CMPE 314: Principles of Electronic Circuits

Dr. Yan

Lab 06 Report

Emitter-Follower Amplifier Circuit

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1. Objective

Construct and study the emitter-follower amplifier circuit.

2. Equipment

a. Resistors;
   - **i.** Given: 1 × 560 Ω, 2 × 2.2 kΩ, 2 × 10 kΩ
   - **ii.** Potentiometer: 1 × 2 MΩ

b. Capacitor; 1 × 0.22 µF, 1 × 1 µF

c. Transistor; 1 × 2N3904 NPN

d. Breadboard, DC power supply, digital multi-meter(s), oscilloscope, function generator

3. Background

A common-collector (also known as an emitter follower or voltage follower) amplifier is one of three basic single-stage bipolar junction transistor (BJT) amplifier topologies, typically used as a voltage buffer. In this circuit the base terminal of the transistor serves as the input, the emitter the output, and the collector is common to both, hence its name. The analogous field-effect transistor circuit is the common drain amplifier.

4. Procedures

4.1 Part A. Study the Voltage Gain

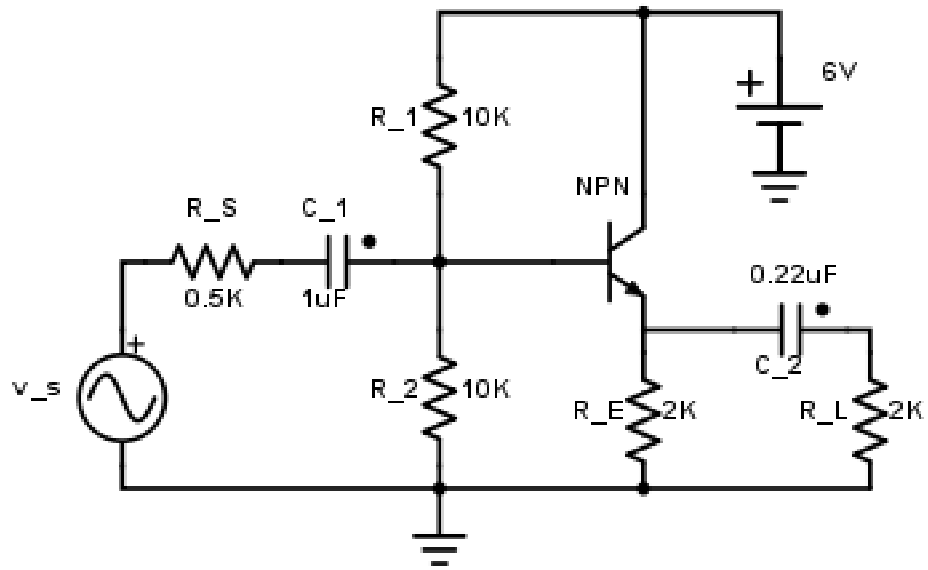

Figure 1: Emitter-Follower Amplifier with an NPN Transistor

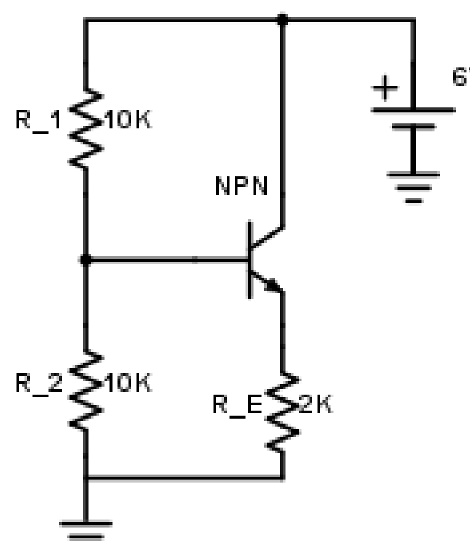

Figure 2: DC Portion of the Emitter-Follower Amplifier

a. Construct the DC portion of the amplifier circuit shown in Figure 2. Set $V_{CC} = 6$ V.
b. Measure V_{R1}, V_{R2}, and V_E to calculate V_{CEQ}, I_{BQ}, and I_{CQ}.
c. Connect the sinusoidal voltage source with amplitude ±100 mV and at frequency 10 kHz to construct the circuit in Figure 1. Capture the input and output voltages. Comment on the phase relationship. Find the small signal voltage gain and compare to the theoretical value.

d. Increase the input sinusoidal voltage, and record down any signal distortion. Comment on whether it is due to cutoff clipping or saturation clipping.

4.2 Part B. Output Resistance

a. Take out R_L and capture the voltage waveforms.
b. Replace the load with a potentiometer. Vary the resistance until the output voltage is a half of the voltage measured in Step a. Measure the resistance of the potentiometer. Compare the output resistance of emitter-follower to a common emitter circuit in Lab 6.
c. Vary the potentiometer and measure at least three different resistances, in order that the output waveform shows three different peak to peak values. Record down the corresponding output waveforms. Comment on how the small signal gain is influenced by the value of the load resistance and output resistance of the amplifier circuit.
d. Calculate the DC Q-parameters (V_{CEQ}, I_{BQ}, I_{CQ}, etc.) and AC parameters (R_i, R_o, A_v, etc.) for the circuit. Compare them with the measured values.

5. Results

The DC portion of the circuit was constructed and the voltages V_{R1}, V_{R2}, and V_E were measured as below.

Table 1. Measured Voltages of the Circuit in DC state

V_{R1} (V)	V_{R2} (V)	V_E (V)
3.02	2.98	2.34

The DC Q-parameters V_{CEQ}, I_{BQ}, and I_{CQ} were also measured and compared against the calculated values from the measured voltages.

The values were computed with the relationships detailed on Table 3.

Table 2. Additional Measurements of the Circuit in DC state

	V_{CEQ} (V)	I_{BQ} (mA)	I_{CQ} (mA)
Measured	3.63	0.00	1.00
Computed	3	0.011	1.11

The AC source was then connected, and the voltage waveforms were captured:

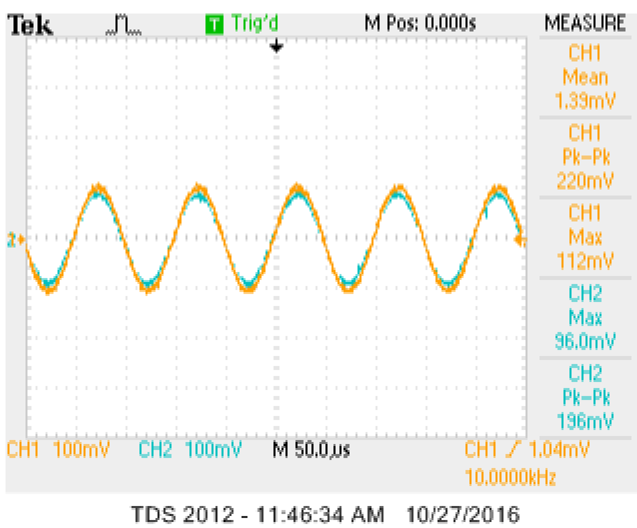

Figure 3: Input and Output Voltages of the Figure 1 Circuit

The gain appears to be almost 1

$$A_v = \frac{v_O}{v_I} = \frac{196\ mV}{220\ mV} = 0.891$$

The input voltage was increased to 1.3 V amplitude, and the output waveforms captured displayed a gain closer to 1 than before:

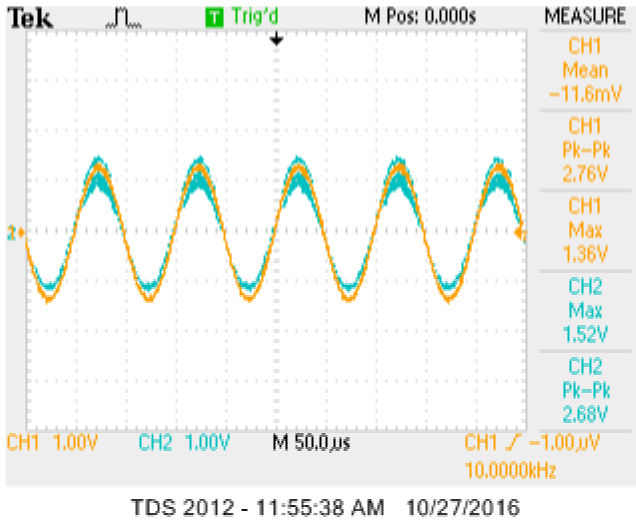

Figure 4: Voltage Waveforms of the Figure 1 Circuit with Larger Input Voltage

$$A_v = \frac{v_O}{v_I} = \frac{2.68\ V}{2.76\ V} = 0.971 \approx 1$$

The input voltage was increased further until a distortion on the output was noticeable, around an input amplitude of 1.7 V.

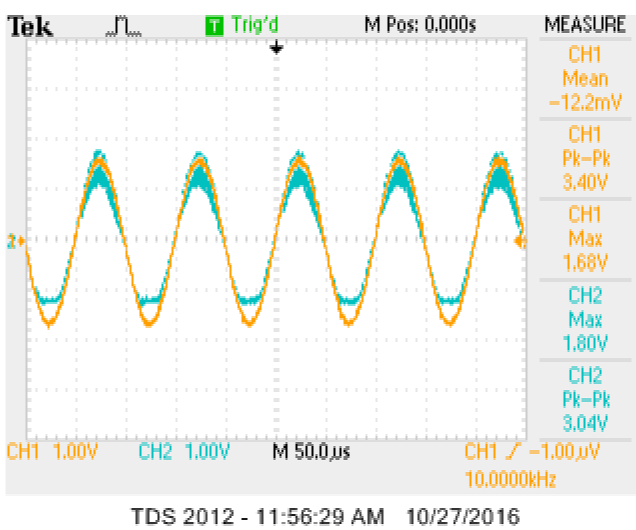

Figure 5: Voltage Waveforms with Input Voltage Clipping the Output Near the Cut-off Region

The load R_L was taken out, and the waveforms were observed and captured:

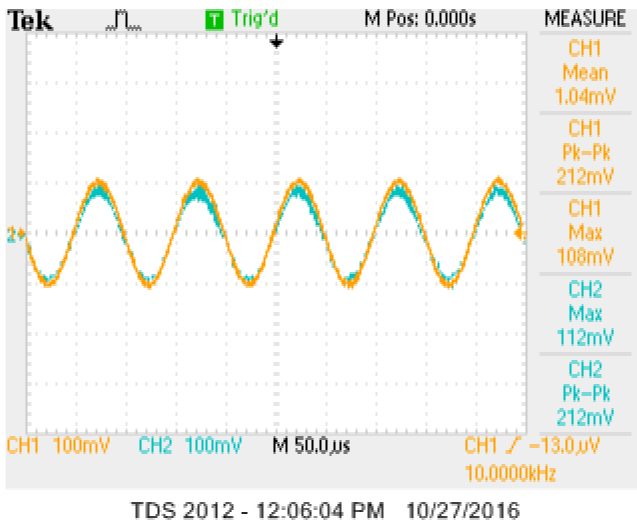

Figure 6: Voltage Waveforms with R_L Removed

The gain appears to be exactly A_v = 1.

The load was replaced with a potentiometer and the resistance was varied until the output voltage value was half of the value without any load, v_O = 106 mV.

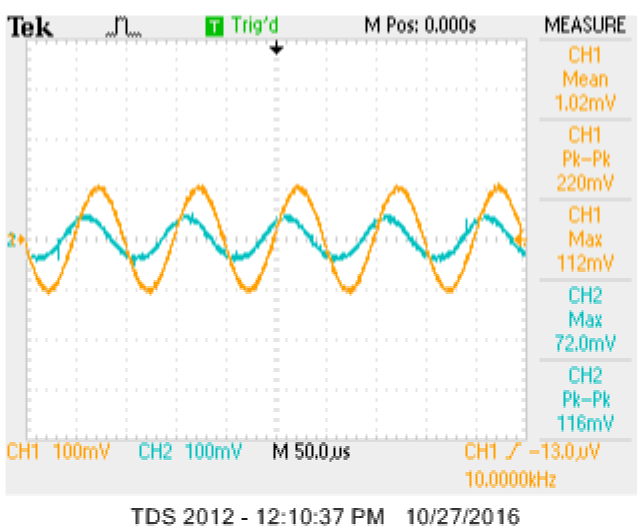

Figure 7: Voltage Waveforms with a Potentiometer as the Load

The resistance was measured to be R_L = 45.9 Ω.

The potentiometer was varied to generate 3 different outputs:

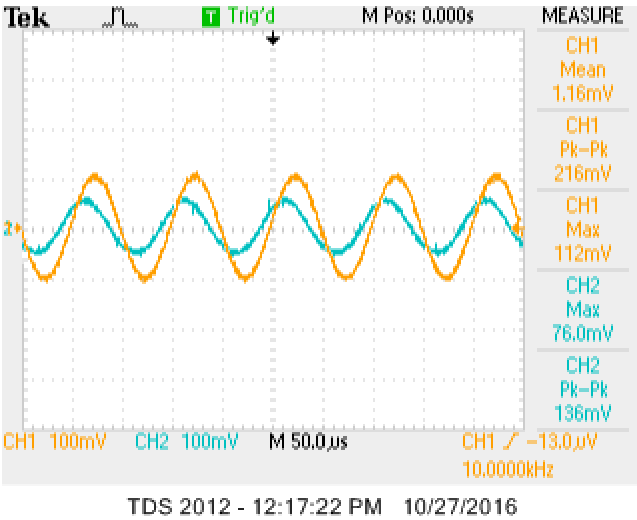

Figure 8: Potentiometer at 99.7 Ω

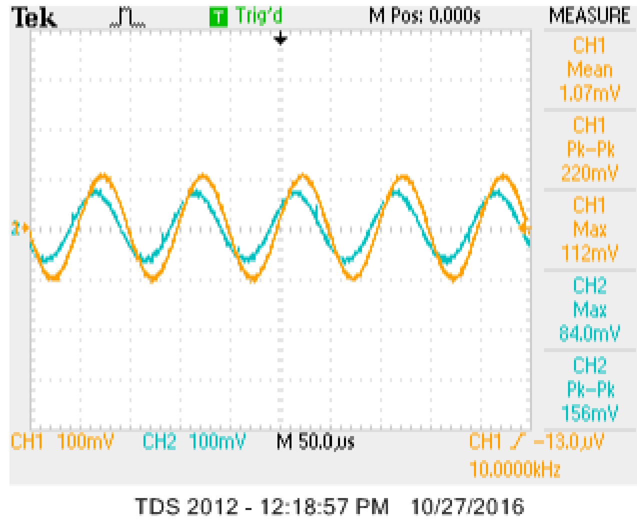

Figure 9: Potentiometer at 141 Ω

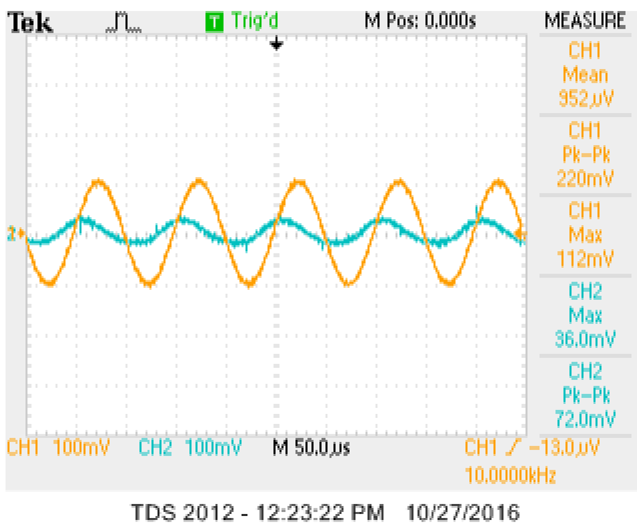

Figure 10: Potentiometer at 30.9 Ω

The DC and AC parameters were all computed with the relationships below:

Table 3. Relationships and Expressions Used to Determine the Values of the Circuit

Expression	**Value**
DC Parameters	
$V_{CEQ} = \frac{V_{CC}}{2} = 3\ V$	3 V
$I_{BQ} = \frac{V_{TH} - V_{BE(on)}}{R_{TH} - (1+\beta)R_E}$ $V_{TH} = \frac{R_2}{R_2 + R_1} V_{CC}, assume\ \beta = 100$	0.011 mA
$I_{CQ} = \beta I_{BQ}$	1.11 mA
AC Parameters	
$R_{in} = r_\pi + (1+\beta)R_L$ $r_\pi = \frac{\beta V_T}{I_{CQ}}$	224.54 kΩ
$R_{out} = \frac{r_\pi}{1+\beta} \| \| R_E \| \| R_L$	22.7 Ω

6. Conclusion

Like the common emitter, the common collector had a similar structure to its circuit design. Computing its values were also similar to that of the values for a common collector, except the noticeable difference in the application from the different configurations. The common collector was used to amplify its input, while the common emitter was used as a voltage buffer.