeat part (b) with different dimmer readings and plot the graph for the reading with the measured amplification.

Warning: Please make sure the output signal won't be saturated when the cell is dark. If the case happens, please adjust the amplitude of the input signal or change the suitable resistor in R_2 but students have to drop down the new value in the log book.

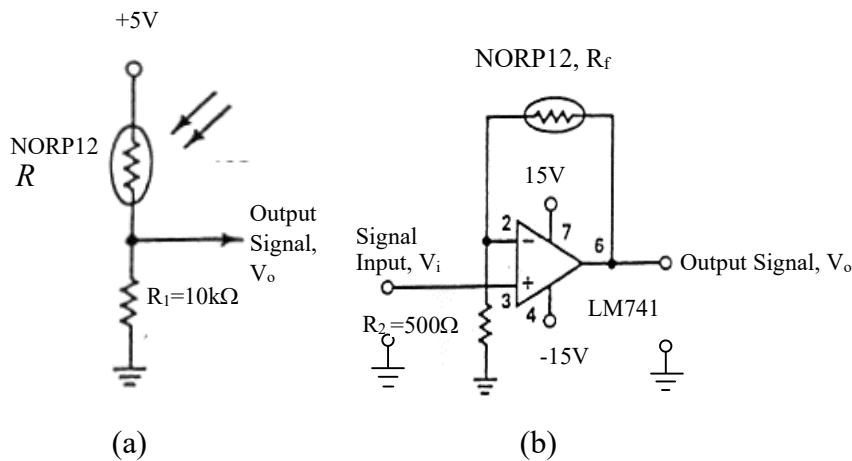


Fig. 2 Evaluating a photoresistor.

3. Oscillator Evaluation

Construct the circuit shown in Figure 3 which is an oscillator circuit and place the photoresistor 6 cm away from the lamp and covered the setup with a box. The frequency of oscillation depends on the amount of light radiation.

- Record the frequency of oscillation when the cell is dark, $f_o(\text{Dark})$.
- Record the frequency of oscillation when the cell is under room light, $f_o(\text{Room light})$.
- Record the frequency of oscillation when the cell is fully exposed to light, $f_o(\text{Light})$.
- Sketch the output waveform V_o , when the cell is illuminated at different levels (i.e. 3a to 3c).
- Does the frequency increase or decrease with different levels of illumination (i.e. 3a to 3c)?
- Does the photoresistor control t_1 or t_2 in the sketch shown in Fig. 4? Explain why.

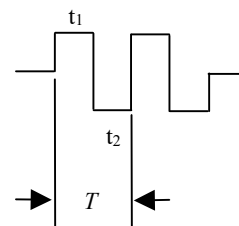
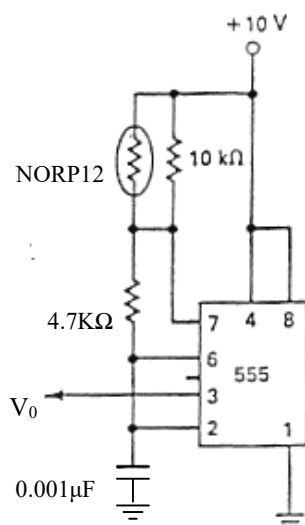


Fig. 3. Oscillator with photoresistor control.

Fig. 4 Square wave