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

EE105 Lab Experiments

Prelab 7: Frequency Response

Solutions

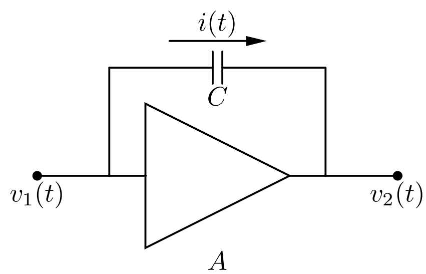

Figure 1: Amplifier with a "Miller" capacitor

The Miller effect plays an important role in determining the poles of an amplifier. If there is a gain A across the capacitor C as shown in Figure 1, the current across C can be written as:

$$i(t) = C\tfrac{d}{dt}(v_1(t) - v_2(t)) = C\tfrac{d}{dt}(v_1(t) - Av_1(t))$$

By distributing the derivative, this simplifies to:

$$i(t) = C(1-A)\tfrac{d}{dt}v_1(t)$$

Therefore, the equivalent capacitance looking into $v_1(t)$ is the capacitance C multiplied by $(1-A)$. If the gain A is large enough, this Miller effect can make the capacitor dominate and contribute to the dominant pole of the amplifier. Using this same method, you can derive the equivalent capacitance looking into $v_2(t)$, which is $C(1-1/A)$.

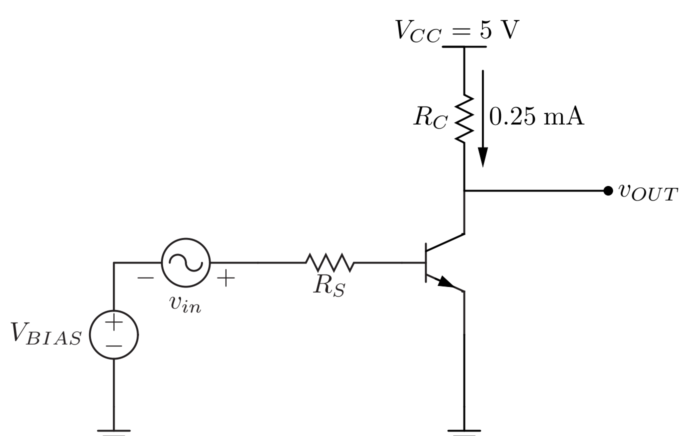

Figure 2: Common emitter amplifier

1. For the common emitter amplifier shown in Figure 2, use the Miller approximation to derive the expressions for the two poles of v_{out}/v_{in} in terms of C_μ, C_π, g_m, R_S, r_π, and r_o. These expressions will help you predict and understand the results of the lab.

The small signal model is shown in Figure 3.

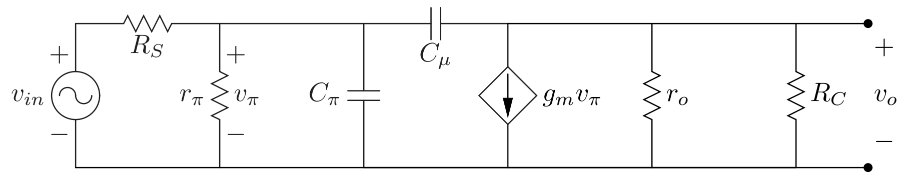

Figure 3: Small signal model of the common emitter amplifier

Using a Thévenin equivalent circuit and the Miller approximation, the small signal model can be reduced to the circuit shown in Figure 4.

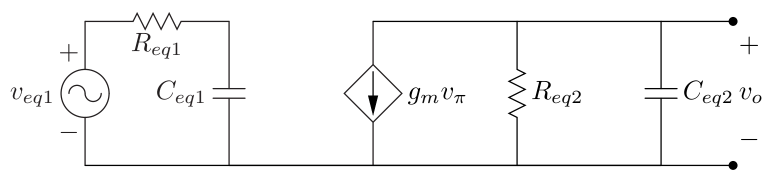

Figure 4: Reduced small signal model of the common emitter amplifier

In Figure 4, $v_{eq1} = v_{in}\frac{R_\pi}{R_S+r_\pi}$, $R_{eq1} = \frac{r_\pi R_S}{R_S+r_\pi}$, $C_{eq1} = C_\pi + C_\mu\left(1+g_m\frac{r_oR_C}{r_o+R_C}\right)$, $R_{eq2} = \frac{r_oR_C}{r_o+R_C}$, and $C_{eq2} = C_\mu\left(1+\frac{1}{g_m}\frac{r_o+R_C}{r_oR_C}\right)$.

So $\omega_{p1} = \frac{1}{R_{eq1}C_{eq1}}$ and $\omega_{p2} = \frac{1}{R_{eq2}C_{eq2}}$.

$$\boxed{\omega_{p1} = \frac{R_S + r_\pi}{R_S r_\pi\left[C_\pi + C_\mu\left(1+g_m * \frac{r_oR_C}{r_o+R_C}\right)\right]}}$$

$$\boxed{\omega_{p2} = \frac{r_o + R_C}{r_oR_CC_\mu\left(1+\frac{1}{g_m}\frac{r_o+R_C}{r_oR_C}\right)}}$$

2. If $R_S = 51\ \Omega$, $R_C = 10\ \mathrm{k\Omega}$, $C_\mu = 11$ pF, $C_\pi = 25$ pF, $g_m = 3$ mS, $r_\pi = 10\ \mathrm{k\Omega}$, and $r_o = 100\ \mathrm{k\Omega}$, what are the poles of this amplifier?

$$\boxed{\omega_{p1} = 58.6543\text{ MHz}}$$

$$\boxed{\omega_{p2} = 9.6463\text{ MHz}}$$

3. What will happen to the poles if a capacitor C_M is added across the base collector junction?

   Adding a capacitor C_M across the base collector junction will add to C_μ. This will reduce the two poles of the amplifier.

4. SPICE

   - Construct the common emitter amplifier circuit shown in Figure 2 in SPICE. Use $V_{BIAS} = 0.56$ V, $R_S = 51\ \Omega$, and $R_C = 10\ \mathrm{k}\Omega$.
   - Use the 2N4401 SPICE model provided on the course website.
   - Perform an AC analysis of the circuit from 100 Hz to 10 GHz in HSPICE.
   - Use Awaves to generate Bode plots (both magnitude and phase) for the circuit for v_{out}/v_{in}. Attach the Bode plots to this prelab worksheet. Do the results agree with your hand calculations (check the pole frequencies)?

   SPICE netlist:

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* EE105 Lab7 Prelab Solution

Vb vin vb ac 1
Vbias Vb gnd 0.58
QBJT Vout Vs gnd N4401
Vcc vc gnd 5
rc vc vout 10k
rs vin Vs 51


.model N4401   NPN(Is=26.03f Xti=3 Eg=1.11 Vaf=90.7 Bf=4.292K Ne=1.244
+               Ise=26.03f Ikf=.2061 Xtb=1.5 Br=1.01 Nc=2 Isc=0 Ikr=0 Rc=.5
+               Cjc=11.01p Mjc=.3763 Vjc=.75 Fc=.5 Cje=24.07p Mje=.3641 Vje=.75
+               Tr=233.7n Tf=466.5p Itf=0 Vtf=0 Xtf=0 Rb=10)

.ac dec 100 1k 1T
.option post=2
.end
```

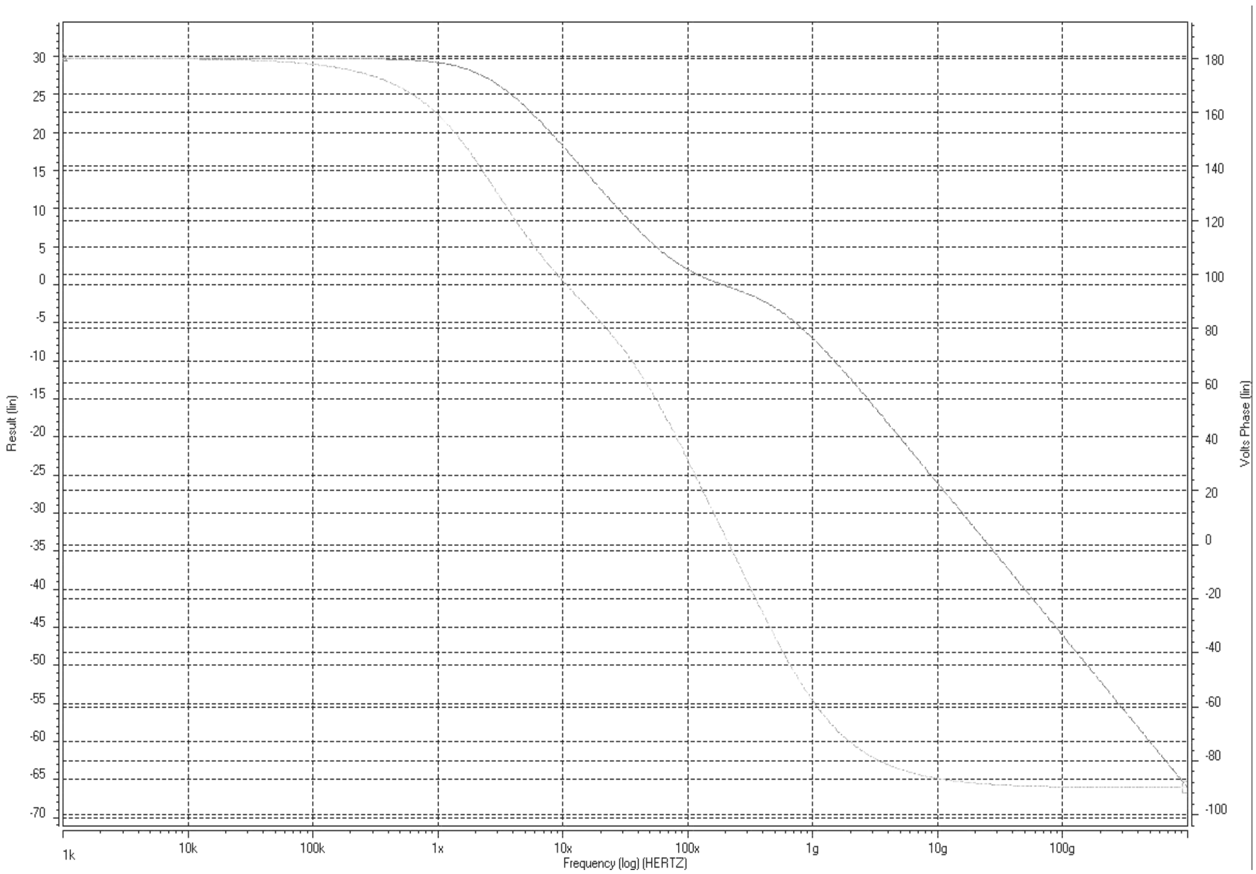

Figure 5: Frequency response from SPICE