

Photoresistor, Transistor, and LED's

Prelab Questions

1. In the following circuit, L1 is a light bulb rated at 0.5 A at 5 V, and the transistor's h_{fe} is 100. The light bulb L1 starts to glow when the current flow through it reaches 100mA, and if the current is higher than 1A, it will burn out. If the resistance of the variable resistor V_R is gradually lowered from 10k Ω , at what value of V_R will the light bulb start to glow? Is there a value of V_R , for which the light bulb will burn out? What is it if so?

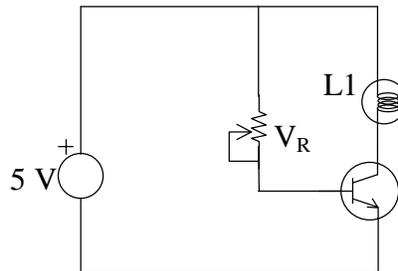


Figure PL-1 Lamp Control Circuit

Purpose

- To introduce photoresistors, LED's, FET's, and transistors used as power switching devices
- To become familiar with the capability of the Basic Stamp to measure the change of resistance of a sensor
- To build and experiment with a light-controlled switch

Components

| <u>Qty.</u> | <u>Item</u> | <u>Qty.</u> | <u>Item</u> |
|-------------|------------------------|-------------|-----------------------|
| 1 | standard component kit | 1 | 1 k Ω resistor |
| 1 | solderless breadboard | 1 | 0.1 μ F capacitor |
| 1 | photoresistor | 1 | OEM Basic Stamp II |
| 1 | red or green LED | 1 | 470 Ω resistor |
| 1 | 2N3904, NPN transistor | 1 | 220 Ω resistor |

Introduction to the Photoresistor

A photoresistor is simply a resistor whose resistance depends on the amount of light incident upon it. They are used to make light-sensitive switching and devices. Photoresistors are often made from cadmium sulfide (CdS). The resistance of a CdS photoresistor varies inversely to the amount of light incident upon it. In other words, its resistance will be high in the dark and low in the light.

Procedure

1. Measure the photo-resistor’s resistance in the ambient lighting of the lab. Once this is recorded, repeat the measurement, only this time covering the cell with your hand. These two extremes will be used in calculations later on.

Introduction to the Light Emitting Diode (LED)

The LED behaves like an ordinary diode except that when it is forward biased, it emits light. The LED’s forward voltage drop is higher than the ordinary diode. Typical LED’s require 5 to 15mA to reach full brightness, but are not designed to handle more than about 20 mA of current. You will therefore *always* need to provide a resistor in series with an LED to limit the current to about 20 mA or less, or else you will burn it out. Also, don’t make the mistake of trying to substitute an LED where a standard diode is called for! Look at the schematic diagram to see which kind of component is needed.

Procedure

1. To verify the behavior of the LED, construct the circuit shown in Figure 1, and vary the supply voltage between 1 to 8 volts at 1-volt increments. **At each voltage, measure the voltage across the LED and the 470 Ω resistor and enter the values into the following table. The LED current can be calculated using Ohm’s law.**

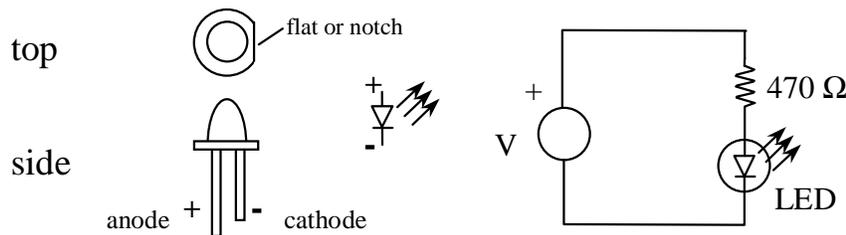


Figure 1 LED circuit

| Supply Voltage, Volts | V _{LED} , Volts | V _R , Volts | Current, mA | Comment on LED Brightness |
|-----------------------|--------------------------|------------------------|-------------|---------------------------|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |

Table 1 LED circuit measurements

2. Figure 2 shows a simple ‘light-controlled-LED’. The circuit should turn-off the LED as the photo resistor is covered. **Explain the theory of operation of this circuit.** Based on the information obtained above, what is a good supply voltage to use? (Hint: V should be high enough so that enough current flows through the LED when the photo resistor has low resistance, and yet should be low enough so that the current is not enough to turn on the LED when the the photo resistor has high resistance.) **Build the circuit and check its function.**

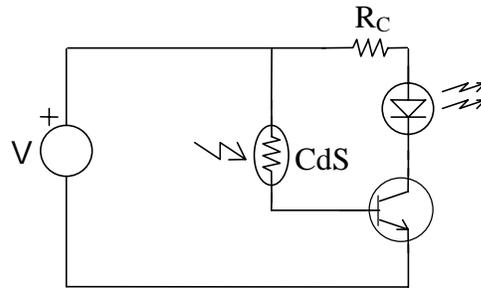
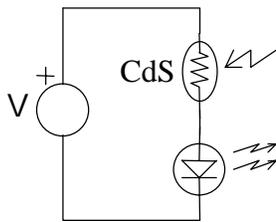


Figure 2 Light-controlled LED Figure 3 Light-controlled using a transistor “switch”

The Light-Controlled Switch Using a Transistor

A transistor can be added to the light-controlled-switch circuit to improve its sensitivity and to eliminate the ‘half-on-half-off’ state of the LED. A rudimentary circuit to do so is shown above in Figure 3 (you don’t have to build this one). Here the photoresistor controls the transistor’s base current, which is then amplified by the transistor. The collector current of the transistor, in turn, controls the LED. Unfortunately, this circuit may not function properly, because when the photoresistor is in the dark state, (and the LED is supposed to be turned off), the base current may be large enough that the LED may stay lit! **Prove this, by calculating the collector current for the circuit in Figure 3 when $V=10\text{ V}$, $R_{CdS}=100\text{ k}\Omega$, $R_c=220\ \Omega$ and $h_{fe}=100$.** Figure 4 shows an improved circuit. This is the circuit that you will build and experiment with next.

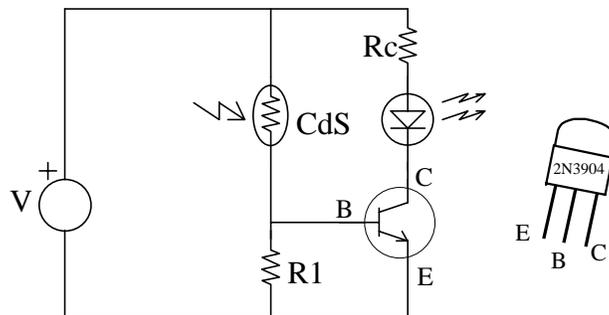


Figure 4 Improved Light-Controlled Switch Using a Transistor

With a properly selected resistor R_1 , the voltage at the base of the transistor in the dark state is less than 0.7 V , and therefore the transistor is in the cut-off state. As the photoresistor’s resistance decreases (as the result of an increase in light intensity), the base voltage increases. Once the base voltage reaches 0.7 V , the base current starts to flow, and any further decrease in the photoresistor’s resistance causes an increase of base current. This base current increment will be amplified by the current gain of the transistor.

Procedure

1. Choose the supply voltage. The supply voltage is often a predetermined value rather than a design choice. For example, if battery is to be used, the voltage should be either 3, 6, or 9 V. In the following calculation and in later circuit construction, use any voltage of your choice between 6 V to 15 V.
2. Select R1. First, determine a value of the photo resistor's resistance (call it R_{on}) at which you would like the LED to be turned on. The resistance value can be that for when the photoresistor is covered or uncovered, it's up to you. (Just make it clear in your report). The value of R1 should be such that $0.7 = V * R1 / (R1 + R_{on})$.

A variable resistor (trim pot) can be used so that the turn-on value can be adjusted.

3. Select R_c , the current limiting resistor. With this resistor, the collector current is limited to $I_{max} = (V - V_{LED} - 0.4) / R_c$, where V_{LED} is the voltage drop across the LED, and 0.4 V is a typical saturation voltage between the collector and emitter. **Select R_c so that the LED current is limited to be less than 20 mA (preferably 5-10 mA).** Using R_c , **construct and test the circuit.**

Using the Basic Stamp to Make a Programmable Light-Controlled Switch

The circuit in Figure 4 is very simple, but it suffers from the disadvantage that once R1 is chosen and the circuit is constructed, you're stuck with its performance unless you physically remove R1 and replace it with a different value. That is not too serious if we are dealing with one circuit on a breadboard, but suppose this circuit were part of a product that you were manufacturing, say 1000 per day. If you wanted to change the performance of the device, you would have to modify the assembly drawings, circuit board artwork, component inventory, rework all the work-in-process, etc. That would be a big deal! Here we will use the Basic Stamp to make a light-controlled switch whose performance can be modified by simply reprogramming the Stamp.

Procedure

1. Build the part of the circuit in Figure 5 labeled 'A'. Connect the 1k resistor to any of pins P0 through P15 on the Basic Stamp (denoted xx below). Don't forget that you need to supply power and ground to the Basic Stamp.

2. Run the following program, and see if you can make the LED blink:

```
'Blinktest
'Put the date here
'Put your name here
```

```
loop: high xx      'substitute the pin number you chose in place of xx
pause 500
low xx            'substitute the pin number you chose in place of xx
pause 500
goto loop
```

3. When you have successfully completed step 2, build the rest of the circuit shown in Figure 5. Connect the 220 ohm resistor to another one of the pins P0 through P15 (but different from the pin you chose in step 2, denoted yy below).

4. Run the following program:

```

'Light-Controlled Switch
'Put the date here
'Put your name here

loop:
result var word
high yy          'substitute the pin number you chose in step 3 in place of yy
pause 1
RCTIME yy,1,result  'substitute pin no. you chose in step 3 in place of yy
debug ? result
if result > 40 then turnON
low xx          'substitute the pin number in step 2 in place of xx
goto loop
turnON:
high xx        'substitute the pin number in step 2 in place of xx
goto loop

```

Look at the value of the variable 'result' in the Debug window. What happens to 'result' when you cover the photoresistor? Based on the value for the variable result that is being displayed in the Debug window, you can adjust the threshold value of 40 to a value that will cause the LED to be off under ambient light conditions, but turn on when a shadow falls on the photoresistor. Experiment with the threshold value.

What changes need to be made to the software (note: no need to change any *hardware*) if you want to have the LED stay on under ambient light conditions and turn off when a shadow falls on the photoresistor? Try it.

Suppose the LED were replaced with a motor? You now have the knowledge to control devices that require more power than the Basic Stamp can supply by itself.

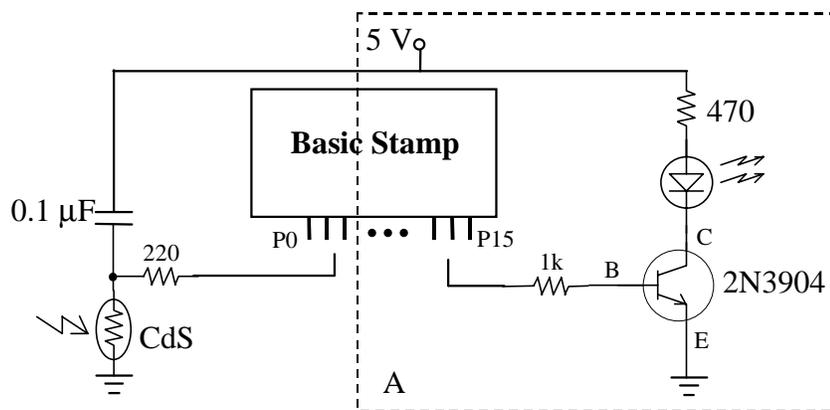


Figure 5 Light-Controlled Switch Using the Basic Stamp

Questions

Questions are those in bold type in the procedures above