Discussion #13

Announcements

1. Lab 9 this week (BJT measurements)
   - turn in Lab 8 reports
   - do Lab 9 problems before lab
   - no Lab 9 report, we will check off in lab

2. Extra office hours before exam
   - what time/day is preferred?
   - early (this week) or right before exam?
   - time of day?

BJT biasing and amplifier example (basic amp equations are in book, this addresses practical issues)

![BJT Circuit Diagram]

Why current mirror biasing?
1. Like in CMOS, gives less sensitivity to temp./process
2. IC in BJT very sensitive to small changes in Vbe, difficult to set Vbe precisely

*Biasing*

\[ I_{c2} = 500\mu A \Rightarrow I_{c1} = V_E = 0.5V \]

\[ V_{be} = V_T/(\alpha + 1) \approx (0.26)/(1 + (500\mu A/0.7A)) = 0.7V \]

\[ V_{bias} = 0.7V + 0.5V = 1.2V \]

\[ V_{out} = 5V - (5k)(500\mu A) = 2.5V \]
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* Small-signal params

\[ g_m = \frac{I_c}{V_t} = 14.2 \text{ mS} \]
\[ r_{in} = \frac{R_s}{g_m} = 5.2 \text{ k\Omega} \]
\[ R_o = \frac{V_A}{I_c} = \frac{20V}{500\mu A} = 40 \text{ k\Omega} \]

* Small-signal model

What to do about bias network?

\[
I_c = \frac{V_c - iRE}{r_{in}} + g_m (V_c - iRE)
\]
\[
\therefore \frac{V_c}{I_c} = \frac{RE/r_{in} + g_m RE + 1}{1/r_{in} + g_m} = \frac{1}{g_m (1 + g_m RE)} = \frac{1}{g_m + RE}
\]
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\[ R_{in2} = \frac{1}{g_m} + R_E + R_{6kh} = 52 + 1000 + 20k \approx 21k\Omega \]

\[ R_{in1} = r_{11} + \beta R_E = 5.2k + 100(1k) = 105k\Omega \]

\[ \Rightarrow R_{in} = R_{in1} // R_{in2} = 17.5k\Omega \ll R_{in1} \]

S-S model

\[ g_m = \frac{g_m}{1 + g_m R_E} \approx 1mS, \quad R_{out} = \frac{V_o}{(1 + g_m (r_{11} // R_E))} = 684k\Omega \]
\[ \frac{V_o}{V_i} = A_v = \frac{R_{in}}{R_{in} + R_S} \frac{g_m \cdot R_C}{\beta \cdot R_C} \cdot \frac{R_{out}}{R_{out} + R_C} \approx 1 \quad (R_{out} \gg R_C) \]

\[ = \frac{R_{in}}{R_{in} + R_S} \frac{g_m \cdot R_C}{\beta} 
= \frac{R_{in}}{R_{in} + R_S} \frac{R_C}{1 + g_m \cdot R_E} \]

\[ = \frac{17.5k}{17.5k + 5k} \cdot \frac{5k}{1k} = (6.78)(5) \approx 3.4 \]

*Summary of degeneration effects*

1. Increases \( R_{in} \) of BJT (good), but watch out for input resistance of bias network

2. Increases \( R_{out} \) of BJT (like cascade, good)

3. Stabilizes operating point, not so sensitive to absolute base voltage (good)

4. Reduces \( g_m \) by \((1 + g_m \cdot R_E)\) and therefore gain goes down (bad) (tradeoff)