Physics 3108 Lab 4: Photodiodes & TIAs

Background

You should now be familiar with the operation of the NI USB-6001 controller. You should be comfortable with LabView and the programming of the controller. Also, you now have at your disposal a voltage controlled current source.

Purpose

To learn about photodiodes and solar cells and their usages. This will be helped by characterising a photodiode and building an amplified photoreceiver using a transimpedance amplifier (TIA).

Summary

In this lab, you will characterise a silicon photodiode, design and build a transimpedance amplifier circuit suitable for further experiments. There are three parts to the lab:

1) In the first part, you will learn about using a transimpedance amplifier with a photodiode and ***design*** a soldered photoreceiver circuit.
2) In the second you will propose a method to fully characterise the photodiode, build a photodiode circuit and design the box assembly.
3) In the third part, you will fully characterise the photodiode using your LabView code, and assemble your photodiode circuit into a box with a single battery, switch, etc.

Background – Photodiode characterisation curves

The photodiode has been discussed in class. In addition, there are many resources on the web for more information, including:
http://en.wikipedia.org/wiki/Photodiodes
http://www.physics.ucc.ie/fpetersweb/FrankWeb/courses/PY3108/Labs/PD_Info.pdf

The second link points to a very complete document. On page 7 of this document is Figure 1 shown to the right. This highlights some of the characteristics of the photodiodes, as does Figure 2-5 in the same document.

Read the document discussing these figures to learn and understand the properties of the photodiode.

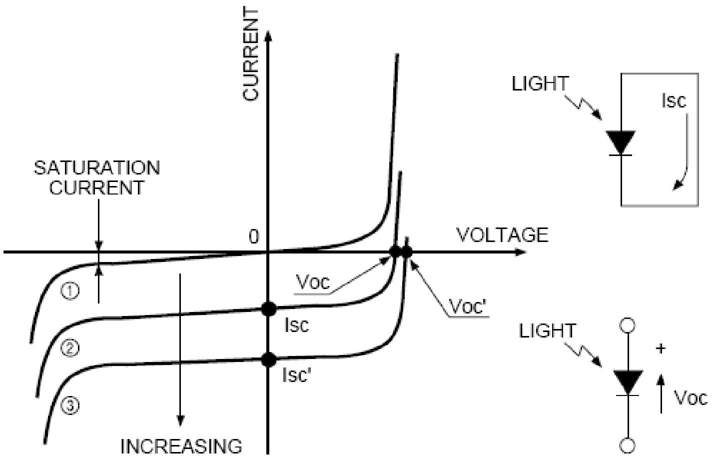

Figure 1 Current Voltage Characterisation

Background – Transimpendance Amplifiers

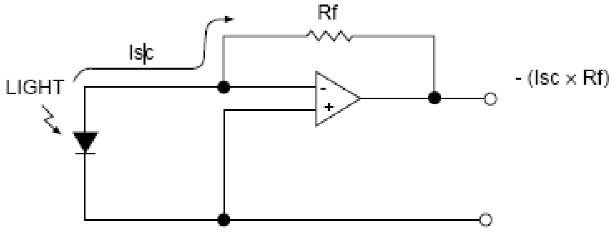

Figure 2 - Transimpedance Amplifier

In the figure a circuit is shown, as a means of converting photocurrent to voltage. This is referred to as a transimpedance amplifier. The analysis is straight forward: If the circuit is operating correctly, the voltage at both inputs to the opamp will be at the same potential. Also, no current flows into the opamp. Therefore, if photocurrent is generated in the photodiode, is must flow toward the output of the opamp passing through the feedback resistor. The voltage drop across the feedback resistor is due to the photocurrent, and therefore the output must accommodate this voltage drop.

The circuit can also be built with the photodiode in facing the other direction. The analysis of the circuit will be identical, except the output voltage will be positive rather than negative due to the direction of the photocurrent. Here I have labeled one side of the photodiode as V_{bias}, which can be ground (as in the circuit that you build) or variable as required when characterising the photodiode itself. The extra resistor (circled in red) is only for protection of the photodiode, and should not have any current flowing through it..

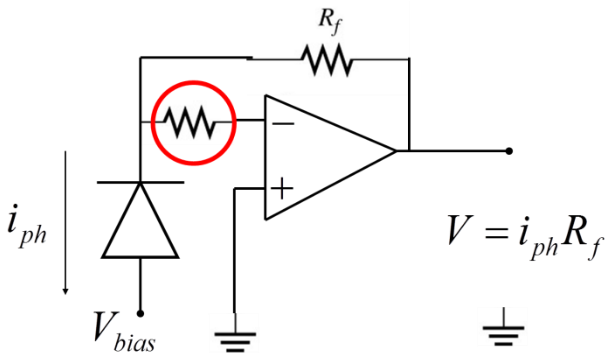

Figure 3 - Transimpedance Amplifier

Part A – The photodiode and transimpedance amplifier

Transimpedance amplifier (the LM258/LM358 OpAmp is recommended)

1. Using the breadboard, build the transimpedance amplifier with the photodiode (feedback resistors should be between of 1kΩ and 1MΩ). Confirm that it works by covering the photodiode with your hand. Provide a picture of your working circuit. For this part use the power supply to power your opamp.
2. Design a transimpedance amplifier circuit to accommodate the testing of a red light source. The optical power of the red light will be **≤0.2 *mW***. For this, you will need to read the spec sheet for the small photodiode that is being used. It would be advisable to explain your design fully.

WARNING: If anything is missing from your design, this will result in a penalty.
NOTES: Part 1, is experimental, while part 2 is purely design. Are you able to propose an alternate design for a photodiode amplifier using either a transistor or opamp? What would be the advantages or disadvantages?

Part A Submission due: Tuesday October 24, 2017

Part B – characterisation design and amplifier circuit construction

Planning the characterisation of the photodiode:

- The requirement is to provide a plan to obtain the photodiode characterisation curves with different amounts of illumination, as shown in Figure 1.
- Since the transimpedance amplifier used in Part A converts photocurrent to voltage, this should be used as part of your characterisation plan, since the current can be calculated from the output signal (as discussed in class).
- Marks will be provided for both good design (including design explanation) and analysis as well as for successful demonstrations.

Building the transimpedance amplifier circuit board.

- Design a full circuit for the transimpedance amplifier. This should include an output connector, a planned internal battery connection to a single 9V battery, a switch to turn on the unit and an LED so that you can see that the unit has been switched on. **WARNING:** For the photodiode characterisation, you will need positive and negative power to the opamp, yet the final circuit should operate with only one battery. Similarly, you will need to be able to access the photodiode V_{bias} (from Figure 3), in order to fully characterise your photodiode, yet in the final circuit this connection should be grounded. This will mean that you should plan to make these alterations as simple as possible.
- Provide a final schematic of the full circuit, including the proposed value of the feedback resistor, battery connections, LEDs, switches and output connectors. Show and describe how you plan to adjust your circuit for both characterising the photodiode and completing the circuit. Are you able to create a design with more than one gain setting for the amplifier?
- Build your photoreceiver circuit including the photodiode and transimpedance amplifier on a circuit board. At this stage, feel free to have wires that go to an external power supply. These can be cut off when the circuit is completed.
- Once your photoreceiver is complete, confirm that it is operational using light and dark conditions (or any other conditions that you believe may be interesting)
- Provide a design for a metal box to be used to house your circuit and photo diode.

Part B Submission due: Tuesday October 31, 2017

Part C – Photodiode characterisation and completing photoreceiver box

The photodiode characterisation should be done using LabView code.

- Run your code and provide as much Current vs. Voltage characterisation data as you are able for light and dark conditions (plus any other conditions that you believe would be interesting).
- NOTES:
    1. you will need to be able to access the photodiode V_{bias} (from Figure 3), in order to fully characterise your photodiode.
    2. The opamp will need +/- power to produce both positive and negative signals, however when the boxes photoreceiver is completed, it should only use one battery.
    3. Both 1) and 2) will require small alterations in your circuit prior to finalising your box.

Complete the Photoreceiver

- The should be done once the characterisation is complete.
- Solder the V_{bias} connector to ground, ensure the circuit works with a battery and then complete your photoreceiver by putting your circuit into a box, and adding any additional components (LEDs, switch, etc.).
- Demonstrate that your photoreceiver (i.e. photodiode plus amplifier) works. If you have implemented multiple gains, then show that it works with multiple gains.
- Use your LabView code to record the signal from your photoreceiver. Try various types of light sources (including an incandescent lamp if you can find one), and comment on what you see.

Part C Submission due: November 7, 2017 (with your LabView code)