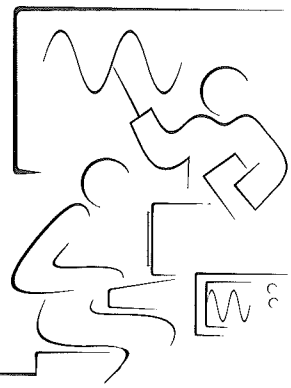
Lab 4
Transistor Circuits



In this exercise you will become acquainted with the operation of transistors in simple analog circuits. You will investigate the characteristics of a simple transistor switch, an emitter follower, and a common emitter amplifier.

Reading Assignment

Building Scientific Apparatus by J. H. Moore, C. C. Davis, and M.A. Coplan (Addison-Wesley, NY 1989). Section 6.3.2 *Transistors* (pages 385-390); Section 6.4.1-6.4.2 *Amplifiers* (pages 395-402); Section 6.9.2-6.9.6 *Electrical pickup* (pages 466-470).

Materials Required

Heathkit ET-1000 Circuit Design Trainer (1); LED: LN21RPHL (1); Transistor, npn: 2N3904 (1); Resistors @ 1/4 W: 270 Ω (1), 1.2 kΩ (1), 4.7 kΩ (1), 8.2 kΩ (1), 10 kΩ (1), 20 kΩ (1), 100 kΩ (1); Capacitor, ceramic @ 25 V: 0.1 μF (1); Hookup wire; Wire stripper (1); Digital multimeter: 4 1/2 digit (1); Oscilloscope (1).

I. Transistors as Diodes

Identify the leads on a 2N3904 transistor (Figure 4-1, left) and verify that it behaves like two diodes in series (Figure 4-1, middle). Measure the resistance of both junctions on the 20 kΩ scale of a digital multimeter. Verify that the resistance of junction BC is lower than the resistance of junction BE (≈6.6 kΩ). Reverse the leads to determine the direction of the current.

II. Transistors as Switches

Transistor switches are very common, often replacing their mechanical counterparts. Construct the transistor switch shown in Figure 4-1 (right) using the breadboard in the Heathkit Circuit Design Trainer. Close and open the switch. Measure all voltages and calculate or measure the appropriate

currents. Discuss the importance of each resistor in your lab report. How are the resistor values selected? A better circuit design would add a 10 kΩ resistor from point A to ground. Why? Add the resistor. Is the operation of the LED affected? With the switch open, apply +5 V to point A. Is this a useful mode of operation?

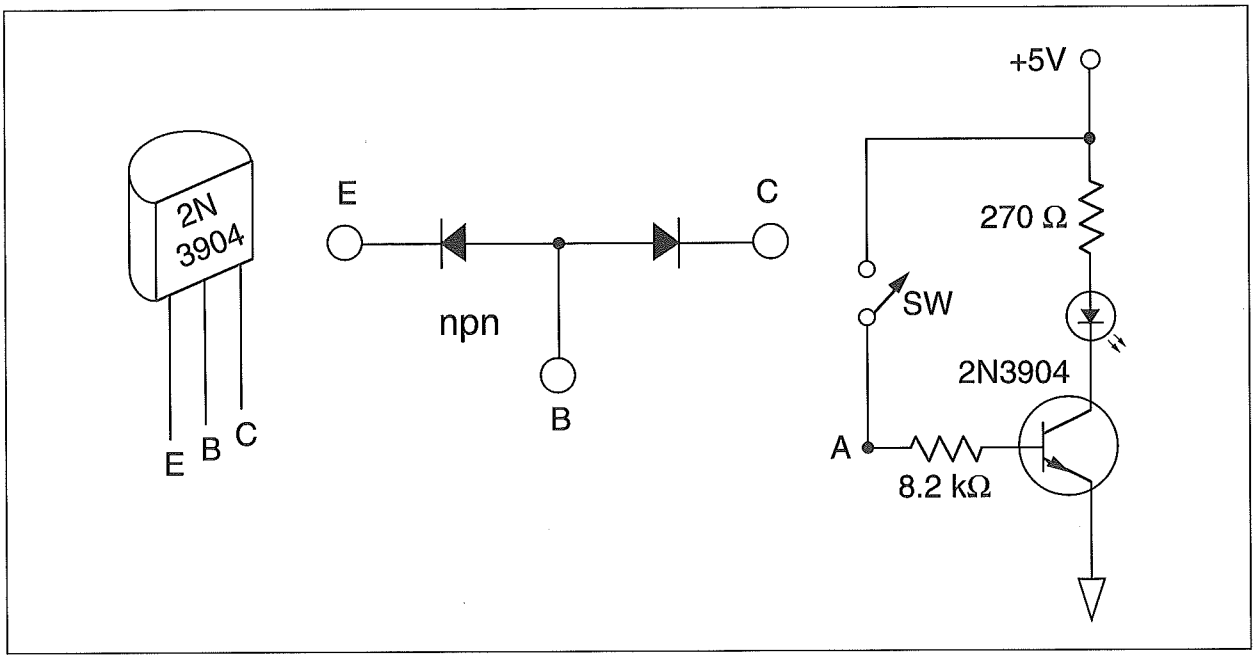


Figure 4-1. A Transistor Switch

III. Voltage Dividers

A voltage divider is a convenient way to attenuate a signal. Construct the voltage divider shown in Figure 4-2 (left). Use the variable resistor (potentiometer) and the function generator in the Heathkit Trainer to apply a 1 kHz sine wave to the input (Vin). Adjust the potentiometer (pot) until the p-p amplitude at the output, Vout ≈1 V. Examine and record the appearance of the output waveform. Measure the resistances in the divider circuit and record their values. In your lab report, derive an expression for the signal attenuation (Vout/Vin) of the divider. Use the measured resistances to confirm the attenuation measured experimentally.

IV. The Emitter Follower

Construct the emitter follower shown in Figure 4-2 (second circuit from left). Use the voltage divider from Part III to apply an attenuated, 1 kHz sine wave to the input of the emitter follower (Vin). Be sure the sine wave is symmetric about zero. Examine and record the appearance of the output waveform as a function of the signal amplitude applied to the input. Connect the emitter resistor to –12 V as shown in the third circuit from the right

(Figure 4-2). Repeat your measurements. Record your observations and explain the improvement in the output waveform.

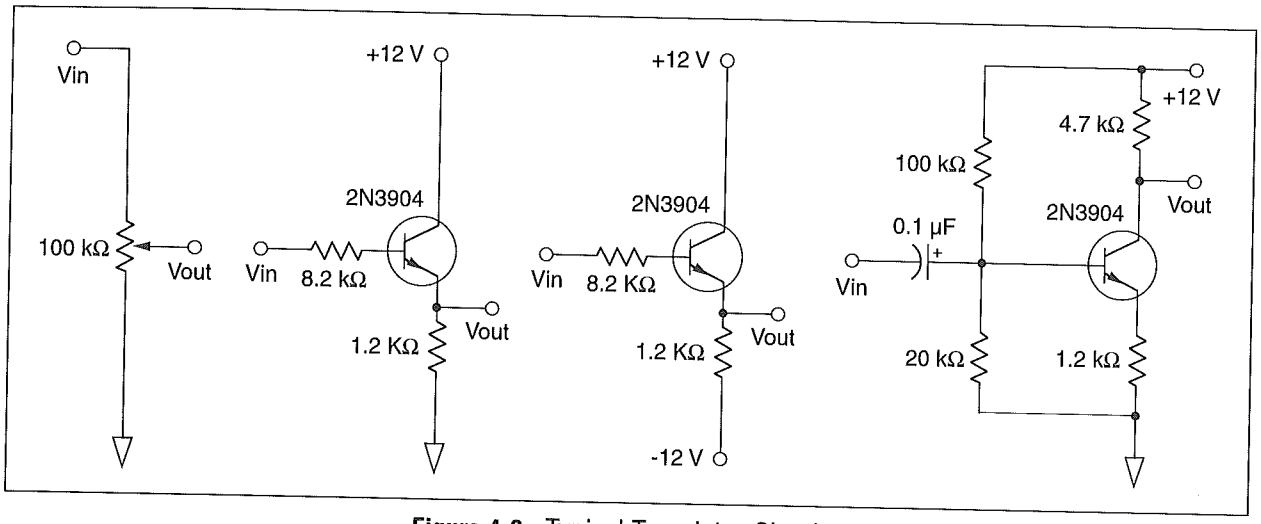


Figure 4-2. Typical Transistor Circuits

V. Common Emitter Amplifier

Construct the common emitter amplifier shown in Figure 4-2 (right). Notice that unlike the emitter follower circuits, there is no base resistor in this circuit. Why? **Hint:** What is the purpose of a base resistor? In order to operate properly, an amplifier must pass a certain amount of current when there is no signal applied to the input. This is called the "quiescent current". Apply voltage and with an oscilloscope or a multimeter measure the voltage across the 1.2 kΩ resistor. Using Ohm's law, determine the current through this resistor. This is the quiescent current. In your lab report, discuss how the quiescent current and the corresponding quiescent voltage (at the output of the circuit) determine the value of the collector resistor. What circuit parameters (components and values) determined the quiescent current once the emitter resistor is known?

VI. Measurement of Gain

Use the voltage divider from Part III to apply a 1 kHz sine wave to the input of the amplifier (Vin). Display the output signal and the input signal on an oscilloscope. Set the vertical amplifier(s) for AC coupling. If the output waveform is a "clipped" sine wave, attenuate the input signal until two clean sine waves are observed. If the signal is "noisy", check for ground loops (see Section 6.9.6, page 468 of your text). Switch the coupling to DC. Why does the display change? Switch the coupling to AC and measure the peak-to-peak amplitude of the output signal. Measure the peak-to-peak amplitude of the input signal. The ratio of the signal amplitudes is the

voltage gain of the amplifier. In your lab report, explain what components and values determined the gain of the amplifier.

Optional Exercise

Vary the frequency of the input signal and record the gain of the amplifier at 25 Hz, 50 Hz, 75 Hz, 100 Hz, 120 Hz, 150 Hz, 200 Hz, 300 Hz, 500 Hz, 1000 Hz, and 3000 Hz. Note that the gain of the amplifier remains fairly constant between ≈1000 Hz and 3000 Hz. Divide the gain at each frequency by the gain at 1000 Hz. This is the "normalized" voltage gain, Gn, of the amplifier. Use the following table to record your results. A graph of the normalized voltage gain as a function of frequency is called the "frequency response" of the amplifier. A calculation of the frequency response of your amplifier is shown in Figure 4-3. Plot your experimental points on the graph on the next page. Include a copy of the table and the graph in your lab report. As the frequency is decreased, the output voltage of the amplifier decreases to 0.707 of its maximum value. This is called the 3 dB (decibel) point of the amplifier. In your lab report, define the meaning of "dB" and show 3 dB = 0.707 Vmax.

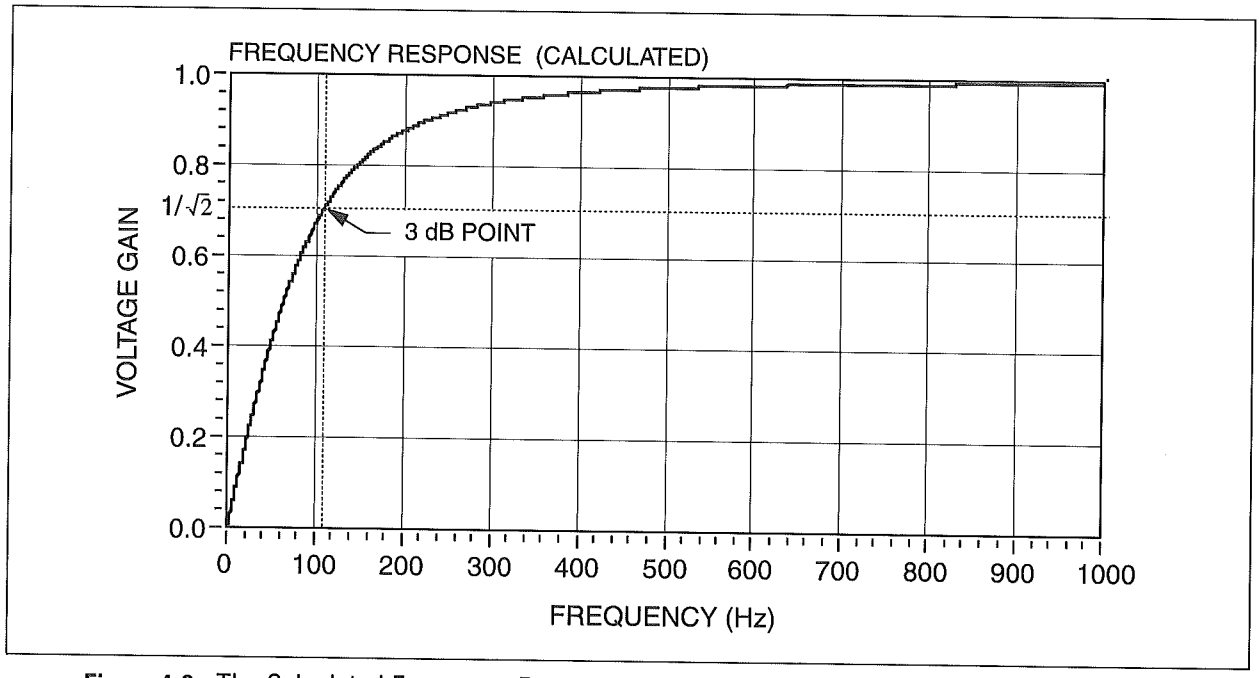


Figure 4-3. The Calculated Frequency Response of the Common Emitter Amplifier in Figure 4-2

Homework Assignment

Prepare a laboratory report in the form of a short paper. The paper should include the usual sections and the answers to any questions posed in this laboratory handout.

f (Hz)	INPUT (V)	OUTPUT (V)	GAIN	Gn
25				
50				
75				
100				
120				
150				
200				
300				
500				
1000				
3000