

## 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 $\Omega$ , 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?

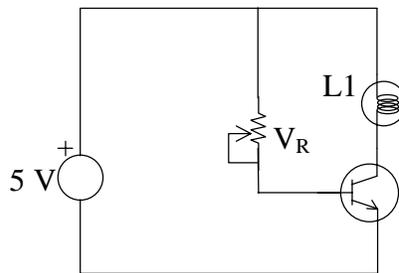


Figure PL-1 Lamp Control Circuit

### Purpose

- To introduce photoresistors, LED's, FET's, and transistors used as power switching devices
- To become familiar with the capability of the OOPic 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 $\Omega$ resistor
1	solderless breadboard	1	22 k $\Omega$ resistor
1	photoresistor	1	470 $\Omega$ resistor
1	red or green LED	1	220 $\Omega$ resistor
1	2N3904, NPN transistor		
1	OOBOT 40-II controller board		

### 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**

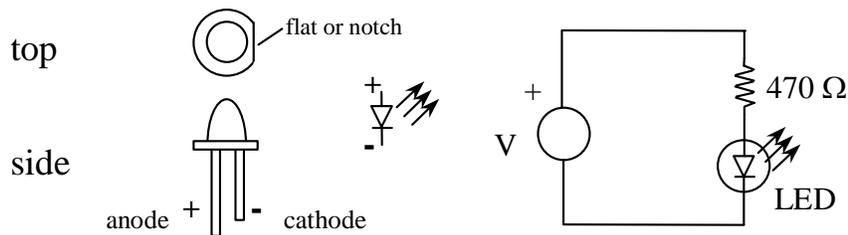
1. Measure the photo-resistor’s resistance in the ambient lighting of the lab. Once this is recorded, repeat the measurement, only this time covering the cell with your hand. These two extremes will be used in calculations later on.

**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 an 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 (though some can handle upwards of 80 mA). 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 by applying Ohm’s law across the resistor.**

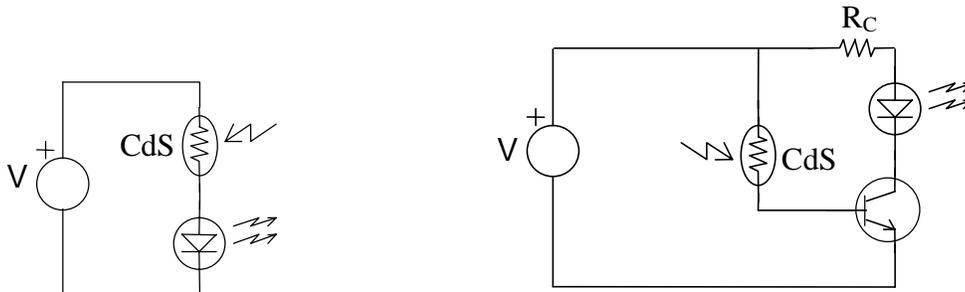


**Figure 1** LED and typical circuit. Note that the anode lead is longer than the cathode. Sometimes there may be a flat on the cathode side of the LED to help you distinguish anode from cathode.

**Table 1** LED circuit measurements (Refer to Figure 1)

$V_{\text{supply}}$ , Volts	$V_{\text{LED}}$ , Volts	$V_{\text{R}}$ , Volts	Current, mA	Comment on LED brightness
1				
2				
3				
4				
5				
6				
7				
8				

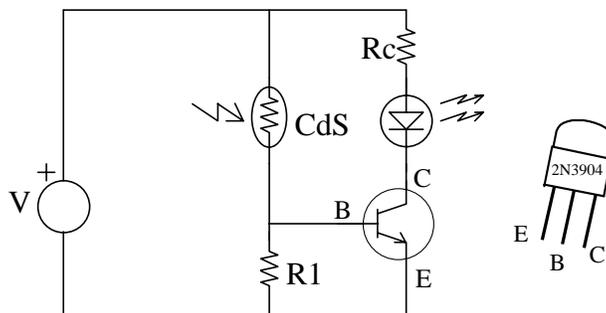
2. Figure 2 shows a simple ‘light-controlled-LED’. The circuit should turn-off the LED as the photo resistor is covered. **Explain the theory of operation of this circuit.** Based on the information obtained above, what is a good supply voltage to use? (Hint:  $V$  should be high enough so that enough 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 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  $0.7\text{ V}$ , 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  $0.7\text{ V}$ , 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 R<sub>1</sub>.** First, determine a value of the photo resistor's resistance (call it R<sub>on</sub>) 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 R<sub>1</sub> should be such that  $0.7 = V * R_1 / (R_1 + R_{on})$ .

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

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

## Using the OOPic to Make a Programmable Light-Controlled Switch

The circuit in Figure 4 is very simple, but it suffers from the disadvantage that once R<sub>1</sub> is chosen and the circuit is constructed, you're stuck with its performance unless you physically remove R<sub>1</sub> 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 the entire work-in-process, etc. That would be a big deal! Here we will use the OOPic to make a light-controlled switch whose performance can be modified by simply reprogramming the OOPic.

## Procedure

1. Build the part of the circuit in Figure 5 labeled **A**. Connect the 1k resistor to pin B7 on the OOPic board using a jumper from the pin to the solderless breadboard. Figure 6 shows the location of pin B7. Don't forget that you need to supply power and ground to the OOPic. Use the fixed power supply for +12 V for the OOPic and +5 for the rest of the circuit.
2. Run the following program, and see if you can make the LED blink:

```
// Blink test program
// This program outputs a 1 Hz square wave on
// pin B7 of the Oricom OOBOT 40-II board
// by BJ Furman 06SEP03
// modified by M. Kearny 11SEP03

oDio1 LED = new oDio1;      // declare 1-bit digital I/O object
oWire Linker = new oWire;  // declare Linker as a processing object
sub void main(void)
{
    // Initialize objects

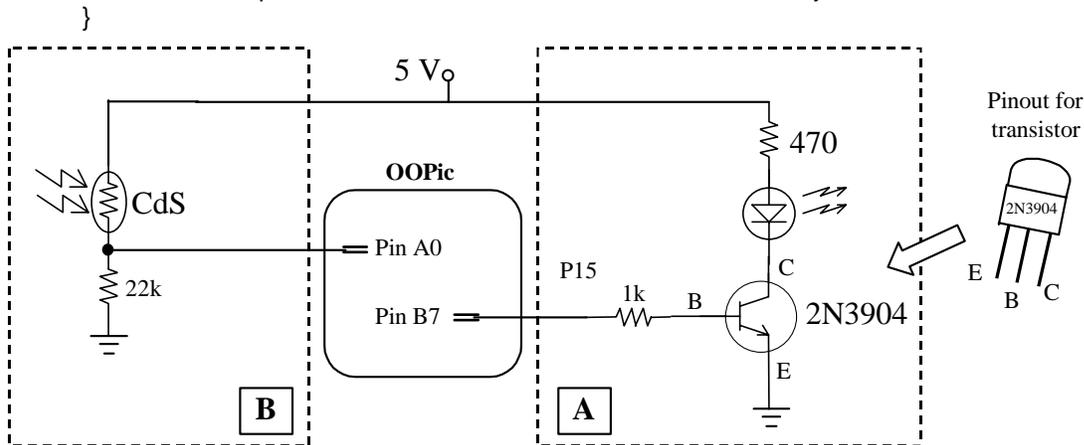
    LED.IOline = 15;        // Map LED object to OOPic IO line 15 == pin B7
    LED.Direction = cvOutput; // Make pin B7 a digital OUTPUT
```

```
// Use the Linker object to pass a 1 Hz squarewave to the LED object.
// The 1 Hz squarewave is generated by the OOPic object.
```

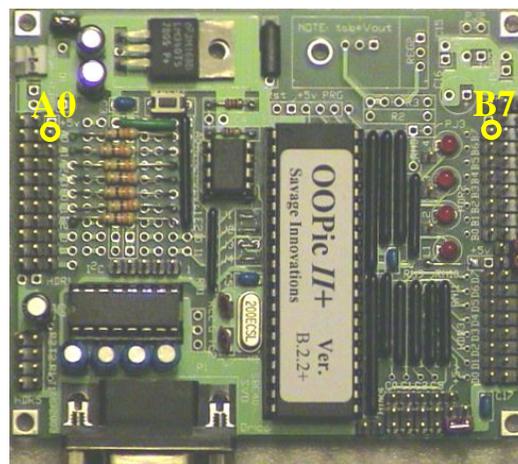
```
Linker.Input.Link(OOPic.Hz1); // Set Linker input to be the 1 Hz squarewave
Linker.Output.Link(LED); // Set Linker output to LED object
```

```
// Note: The default property of the oDio1 object is "Value".
// When the property name is not used with the object, then the
// default property is implied (i.e. "Value"). The above line
// of code could also be written as: Linker.Output.Link(LED.Value);
```

```
Linker.Operate = cvTrue; // Turn on the Linker object
```



**Figure 5** Light-controlled switch using the OOPic. The photoresistor (in **B**) is part of a voltage divider, the output of which is connected to pin A0, one of the pins that can be used for analog-to-digital conversion. Pin B7 is connected to the base of a transistor (in **A**), which is used as a switch for illuminating the LED when the light level on the photoresistor is beyond a certain threshold value.



**Figure 6** OOBOT 40-II board showing the location of pins A0 and B7.

- When you have successfully completed step 2, build the circuit in **B** shown in Figure 5, and run the following program:

```

// Photoresistor and A/D test program
// This program reads the voltage associated with a voltage divider
// that contains a photoresistor and continuously prints the output
// to the OOPic Communications window
// by BJ Furman 06SEP03
// modified by M. Kearny 11SEP03

oA2D10 light_level = new oA2D10; // Declare 10 bit analog-to-digital object
oSerial PCterm = new oSerial; // Declare Serial object for communication to PC

sub void main(void)
{
    // Initialize objects

    light_level.IOLine = 1; // Map A2D10 object to A/D line 1
    light_level.Operate = cvTrue; // Enable A2D10 object to perform A2D conversions

    PCterm.Baud=cv9600; // Set serial communication baud rate to 9600
    PCterm.Mode=0; // Asynchronous serial communication
    PCterm.Operate=cvTrue; // Enable serial object

    While (1) // Continuous loop
    {
        PCterm.string="Light Level="; // Tell the user what the voltage value is
        PCterm.string=str$(light_level); // Send the light level value

        PCterm.value=13; // Carriage return character
        PCterm.value=10; // Line feed character
    }
}

```

What happens when you cover the photoresistor? What range of values are shown in the OOPic Communications window? What voltage do these correspond to?

4. When you have successfully completed step 3, write a program that will turn the LED on when you cover the photoresistor with your hand. (Hint: add a test in the While loop that compares the value of light\_level with a value slightly higher than that value for when the photoresistor is covered. 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 (i.e. the opposite function to what you programmed in step 4? Try it.**

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

## **Questions**

Questions are those in bold type in the procedures above