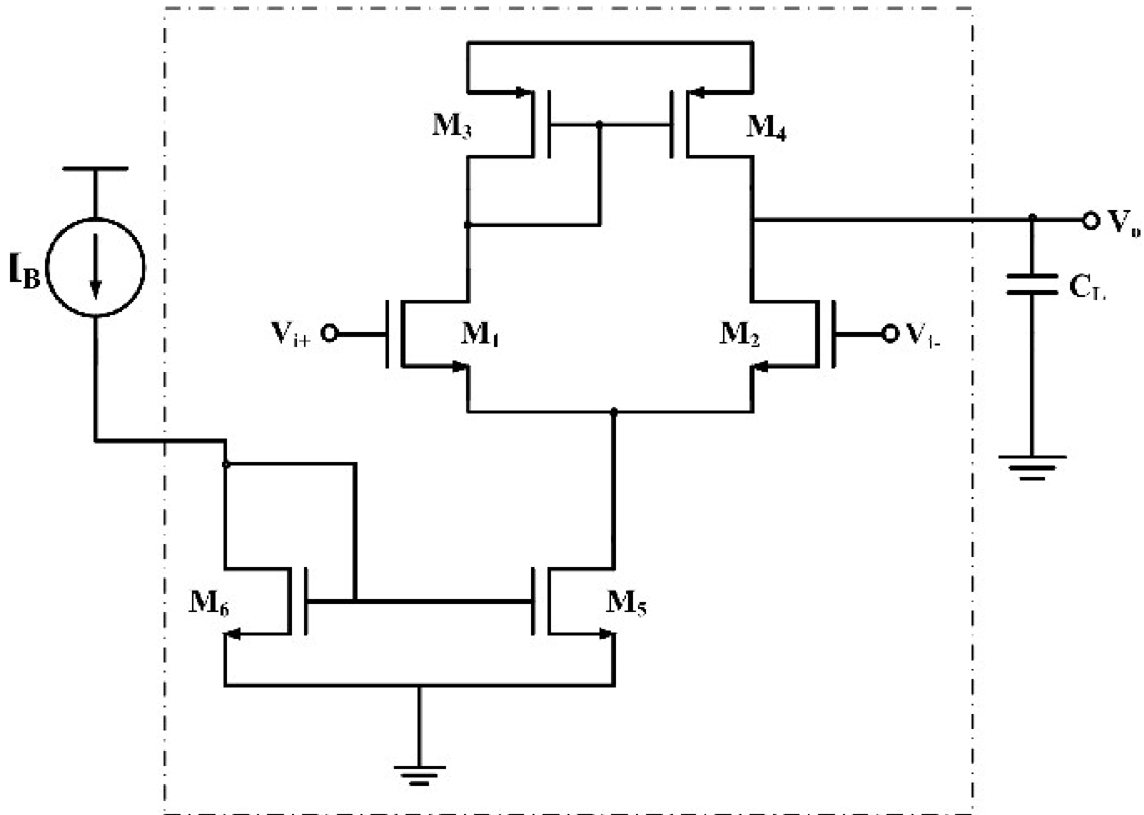
Differential Amplifier



Question: Given: Obtain $|A_v|$=20dB, bandwidth = 5MHz, and V_{DD} = 1.8V, C_{LOAD}=10pF, ($\mu_n C_{ox}$ = given or take it from previous chapter of nch_25 mosfet), slew rate =5 V/µsec, Input common mode range = 0.8V to 1.6V, power dissipation = 0.3mW .(betaeff = $\mu_n C_{ox}(W/L)$, and $\mu_n C_{ox}$ of nch_25=276µA/V^2 and and $\mu_p C_{ox}$ of pch_25=88µA/V^2 and nmos to be used nch_25 and pmos to be used pch_25, V_{th} of nch_25=552mV and V_{th} of pch_25=500mV, V_{OV} of nmos =350mV and V_{OV} of pmos=380mV)

Answer: follow the below steps:

1. Make sure the transistor is in saturation region for amplifier case.
2. Tail current $I_0 = C_L$*(Slew rate) = (10pF)*(5 V/µsec) = 50µA=I_B
3. General equation of Input common mode range,

   i) If V_{CM} decreases, M_5 is carrying a current I_0 and M_1 and M_2 is carrying current $I_0/2$. For carrying a current $I_0/2$, the transistor must have fixed V_{GS}, therefore if V_{CM} decreases, (here $V_{i+}=V_{i-}=V_{CM}$),

V_X decreases and M_0 will go to triode region.

$$(V_{i,CM})_{min}=V_{GS1}+V_{DSAT}(\text{of } M_5)$$

If V_{CM} increases, M_1 and M_2 gets affected and will go to triode region,

$$(V_{i,CM})_{max}=V_{DD} - V_{SG}(\text{of } M_3) + V_{th}(\text{of } M_1)$$

Note: The same logic of calculating input biasing range holds good for any circuit.

4. Output common mode range;
   If V_{out} decreases, M_2 gets in triode region, and to keep it in saturation region $(V_{out})_{min} = V_{OV}(\text{of } M_5)) + (V_{OV}(\text{of } M_2)$
   If V_{out} increases, M_4 gets in triode region, and to keep it in saturation region $(V_{out})_{max} = V_{DD} – V_{OV}(\text{of } M_4)$

5. Calculate g_m,

$$g_m = \text{Bandwidth}*2*\pi *C_L,$$

$$g_m = 314.16\ \mu A/V^2$$

6. Calculation of W/L ratio of all the Mosfets:

For M_3 and M_4: (calculate it from drain current equation in saturation region)

$$I_D =1/2(\mu_p C_{ox}(W/L)(V_{SG}−|V_{th}|)^2$$

Note: $I_0 = 50\mu A$(flowing in tail mosfet M_5), the currents flowing in M_1 and $M_3 = I_0/2 = 25\mu A$ and the currents flowing in M_2 and $M_4 = I_0/2 = 25\mu A$. Basically, tail current flowing is divide by 2 in differential amplifier as it almost symmetrical circuit.

$$I_3 = I_4 = I_0/2 = 25\mu A =(1/2)(\mu_n C_{ox}(W/L)(V_{GS}−V_{th})^2$$

$$50\mu = 87.2013\mu(W/L)_{3,4}(0.38)^2$$

$$(W/L)_{3,4} = 3.97$$

$$(W/L)_{3,4} = 4$$

For M_1 and M_2: (calculate it from g_m)

M_1, M_2 current flowing is 25µA ie $I_0/2$

$$\frac{\partial I}{\partial v_{GS}} = g_m = \mu_n C_{ox}(W/L)_{1,2}(V_{GS}-V_{th})$$

$$(W/L)_{1,2} = g_m{}^2/(2I_D\ \mu_n C_{ox}) \text{ ....here } I_D = I_0/2$$

$$(W/L)_{1,2} = 7$$

For $M_{5,6}$: (calculate by drain current equation in saturation region and take $V_{overdrive} = V_{DSAT} = V_{GS}-V_{th} = V_{OV}$)

For M_5 and M_6, current flowing is 50µA ie I_0 and for M_1, M_2, M_3, M_4 current flowing is 25µA ie $I_0/2$

$$I_0 = I_D = 1/2(\mu_n C_{ox}(W/L)(V_{GS}-V_{th})^2$$

$$50\mu = (1/2)(\ 275.78\mu)(W/L)_{5,6}(0.3)^2$$

$$(W/L)_{5,6} = 4$$

7. For these calculated values, we will not get the desired specification and after above all the steps, we next improvise accordingly.