Lesson 1452, Optoelectronics

Experiment 6, Photodiode and Phototransistor Current Measurements
Objectives

1) To show that current through a photodiode increases as the light falling on the device increases.

2) To verify that current through a phototransistor varies with varying light
Introduction

- We have seen in a previous experiment that the resistance of both a photodiode and a phototransistor changes as the intensity of the light hitting the device varies.
Today we will continue studying these important devices by measuring the current characteristics under various light conditions.

The diagram on the next slide shows a properly biased photodiode.

Note: The polarity of the voltage source is such that the photodiode is reversed biased.
Properly Biased Photodiode
Properly Biased Phototransistor

- A similar situation exists in the circuit on the next slide, which shows a properly biased phototransistor.

- Note the base and collector are still reverse-biased with this arrangement.

- The collector-base junction is reverse-biased as well.
Properly Biased Phototransistor
- The photodiode resistance will change as the light changes, causing the base current to change as well.
- This changing current will be amplified by the transistor, resulting in a change in collector current.
- The current gain of the transistor is the reason the current carrying capability of the phototransistor is generally much larger than that of the photodiode alone.
Procedure

- In this experiment, you will be using the same phototransistor you used in the last experiment.
- Photodiode measurements will be made between the base and collector terminals of the device.
Phototransistor measurements will be made between the collector and emitter terminals of the device.

We will be using a small lamp as a light source.

- The lamp will be set at a fixed distance from the transistor.
- By varying the lamp voltage, we can change its brightness and observe how the photodiode and phototransistor currents vary.
1. Before constructing the circuit, turn the power supply on and set the positive supply to $+15\text{V}$ and set the negative supply to $-6\text{V}$. Be careful not to change these settings throughout the experiment!

2. Mount the phototransistor on the breadboard as shown on the slide after next

   a) Carefully bend the leads at a 90° so the device points horizontally
3. Mount the lamp on the breadboard about 1 inch from the transistor
   a) Depending on the type of lamp supplied, you may have to solder leads onto the lamp or socket before mounting it to the breadboard

4. With the power off, construct the circuit shown on the following slide
   a) The base lead is to be connected to ground
b) The collector lead is to be connected to $R_2$

c) Note: The emitter lead is left unconnected

- 6 V (Negative Supply)
Photodiode Measurement Ckt

Make a 1 inch separation

Emitter is open
5. Switch your meter to the 50Ω range and connect it in series as shown on the schematic and in the pictorial.

6. Turn on the power and set \( R_1 \) so that the lamp is off.

a) Measure the current through the photodiode and record the voltage in the table on the following slide.
Data Table for Experiment 6

<table>
<thead>
<tr>
<th>Lamp Voltage</th>
<th>Photodiode Current</th>
<th>Phototransistor Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-1 V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-2 V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-3 V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-4 V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-5 V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-6 V</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7. Using your volt meter, set voltage on the meter across the lamp to 1 V
   a) Replace meter with a jumper
   b) Set meter to the 10 VDC range to measure the voltage across the lamp
8. Return the meter to measure the current again and place the value in the data table
9. Continue with each of the lamp voltages in the table and measure & record the current for each in the data table
10. Turn off the power and modify the circuit using the following schematic to guide you.
Phototransistor Measurement Ckt

Make a 1 inch separation

Base is open
11. Turn on the power and repeat all the measurements for the various lamp voltages in the data table and set your meter to the 2.5 mA range

a) Mark the results in the table

12. Our results can be seen on the following slides
Results

- Your results should be similar to ours, but don’t worry if there are some discrepancies.
  - Variations in lamp output, distance, and photodiode and phototransistor characteristics can all contribute to experimental error
## Data table with CIE Results

<table>
<thead>
<tr>
<th>Lamp Voltage</th>
<th>Photodiode Current</th>
<th>Phototransistor Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 V</td>
<td>0</td>
<td>5μA</td>
</tr>
<tr>
<td>-1 V</td>
<td>5μA</td>
<td>100μA</td>
</tr>
<tr>
<td>-2 V</td>
<td>20μA</td>
<td>250μA</td>
</tr>
<tr>
<td>-3 V</td>
<td>25μA</td>
<td>400μA</td>
</tr>
<tr>
<td>-4 V</td>
<td>27μA</td>
<td>600μA</td>
</tr>
<tr>
<td>-5 V</td>
<td>35μA</td>
<td>1.2mA</td>
</tr>
<tr>
<td>-6 V</td>
<td>40μA</td>
<td>1.45mA</td>
</tr>
</tbody>
</table>
However; you should see the same general trend.

- As the lamp intensity increased, the current should have increased as well, because of the decreased resistance.

The phototransistor current should have been much greater than the photodiode current.

- This is because of the current gain of the transistor.
Final Discussion

- You measured both the photodiode and the phototransistor characteristics.
  - With each of these devices, the current increased as the light increased.
- The photodiode was measured by using the base and collector leads of the phototransistor.
The phototransistor measurements were made between the emitter and collector leads of the this transistor. This is the normal operating mode for a phototransistor, although you’ll often see additional base bias applied through an external resistor.
To make the results repeatable, we used a standard lamp to provide the light for the phototransistors.

- However, because of component tolerances or differences, a wide range of variations from device to device is to be expected.
- Your results probably were not linear, in that the current did not increase as much as the lamp voltage did.
Not only is the phototransistor itself less than perfect, but the intensity of the lamp probably didn’t increase linearly with changes in lamp voltage either; all of which would affect the results.

Phototransistors are often used as discrete devices, but they will be found combined with other components in some applications.
Questions?
Resources

The End

Developed and Produced by the Instructors in the CIE Instruction Department.

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