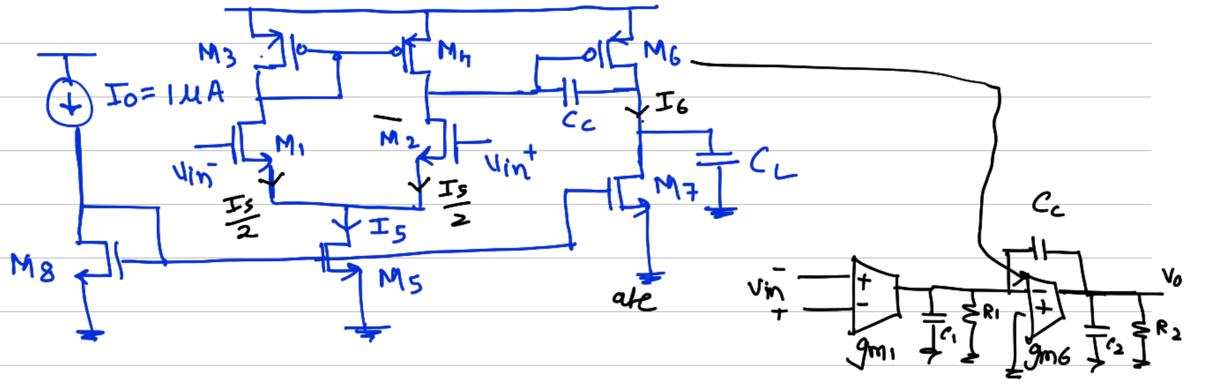
• Required specifications:

1) $A_{dc} = 60\ dB$ (1000 V/V) 2) GBW = 10 MHz 3) PM = 75°

4) CMRR = 50 dB 5) $P_{diss} = 30\ \mu W$ 6) $V_{dd} = 1.2\ V$ 7) $C_L = 100 fF$



Design:

① Assume $(Gain)_{1^{st}\ stage} = 40$ $(Gain)_{2^{nd}\ stage} = 25$

② $$P_{dominant} \simeq \frac{(g_{ds2} + g_{ds4})}{\left[1 + \frac{g_{m6}}{(g_{ds6} + g_{ds7})}\right] C_c} \quad ; \quad P_{Non\text{-}dominant} \simeq \frac{g_{m6}}{(C_L + C_c)}$$

③ PM: $-180 + 75^\circ = -105^\circ = -\tan^{-1}\left[\frac{GBW}{P_{dom}}\right] - \tan^{-1}\left[\frac{GBW}{P_{nondom}}\right] - \tan^{-1}\left[\frac{GBW}{Z}\right]$

we employ zero cancelling resistor ∴ '0'

assume $Z \geq 10\,GBW$.

$$-105^\circ = -90^\circ - \tan^{-1}\left(\frac{GBW}{P_{nd}}\right)$$

$$\Rightarrow \boxed{P_{nd} = 3.73 \times GBW}$$

$$\Rightarrow P_{nd} = \frac{g_{m6}}{C_L + C_c} \simeq \frac{g_{m6}}{C_L}$$

(∵ C_c is smaller than C_L. But if comparable, let $C_{c\,max} = 2 \cdot C_L$

∴ whatever value comes from g_{m6}/C_L, we will take 3 times of calculated g_{m6})

$$\Rightarrow \frac{g_{m6}}{C_L} = 3.73 \times 2\pi \times 10^7$$

$$\Rightarrow g_{m6} = 3.73 \times 2\pi \times 10^7 \times 100 \times 10^{-15}$$

$$g_{m6} = 23.43\ \mu S$$

$$\Rightarrow \boxed{g_{m6} = (25 \times 3) = 75\ \mu S}$$

④ First stage gain = 40 ; $\frac{g_{m1}}{g_{ds2} + g_{ds4}} > 40$

assuming $g_{ds2} = g_{ds4}$

$$\Rightarrow \frac{g_{m1}}{g_{ds2}} > 80$$

From GBW, $\frac{g_{m1}}{C_c} \geq 2\pi \times 10^7$

Here we considered $C_{cmax} = 2C_L$

$\Rightarrow$ assume $C_c = 100\,fF$ for now.

$\Rightarrow g_{m1} \geq 2\pi \times 100f \times 10^7$

$\Rightarrow g_{m1} \geq 6.28\,\mu S$

$\Rightarrow \boxed{g_{m1,2} = 7\,\mu S}$

Now we assume $\left(\frac{g_m}{I_d}\right)_{1,2} = 20$ ($\because$ we require high-gain from these)

$\therefore (I_d)_{1,2} = \frac{7\mu}{20} = \underline{\underline{0.35\,\mu A}}$.

we look into $\frac{g_m}{g_{ds}}$ Vs $\frac{g_m}{I_d}$ for nMOS at $\frac{g_m}{I_d} = 20$

$\Rightarrow$ for $\boxed{L = 1.1\,\mu m}$ we satisfy the cond^n of $\frac{g_{m1}}{g_{ds}} \geq 80$.

$\therefore$ Choose $\boxed{L_{1,2} = 1.1\,\mu m}$

From $\frac{I_d}{W}$ vs $\frac{g_m}{I_d}$ of nmos at $L = 1.1\mu$ & $\frac{g_m}{I_d} = 20$

we get $\boxed{W_{1,2} = 526\,nM}$

(5) For M_3, M_4, assume $\frac{g_m}{I_d} = 10$. We calculated $(I_d)_{3,4} = 0.35\,\mu$.

$\Rightarrow \boxed{(g_m)_{3,4} = 3.5\,\mu S}$

We had assumpt^n $\frac{g_{m1}}{g_{ds2}} > 80 \Rightarrow \frac{7\mu}{80} > g_{ds2}$

$\Rightarrow g_{ds2} < 87.5\,n$

$\therefore g_{ds4} < 87.5\,n$

$\therefore \frac{(g_m)_{3,4}}{(g_{ds})_{3,4}} = \frac{3.5\mu}{87.5n} > 40$

Repeating the step of (5) for calculation of M_3, M_4 of PMOS we get $\boxed{L_{3,4} = 700\,nM}$

$\boxed{W_{3,4} = 133\,n}$

(6) For calculation of M_6:

Assume $\left(\frac{g_m}{I_d}\right)_6 = 15$ [Since it is a driver for 2nd stage]

From point (3), we assumed $g_{m6} = 75\,\mu S$

$\therefore \boxed{I_{d6} = \underline{5\,\mu A}}$

We assumed 2^{nd} stage gain > 25 : $\dfrac{g_{m6}}{g_{ds6}+g_{ds7}} > 25$

assuming $g_{ds6} = g_{ds7}$: $\boxed{\dfrac{g_{m6}}{g_{ds6}} > 50}$

$\therefore (g_{ds6}) < \dfrac{75\,\mu}{50} = 1.5\,n.$

Again repeating steps from (5) to get 'L' where $\dfrac{g_m}{g_{ds}} > 50$

we get $\boxed{\begin{array}{l} L_6 = 600\,n \\ W_6 = 3.93\,\mu \end{array}}$

(7) Design of M_5 & M_7: done using current Mirror.

⇒ Assume current mirror's $\dfrac{g_m}{I_d} = 15.$

⇒ From V_{th} vs $\dfrac{g_m}{I_d}$ plots, we found range of $V_{th} = 330$ to 350 mV.

⇒ We will try to select V_{gs} such that $V_{gs} > 350$ mV.

⇒ Then by looking at V_{gs} vs g_m/I_d plots for $\dfrac{g_m}{I_d} = 15$, we observe that $L = 500$ nM satisfies above condn.

⇒ Now from $\dfrac{I_d}{W}$ vs g_m/I_d plot at $\dfrac{g_m}{I_d} = 15$ & $L = 500$ nM.

we get $\boxed{W_8 = 246\text{ nM}}$ (it carries 1 μA current)

$\therefore$ W_5 gets by scaling : $W_5 = \dfrac{I_5}{I_6} \times W_6 = \dfrac{0.7\,\mu}{1\,\mu} \times 246$

⇒ $\boxed{W_5 = 172.2\text{ nM}}$

& similarly for W_7 : $\dfrac{I_7}{I_6} \times W_6 = \dfrac{5}{1} \times 246$ ⇒ $\boxed{W_7 = 1.23\,\mu\text{M}}$

But on simulation, we got less current $\therefore$ we tuned it to increase $\boxed{W_7 = 1.7\,\mu}$

Here we keep $\boxed{L_{7,6} = 500\text{ nM}}$.

(8) We employed zero cancling resistor $\boxed{= \dfrac{1}{g_{m6}} = 13.33K}$