The George Washington University
School of Engineering and Applied Science
Department of Electrical and Computer Engineering
ECE 20 – SPICE Tutorial 6

Designing a Common-Collector Amplifier

Background:

In the previous lab you design a common-emitter (CE) amplifier. Voltage gain (Av) is easy to achieve with this type of amplifier. As you discovered the input impedance (RIN) of the CE is moderate-to-high (on the order of a few kilo-Ohms). The output impedance (ROUT) is high (roughly the value of RC). 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 kilo-Ohm range) and a very low output impedance (from 1 to ~tens of Ohms). This makes the common-collector amplifier excellent for 'driving' small loads. As you discovered in lab 5, the common-collector amplifier has a voltage gain of about 1, or unity. The common-collector amplifier is considered a voltage-buffer, as 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 a "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 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 1.1 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.

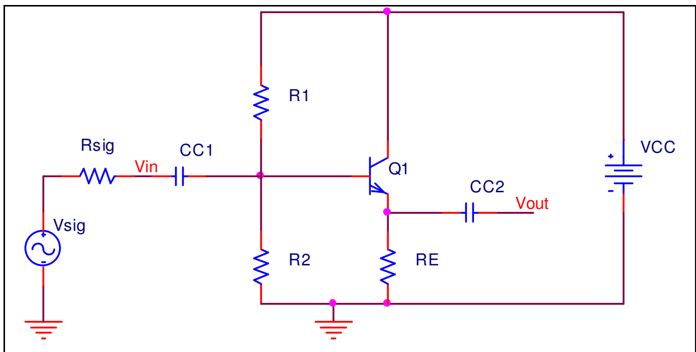

Fig 1.1 – Common Collector Amplifier

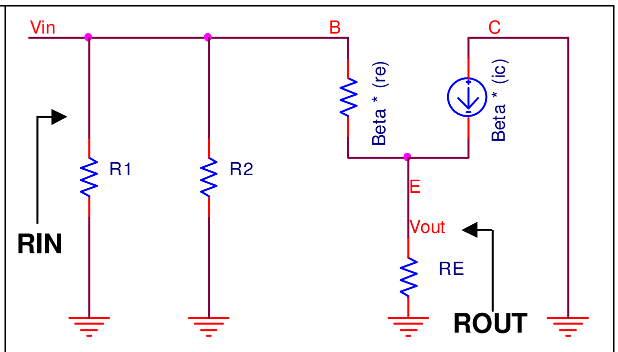

Fig 1.2 - Small Signal (AC) equivalent (neglecting Rsig)

From the AC equivalent of the common-collector amplifier in figure 1.2, we can derive the input impedance, output impedance, and voltage gain:

RIN = R1 || R2 || [βre + (β+1) RE] (no load) (Remember: re = VT / IE, where VT = 26mV

ROUT = RE || re but re << RE → Zo ≈ re (notice this is VERY small)

$$Av = \frac{Vout}{Vin} = \frac{(\beta+1)ib * RE}{(\beta)(ib)(re) + (\beta+1)(ib)(RE)} \cong \frac{(\beta)ib * RE}{(\beta)ib(re+RE)} = \frac{RE}{(re+RE)}$$, but since re << RE, then:

$$Av \approx 1$$

Designing a Common-Collector Amplifier

Problem: Design a Common-Collector Amplifier using the 2N3904 transistor that meets the following specifications:

IC = 1mA
VCC = 20 Volts
Rin = 70KΩ
RL = 510Ω
v*in* = 10mV @ 10kHz

Step 1) Determine the size of RE

- We typically make VE = ½ VCC, to ensure the largest possible symmetric output voltage swing (around VE)
- It is safe to assume that IE ≈ IC
- Calculate the value of RE

Step 2) Determine the "Q" point of the transistor

- Because you now know VCE & IC, you can use the same procedure from the "Designing a Common-Emitter Amplifier Tutorial" to create an IV-curve for the transistor & determine the Q-point of the transistor. This will help you determine the necessary "base current" needed to achieve the specified IC.
- Use the Q-point data to find DC values for: IB, VB, IE, β

Step 3) Use VCC, VB, IB, IE, and RIN, to find R1 and R2

- Follow the procedure from the "*Designing a Common-Emitter Amplifier Tutorial"* to generate the same 3 equations for VBB (**eqn 1**); RB (**eqn 2**); and IB (**eqn 3**).
- Use the equation derived the first part of *this* tutorial for **RIN** as **equation 4**.
- Calculate R1 and R2 using the 4 equations

Step 4) Check your calculations
- Using the RIN equation, calculate RIN. Is it 70k?
- Using the ROUT equation, calculate ROUT, is it very small?

Step 5) Set values for CC1 & CC2

- The impedance of a capacitor Zc = 1/j2πfC, make CC1, CC2 look like a 'short' at 10kHz (the input frequency), and make sure the size you choose for CC1 and CC2 matches a capacitor value you have in your ECE 20 kit.

Step 6) Determine Current Gain (Ai) for the amplifier

- Current gain is defined as: Ai= Iout / Iin
- Use the equations for Av, RIN, and ROUT, ohms law & a little algebra to determine the equation for Ai
- Calculate Ai for your amplifier, verify current gain using a SPICE transient simulation.

Step 7) Verify your calculations using SPICE

- Simulate your amplifier. Check the bias-point analysis to determine if your transistor is at the Q-point you desire.
- Perform a transient simulation to very the Voltage gain, current gain, RIN and ROUT.