Circuit Prototyping

OBJECTIVES

In this lab you will create a prototype of an electronic speed sensor that you will use to measure the speed of the roller coaster ball on your roller coaster. The lab has the following objectives:

- to understand the workings of a speed sensor using an LED (Light Emitting Diode) and a phototransistor
- to illustrate how engineers build prototype electronic circuits
- to introduce some basic concepts about electronic circuitry

LOGISTICS: Each team will be split into two halves, each half comprising of two students. Tasks 1, 2 and 3 will be carried out independently by the two halves. In Task 4, the two halves will rejoin and perform Task 4 together.

LOOK AT THE NETWORK OF METAL STRIPS ON THE BACKSIDE OF THE PROTOTYPING BOARD (called a “Bread Board”). Note that the metal ‘Strips’ connect to the holes on the top side of the bread board, tying strips of holes together in horizontal or vertical banks.

INTRODUCTION

The lecture slides lead you through Tasks 1 and 2 of this lab. The lab procedure for the first two tasks should be used to record data collected in these tasks. The lab procedure is to be used to accomplish Tasks 3 and 4 and also to record the associated measurements related to these two tasks. All the recorded data along with the responses to all the discussion questions need to be typed and inserted into the lab memo.
Task I. Review of Kirchhoff’s Voltage Law (KVL)

1. Measure Supply voltage, call it $V_T$; $V_T = \underline{\text{volts}}$

2. Measure voltage across $R_1$, Call it $V_{R1}$; $V_{R1} = \underline{\text{volts}}$

3. Measure voltage across $R_2$, Call it $V_{R2}$; $V_{R2} = \underline{\text{volts}}$

4. Verify, is $V_T = V_{R1} + V_{R2}$? (with a minor variation) (YES/NO)

Properties of wires: The straight lines in a circuit diagram (above) that connect the components (resistor, diode and switch) together are wires. Since wires are excellent electrical conductors, they are always assumed to have zero resistance (this is generally a good approximation). So, when current flows through a wire, there is no voltage drop along the wire. Therefore the voltage at every point on a wire is the same.

Properties of switches: A switch (as the one in the circuit) has the following properties:
(1) when the switch is “OFF” or “OPEN”, its resistance is infinite
(2) when the switch is “ON” or “CLOSED”, its resistance is zero.
Task II. Construction and analysis of LED circuit

![LED circuit configurations](image)

Figure 2: LED circuit configurations

Record the following values when the switch is “open”/off

1. Use the DVM probe wires to measure and record \( V_{LED} \) and \( V_{R1} \)
   \[ V_{LED} = \underline{\quad} \text{volts} \]
   \[ V_{R1} = \underline{\quad} \text{volts} \]

2. Is \( V_{LED} + V_{R1} = V_T \)? (YES/NO)

3. Using Ohm’s law, calculate the Current, \( I = \underline{\quad} \text{amps} \)

Questions: (For the following question, refer to properties of switches mentioned earlier in the procedure and lecture slides discussing the direction of current flow when switch is on and off)

When the switch is “OPEN”:
- The current through the Green LED = \( \underline{\quad} \text{amps} \)
- The current through the switch circuit = \( \underline{\quad} \text{amps} \)

When the switch is “CLOSED”:
- The current through the Green LED = \( \underline{\quad} \text{amps} \)
- The current through the switch circuit = \( \underline{\quad} \text{amps} \)
- The voltage across the Green LED = \( \underline{\quad} \text{volts} \)
Task III. Construction and analysis of the phototransistor circuit

![Phototransistor circuit diagram](image)

**Figure 3: Phototransistor circuit**

Constructing the Phototransistor circuit:

1. Place the Phototransistor and the Green LED on the bread board in the locations shown in Figure 4. The phototransistor should point to the left. Note: make sure that the black mark on the phototransistor points toward the ground. (Leave enough space shown in Figure 4 between the phototransistor and the green LED so that the roller coaster track can fit between them).

2. Put the 3" x 5" file card (from kit) right in front of the phototransistor lens, to verify that the Red LED beam points directly at the phototransistor.

3. Verify that the phototransistor circuit works by placing an opaque object (finger, Buck ID card, etc.) between the Red LED and the phototransistor. The circuit works properly if the green LED turns “ON” when the light beam is interrupted.

4. If the Red LED beam is not centered on the phototransistor lens, gently adjust the angle of the Red LED to center the beam.

5. Use the black and orange DVM probe wires to measure and record $V_{\text{phototransistor}}$ for conditions “Beam ON” and “Beam OFF”

\[
V_{\text{phototransistor}} \text{ (Beam ON)} = \text{___________ volts}
\]

\[
V_{\text{phototransistor}} \text{ (Beam OFF)} = \text{___________ volts}
\]
Task IV: Use the speed sensor circuit to measure the speed of a coaster ball

1. Locate the BNC to alligator clip test lead that looks like this shown in Figure 5:
2. Connect the “BNC Connector” to the mating BNC connector labeled “Channel 0” on the rear panel of the digitizer.

3. Connect the “Ground Clip” to any ground point in the circuit.

4. Connect the “Signal Clip” to the output of the Phototransistor.

5. On your computer, open the LabView application called “Coaster”, which should look like Figure 6.

![Image of LabView application](image)

Figure 6: LabView application “Coaster” screenshot

- Click the “Sensor Enable Control” button for each of the eight windows.
- Adjust window width above each window to capture full square pulse.

Have one member of the team hold the track firmly and have another team member press the on-screen button “Begin Data Acquisition”. Then release the ball from the top of one end of the track and let it oscillate back and forth.

The LabView application will record the time the coaster ball takes to pass through the speed sensor beam. The “velocity window” will show the coaster ball speed in m/s.

If the width of any pulse is not fully displayed within its window, use the “adjust window button” to lengthen the window width (in time).

Capture a print (Alt+PrintScrn) of the LabView window showing all the pulse data, paste it into a word document, and save the file to a memory device.
Task IV Data and Discussion Questions:

Attach the Screen capture as shown as figure 6 from LabView “Coaster” application showing speed sensor data (coaster ball velocity) which should like figure 7.

![Sample Screen capture with speed sensor data](image)

Figure 7: Sample Screen capture with speed sensor data

Read the speed values from the speed measurement windows, enter the values into an Excel spreadsheet, and plot the data in an Excel graph. Attach the spreadsheet and plot to your lab memos and answer the discussion question given below:

<table>
<thead>
<tr>
<th>Window Number</th>
<th>Pulse Width (ms)</th>
<th>Speed (m/s)</th>
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**After-Lab cleanup:** Disconnect all of the electrical components from the bread board and carefully and place them back in their designated bags and boxes.
WORKSHEET FOR CIRCUIT PROTOTYPING LAB (SUBMIT WITH MEMO)

**Task 1**

\[ V_T = \underline{\text{___________}} \text{ volts (Power Supply Voltage)} \]

\[ V_{R1} = \underline{\text{___________}} \text{ volts} \]

\[ V_{R2} = \underline{\text{___________}} \text{ volts} \]

Calculate: \[ V_{R1} + V_{R2} = \underline{\text{___________}} \text{ volts}. \text{ Is this} = V_T \text{ (Power Supply Voltage)?} \]

**Task 2**

\[ V_{LED} = \underline{\text{___________}} \text{ volts} \]

\[ V_{R1} = \underline{\text{___________}} \text{ volts} \]

Is \[ V_{LED} + V_{R1} = V_T \]? (YES/NO)

Using Ohm's law, calculate the Current, \[ I = \underline{\text{___________}} \text{ amps} \]

**Task 2 Questions.**

When the switch is “OPEN”:

- The current through the Green LED = \[ \underline{\text{___________}} \text{ amps} \]
- The current through the switch circuit = \[ \underline{\text{___________}} \text{ amps} \]

When the switch is “CLOSED”:

- The current through the Green LED = \[ \underline{\text{___________}} \text{ amps} \]
- The current through the switch circuit = \[ \underline{\text{___________}} \text{ amps} \]
- The voltage across the Green LED = \[ \underline{\text{___________}} \text{ volts} \]

**Task 3**

\[ V_{\text{phototransistor (Beam ON)}} = \underline{\text{___________}} \text{ volts} \]

\[ V_{\text{phototransistor (Beam OFF)}} = \underline{\text{___________}} \text{ volts} \]
Task 4
Show or attach the following items here:

1. Screen capture from LabView “Coaster” application showing speed sensor data.

2. Pulse widths and speeds from each window and Excel plot based on your lab ata.

<table>
<thead>
<tr>
<th>Window Number</th>
<th>∆t (ms)</th>
<th>Speed (m/s)</th>
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Task 4 Discussion Question 1
As the ball slows down, notice that the pulse width in the LabView application window gets wider. Why?

Task 4 Discussion Question 2
Why did the green LED light turn “on” when an object such as the nylon ball passed between the phototransistor and red LED?

Task 4 Discussion Question 3
Please describe (in your own words) how a phototransistor works?
### Circuit Prototyping Lab Memo Guidelines:

<table>
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<th>Points Worth</th>
<th>Point Value</th>
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</thead>
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<tr>
<td><strong>Introduction</strong></td>
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<tr>
<td>1. Brief Introduction of objectives/ goals of the labs.</td>
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<td>2. Introduction to contents of the memo.</td>
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<td><strong>Results and Discussions</strong></td>
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<tr>
<td>1. Task 1 Data</td>
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<tr>
<td>2. Task 2 Data. Show calculations.</td>
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<tr>
<td>3. Task 2 Questions. Show calculations.</td>
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<td>4. Task 3 Data</td>
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<td>5. Task 4 Data Table</td>
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<td>6. Task 4 Excel Data Plot</td>
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<td>7. Task 4 Discussion Question #1</td>
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<td>8. Task 4 Discussion Question #2</td>
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<tr>
<td>9. Task 4 Discussion Question #3</td>
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<tr>
<td><strong>Conclusion</strong></td>
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<td>o Briefly state the goals achieved by undertaking this lab activity.</td>
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<td>o Briefly mention any difficulties that you came across during this lab.</td>
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<tr>
<td><strong>Lab Participation Agreement</strong></td>
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<tr>
<td><strong>Checklist</strong></td>
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</tbody>
</table>

**Note:** The GRADING NOTES below apply to ALL memos/reports for the quarter.

**Expectations**
- All memos should be considered as business communication tools between yourself and the instructor (manager, in a professional setting).
- Worksheets should be attached with the memo.
- Neat sketches, with title and detailed labeling should be attached with the memo.
- Sketches and plots may be embedded in the text of the memo. Otherwise they must be at the end.
- Follow standard memo organization that provides good information flow, like the one detailed above.

**Point Deduction**
- Spelling and grammar – 0.5 for each error (max. of 5 points).
- Untidy sketches – 2 to 4 points each. (max. of 10 points).

**Sample Calculations**—Show correct formulae and substitute appropriate values to calculate the final result.