

Photodiode Characteristics and Applications

Electronic Devices Lab : Experiment 3

Department of Electrical Engineering
Indian Institute of Technology, Bombay

Aim of the experiment

- To study the forward and reverse bias I/V characteristics of a Photodiode.
- To measure the response of the Photodiode for different lights and different intensities. (4 LEDs are provided, along with their current vs intensity data)
- To use the Photodiode as an optical signal sensor in combination with an Infra-red LED.

Background Information

Photodiode:

A photodiode is a light-sensitive semiconductor diode i.e it produces current when it absorbs photons.

Under dark conditions, a photodiode behaves like a regular P-N junction diode. But when photons are incident on it, the I-V curve shifts downwards, increasing the reverse current. Hence, a photodiode is operated in reverse bias (because different types of incident light will give different reverse currents).

A photodiode can be used as an optical sensor.

Background Information

Infra-red LED:

Infra-red LEDs are just regular LEDs with wavelength ranges between 800 *nm* and 980 *nm*. Hence it falls outside the visible light range.

Since the light emitted by IR LEDs are not visible to the human eye, they are used in applications such as remote control, motion sensing, security cameras, etc.

You may be familiar with the basic line following robot made using IR sensors. The IR sensors use IR LED and Photodiode pair (opto-coupler).

Components required

- Photodiode
- LEDs (Infra-red, Red, Green, Blue)
- Resistors - 100Ω ($\times 2$), $1k\Omega$ ($\times 1$)
- Potentiometer - $1k\Omega$, 500Ω
- Black cone/box/cylinder/something
- Breadboard, connecting wires

Experiment Setup

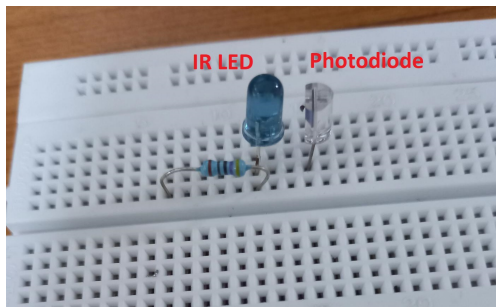


Figure: Relative positions of LED and photodiode

The LED and the photodiode should be very close to each other as shown in the above figure. The flat surface of the photodiode must face the LED.

Experiment Setup

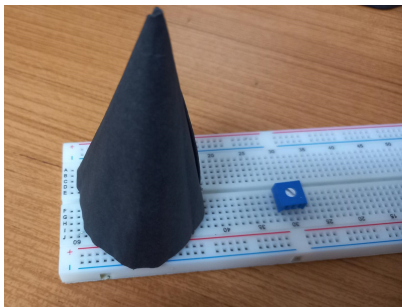
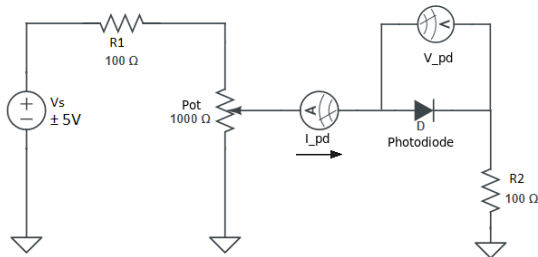


Figure: Black cap to cover photodiode

While measuring any characteristics, use the cap to cover the circuit to make sure light from outside does not fall on the photodiode.

Part 1 : Dark I-V Characteristics of Photodiode

- Obtain the dark I-V characteristics of the given photodiode for forward as well as reverse bias. You can refer to the following circuit.



(Note that the voltage should be varied using the potentiometer)

- Plot the I_{pd} vs V_{pd} and the $\log(\text{abs}(I_{pd}))$ vs V_{pd} curves.
- Extract the ideality factor from the low forward bias ($0.2V - 0.6V$) region of the I-V data.

Part 2 : Photodiode response to lights of different intensities and wavelengths

i Choose any LED, say IR. Rig up the circuit shown below.

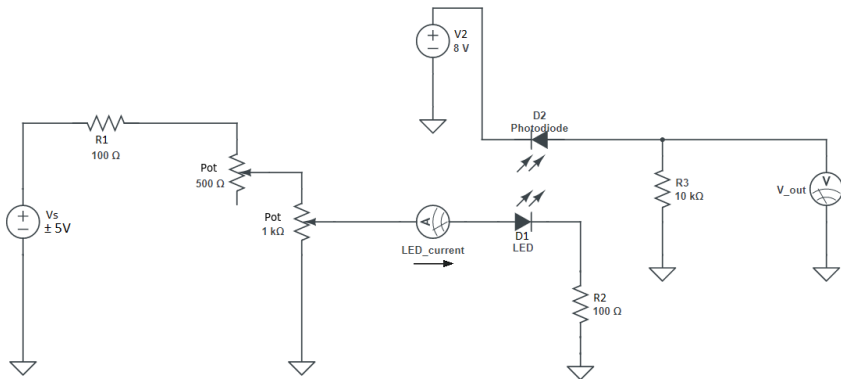


Figure: Circuit for Part 2

Part 2 : Photodiode response to lights of different intensities and wavelengths

- ii Bias the IR LED to get the current corresponding to each intensity given in the IR LED table (refer end), and note down the output voltage V_{out} which is proportional to the photodiode current under LED illumination.
- iii Repeat the same for other LEDs. You should have the responses of the photodiode for each LED at 3 given intensities (refer to tables in the end).
- iv Once you have all the readings, plot the following-
 - a V_{out} vs wavelength for each intensity.
 - b V_{out} vs intensity for each LED.
- iv Calculate efficiency of each LED using photodiode response at each intensity using the formula: $\eta = V_{out}/I_{led}$. Then plot efficiency vs wavelength for each intensity. Which LED is the most efficient?

Part 3 : Application of photodiode as optical signal sensor

Make minor modifications for the existing circuit to obtain the circuit shown below. Use just the IR LED for this part.

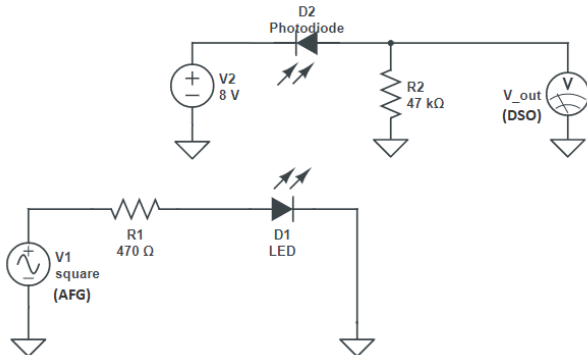


Figure: Circuit for Part 3

Part 3 : Application of photodiode as optical signal sensor

- i Apply a pulse of amplitude $5V$ at $1kHz$ frequency and 50% duty cycle using the function generator. Observe photodiode output voltage on the DSO and measure its rise and fall times.
- ii Increase the frequency (go in steps of $4-5kHz$) and notice the change in the output. What is the maximum frequency of IR LED switching that the photodiode can follow the input pulse? Which device processes limit the photodiode response during the LED on and off cycles?

Current vs Intensity Data

Infra-RED Led: ($\lambda = 950nm$)

Current (mA)	Intensity (lux)
4.51	1000
5.17	1500
6.28	2000

RED Led: ($\lambda = 750nm$)

Current (mA)	Intensity (lux)
2	1000
3	1500
4	2000

Current vs Intensity Data

GREEN Led: ($\lambda = 520nm$)

Current (<i>mA</i>)	Intensity (<i>lux</i>)
0.188	1000
0.294	1500
0.371	2000

BLUE Led: ($\lambda = 450nm$)

Current (<i>mA</i>)	Intensity (<i>lux</i>)
0.301	1000
0.416	1500
0.572	2000