

CHAPTER

4

Light Emitting Diodes

Beginning with this lab, you will start assembling your robot. The robot basically does three things: it can turn on a LED, make a beep, and drive around. In this lab, you will learn how the robot controls the LED.



Background

Fig. 4.1 shows the light emitting diode (LED) driver circuit that you will be building in this laboratory exercise. The heart of this circuit is an LED. Remember that an LED is simply a diode which has an ON voltage that is much higher than the 0.7V typical of silicon diodes. The LED in your robot kit turns on with approximately 1.8V forward voltage (it is made from semiconductor materials that are different from those used in the diodes and transistors in your lab kit, which is why the forward voltage is not 0.7V). The intensity of the light emitted by the LED is proportional to the current flowing through the diode.

The input voltage to the LED driver circuit is “digital,” meaning that it will either be high (very close to 5V), or low (very close to 0V). When the input is close to 5V the LED should light. At 0V there is no light. With a high input, current goes through D6, then R8, and finally through the transistor Tr1 to ground. The base current is large enough that the transistor is in “SATURATED.” This means that the voltage difference between the collector and emitter of the transistor is $V_{CE} = 0.2V$. When base current is flowing we

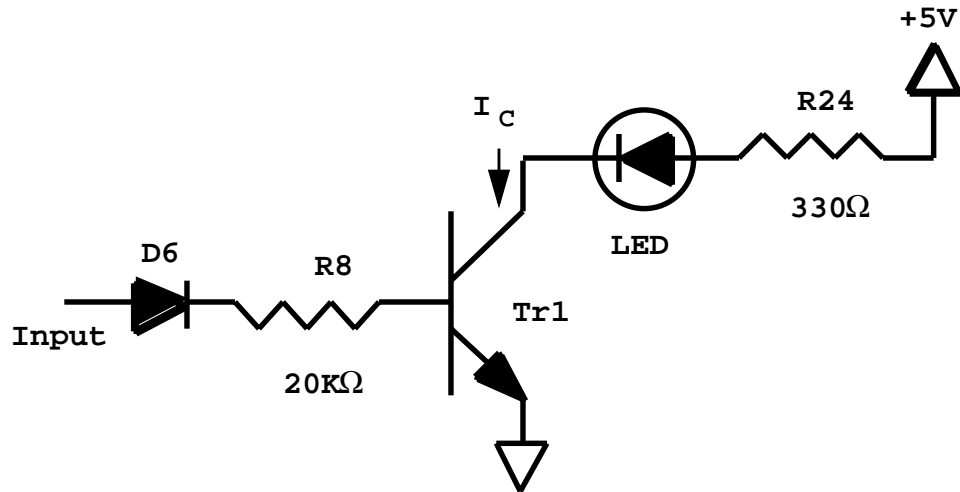


Figure 4.1 LED driver circuit.

can regard the transistor as a 0.2V battery in series with the LED and R24. Current flows out of the +5V supply and down through R24, then through the LED (causing it to light up) and finally through the transistor to ground. If the input is a voltage low, there is not enough voltage to turn on both D6 and the diode between the transistor's base and emitter. Consequently, no current can flow into the transistor, so no current will go through the LED, and it will not light. The transistor is in the "cutoff" region of operation and we can model it as an open circuit between all 3 terminals. Ideally, the input must reach approximately 1.4V (two diode drops) to start current flowing into the transistor's base terminal, though your laboratory observations may differ. Any additional voltage above 1.4V will appear across R8, slowly increasing the base current. When there is a 5V input, the voltage across R8 can reach approximately 3.8V. Since R8 is large, it does not allow much current to flow—in this case $3.8\text{V} / 20\text{K}\Omega = 0.19\text{mA}$. Therefore with a logical 1 input (5V) $I_B = 0.19\text{mA}$. R24 controls the maximum amount of current that can flow through the LED. For example, even if the collector voltage is 0.2V, and the LED drop is 1.8V, then the voltage across R24 is 3.2V. Hence, the current through the LED is at most $3.2\text{V} / 330\Omega = 10\text{mA}$.



The Laboratory Exercises

In this laboratory exercise, you will build and test the LED driver circuit.

1. First, build the LED circuit on the protoboard as is shown in Fig. 4.1. The transistor is TR1, a 2SC1815Y (see Fig. 4.2 for a reminder of the lead positions for the transistor). Set the +20V part of the power supply to +5V and connect it to power your circuit (connect to R24). Don't forget to connect the common terminal of the power supply to the emitter of Tr1. We will use the +6V part of the power supply to act as an input signal that we will vary between 0V and 5V. Set the voltage output of the +6V part of the power supply to 0V and connect it as the input to your circuit (connect to D6). Note, the meter on the power supply is not very accurate; you should measure the actual input voltage with the DMM. Make sure the leads of the DMM are in the LO and Volt-Ohm jack not the AMP jack.
2. With the +6V power supply set to generate an input of 0V, measure the current flowing into the base of the transistor and the current flowing into the collector of the transistor (you will need to use the DMM with the leads in the LO and AMP jacks). Does the LED light up?
3. With the +6V power supply set to generate an input of 5V, measure the current flowing into the base of the transistor and the current flowing into the collector of the transistor (you will need to use the DMM set to AMP mode and with the leads in the LO and AMP jacks). Does the LED light up?
4. Mount the LED circuit onto the robot PC board, leaving the input lead of diode D6 (the side WITHOUT the black band) unconnected.

Set the +20V part of your power supply to +5V and attach it to pin 22 of the 22 pin IC socket. Note, if you hold the PC board so that the writing is vertical, the notch in the 22 pin IC socket should be at the top of the socket and pin 22 should be the upper right hole in the socket. You should insert a short length of jumper wire

into pin 22 and clip the power supply lead onto it. Be careful to support the power supply lead so that its weight does not pull the jumper out of pin 22 of the 22 pin socket. Attach the power supply common to the common pin of the robot PC board. Attach the +6V part of your power supply to the input end of D6. By setting the power supply to 0V or +5V, turn the LED on and off. If there are any problems, identify them and fix them. If you have a problem ask your TA for help. When you are done, solder the free end of D6 into the robot PC Board.

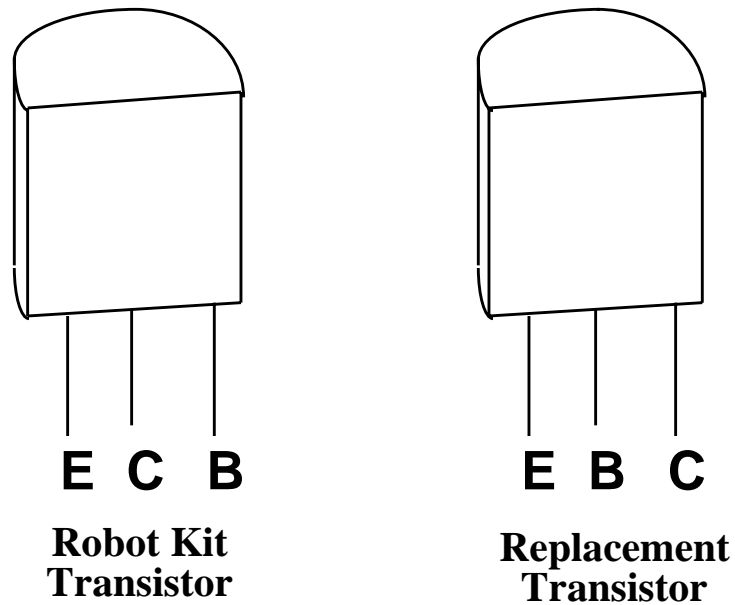


Figure 4.2 The physical appearance of the Bipolar transistor. Use the diagram on the left for the transistors that are included in your lab kit. Use the diagram on the right only if you have obtained a replacement transistor.