Light Gate

In this project you design, build, and test a "light gate". A light gate uses a light source directed to a photodetector to detect interruptions of the light beam. Applications include automatic doors or intrusion alarms.

This project includes two main parts:

a) Pre-lab: follow the direction given in this document and complete the schematic design of your Light Gate circuit. **Note:** You must have your schematic ready and checked off by a GSI before you start building the actual circuit in the lab (50 % of the grade).

b) Lab and Post-lab: Build and test your Light Gate circuit in the lab base on your design. show your working circuit to GSI and answer the post-lab questions (50 % of the grade).

Guidlines

We will be using the halogen lamp and solar cell from an earlier lab as the light source and detector and display the output on LED (light emitting diode) that turns on (or off) when the light beam is interrupted and off otherwise. You are to design the electronic circuit between the solar cell and the LED.

Figure 1 shows a block diagram of the light gate. Since the output of the solar cell is a small current, it needs to be amplified to drive the LED. A Schmitt Trigger is also needed to ensure that the light reliable turns on and off without intermediate states that are difficult to interprete. You can tie the LED directly to the output of the Schmitt Trigger through a resistor.

Suggested plan

Pre-Lab

a) First we determine how to best use the solar cell as a sensor. We want to maximize the ratio of the output $S_{s,on}$ with full light (beam not blocked) at maximum distance to the output $S_{s,off}$ with the light blocked at minimum distance. We use maximum and minimum distance respectively since that's the most challenging situation our circuit has to deal with: if it meets these requirements, it most likely will also work in the other, less demanding situations.

We can either sense the open loop voltage ($V_{s,on}$, $V_{s,off}$) from the solar cell, or the short circuit current ($I_{s,on}$, $I_{s,off}$). Fill in the table below, reusing your measurements from the solar cell lab.

$V_{s,on}$ for $L = 20\,\text{cm}$		1 pt. 0
$V_{s,off}$ for $L = 10\,\text{cm}$		1 pt. 1
$r_v = V_{s,on}/V_{s,off}$		1 pt. 2
$I_{s,on}$ for $L = 20\,\text{cm}$		1 pt. 3
$I_{s,off}$ for $L = 10\,\text{cm}$		1 pt. 4
$r_i = I_{s,on}/I_{s,off}$		1 pt. 5

Which of the two ratios r_v and r_i is larger? Depending on the answer, we are better off treating the solar cell as a voltage or current source and then design our circuit appropriately. Enter your choice in the box below (enter the text `voltage source` or `current source`):

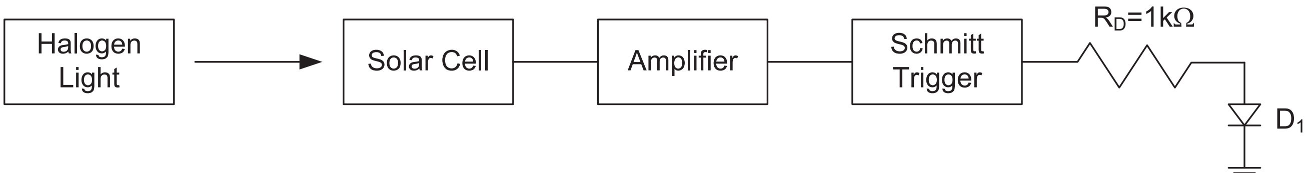

Figure 1 Block diagram of the light gate.

1 pt.
6

b) Design the amplifier circuit to gain up this signal to 5 V (V_{on}) for maximum solar cell output. What is the output voltage V_{off} for $S_{s,off}$ (S is either V or I, depending on your answer above)? Verify your circuit in the lab.

	calculated	measured
V_{on}	1 pt. 0	1 pt. 1
V_{off}	1 pt. 2	1 pt. 3

c) Determine thresholds $V_{th\text{-}on}$ and $V_{th\text{-}off}$ for the Schmitt Trigger to achieve reliable operation for distances between the light and the detector of 10 to 20 cm based on the range of values you determined for V_{on} and V_{off}. The output of the Schmitt Trigger should be a reliable indicator of the beam for any distance L between 10 cm and 20 cm.

	calculated	measured
$V_{th\text{-}on}$	1 pt. 4	1 pt. 5
$V_{th\text{-}off}$	1 pt. 6	1 pt. 7

d) Draw the complete circuit diagram including the amplifier and the Schmitt Trigger. Include all derivations and calculations of the component values. Attach extra sheet if necessary and draw nicely for full credit.

20 pts.
8

e) Verify your design with SPICE (optional). In practice you would always do this before going to the lab with a circuit of any complexity. Debugging in the lab is much more time consuming than with the simulator and paper and pencil.

Note: To simulate the complete circuit, replace the sensor with a *piece-wise linear (PWL) current source* in SPICE ramping the current linearly up and down between zero and an appropriate maximum value. Then perform a transient simulation. Please come to office hours if you have difficulty.

f) Ask the GSI to check your schmatic and calculation at the start of the lab session (50 % of the grade).

Lab (Experimental Verification)

Now you are ready to build and verify the operation of your circuit. It's a good idea to work in steps. For example, we verify first the light sensor (did that in Lab 1 already) and then the amplifier and the Schmitt Trigger separately. When we have convinced ourselves (using e.g. the DVM) that each part works satisfacorily we connect all parts and verify again.

a) Build and test your amplifier circuit in the lab.

b) Test Schmitt Trigger circuit in the lab (use the power supply to apply test inputs). Add the LED and verify its operation. Use a smaller resistor if it is too dim.

c) Once the amplifier circuit and Schmitt Trigger are fully functional, complete the circuit.

d) Draw your final complete circuit diagram including all component values (if different from your original design). Draw nicely for full credit. Use extra sheets if needed.

1 pt.
10

e) Show your working circuit to the GSI (for $L = 10\,\text{cm}$ and $L = 20\,\text{cm}$).

Post-Lab

a) Report difficulties you encountered, if any.

1 pt.
12

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b) Did you make changes to your original design? If so, why?

1 pt.
13

In a product design all involved (marketing, designers, and product, test, and quality control engineers) get together at this point to discuss the need for further changes and improvements. Once everyone is happy you will build a few samples for further testing and show them to potential customers. For these samples you design custom printed circuit boards (PCBs) and use an attractive package to give the entire system a professional appearance. While the salesforce shops the new product around with customers, the product engineers start readying the production chain. Often third parties are involved, e.g. to assemble and test the cirucit boards and to fabricate the case.

Password:

EE 42/100 Proj1 Light Gate

Prelab Summary

Name:____

SID: ____

Answers

0.____

1.____

2.____

3.____

4.____

5.____

6.____