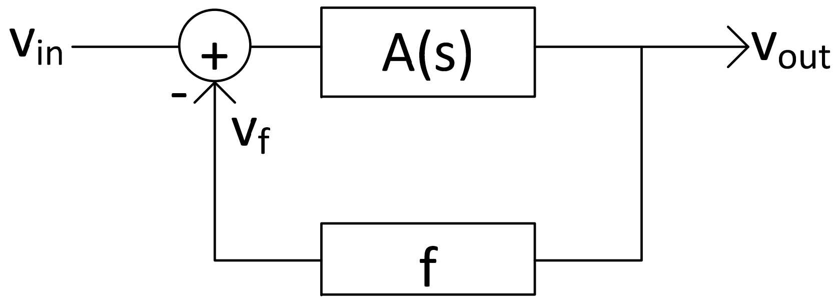
ECE 4220 Final Exam (Take Home)

Due Date: 12/17/2012, 3PM

Full Credit: 150-pt

- **No collaboration**
- **No discussion with any other**
- **No software simulation**
- **Only handcalculator allowed**

Some clarifications on feedback loop amounts

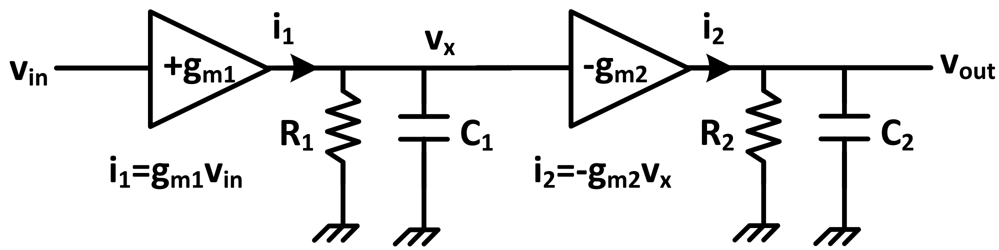


- In typical two-pole amplifier: $\mathrm{A}(s) = -A_o \frac{\omega_o{}^2}{s^2+\frac{\omega_o}{Q}s+\omega_o{}^2}$, **note: A_o is a positive number.**
- Loop gain: $\mathrm{T}(s) = -fA(s) = A_o \frac{\omega_o{}^2}{s^2+\frac{\omega_o}{Q}s+\omega_o{}^2} \times f$, **note: $A_o \times f$ is a positive number.**
- Overall gain: $A_f(s) = \frac{V_{out}}{V_{in}} = -A_{of} \frac{\omega_{of}{}^2}{s^2+\frac{\omega_{of}}{Q_f}s+\omega_{of}{}^2}$, **note: A_{of} is a positive number.**

Problem Set-1: Feedback Amplifier Design

- Consider an open-loop 2-stage amplifier in abstract level shown below. The transconductors are ideal transconductors, i.e., input and output impedances are infinite. Each parameter is given as:

$$g_{m1} = 2\ m\Omega^{-1}, R_1 = 100\ k\Omega, C_1 = 100\ fF$$
$$g_{m2} = 4\ m\Omega^{-1}, R_2 = 10\ k\Omega, C_2 = 200\ fF.$$

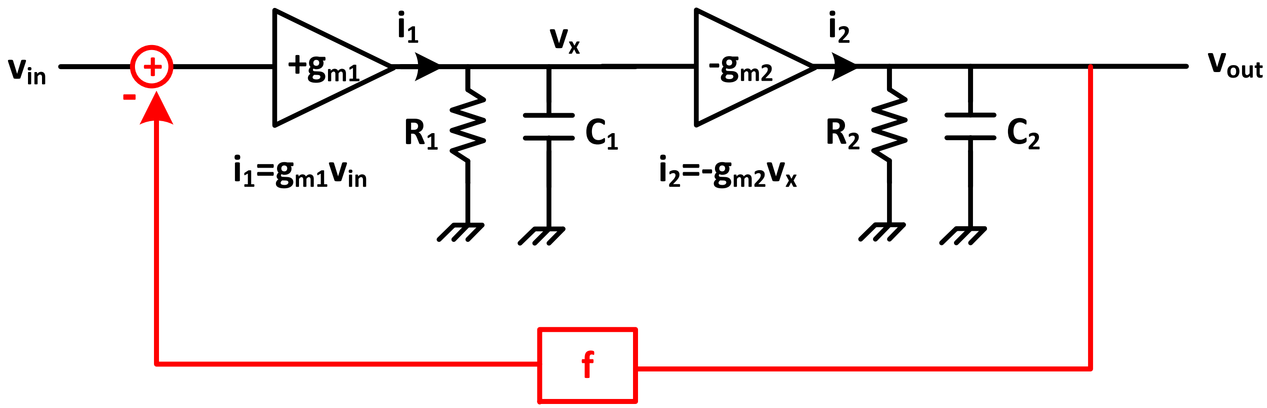


Q-1) Draw Bode plots (gain and phase plots) of transfer function, $A(s) = \frac{V_{out}}{V_{in}}$ (5pt).

Q-2) Find the canonical form of open-loop gain, $A(s) = -A_o \frac{{\omega_o}^2}{s^2+\frac{\omega_o}{Q}s+{\omega_o}^2}$. What are the system Q and the natural frequency ω_o? (5pt)

Problem Set-1: Feedback Amplifier Design

- Now let's apply a negative feedback. All the components values are the same as previous.



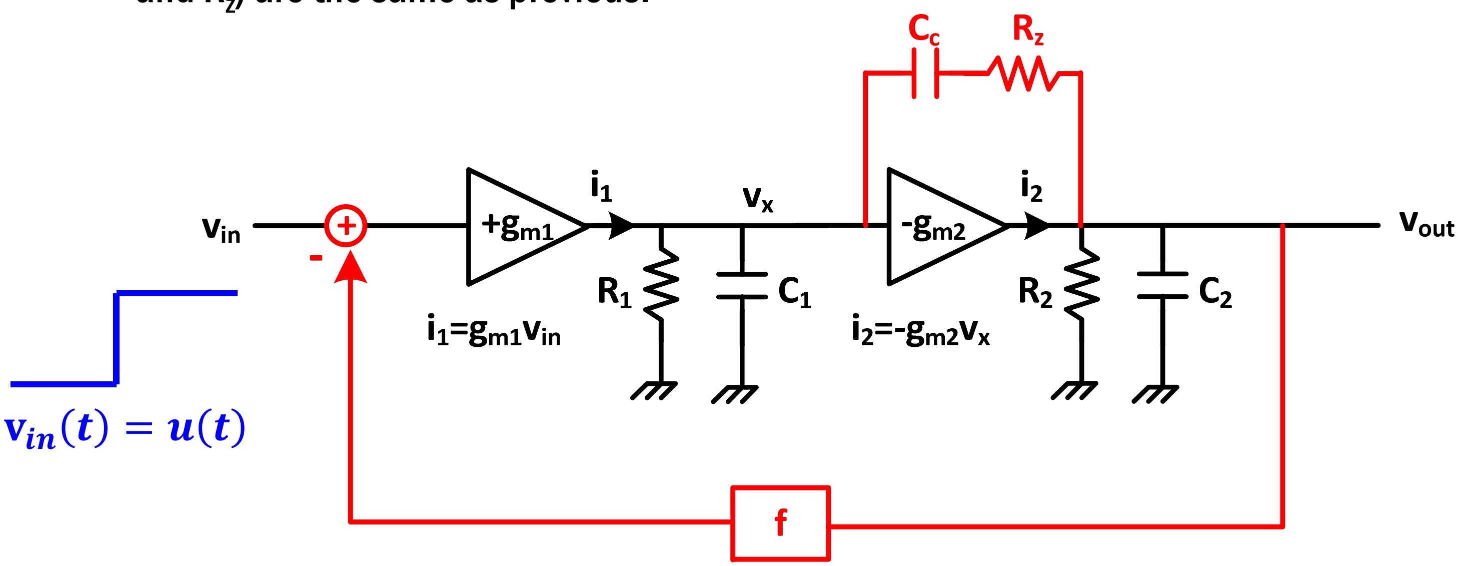
Q-3) Find the canonical form of overall closed-loop gain under the unity feedback (f=1), $A_f(s) = \frac{V_{out}}{V_{in}} = -A_{of}\frac{{\omega_{of}}^2}{s^2+\frac{\omega_{of}}{Q_f}s+{\omega_{of}}^2}$. Determine the system Q_f, peaking frequency ω_{pk}, relative peaking magnitude of $\left|\frac{A_f(j\omega_{pk})}{A_f(0)}\right|$, and phase margin (PM) (20pt).

Q-4) Determine the range of feedback factor f, where phase margin (PM) is larger than 45º (15pt).

Q-5) Set feedback factor f to get PM=45º. Determine the system Q_f, peaking frequency ω_{pk}, and relative peaking magnitude of $\left|\frac{A_f(j\omega_{pk})}{A_f(0)}\right|$ (10pt).

Problem Set-1: Feedback Amplifier Design

- Apply a frequency compensation network as shown below. All the components values (except for C_c and R_z) are the same as previous.



$\mathbf{v}_{in}(t) = u(t)$

Q-6) Design the frequency compensation network Cc and Rz to meet the following conditions when unity feedback f=1(15pt):

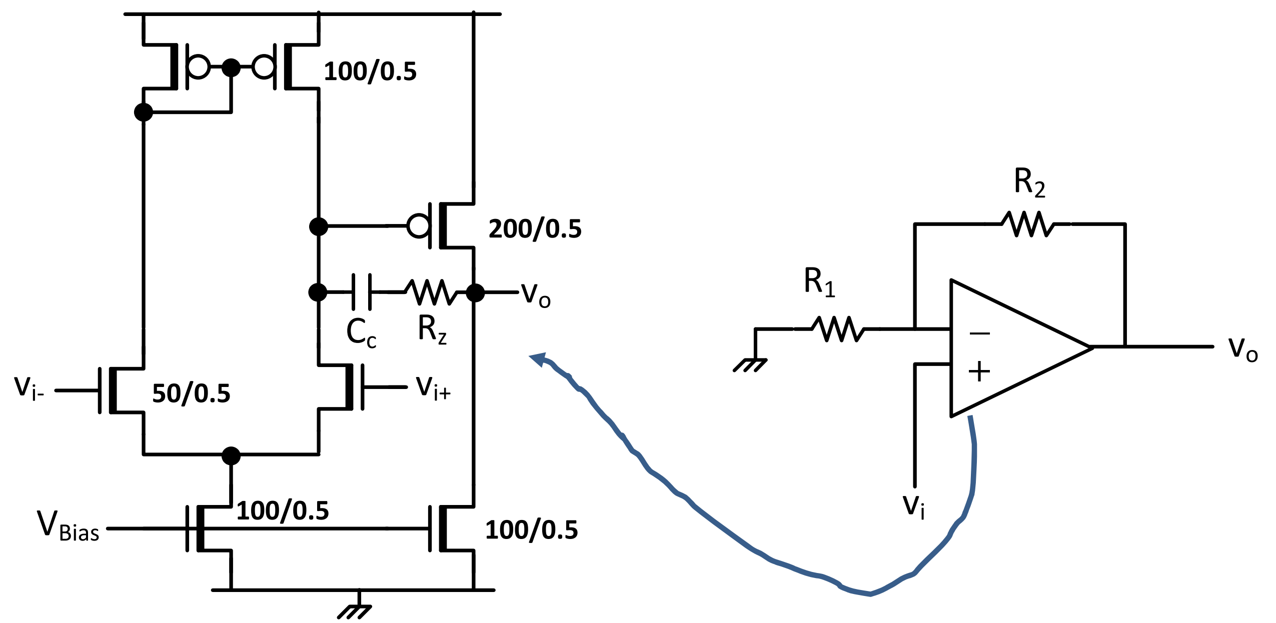
① PM=80º,

② Overall system has only 2 poles (no zero).

Q-7) When f=1 with PM=80º, apply a step input $\mathbf{v}_{in}(t) = u(t)$. Find output and sketch the output wave form. What is 0.1% settling time (0.1% settling time=the time when output reach 99.9% of its final value) (10pt)?

Problem Set-2: OP-AMP Application

- An opamp shown below has an open-loop gain of 80dB, and it has two negative poles and one negative zero at ω_{p1}=5x10^3, ω_{p2}=10^8, and ω_z=5x10^8 rad/s after standard miller compensation (Cc=30 pF). $\mu_n C_{ox}$=150 μA/V^2 and $\mu_p C_{ox}$=75 μA/V^2. Supply voltage is 3 V. A non-inverting amplifier with 20 dB of gain is configured based on the opamp.



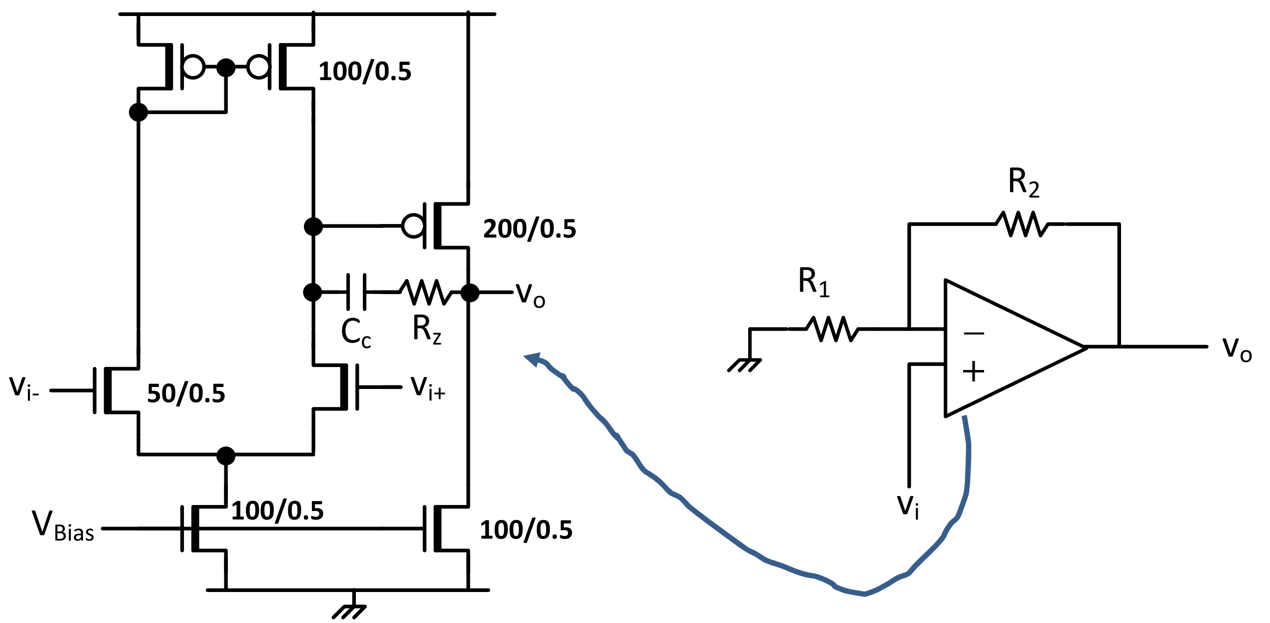
Q-8) Determine feedback factor (f) and estimate BW of the non-inverting amplifier (5pt).

Q-9) What's the phase margin of the non-inverting amplifier (10pt)?

Q-10) What are the maximum linear input and output signal range of the non-inverting amplifier (5pt)?

Problem Set-2: OP-AMP Application

- An opamp shown below has an open-loop gain of 80dB, and it has two negative poles and one negative zero at $\omega_{p1}=5\times10^3$, $\omega_{p2}=10^8$, and $\omega_z=5\times10^8$ rad/s after standard miller compensation (Cc=30 pF). $\mu_n C_{ox}=150\ \mu A/V^2$ and $\mu_p C_{ox}=75\ \mu A/V^2$. Supply voltage is 3 V. A non-inverting amplifier with 20 dB of gain is configured based on the opamp.



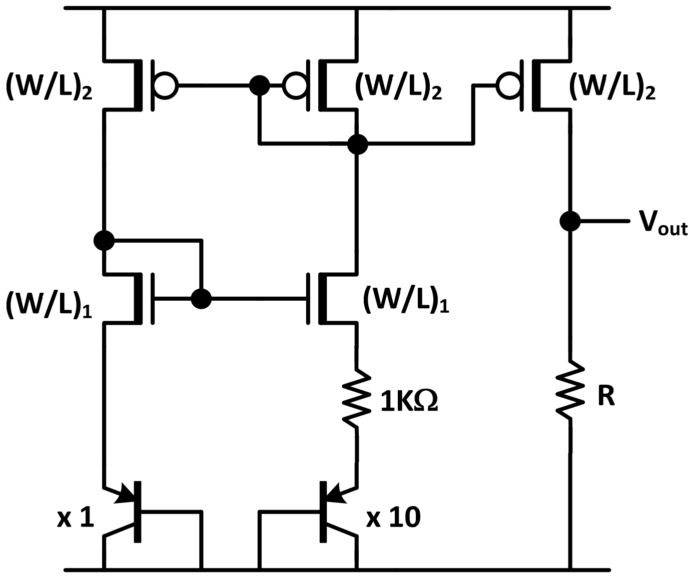
Q-11) Assume that you apply the maximum sinusoidal input to the non-inverting amplifier. Now you increase the inp ut frequency. What's the maximum input frequency at which the output is not distorted due to slew-rate limitation (10pt)?

Q-12) If you change the feedback factor so that the non-inverting amplifier has 10 dB gain while using the same op amp, then what are the BW and phase margin of the non-inverting amplifier (5pt)?

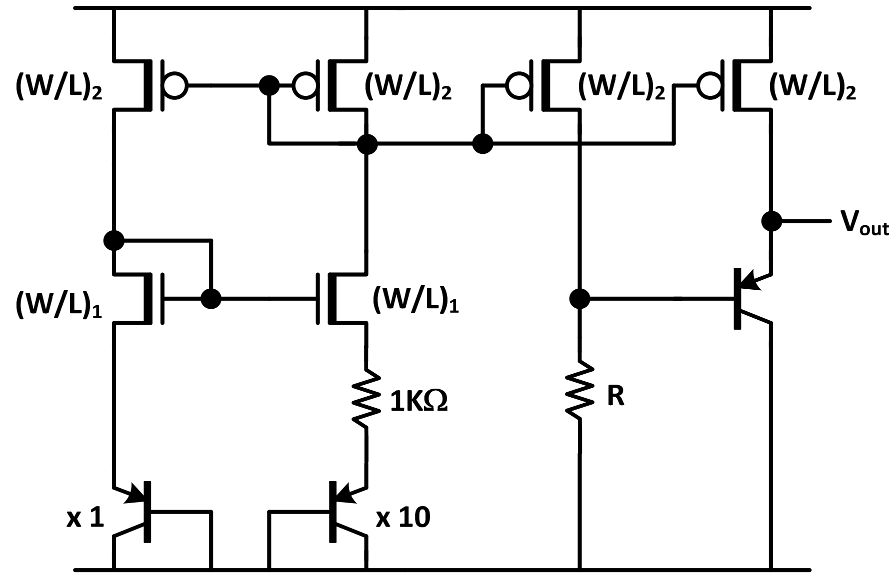
Problem Set-3: PTAT & Bandgap Reference

- Use these parameters for the question in this part: V_T=KT/q=26 mV at 300 ºK, $|V_{be}|$=0.7 V, $\frac{\partial |V_{be}|}{\partial T} = -1.65\ \mathrm{mV}/{}^{o}\boldsymbol{C}$.

<Electronic Thermometer>



<Bandgap Reference>

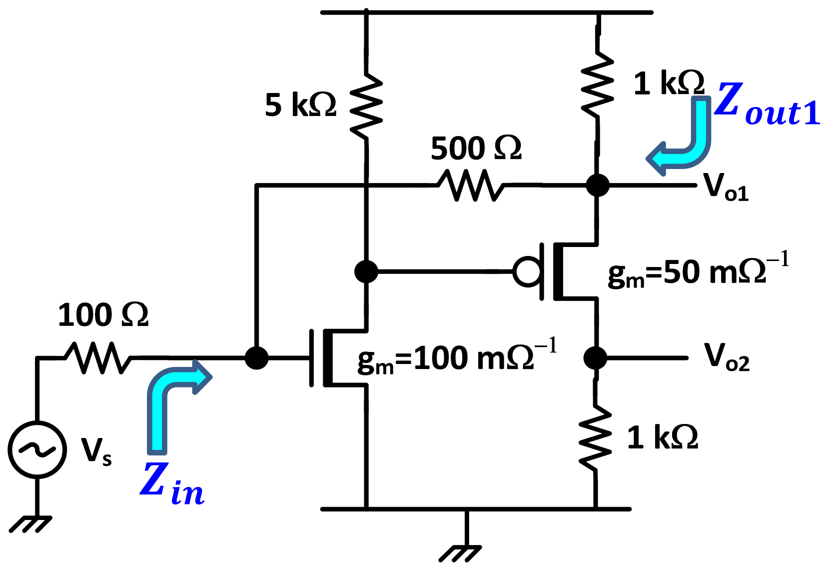


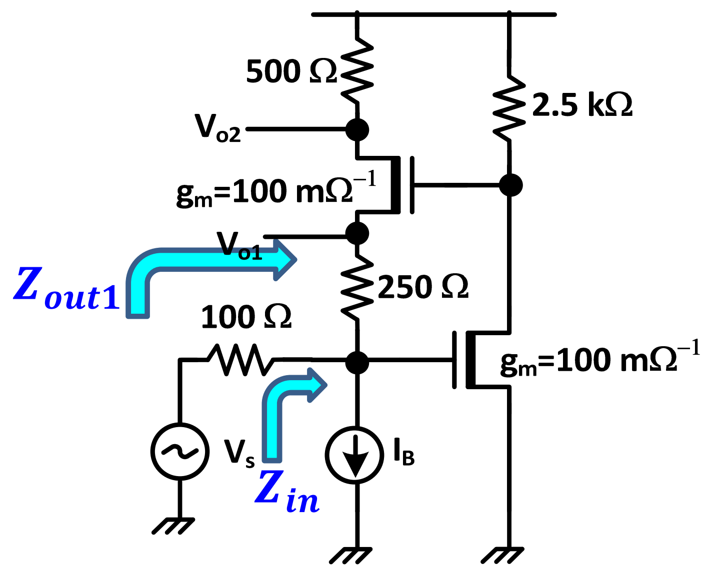
Q-13) In the electronic thermometer, let's assume all PMOS and NMOS have no effect of channel length modulatio n. Set R value so that we can read the absolute temperature T as V_{out}=T/1000. For example, V_{out}=0.3V at 300ºK, and Vout=0.4V at 400ºK (10pt).

Q-14) In the Bandgap reference, determine R so that V_{out} is insensitive to temperature variation at 300ºK (5pt).

Problem Set-4: Shunt Feedback Amplifiers

- Assume output impedance (r_o) of NMOS and PMOS is infinite.





Q-15) For the left side amplifier, Find loop gain (T), input impedance (Z_{in}), output impedance (Z_{out1}), voltage gains $\frac{V_{o1}}{V_s}$ and $\frac{V_{o2}}{V_s}$ (10pt).

Q-16) For the right side amplifier, Find loop gain (T), input impedance (Z_{in}), output impedance (Z_{out1}), voltage gains $\frac{V_{o1}}{V_s}$ and $\frac{V_{o2}}{V_s}$ (10pt).