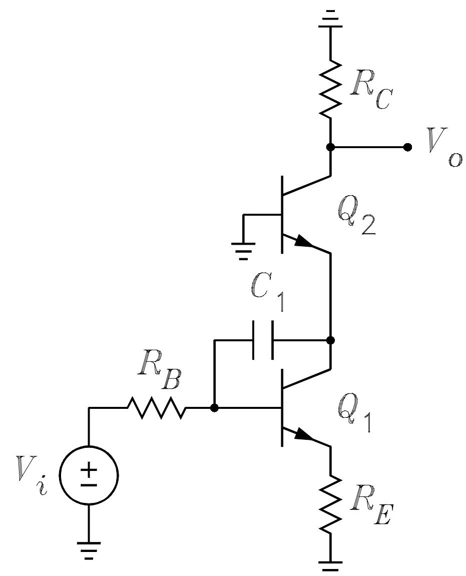
EE3050 Spring 2001
Some Practice Problems

1. The figure shows the ac signal circuit of a cascode amplifier. It is given that $\beta = 199$, $r_x = 20$, $V_T = 0.025$, $r_0 = \infty$, $I_{E1} = 1$ mA, $C_2 = 100$ pF, $R_B = 1$ kΩ, $R_E = 20$ Ω, and $R_C = 10$ kΩ. Note that the answers below would be more complicated if r_0 is not infinity.



(a) What is the low-frequency gain of the amplifier? Calculate this with C_1 an open circuit.

$$\frac{v_o}{v_i} = \frac{i_{c1}}{v_i} \times \frac{i_{c2}}{i_{c1}} \times \frac{v_o}{i_{c2}} = G_{mb1} \times \alpha_2 \times (-R_C)$$

where $R_{tb1} = R_B$ and $R_{te1} = R_E$.

(b) What is K in applying the Miller theorem to C_1?

$$K = -G_{mb1} \times (-r_{ie2})$$

where $r_x = 0$, $R_{tb1} = 0$, and $R_{te1} = R_E$.

(c) What is the time constant for the base circuit of Q_1?

$$\tau_{b1} = [R_B \| r_{ib}] (1 + K) C_1$$

(d) What is the time constant for the collector circuit of Q_1?

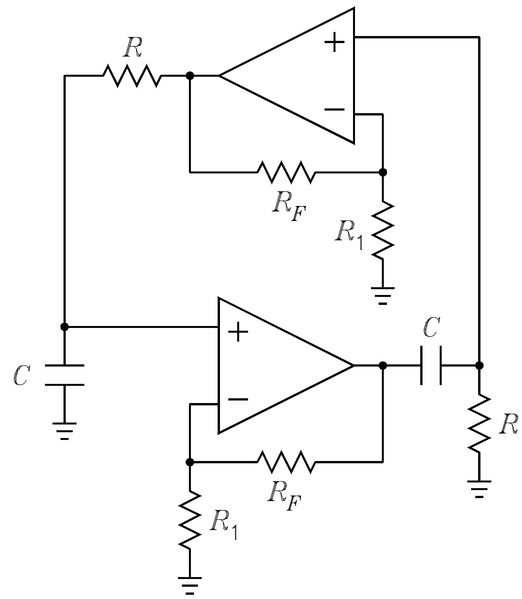
$$\tau_{c1} = r_{ie2} C_1$$

(e) What is the approximate upper cutoff frequency of the amplifier?

$$f_H \simeq \frac{1}{2\pi} \left(\frac{1}{\tau_{b1}^2} + \frac{1}{\tau_{c1}^2} \right)^{1/2}$$

(f) Repeat the problem with Q_2 removed and R_C connected to the collector of Q_1. [Leave the α_2 out of the equation for v_o/v_i, replace r_{ie2} with R_C in the equation for K, and replace r_{ie2} with R_C in the equation for τ_{c1}.] Calculate the percentage changes in the low-frequency gain and in the bandwidth.

2. The figure shows an oscillator circuit. Let $K = 1 + R_F/R_1$, i.e. the gain of each non-inverting op amp.



(a) Break the loop at the + input to the upper op amp and solve for the loop-gain transfer function.

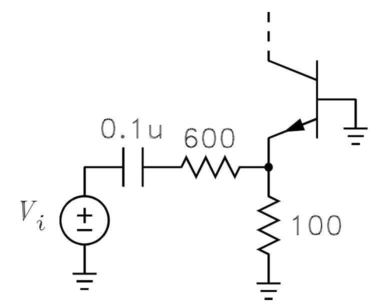
(b) Solve for the frequency at which the phase of the loop-gain transfer function is zero degrees. [$f = 1/2\pi RC$] This is the frequency at which the circuit can oscillate with a constant amplitude output if the magnitude of the loop-gain transfer function is unity at this frequency.

(c) Solve for K for the circuit to oscillate with a constant amplitude output. [$K = \sqrt{2}$]

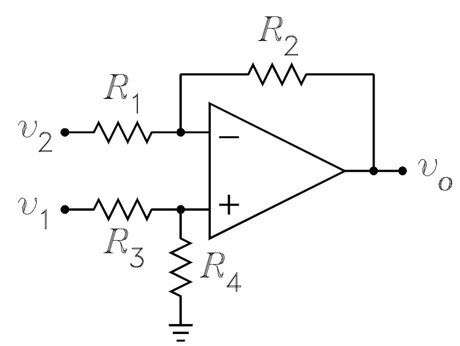
(d) If $C = 0.1\ \mu$F and $R_1 = 1$ kΩ, solve for R and R_F for a frequency of oscillation of $f_0 = 5$ kHz.

(e) Sketch the output voltage waveforms of the two op amps when the circuit operates as an oscillator. Assume that the relative phase of the output voltage from the upper op amp is 0^o. What is the phase difference between the two outputs? What is the amplitude difference?

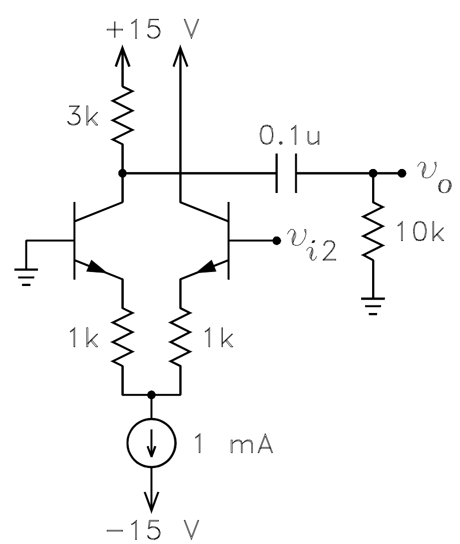
3. The BJT shown is biased at $I_E = 2$ mA. If $\beta = 199$, $r_0 = \infty$, and $r_x = 20\ \Omega$, solve for the time constant and pole frequency for the $0.1\ \mu$F capacitor. [$\tau = (600 \| 100 \| r_{ie}) \times 0.1\mu$] What is the transfer function that accounts for the effect of the capacitor on the gain of the circuit?



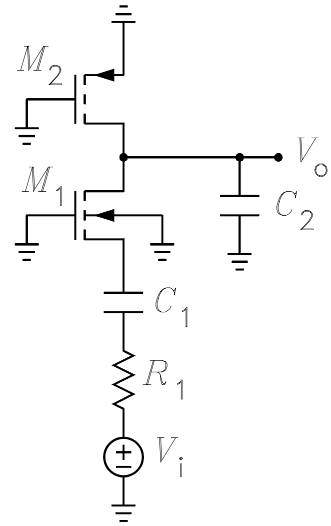
4. Use superposition of v_1 and v_2 to solve for v_o. What is the condition on the resistors for $v_o = A(v_1 - v_2)$ and what is the equation for A?



5. Each BJT has the parameters $\beta = 199$, $r_x = 20\ \Omega$, $r_0 = 30\ \text{k}\Omega$, and $V_T = 0.025$ V. Solve for the time constant for the 0.1 μF capacitor and the pole frequency. $[\tau = (3\text{k}\|r_{ic1} + 10\text{k}) \times 0.1\mu]$What is the transfer function that accounts for the effect of the capacitor on the gain of the circuit?



6. The figure shows a MOSFET amplifier. It is given that $R_1 = 50\ \Omega$, $C_1 = 0.1\ \mu$F, $C_2 = 10$ pF, $r_0 = 20\ \text{k}\Omega$, $\chi = 0.4$, and $g_m = 1/250$.



(a) Solve for the midband voltage gain of the circuit. [$v_o/v_i = G_{ms1} \times (-r_{id1} \| r_{02})$] [

(b) Solve for the transfer function for the effect of C_1. [High pass with $\tau_1 = (R_1 + r_{iso1})\, C_1$]

(c) Solve for the transfer function for the effect of C_2. [Low pass with $\tau_2 = r_{id1} \| r_{02} \times C_2$]