UNIVERSITY OF CALIFORNIA AT BERKELEY
College of Engineering
Department of Electrical Engineering and Computer Sciences

EE105 Lab Experiments

Report 4: Single Stage BJT Amplifiers: Common Emitter

Solutions

1 Lab Questions

3.1.2 DC values and gain when biased at maximum gain:

$\boxed{V_{IN} = 642 \text{ mV}}$

$\boxed{V_{OUT} = 2.4 \text{ V}}$

$\boxed{A_v = -101}$

3.1.3 Using a load line for the pull up resistor on a BJT I-V curve, explain why a BJT has very low gain if it is not biased in the forward active region.

Each intersection of the load line and a BJT I-V curve denotes the operating point of the transistor given the V_{BE} corresponding to the BJT curve. I_C and V_{CE} are uniquely determined at each of these points. The input corresponds to a change in V_{BE}, which results in a change in V_{CE}. In the forward active region, the constant V_{BE} curves are spaced far apart, meaning that a small change in V_{BE} results in a huge change in V_{CE}. In the saturation region, these curves are very close together, meaning that small change in V_{BE} will not create a significant change in V_{CE}.

3.2.1 What is the input resistance?

$\boxed{R_{in} = 2.802 \text{ k}\Omega}$

3.2.2 What is the gain measured with the oscilloscope? Is the gain measured with the oscilloscope roughly the same as the gain you measured with ICS?

$\boxed{A_v = -100}$

3.2.3 Why does clipping happen at the top? Why does clipping happen at the bottom? What is the output voltage swing?

Clipping at the top occurs because the output is limited by V_{CC}. Clipping at the bottom occurs because the transistor goes into deep saturation.

$\boxed{\text{Output Voltage Swing} = 3.750 \text{ V}}$

3.2.4 Why is the capacitor needed when we attach the load?

The load itself is a part of the circuit. Attaching the load directly to V_{OUT} will affect the DC bias of the transistor. The capacitor is used to block DC signals from reaching the node (remember that a capacitor acts like an open circuit for DC) while allowing AC signals to freely pass through.

3.2.5 What is the output resistance of the amplifier?

$\boxed{R_{out} = 1\ \text{k}\Omega}$

3.3.2 DC values and gain when biased for maximum gain:

$\boxed{V_{IN} = 980\ \text{mV}}$

$\boxed{V_{OUT} = 1.3\ \text{V}}$

$\boxed{A_v = -9.25}$

Is the gain more or less than the gain found without the degenerating resistor? Give an explanation for what's going on in the circuit that causes this change in gain.

The gain is reduced by the emitter degeneration resistor. As V_{BE} is increased, I_C increases. This same I_C will flow through R_E, and increases the voltage at the emitter. This effectively reduces V_{BE} and creates a negative feedback to V_{BE} for any attempted increase in V_{BE}. Thus, the gain is reduced.

3.3.3 Measured amplifier parameters:

$\boxed{R_{in} = 230.8\ \text{k}\Omega}$

$\boxed{R_{out} = 9.5\ \text{k}\Omega}$

How are these affected by the emitter degeneration resistor? Why?

$R_{in} = r_\pi + (1+\beta)R_E$ will increase, since R_E is now non-zero. $R_{out} = r_o + r_\pi \parallel R_E + g_m r_o (r_\pi \parallel R_E)$ will also increase due to a non-zero R_E.

3.3.4 Theoretical amplifier parameters:

$\boxed{R_{in} = 270\ \text{k}\Omega}$

$\boxed{R_{out} = 10\ \text{k}\Omega}$

$\boxed{A_v = -10}$

3.3.5 Why might emitter degeneration be useful?

Decreased gain results in a more stable circuit. Negative feedback also improves resistance to temperature effects. The boost to the input resistance would be useful if the source driving the amplifier has a large output resistance.

3.4.1–4 Compare the loudness of the speaker for the two following cases: 10 mV, 1 kHz signal applied directly to speaker, and speaker placed on the output of the CE amplifier biased with a 1 kΩ resistor. Which is the loudest and why?

Nothing should be heard for any of these cases. The impedance of the speaker is too low to be driven by the CE, despite its huge gain.

2 Post-Lab Questions

2.1 Amplifier Two-Port Model

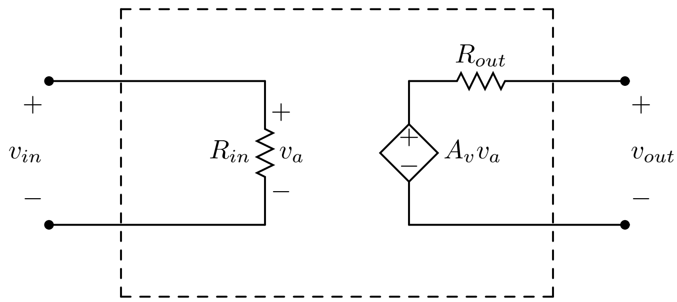


Figure 1: Generalized voltage amplifier

1. A CE amplifier can be represented as a generalized voltage amplifier shown in Figure 1, where R_{in}, R_{out}, and A_v are the values you found for input resistance, output resistance, and voltage gain, respectively. This generalization was accomplished by applying the concept of a Thévenin equivalent circuit on its small signal model. Now suppose that v_{in} is an ideal source supplying a 1 kHz, 20 mV peak-to-peak sine wave. What is v_{out}? Use the values obtained from the lab (no emitter degeneration, 10 kΩ biasing resistor) for R_{in}, R_{out}, and A_v.

$$\begin{aligned} v_{out} &= A_v v_{in} \\ &= (-101)\,(10\text{ mV} \times \sin(1\text{ kHz} \times t)) \\ &= -1.01\text{ V} \times \sin(1\text{ kHz} \times t) \end{aligned}$$

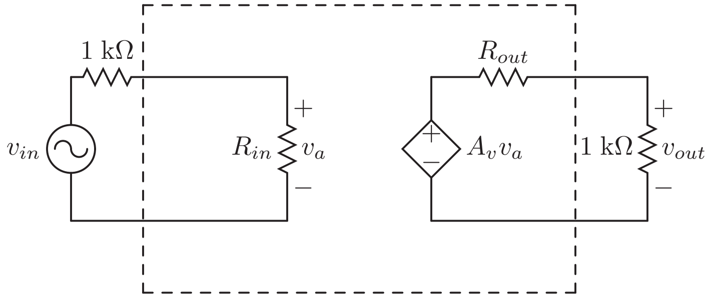


Figure 2: Voltage amplifier with non-ideal source and load attached

2. Now suppose a non-ideal voltage source with an internal source resistance of 1 kΩ was attached at v_{in}, and a load resistance of 1 kΩ was attached at the output as shown in Figure 2. If a 10 mV peak-to-peak sine wave was applied at the input, what would be the signal across the load?

$$v_{in}\left(\frac{R_{in}}{1\text{ k}\Omega + R_{in}}\right) A_v \left(\frac{1\text{ k}\Omega}{1\text{ k}\Omega + R_{out}}\right) = v_{out}$$

Given $R_{in} = 38.2$ kΩ, $R_{out} = 9.3$ kΩ, $A_v = -101$, and $v_{in} = 10\text{ mV} \times \sin(1\text{ kHz} \times t)$.

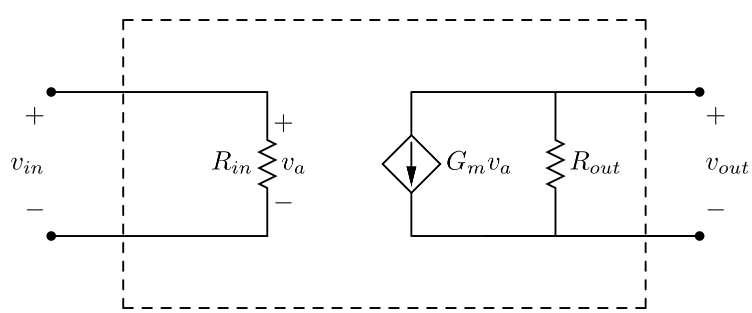
$$v_{out} = -95.6\text{ mV}\sin(1\text{ kHz} \times t)$$

3. A good voltage amplifier is one that can get the greatest possible voltage drop across the load given an input. If the gain was fixed, what input and output impedances would the ideal voltage amplifier have? Why?

$$R_{in} = \infty$$
$$R_{out} = 0\ \Omega$$

This input impedance would allow all of the input voltage to be used towards amplification, and the output impedance of 0 Ω would allow the entirety of the output voltage to be dropped across the load.

4. A CE amplifier can also be generalized as a transconductance amplifier (input is a voltage, but output is a current related to the input voltage by the transconductance G_m). Using a Norton equivalent cicuit on the CE small signal model, draw the CE amplifier as a generalized transconductance amplifier (*Hint: It will look similar, but not completely identical to Figure 1*). Find G_m using the data you have collected from the lab (no emitter degeneration, 10 kΩ biasing resistor).



$$G_m = \frac{A_v}{R_{out}} = \frac{-101}{9.3\text{ k}\Omega} = -10.86\text{ mS}$$

5. A good transconductance amplifier is one that can get the greatest possible current through the load given an input voltage. Given a fixed gain, what input and output impedances would the ideal transconductance amplifier have? Why?

$$R_{in} = \infty$$
$$R_{out} = \infty$$

The input impedance, again, allows all input voltage to be utilized for amplification, and the output resistance here is high enough to divert all of the current to the output port.

6. Extending the idea further, we can also talk about current amplifiers. If a good current amplifier is one that can get the greatest current through the load, what input and output impedances would the ideal current amplifier have? Why?

$$R_{in} = 0\ \Omega$$
$$R_{out} = \infty$$

The input impedance allows maximum input current to be utilized for amplification, and the output impedance forces all current to be delivered to the load.