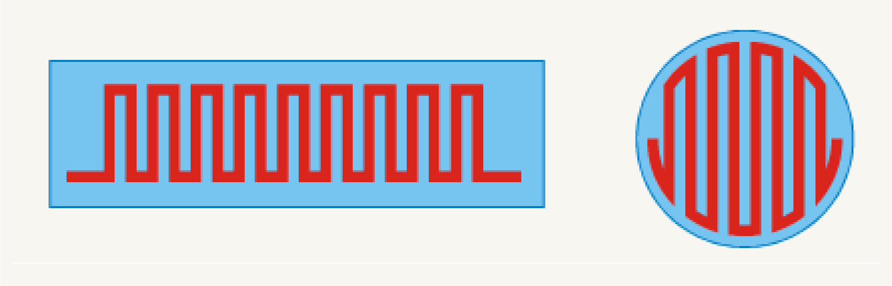
Photosensors

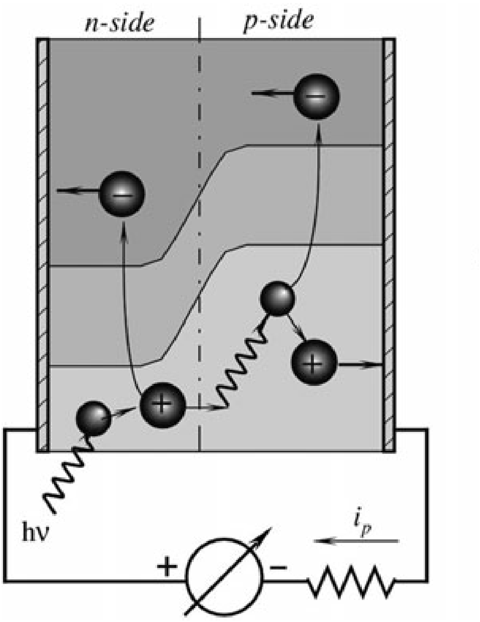
Theory: photoconductive effect, photoconductivity, photoresistor, photoelectric effect, photodiode, phototransistor

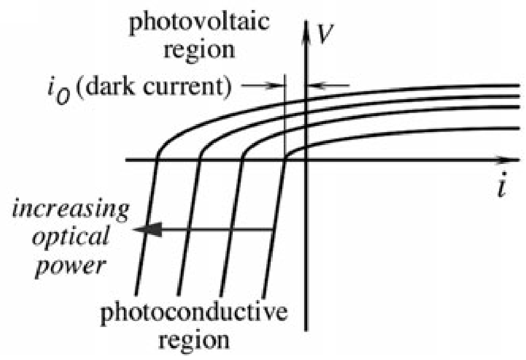
Photorezistor (LDR - Light Dependent Resistor) is a passive sensor which operates based on photoconductive effect, meaning its conductivity (resistance) changes as a function of incident light. In the darkness there is only a limited concentration of charge carriers in photoresistive material and the resistance is high. Incident light generates free charge carriers and lowers the resistance.



Transfer function of a photoresistor is non-linear and it also depends on temperature. In pitch dark the resistance is finite, but it can exceed 10MΩ. This property is called the *dark resistance*. Photoresistors change their resistance relatively slowly. Resistance transition time is about 10ms when illuminated, and cca. tenths of a second when illumination is decreased. Photoresistor conductivity is dependent on incident light wavelength. Photoresistive material (CdS, CdSe) is usually deposited on ceramic substrate between meander shaped electrodes, which allows for low resistance and small size at the same time.

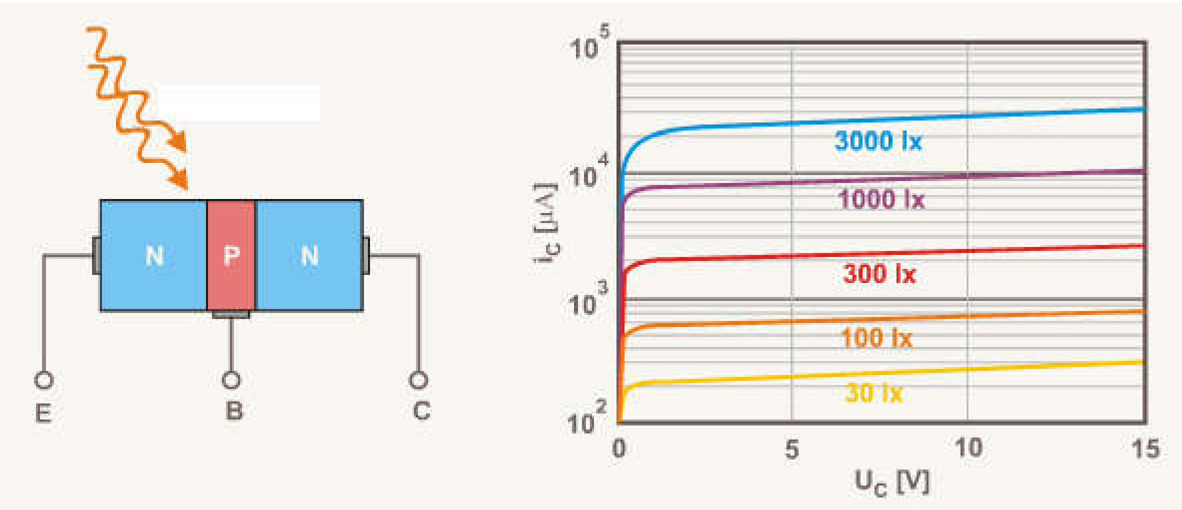
Photodiode is based on photoelectric effect on a PN or Schottky junction. Photons impinging on the sensing junction create electron-hole pairs, which are separated by an internal potential barrier.





Depending on external polarization of the junction, these pairs create a photovoltage (open circuit) or photocurrent (reverse polarization). Created photo signal ceases once one charge carrier of the created electron-hole pair recombinates. As a result, photoelectric sensors are much faster than photoconductors. Ideal photodiode has no dark current and thus is better suited for low intensity light measurement.

Phototransistor is basically a bipolar junction transistor (BJT) of NPN or PNP type, the base of which is not electrically connected, and it is controlled by incident light instead. With a normal transistor the collector current is proportional to the base current. In a phototransistor, the collector-base junction is a reverse biased photodiode. Its photocurrent flows through a loop including the base-emitter region, and this photocurrent is amplified in the same manner as in a conventional BJT. As a result, measured collector current is proportional to the light intensity. Phototransistor has a greater sensitivity than a photodiode and the current to be measured is greater by cca. two orders of magnitude.

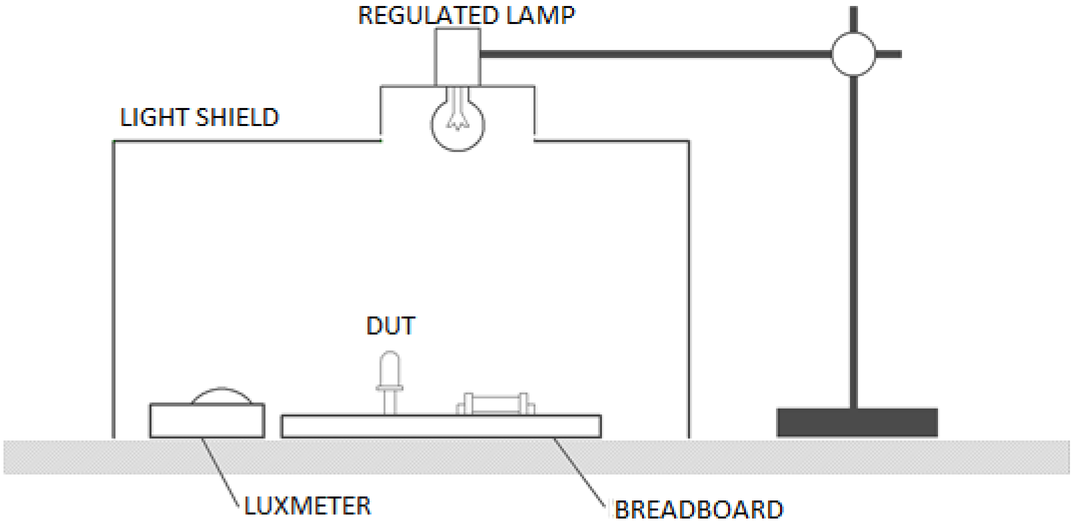


Exercises:

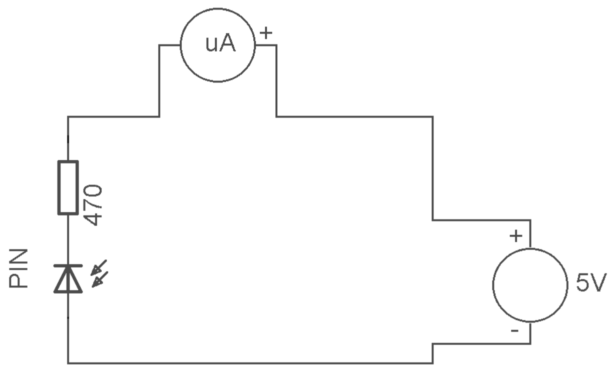
1. Familiarize yourself with the photosensor characteristics measurement workstation.
2. Measure the transfer characteristics of a photoresistor – resistance as a function of illuminance.
3. Measure the transfer characteristics of a photodiode –reverse current as a function of illuminance.
4. Measure the transfer characteristics of a phototransistor – collector/emitter current as a function of illuminance.

Measurement guide:

1. Photosensor characteristics measurement workstation is illustrated in the figure below. The device under test (DUT) is connected to power supplies and instruments through the breadboard. The breadboard with DUT is covered by a light shield to prevent the interference of ambient light. DUT is illuminated by a regulated lamp placed in the shielding aperture. Intensity of DUT illumination is measured by a reference luxmeter and can be set in a range of app. 0-500lux.



2. Connect the **photoresistor** to the breadboard, with the sensitive film facing the source of light. Place the reference luxmeter as close to DUT as possible and connect an ohmmeter to DUT. Cover the assembly with light shield and place the lamp in the aperture. Set the lamp supply current to 0A, what is the illuminance? What is the dark resistance of your photoresistor? Change the supply current of the lamp in order to adjust the photoresistor illuminance and make notes of its resistance. Start with the smallest illuminance possible and increase it with small steps (1-2lux), then gradually increase the steps. Both the lightbulb and the photoresistor have a considerable reaction time, always make sure that the resistance is settled before measuring it. Use measured values to chart the transfer characteristic of the photoresistor. Assess its linearity.
3. Connect the **photodiode**, microammeter and power supply to the breadboard according to the schematics below. The photodiode is directional, make sure it is pointed to the light source. Place the reference luxmeter as close to DUT as possible, cover the assembly with light shield and place the lamp in the aperture. Change the supply current of the lamp in order to adjust the photodiode illuminance and make notes of the photocurrent. Start with the smallest illuminance possible and increase it with small steps (5-10lux), then gradually increase the steps. Use measured values to chart the transfer characteristic of the photodiode. Assess its linearity.



4. Connect the **phototransistor**, milliammeter and power supply to the breadboard according to the schematics below. The phottransistor is directional, make sure it is pointed to the light source. Place the reference luxmeter as close to DUT as possible, cover the assembly with

light shield and place the lamp in the aperture. Change the supply current of the lamp in order to adjust the phottransistor illuminance and make notes of the collector current. Start with the smallest illuminance possible and increase it with small steps (5-10lux), then gradually increase the steps. Use measured values to chart the transfer characteristic of the phototransistor. Assess its linearity.