Analog Electronic Circuits
Department of Electrical and Computer Engineering
Seoul National University

Final exam

December 21, 2020 D.K. Jeong

A sheet of one-sided, A4-size note is allowed.

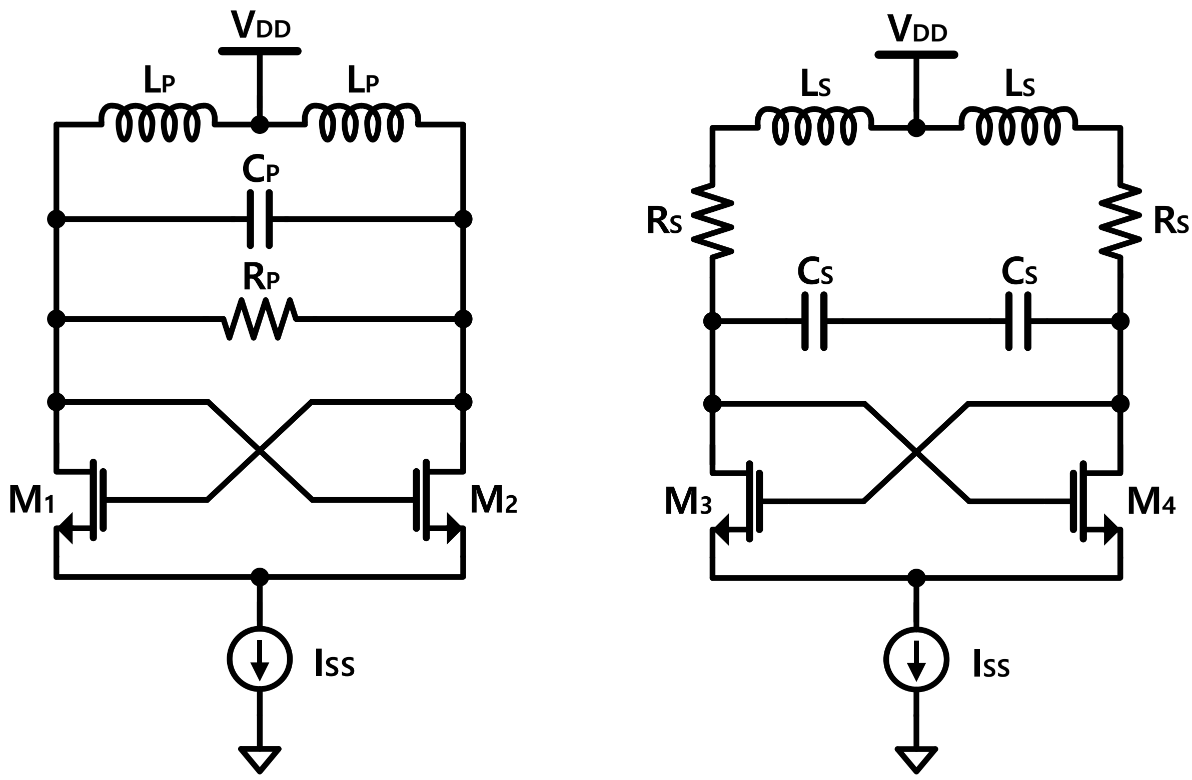
Roster Number (학번):

Name:

Signature:

Problem	**Max Score**	**Score**
1	18	
2	12	
3	10	
4	20	
5	15	
6	25	
Total	100	

[1] Answer the following questions. Assume all the transistors are identical and $r_o = \infty$.



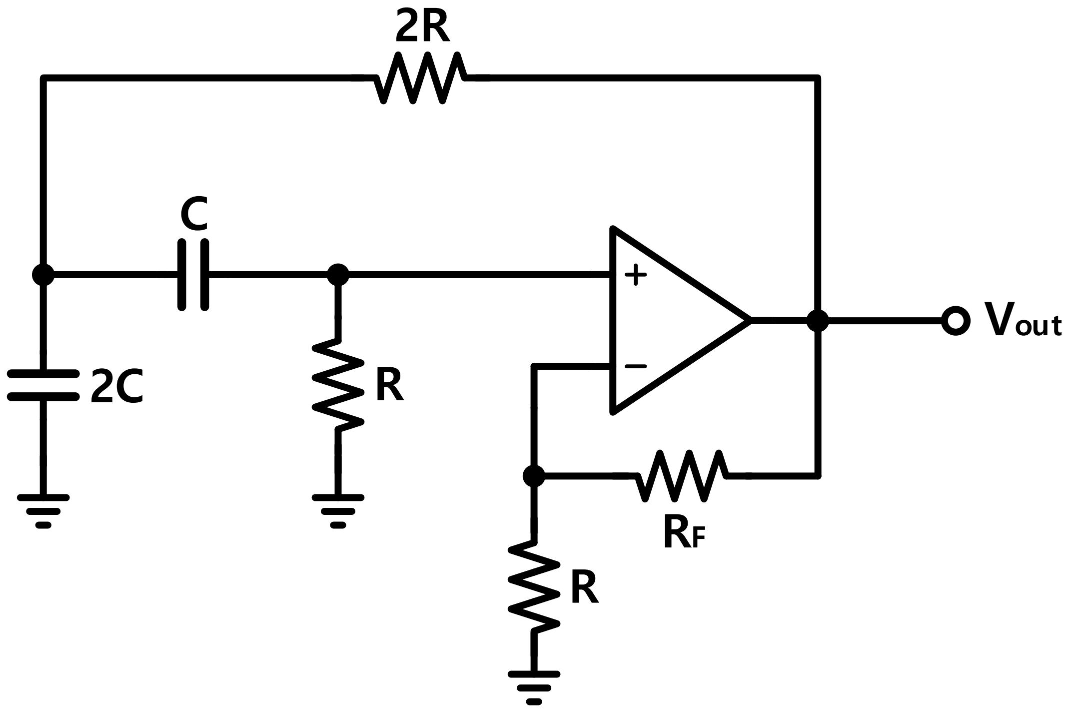
Circuit A **Circuit B**

A. Find the oscillation frequency of the LC oscillator shown in Circuit A.

B. Determine the values of R_S, L_S, and C_S in terms of R_P, L_P, and C_P so that the impedance of Circuit B is the same as Circuit A. Use the oscillation frequency found from A. (Hint : Assume $R_P/2 \gg wL_P$)

C. Determine whether the LC oscillator oscillates when g_m=1mS, R_S=1Ω, and L_S=1uH, and C_S=1nF.

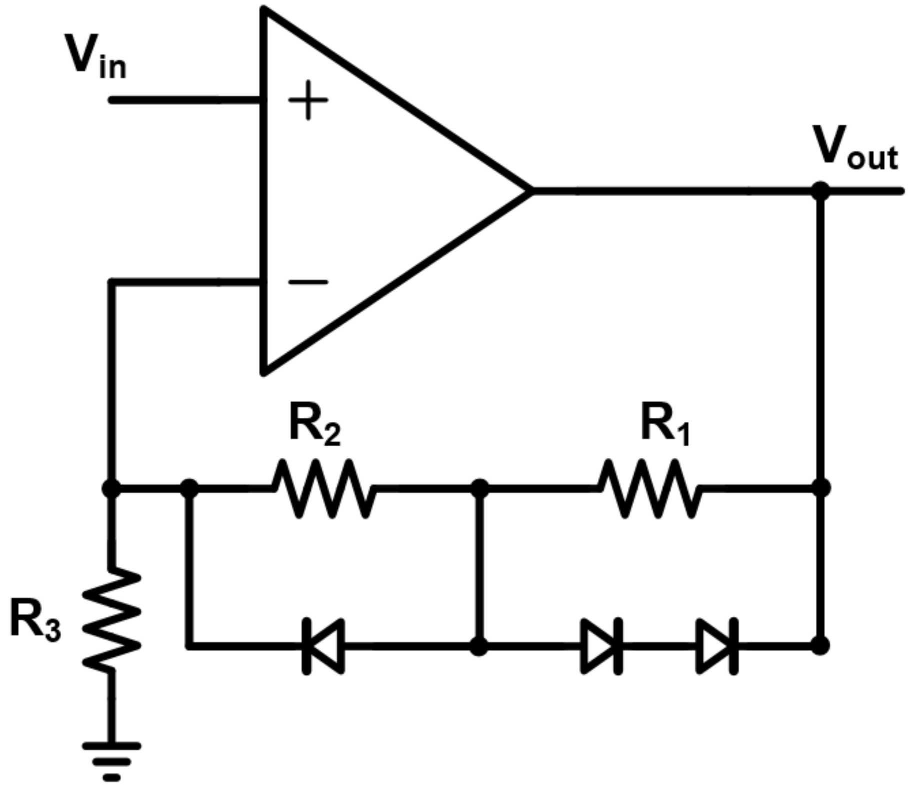
[2] Answer the following questions. Assume the amplifier is ideal.



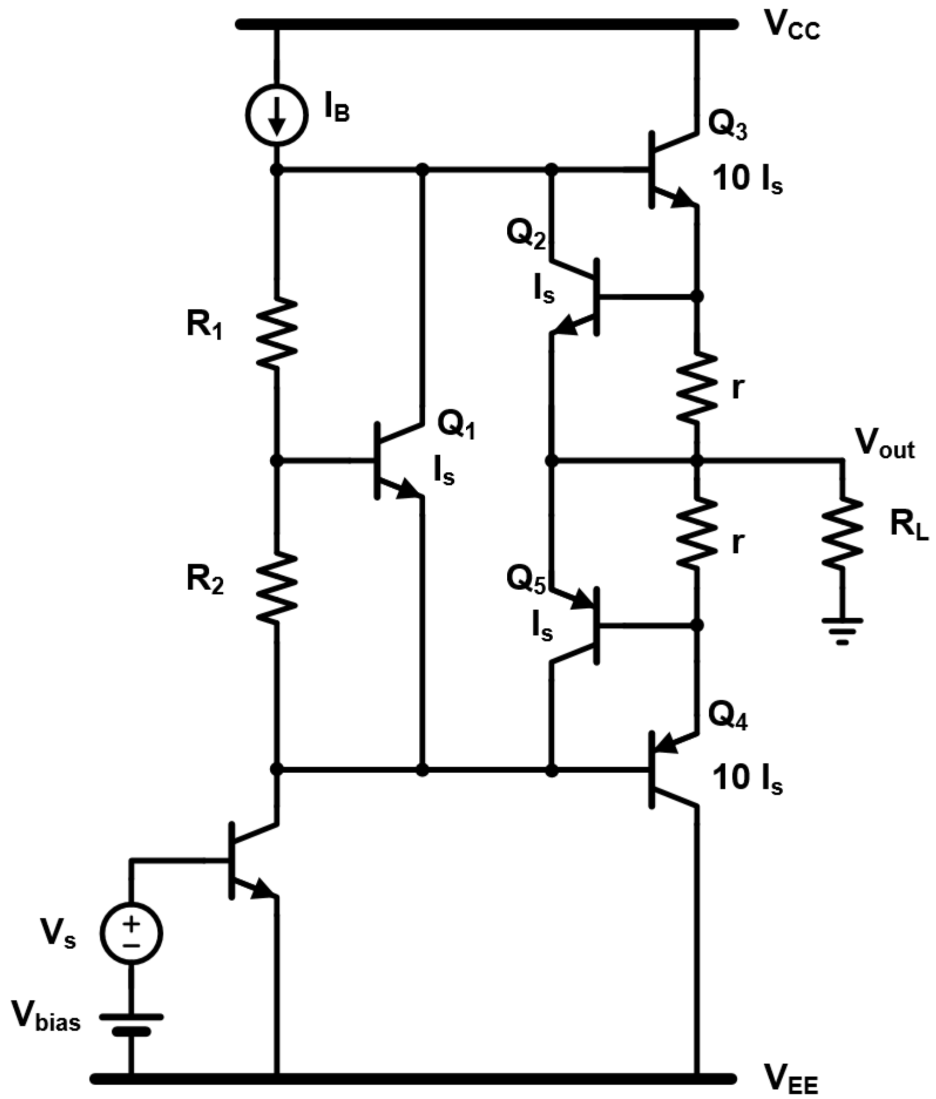
A. Derive the transfer function of the loop gain.

B. Find the minimum value of R_F for starting oscillation. Assume R=1kΩ, C=1uF.

[3] Draw a $V_{in} - V_{out}$ curve of the circuit below. Specify the slope, condition of V_{in} or V_{out} when the diode turned on. (The voltage when the diode is turned on is $V_{D,ON}$)



[4] Consider the following output stage circuit. (Assume $V_A = \infty$)
$V_T = 26\text{mV},\ I_s = 1 \times 10^{-13} A, R_L = 10\Omega.$



A. Find the resistor r, to limit the output current with 8 A. Assume Q2, Q5 is active when collector current is 1mA and $|V_{cc}|, |V_{EE}|$ are enough big.

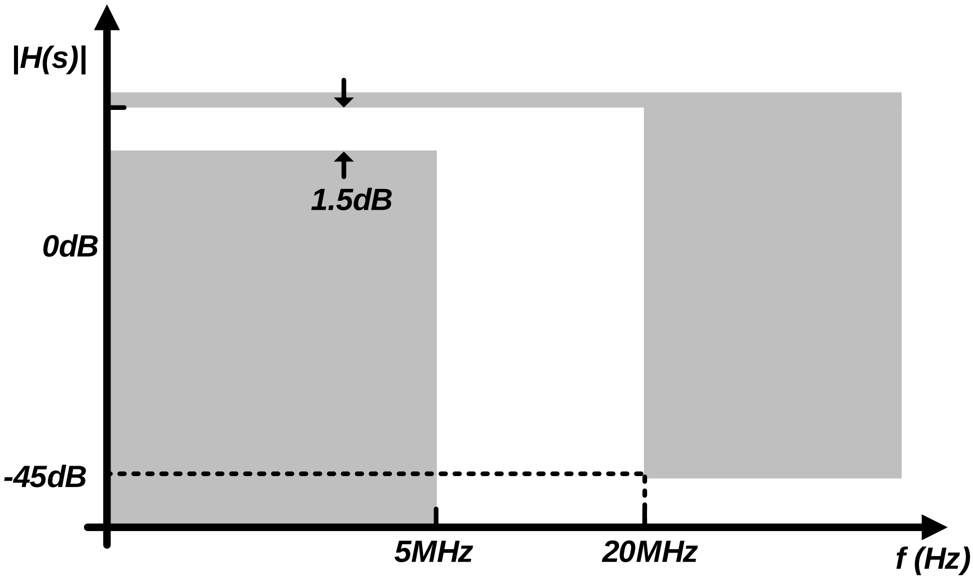
B. Find the minimum bias current I_B to deliver 80W power on 10Ω load with sinusoidal signal. Assume $\beta = 100$.

C. Find the R_1 using the bias current I_B of problem B, when the Quiescent current at the output is

100mA. (Quiescent current is the current when it is producing an output of zero, $V_{out} = 0$)
Assume $R_2 = 1k\Omega$, r $= 0\Omega$, and β of Q_1 is big enough, that is, $I_{C1} \approx I_{E1}$.)

D. Find the power efficiency when $V_{out} = 10 \sin \omega t$ when $V_{CC} = -V_{EE} = 42$V?
Ignore the power dissipation at pre-driver and assume that each transistor carries a negligible current around $V_{out} = 0$ and turns off for half of the period.

[5] Answer the following questions.



Transfer function & Poles of the Butterworth Response

$$|H(jw)| = \frac{1}{\sqrt{1+\left(\frac{\omega}{\omega_o}\right)^{2n}}}$$

$$p_k = \omega_o \exp\frac{j\pi}{2}\exp\left(j\frac{(2k-1)\pi}{2n}\right), k = 1,2,\ldots,n$$

Transfer function & Poles of the Chebyshev Response

$$|H_{PB}(jw)| = \frac{1}{\sqrt{1+\epsilon^2\cos^2\left(n\cos^{-1}\left(\frac{\omega}{\omega_0}\right)\right)}} \quad |H_{SB}(jw)| = \frac{1}{\sqrt{1+\epsilon^2\cosh^2\left(n\cosh^{-1}\left(\frac{\omega}{\omega_0}\right)\right)}}$$

$$p_k = -\omega_0 \sin\frac{(2k-1)\pi}{2n}\sinh\left(\frac{1}{n}\sinh^{-1}\frac{1}{\epsilon}\right) + j\omega_0\cos\frac{(2k-1)\pi}{2n}\cosh\left(\frac{1}{n}\sinh^{-1}\frac{1}{\epsilon}\right), k = 1,2,\ldots,n$$

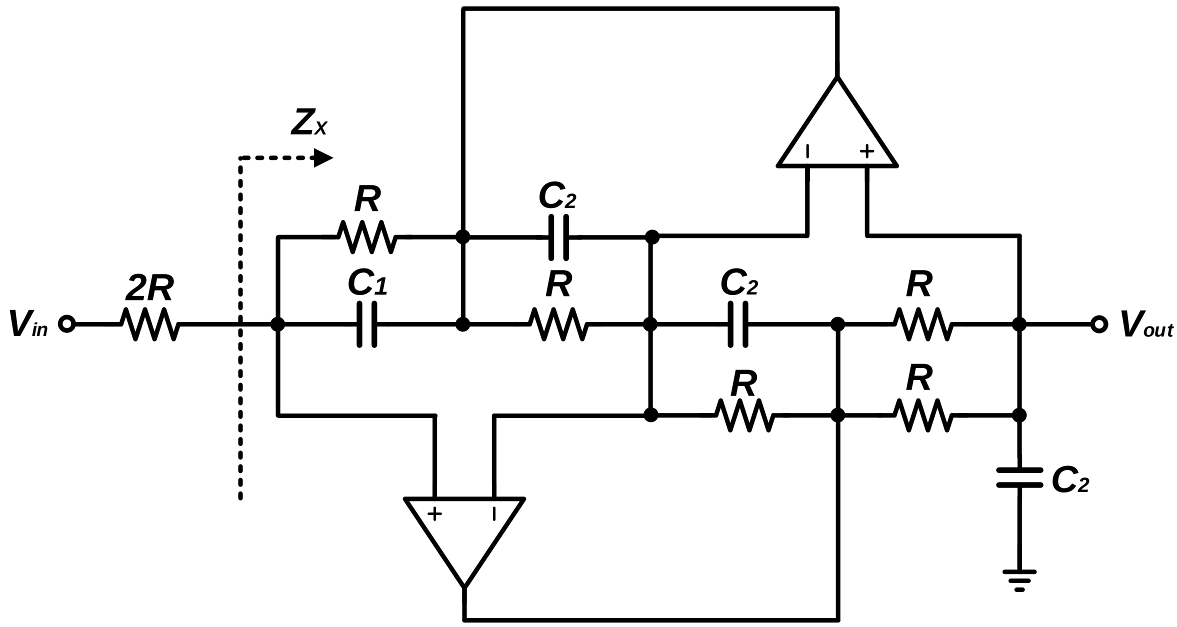
Useful Equations

$$\sinh(x) = \frac{e^x - e^{-x}}{2}, \quad \cosh(x) = \frac{e^x + e^{-x}}{2}, \quad \sinh^{-1}(x) = \ln\left(x+\sqrt{x^2+1}\right), \quad \cosh^{-1}(x) = \ln\left(x+\sqrt{x^2-1}\right)$$

A. Determine the minimum order of each filter (Butterworth Response & Chebyshev Response). Assume the bandwidth of Chebyshev filter is 5MHz.

B. Using determined value of n above, get the range of the optimal natural frequency (ω_o) of the Butterworth filter.

[6] Answer the following questions. Assume all op-amps are ideal.



A. Calculate $Z_X(s)$.

B. Derive the transfer function H(s).

C. Determine the sensitivity of Q to a change in C1, S_{C1}^{Q}, and the sensitivity of ω_n to a change in R, $S_R^{w_n}$.

D. Design a Chebyshev filter of the problem 4 having high Q factor based on this filter structure, ‘General Impedance Converter’. Every R is 1k ohm and you need to get the value of C1, C2.