THE GEORGE WASHINGTON UNIVERSITY

WASHINGTON, DC

SCHOOL OF ENGINEERING AND APPLIED SCIENCE
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
ECE 2115: ENGINEERING ELECTRONICS LABORATORY

Tutorial #6:
Designing a Common-Collector Amplifier

BACKGROUND

In the previous lab, you designed a common-emitter (CE) amplifier. Voltage gain (A_V) is easy to achieve with this type of amplifier. As you discovered, the input impedance (R_{in}) of the CE amplifier is moderate-to-high (on the order of a few kΩ). The output impedance (R_{out}) is high (roughly the value of R_C). This makes the common-emitter amplifier a poor choice for "driving" small loads.

A common-collector (CC) amplifier typically has a **high input impedance** (typically in the hundred kΩ range) and a very **low output impedance** (on the order of 1Ω or 10Ω). This makes the common-collector amplifier excellent for "driving" small loads. As you discovered in Lab 6, the common-collector amplifier has a voltage gain of about 1, or **unity gain**. The common-collector amplifier is considered a **voltage-buffer** since the voltage gain is unity. The voltage signal applied at the input will be duplicated at the output; for this reason, the common-collector amplifier is typically called an **emitter-follow amplifier**. The common-collector amplifier can be thought of as a **current amplifier**.

When the common-emitter amplifier is cascaded to a common-collector amplifier, the CC amplifier can be thought of as an "**impedance transformer**." It can take the high output impedance of the CE amplifier and "transform" it to a low output impedance capable of driving small loads.

Figure 1 shows a typical configuration for a common-collector amplifier. The input voltage is applied to the base while the output voltage is measured at the emitter.

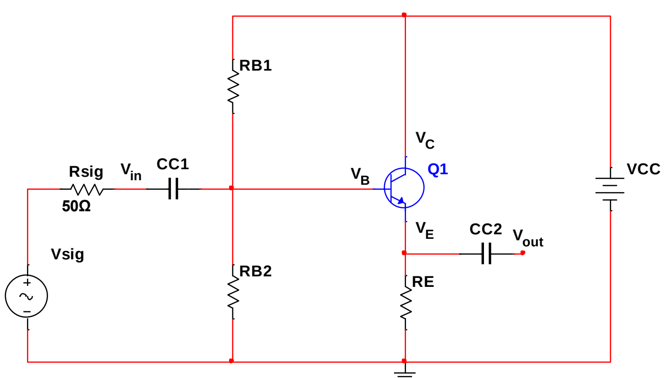

Figure 1 – Common-Collector Amplifier

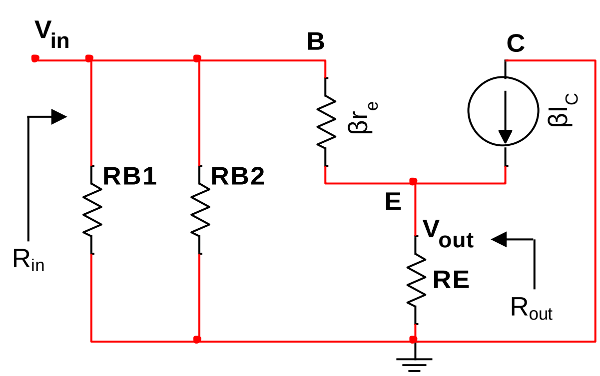

Figure 2 – Small Signal (AC) Equivalent (Neglecting R_{sig})

From the AC equivalent of the common-collector amplifier in **Figure 2**, we can derive expressions for the **input impedance**, **output impedance**, and **voltage gain**:

$\boldsymbol{R_{in}} = R_{B1}||R_{B2}||[\beta r_e + (\beta+1)R_E]$ (no load) (Remember: $r_e = V_T / I_E$, where V_T = 26mV)

$\boldsymbol{R_{out}} = R_E||r_e$ but $r_e << R_E \rightarrow Z_o \approx r_e$ (notice this is VERY small)

$\boldsymbol{A_V} = \frac{V_{out}}{V_{in}} = \frac{(\beta+1)i_b R_E}{\beta i_b r_e + (\beta+1) i_b R_E} \cong \frac{\beta i_b R_E}{\beta i_b (r_e + R_E)} = \frac{R_E}{r_e + R_E}$, but since $r_e << R_E$, then
$\boldsymbol{A_V} \approx 1$

INSTRUCTIONS

Designing a Common-Collector Amplifier

Problem: Design a common-collector amplifier using the 2N3904 transistor that meets the following specs:

- I_C = 1mA
- V_{CC} = 20V
- R_{in} = 70kΩ
- R_L = 510Ω
- V_{in} = 10mV @ 10kHz

1. **Determine** the value of $\mathbf{R_E}$.
    a. We typically make $\mathbf{V_E = ½ V_{CC}}$ to ensure the largest possible symmetric output voltage swing around V_E.
    b. It is safe to assume that $\mathbf{I_E \approx I_C}$.
    c. **Calculate** the value of $\mathbf{R_E}$.

2. **Determine** the **"Q" point** of the transistor.
    a. Because you now know V_{CE} and I_C, you can use the same procedure from the "**Designing a Common-Emitter Amplifier**" tutorial to create an IV-curve for the transistor and determine the Q-point of the transistor. This will help you determine the necessary "base current" needed to achieve the specified I_C.
    b. **Use** the Q-point data to find DC values for: I_B, V_B, I_E, and β.

3. **Use** $\mathbf{V_{CC}}$, $\mathbf{V_B}$, $\mathbf{I_B}$, $\mathbf{I_E}$, and $\mathbf{R_{in}}$ to find $\mathbf{R_{B1}}$ and $\mathbf{R_{B2}}$.
    a. **Follow** the procedure from the previous tutorial to generate the same **three** equations for V_{BB} (**Equation 1**), R_B (**Equation 2**), and I_B (**Equation 3**).
    b. **Use** the equation derived in the first part of *this* tutorial for $\mathbf{R_{in}}$ as **Equation 4**.
    c. **Calculate** $\mathbf{R_{B1}}$ and $\mathbf{R_{B2}}$ using the four equations.

4. **Check** your calculations.
    a. **Use** the R_{in} equation to calculate $\mathbf{R_{in}}$. Is it 70kΩ?
    b. **Use** the R_{out} equation to calculate $\mathbf{R_{out}}$. Is it very small?

5. **Set** values for $\mathbf{C_{C1}}$ and $\mathbf{C_{C2}}$.
    a. The impedance of a capacitor is $Z_C = \frac{1}{j2\pi fC}$. We can use this knowing that we want $\mathbf{C_{C1}}$ and $\mathbf{C_{C2}}$ to all look like "shorts" at 10kHz (the input frequency), and select a value that we have in the ECE 2115 kit.

6. **Determine** the **current gain** ($\mathbf{A_i}$) of the amplifier.
    a. **Current gain** is defined as $\mathbf{A_i = I_{out} / I_{in}}$.
    b. **Use** the equations for $\mathbf{A_V}$, $\mathbf{R_{in}}$, and $\mathbf{R_{out}}$, Ohm's law, and a little algebra to determine the equation for $\mathbf{A_i}$.
    c. **Calculate** $\mathbf{A_i}$ for your amplifier. **Verify** current gain using a Multisim transient simulation.

7. **Verify** your calculations using Multisim.
    a. **Simulate** your amplifier. **Check** the bias-point (DC) analysis to determine if your transistor is at the Q-point you desire.
    b. **Perform** a transient simulation to verify the **voltage gain**, **current gain**, $\mathbf{R_{in}}$, and $\mathbf{R_{out}}$.