CHAPTER 9

Speaker Driver

In this lab, we will study the circuit that makes the "beeping" sound for your robot. Just as for the motor driver and the LED circuit, the beeper is turned on and off digitally. As you may know, sound is really just a longitudinal compression wave traveling through the air to your ear. Sound can be created electronically using a speaker that consists of a coil attached to a plastic or paper cone and a fixed permanent magnet. An oscillating current can induce magnetic fields in the coil that cause the coil to be attracted to or repelled from the permanent magnet, making the cone move in and out, and sending pressure waves into the air.

In your robot, the speaker is driven by an oscillating signal that is created by a circuit similar to the clock circuit used in the last lab. However, the frequency of oscillation of the clock circuit only went up to 4Hz. The lowest frequency that the human ear can hear is about 20Hz, and even that is very low. The frequency at which the robot beeps is about 2500Hz. In addition to a higher frequency, the beeper circuit will need to be turned on and off (gated), whereas the clock circuit runs continuously.

Background

The gated oscillator circuit used in the robot is shown in Fig. 9.1. It uses a PNP bipolar transistor. Remember that all of the terminal voltages and the currents in a PNP are the negative of those normally found in an NPN transistor. When the input voltage is close to zero (low), the base of the PNP transistor is also close to zero. The input voltage to inverter 1 is low because it is 0.7V higher than the base voltage. This makes the output voltage of inverter 3 a high. So, when the input voltage to the beeper circuit is low, a current flows out of inverter 3, through R12, and then through R13. This current then enters the transistor through the emitter, and most of it leaves through the collector, to ground. Note, this is the normal direction of current flow for a PNP transistor. The rest leaves through the base, and flows through the resistors into ground. The circuit does not oscillate with a low input because the PNP transistor is draining the current which would otherwise charge up the capacitor.

Once the input to the beeper circuit goes high, the PNP base is at approximately 5V, which turns the PNP transistor off. Since the power supply is +5V also, the Base-Emitter junction of the PNP transistor cannot become forward biased. Now, current cannot flow through R13, hence the current through R12 charges the capacitor, and the voltage at point A begins rising toward the high output level (+5V) of the 3rd inverter. No current will flow into the input of the 1st inverter, pin 13, or the emitter of the transistor, so the input voltage to inverter 1, pin 13, rises with point A. When point A reaches the threshold voltage of the 1st inverter, all of the inverter outputs flip. When this happens, the charged capacitor discharges into the low output of the 3rd inverter, and the voltage at point A goes down until it reaches the threshold voltage of input 1 again. When it does, all the inverters will flip back to the original state. In this manner the output oscillates. The operation of this oscillator is quite similar to the basic clock oscillator circuit that you already studied.

The output of the oscillator is taken from pin 10, the output of the 2nd inverter. The reason the 2nd inverter’s output is used instead of the third inverter’s output is that the 2nd inverter has a zero output when the oscillator is turned off and we do not want to use battery power to drive DC current through the speaker. The frequency of the output is inversely proportional to the values of R12 and the capacitor. In the robot’s oscillator, the frequency should be about 2500Hz.

Now that we have a signal, we need to send it to the speaker. This is accomplished by the circuit shown in Fig. 9.2. When the signal in is high, the transistor turns on, and current is pulled through the speaker. For a low signal, no current flows. The signal is a square-wave between 0V and 5V with the frequency of the oscillator, and

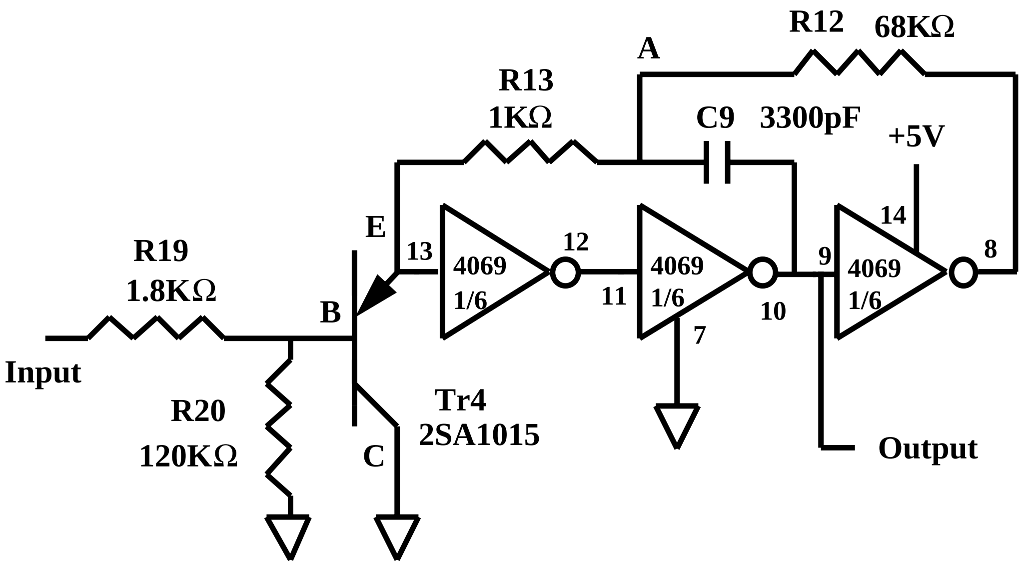

Figure 9.1 Gated oscillator circuit.

it causes the speaker to make a beeping sound. Note, just as with the motor driver circuit, transistor Tr2 will act as a switch, and its collector current will be limited by the current that flows through the speaker with 4.8V across it.

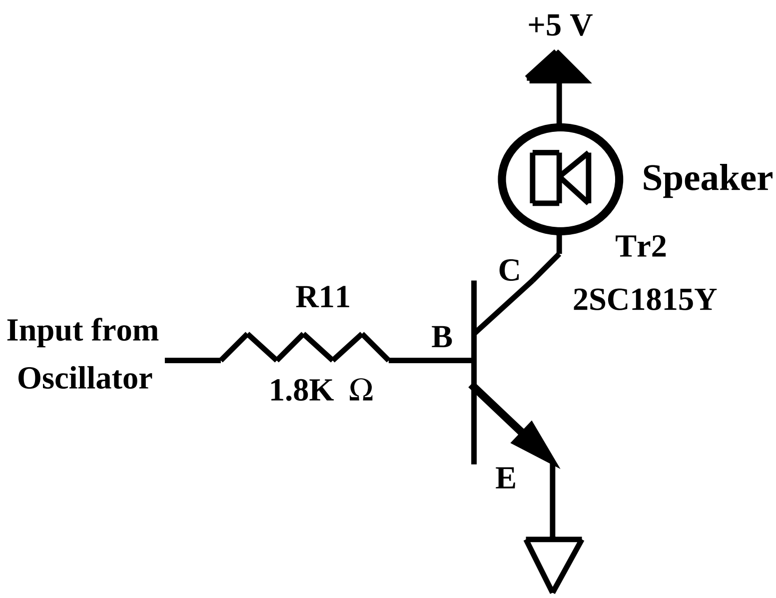

Figure 9.2 Speaker driver circuit.

Laboratory Exercises

1. Construct the circuit shown in Fig. 9.2 on your protoboard. Set the function generator to generate a 0V to 5V square wave with a frequency of 2500Hz. Verify this waveform with your scope. Then connect the function generator as the input signal to the circuit of Fig. 9.2. The top of the beeper element should have a dot on it or else a “+” on the bottom next to one of the leads. The lead directly below this dot or next to the “+” should go to the +5V side. You should hear a tone when you power up the circuit. Now vary the input frequency slowly from 100Hz to 5kHz.

2. Next, build the oscillator circuit of Fig. 9.1 on your protoboard. Use the +20V part of your power supply to provide +5V power for this circuit. You will need to remove the inverter chip that you installed last lab from the robot to do this. Never pry an IC out of an IC socket. In the tool kit you should find an IC extractor. Use the extractor to remove the IC lifting evenly at both ends. Your lab TA will demonstrate. Do not connect the gated oscillator’s output to the beeper driver transistor yet. If your circuit doesn't oscillate when the input to TR4 is either 0 V or 5 V, try removing TR4. If your circuit now works, switch your C and B leads. Observe the output voltage of the oscillator with your oscilloscope.

3. Put the 68kΩ resistor for R12, and hook the output of your oscillator to the beeper driver. Using the other section of your power supply, slowly vary the input to the oscillator from 0 to 5V and back to 0V. Note the input voltage at which the beeper first begins to sound and the voltage at which it turns off. They should be nearly equal, but we expect the turn off voltage to be slightly lower because it is always more difficult to get an oscillator started than it is to keep one going.

4. After you have the beeper working on the protoboard, you can install it on the robot’s PC board. When mounting the components on the PC board, leave the input end of R19 out of the board. Set the +20V part of your

power supply to +9V and attach it to the +9 V pin of the robot PC board to the right of SW1. Attach the power supply common to one of the GND pins of the robot PC board. Turn SW1 on and check that the output of your voltage regulator is still +5V. Attach the +6V part of your power supply to the free end of R19. By varying the +6V power supply voltage from 0V to 5V, you should be able to test the beeper function. If there is a problem, identify and fix it, and then explain what went wrong. If you cannot solve the problem ask your TA for help. When you are done, solder the free end of R19 into the robot PC Board.