ECS Undergraduate

Problem #1:

An operational amplifier is used to make a feedback amplifier as shown above. Its open-loop Bode gain plot is approximated as sketched on the right side with straight lines. Assume that the second pole frequency $\omega_0$ of the open-loop transfer function is the same as the unity-gain frequency.

1. What is the low-frequency gain of this amplifier?

$$\frac{V_o}{V_i} = \frac{90k + 10k}{10k} = 10 \text{ (20dB)}$$

2. Estimate the bandwidth of this amplifier.

$$\text{BW} = \omega_m \times \frac{1}{10} = 10^6 \text{ rad/s}$$

3. Using the same straight-line approximation, sketch the frequency response of the amplifier on the same plot, and mark important points with proper gain and frequency.

4. Approximate the phase margin of this feedback configuration.

$$\rho M = 90^\circ - \phi_m - \frac{1}{10}$$

5. Repeat the above questions 2 and 3 if the feedback resistor $R_2$ is bypassed using a 100pF capacitor.

$$\text{BW} = \frac{1}{90k \times 100 \text{pF}} \approx 1.1 \times 10^5 \text{ rad/s}$$
Problem #2:

A BJT amplifier is shown with the input bias voltage $V_i$ to set the collector current. Both the input and output small signals are marked as the low-case $v_i$ and $v_o$, respectively. Neglect other parameters unless specified except for the followings: $kT/q = 25mV$, $V_{BE} = 0.7V$, $V_{CESat} = 0.2V$. First assume that the emitter resistor $R_E$ is set to 0.

1. Sketch the DC transfer function of $V_o$ vs. $V_i$ in the above space, and add proper voltage scales.

2. If the DC bias voltage $V_i$ is applied to set the collector current to be $1mA$, what is the output DC voltage?

   \[ V_o = 5V - 2kT/q \times 1mA = 3V \]

3. Estimate the low-frequency small-signal voltage gain $v_o/v_i$ and the -3dB bandwidth.

   \[ g_m = \frac{1mA}{25mV} = \frac{1}{25} \]

   \[ \frac{v_o}{v_i} = -g_m R_L = -\frac{2kT/q}{25\Omega} = -10 \]

   \[ \beta_{BW} = \frac{1}{2kT/q \times 10pF} = 5 \times 10^7 \text{ rad/s} \]

4. Estimate $V_i$ to set the collector current to be $1mA$ if the emitter resistance $R_E$ is $1k\Omega$.

   \[ V_i = 1k\Omega \times 1mA + 0.7V = 1.7V \]

5. Repeat the above question 3 with the emitter resistance $R_E$ set to $1k\Omega$.

   \[ \frac{v_o}{v_i} = -\frac{g_m R_L}{1 + g_m R_E} = -\frac{2kT/q \times 25\Omega}{1 + \frac{kT/q}{25\Omega}} \approx -2 \]

   \[ \beta_{BW} \text{ stays the same.} \]