ELEC-313
Lab 9: Common-Emitter Transistor Amplifier

December 4, 2013

Date Performed:	November 20, 2013
Partners:	Charles Pittman
	Stephen Wilson

1 Objective

The objective is to construct and observe the operation of a common-emitter transistor amplifier.

2 Equipment

Transistor: 2N2222A	Capacitor: 0.1 µF
Resistors: 100 kΩ, 20 kΩ, 1 kΩ, 470 Ω	Power supply: HP E3631A
Function generator: HP 33120	Oscilloscope: Agilent 54622D
Multimeters: HP 34401A, Fluke 8010A (x2)	

3 Schematics

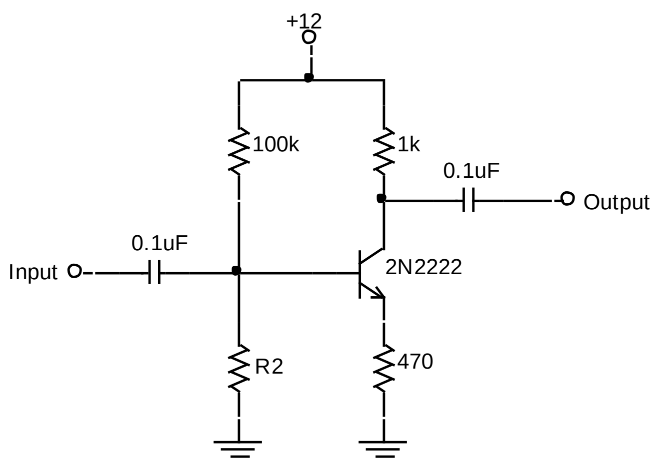

Figure 1: Common-emitter transistor amplifier (without the emitter bypass capacitor). $R_2 = 20\,\mathrm{k\Omega}$

4 Procedure

The following procedure was used to evaluate the transistor amplifier of Figure 1:

1. The circuit of Figure 1 was constructed.
2. The DC voltage at each terminal of the transistor was measured and the values were recorded in Table 1.
3. The output of the function generator was connected to the input of the circuit. Then the function generator was set to a frequency of 30 kHz as a sine wave.

4. Channel 1 of the oscilloscope was connected to the input of the circuit and channel 2 connected to the output.

5. The amplitude of the sinusoidal waveform was adjusted to -250 mV to +250 mV (500 mVpp) at the circuit input as measured on the oscilloscope.

6. The peak-to-peak amplitude of the output waveform (V_o) was measured and recorded in Table 1.

7. Then the voltage gain (A_V) of the amplifier was computed and recorded in Table 1.

8. The decade resistance box was connected to the output of the circuit and adjusted until the output voltage read as one-half the open circuit value measured in step 6. The displayed resistance value, which is also equivalent to the output resistance (R_o) of the circuit, was recorded in Table 2.

9. The function generator was disconnected from the circuit input and then connected to the oscilloscope to measure the open circuit voltage (V_{OC}) produced by the generator. The open-circuit voltage was recorded in Table 2.

10. The decade box was removed from the output and reconnected between the function generator and the open circuit input, so that the signal travels from the function generator and through the resistance box on its way to the circuit input.

11. The decade resistance box was adjusted so that the voltage measured at the circuit input is one-half the open circuit voltage measured in step 9. That displayed resistance is 50 Ω less than the input resistance (R_i) of the circuit. The input resistance was recorded in Table 3.

12. The decade resistance box was removed and the function generator was reconnected directly to the circuit input, and its frequency was left at 30 kHz.

13. The amplitude of the generator was slowly increased while the output waveform was carefully observed to determine the point at which the output waveform began to clip (V_{clip}). The peak-to-peak voltage was recorded in Table 3.

14. The 10 µF emitter bypass capacitor was inserted into the circuit.

15. Steps 2 through 7 were repeated, except the input voltage was first reduced until the waveform didnt clip, and values recorded in Table 4

5 Results

V_B (V)	V_C (V)	V_E (V)	V_i (mV)	V_o (mV)	A_V
1.788	9.58	1.153	500	970	1.94

Table 1: Transistor amplifier characteristics

R (Ω)	V_{OC} (mV)
958	477

Table 2: Port impedances

R (kΩ)	V_i (V)
13.9	2.57

Table 3: Large-signal performance

V_B (V)	V_C (V)	V_E (V)	V_i (V)	V_o (V)	A_V
1.783	9.547	1.164	0.122	6.19	52.0

Table 4: Transistor amplifier characteristics (with emitter bypass capacitor)

	Measured	Calculated	% Diff.
R_o	$958\,\Omega$	$1\,\mathrm{k}\Omega$	4.20%
R_i	$13.95\,\mathrm{k}\Omega$	$13.543\,\mathrm{k}\Omega$	3.01%
A_V (no bypass)	-1.94	-2.06	5.83$
A_V (with bypass)	-50.9	-111	54.14%

Table 5: Percent differences

6 Conclusion

As seen in Table 4, the small signal voltage gain A_V increased once the emitter bypass capacitor was added, even though it had relatively insignificant impact to the DC voltages of each terminal. The DC voltages shouldnt change because the capacitor that was added is ideally an open circuit. But the emitter bypass resistor has a significant impact to the AC analysis because it is seen as a closed circuit and allows the I_E to pass through. As seen in Eq 7, the addition of the emitter bypass capacitor, reduced the denominator of the A_V Eq 4, thus increasing gain.

Table 5 shows the percent differences of the small signal gains along with input and output impedances (R_i and R_o) both with and without the bypass capacitor. The 5.7 percent difference between the A_V (no bypass) is caused from a combination of using nominal instead of measured resistance values, and the assumptions that β was assumed to be 150 and I_{CQ} was assumed to be 3 mA (from the pre-lab). I_{CQ} was probably less than 3 mA because the voltage drop between the 12 VDC input and terminal C is smaller. There is significant percent difference between the theoretical A_V versus the measured A_V with the bypass emitter. Eq 7 shows that the calculated A_V is affected more by I_{CQ}. Also, when calculating the theoretical votage gain, r_o is assumed to be infinite (i.e. an open circuit), which is not entirely true.

7 Equations

$$R_i = R_1 | R_2 | R_3 \tag{1}$$

$$R_{ib} = r_\pi + (1 + \beta) R_E \tag{2}$$

$$r_\pi = \frac{V_T \beta}{I_{CQ}} \tag{3}$$

$$A_V = \frac{-\beta R_o}{R_{ib}} \cdot \left(\frac{R_i}{R_i + R_S} \right) \tag{4}$$

$$g_m = \frac{\beta}{r_\pi} \tag{5}$$

$$-g_m R_o \cdot \left(\frac{R_i}{R_i + R_S} \right) = \frac{I_{CQ} R_o R_i}{R_i + R_S} \tag{6}$$

$$g_m = \frac{I_{CQ}}{V_T} \tag{7}$$