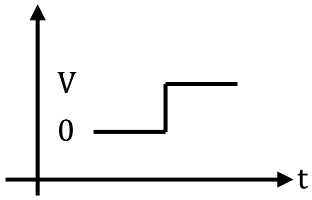
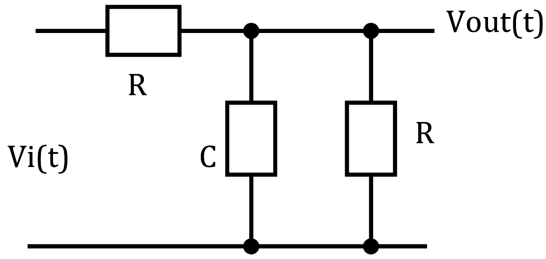
Cosmic Circuits@IISc, Feb 06, 2007 by Raja Reddy P

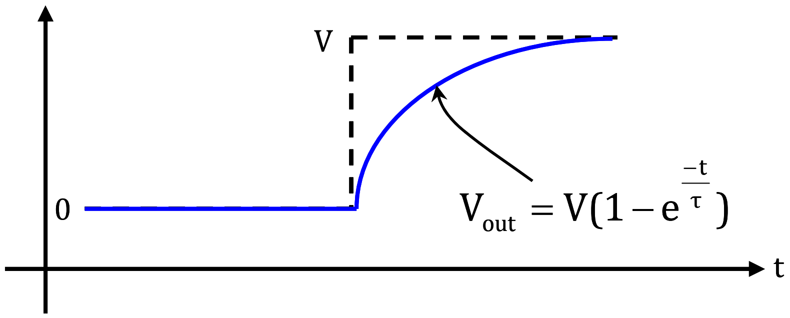
1.





Calculate *Vout(s)/Vin(s)*. plot *Vo(t)*. calculate time constant and pole frequency.

Ans:



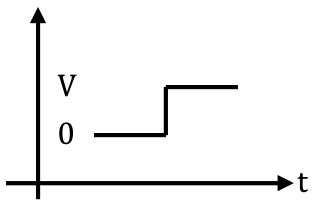
$$V_{out} = V(1 - e^{\frac{-t}{\tau}})$$

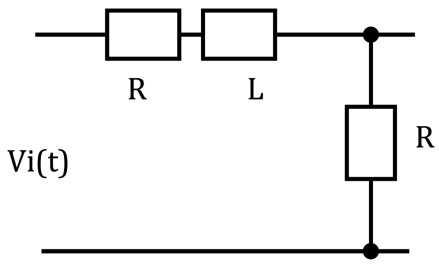
$$\frac{Vout}{Vin}(s) = \frac{1}{2(1 + sRC)}$$

Time constant = (R/2)C

Pole frequency : $\omega_p = \dfrac{2}{RC}$

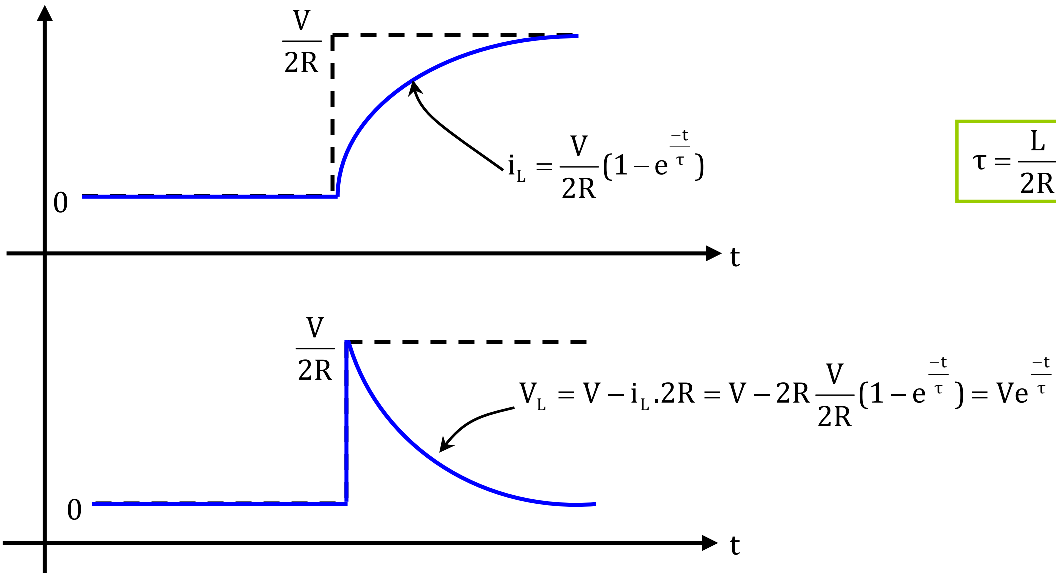
2.





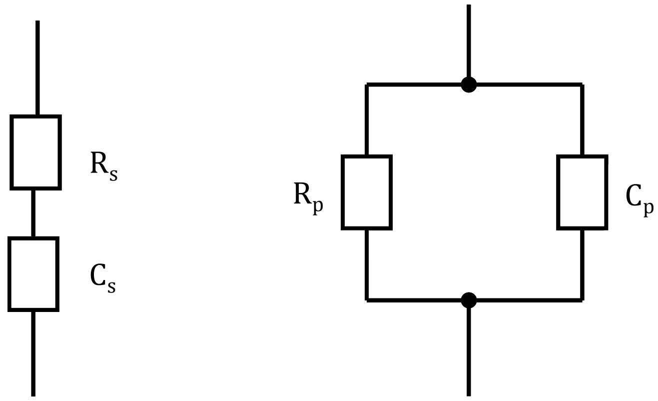
In the above circuit plot $i_L(t)$, $V_L(t)$

Ans:



$$\boxed{\tau = \frac{L}{2R}}$$

3.



Both circuits are equivalent. Express *Rp* and *Cp* in terms of *Rs* and *Cs*. Find '*ω*' range for which these both are equivalent. Assume high quality factor.

Ans:

$$R_s + \frac{1}{sC_s} = \frac{R_p \frac{1}{cC_p}}{R_p + \frac{1}{sC_p}} \qquad \text{where} \quad s = j\omega$$

On solving this equation we will get

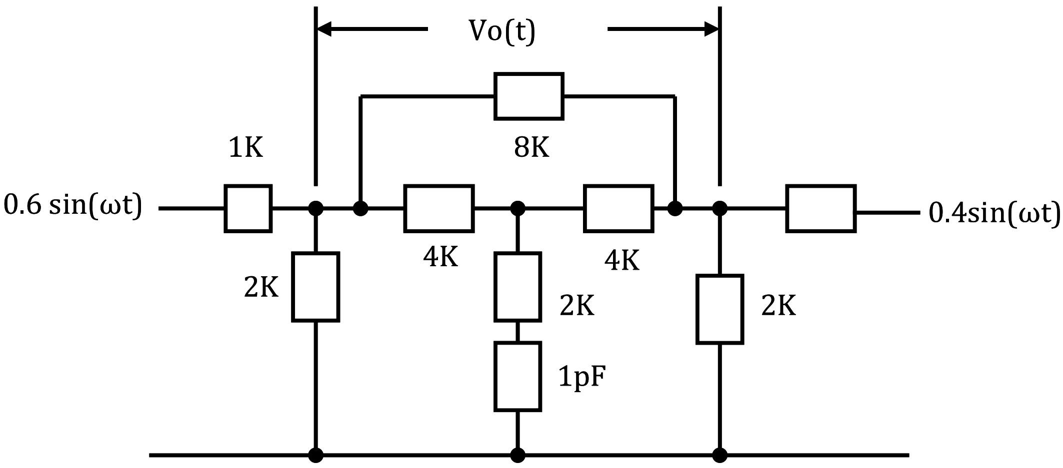
$$R_p = (Q^2 + 1)R_s$$

$$C_p = \frac{C_s}{(1 + \frac{1}{Q^2})} \qquad \text{where} \qquad Q = \frac{1}{\omega RC}$$

4. A system has an SNR of 60 dB. If an uncorrelated noise of 1 mV is added in a 1 V of signal to it, then what is the SNR?

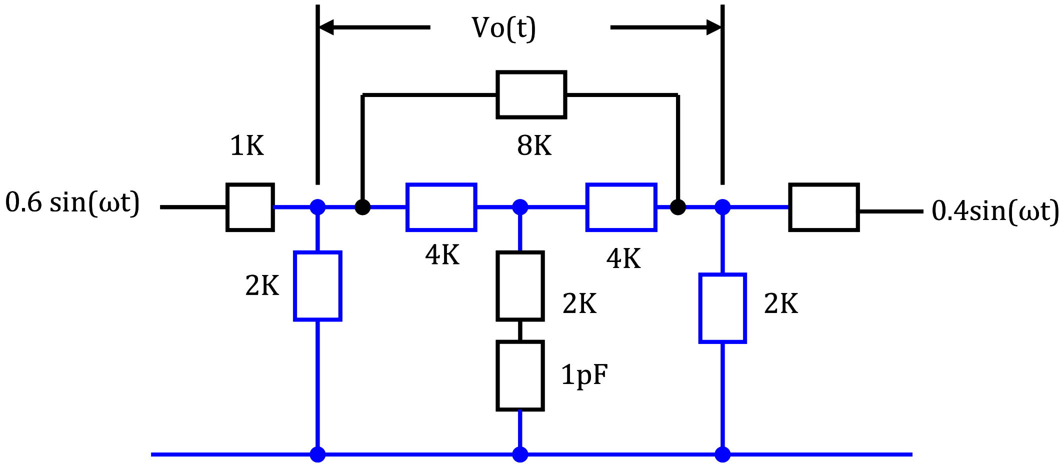
Ans: 57 dB

5.

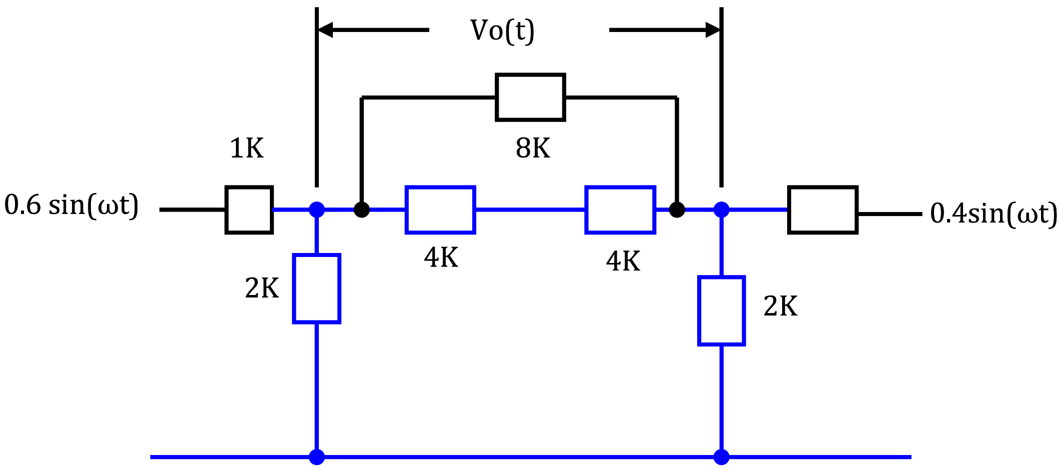


Find *Vo(t)* in the above circuit

Ans: If you observe the circuit carefully, you can notice that four resistors in blue in the figure below forms a wheatstone bridge, and you can eliminate the branch with capacitance.



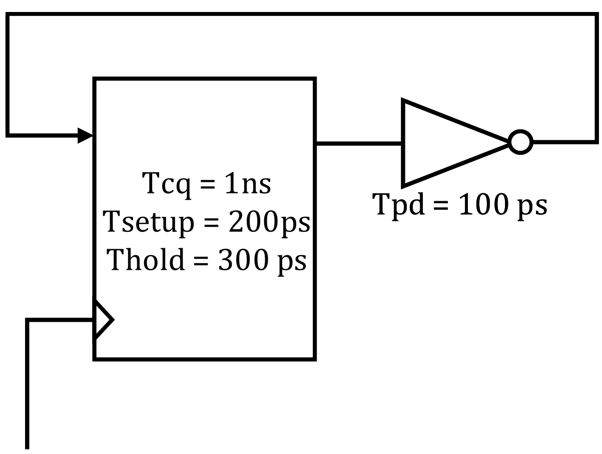
The resulting circuit is



Now you can solve it directly.

$$Vo = 0.1\sin(\omega t)$$

6.

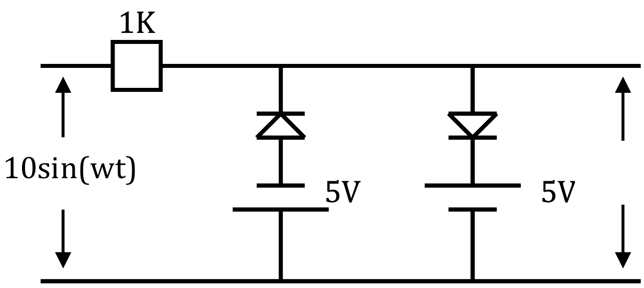


Calculate the maximum clock frequency.

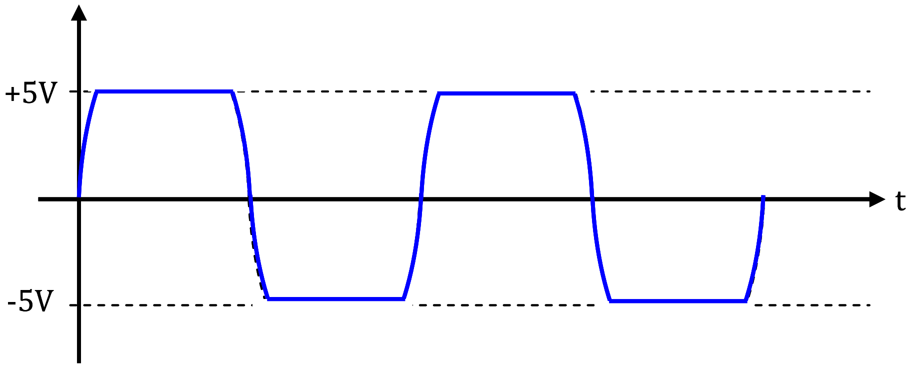
Ans: Tclk > Tcq + Tpd + Tsetup = 1ns + 100ps + 200ps = 1.3 ns

fmax =1/(1.3ns)

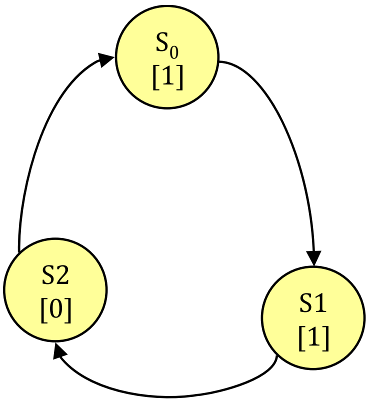
7. Plot *Vout*.



Ans: This is a clipper circuit.



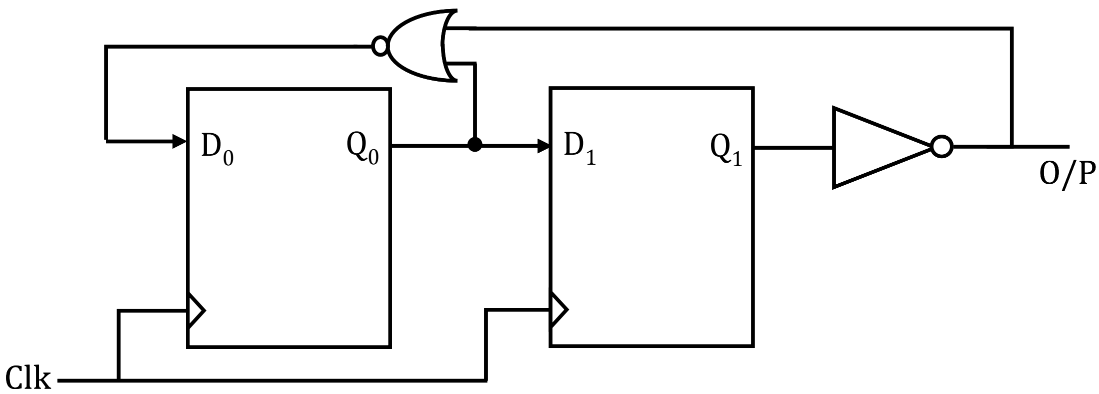
8. Design a divide-by-3 counter using D-flip-flops. The duty cycle of the divided clock should be 2/3.



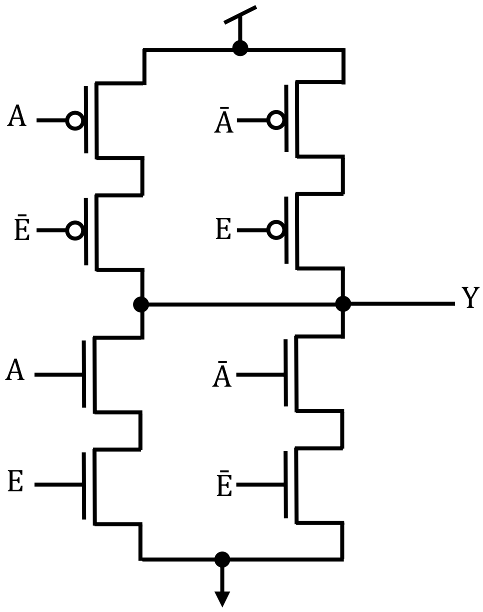
Present state Q_1Q_0	Next Sate D_1D_0	o/p
00	01	1
01	10	1
10	00	0
11	xx	x

From the table

$$D_1 = Q_0$$
$$D_0 = \overline{Q_0 + Q_1}$$
$$o/p = \overline{Q_1}$$

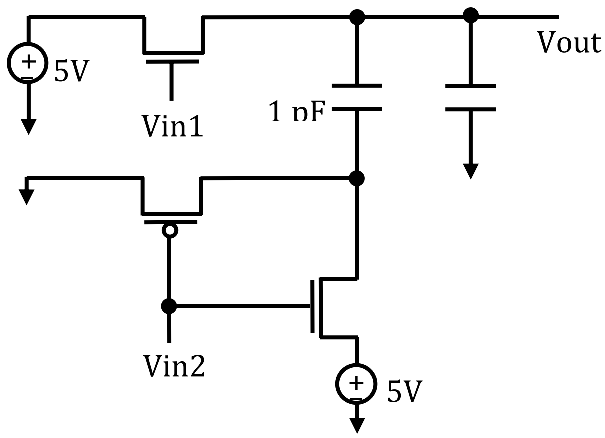


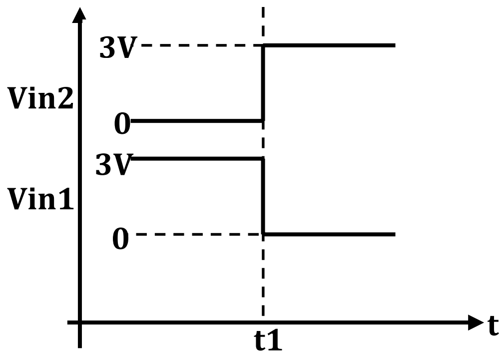
9. What is the function of the following circuit?



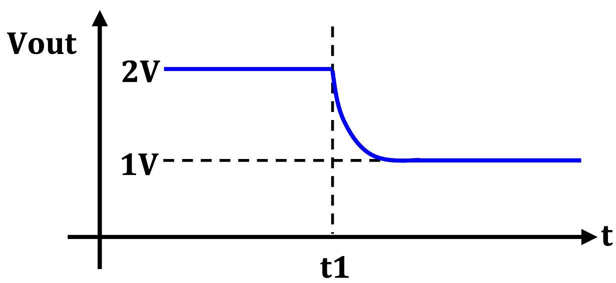
Ans: XOR

10. Plot *Vout* with respect to the given input waveforms.

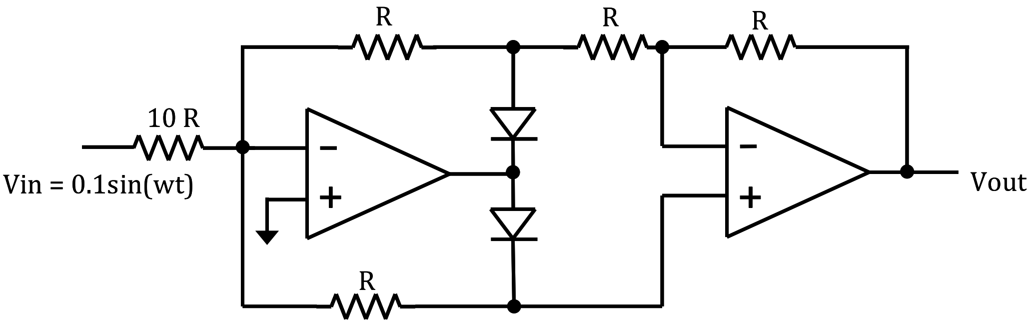




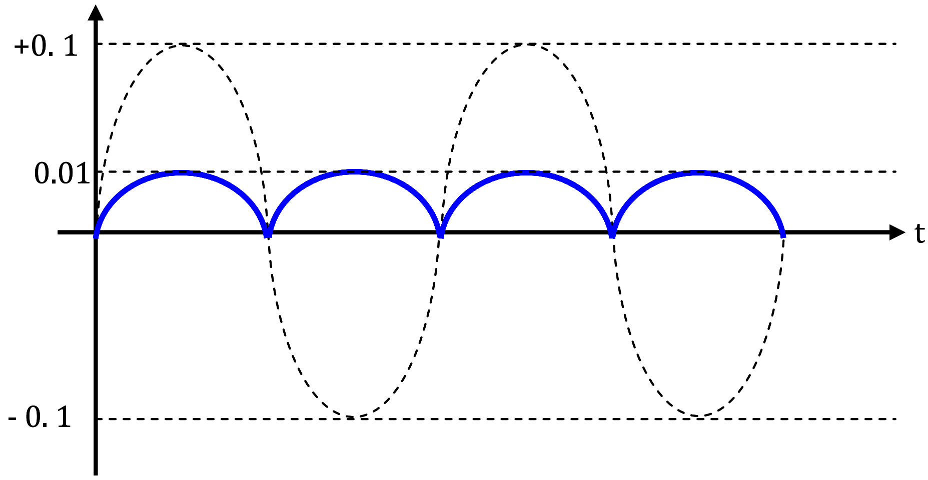
Ans:



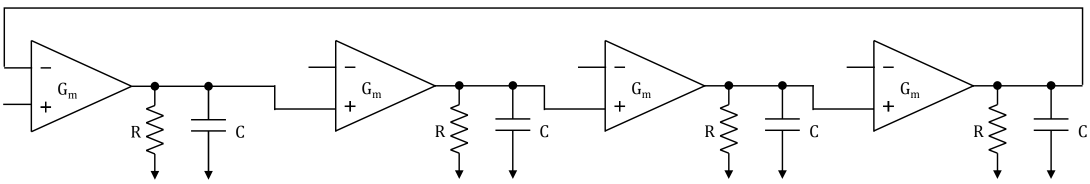
11. Plot the output *Vout.*



Ans: The given circuit is a full-eave rectifier. Observe the gain, it is equal to 0.1.



12. Calculate the frequency of oscillation. What is the minimum required G_m for oscillation?



Ans: In the given oscillator there are four gain stages. One of them operates in inverting mode and the remaining in non-inverting mode. So the phase shift provided is 180° and the remaining 180° phase shift should be provided by four the RC-stages, to make the feedback positive. The transfer function of each stage is

$$H_1(j\omega) = \frac{G_m R}{1 + j\omega RC}$$

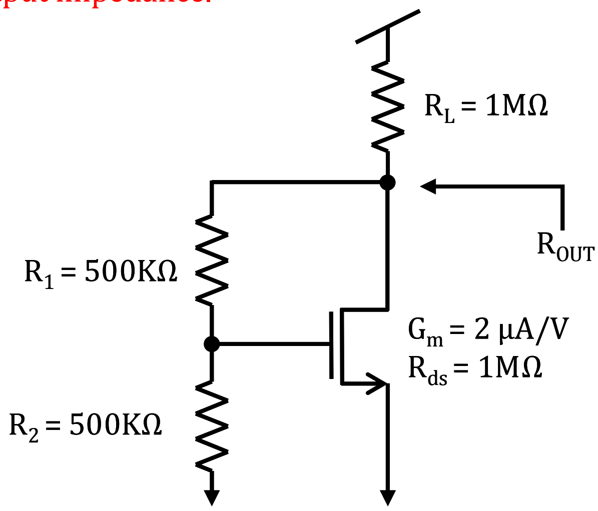
So the phase shift provided by each RC-stage is $\tan^{-1}(\omega RC)$ and should be equal to 45 º.

$$\tan^{-1}(\omega_o RC) = 45^o \Rightarrow \omega_o RC = 1 \Rightarrow f_o = \frac{1}{2\pi RC}$$

At f_o the attenuation provided by each RC-stage is $1/\sqrt{2}$. So for loop gain to be greater than or equal to one, each gain stage should at least provide a gain of $\sqrt{2}$.

$$G_m R \geq \sqrt{2} \Rightarrow G_m \geq \frac{\sqrt{2}}{R}$$

13. Calculate the output impedance.



Ans:

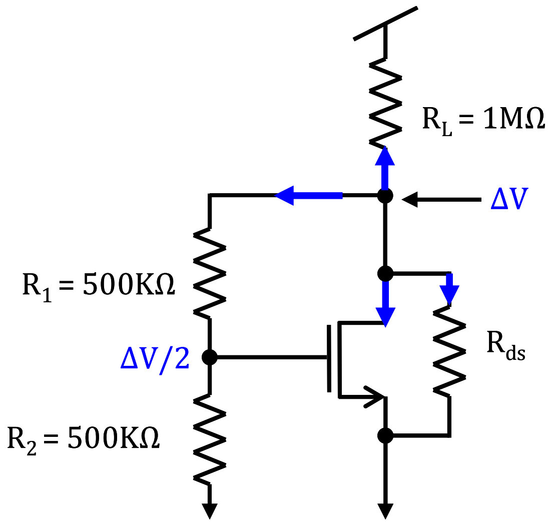
Apply a small voltage at the drain node and observe the current flowing. Total current flowing into the drain (output) node is

$$\Delta I = \frac{\Delta V}{R_L} + \frac{\Delta V}{R_{ds}} + \frac{\Delta V/2}{R_1} + (\Delta V/2)G_m$$

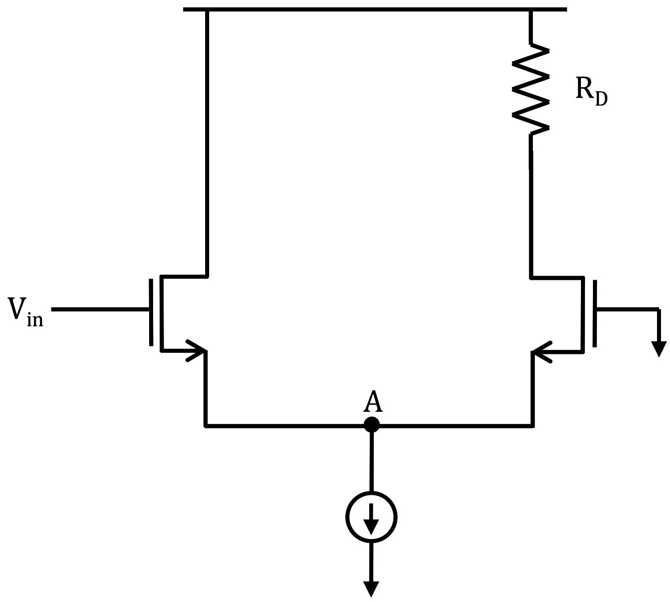
$$\Rightarrow R_{OUT} = \frac{\Delta V}{\Delta I} = \frac{1}{\frac{1}{R_L} + \frac{1}{R_{ds}} + \frac{1}{2R_1} + (1/2)G_m}$$

$$\Rightarrow R_{OUT} = R_L \,||\, R_{ds} \,||\, 2R_1 \,||\, \frac{G_m}{2}$$

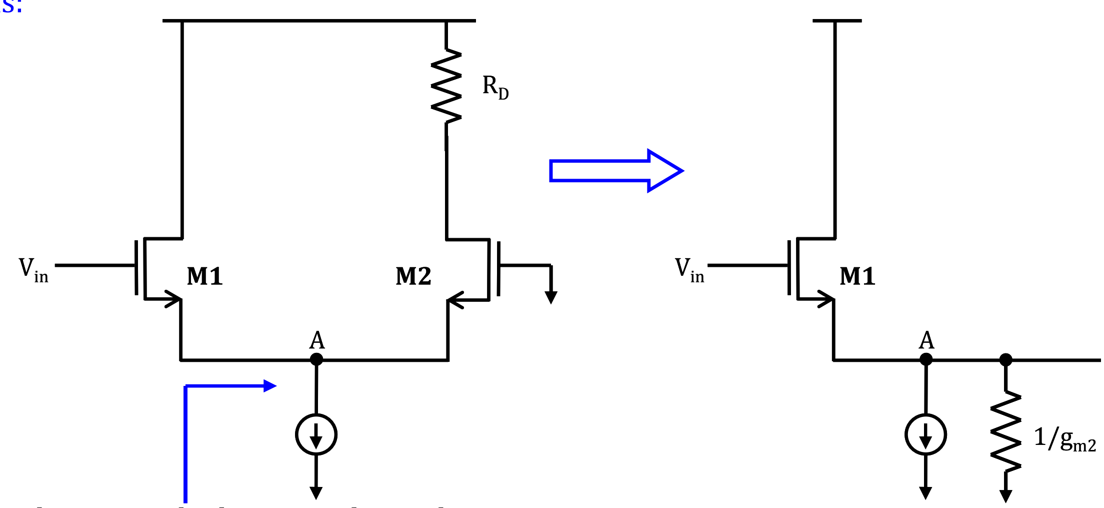
$$\Rightarrow R_{OUT} = 1M\Omega \,||\, 1M\Omega \,||\, 1M\Omega \,||\, 1M\Omega \,||= 250K\Omega$$



14. Both transistors are biased in saturation. Calculate "VA/V_{in}". Neglect the body effect.



Ans:

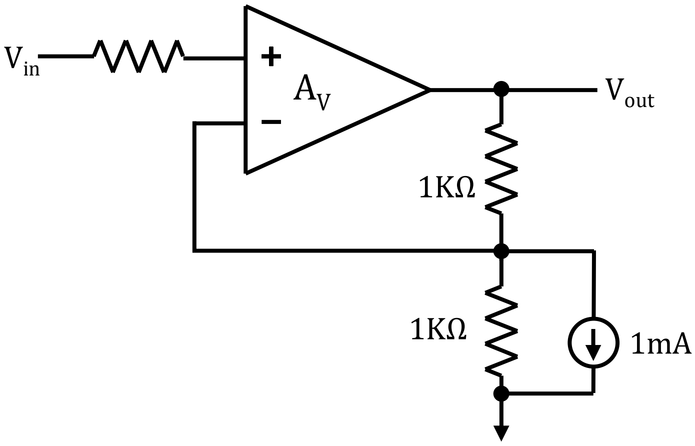


Impedance seen looking into this node is
$(1/g_{m2}) + R_D/(g_{m2}r_{o2}) \approx 1/g_{m2}$

Now the simplified circuit is a source follower with a load resistance of $1/g_{m2}$. So gain

$$\frac{V_A}{V_{in}} = \frac{g_{m1}}{g_{m1}+g_{m2}} = \frac{1}{2} \qquad \text{assuming } g_{m1} = g_{m2}$$

15. Calculate the output if (i) gain A_v = infinity (ii) gain A_v = 10



Ans:

$$V_{out} = A_v(V_{in}^{+} - V_{in}^{+})$$

$$\frac{V_{in}^{-}}{1K\Omega} + \frac{V_{in}^{-} - V_{out}}{1K\Omega} + 1mA = 0 \Rightarrow V_{in}^{-} = \frac{V_{out} - 1}{2}$$

Solving the above two equations, we will get

$$V_{out} = \frac{A_v(2V_{in}^{+} + 1)}{2 + A_v}$$

$$Av = \infty \Rightarrow V_{out} = 2V_{in}^{+} + 1$$

$$Av = 10 \Rightarrow V_{out} = \frac{5}{6}(2V_{in}^{+} + 1)$$

Interview Questions

1. In interview mainly your knowledge about RC-circuits will be tested.
2. For me they have asked about my approach to solve the problems given in the exam
3. About my final project
4. Some questions about oscillators (mainly Wein-Bridge Oscillator):
    a. how it works, and
    b. what happens if you interchange the series-RC and parallel-RC branches in Wein-Bridge Oscillator

        Ans: If you interchange series-RC and parallel-RC branches, there will be more positive feedback at DC and hence the output saturates to "$+V_{osat}$".

***The interview will be very cool, they will help you in answering the questions!!!. And the most important thing is there is no separate HR interview.