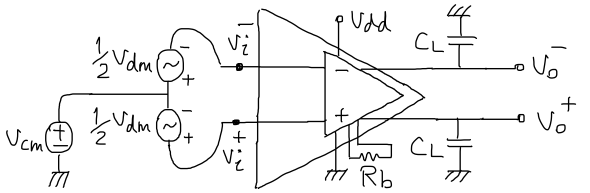
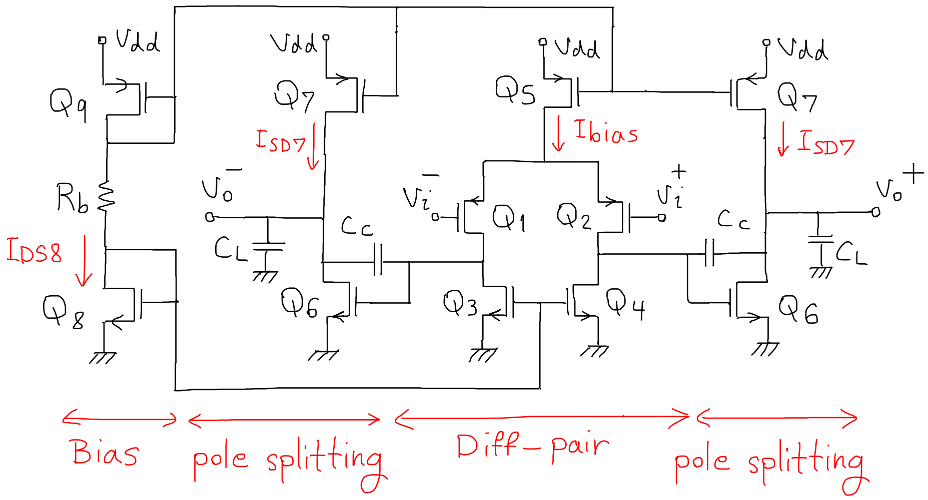
* Question:





Vdd	1.5 V
C_c	1 pF
C_L	100 fF
C_{gs}	$0.2\frac{W}{L}$ fF
C_{gd}	$0.1\frac{W}{L}$ fF
C_{db}	$0.05\frac{W}{L}$ fF
C_{sb}	$0.1\frac{W}{L}$ fF
R_b	1 KΩ
λ	$0.01\ \frac{1}{V}$
$\mu_n C_{ox}$	$125\mu\ A/V^2$
$\mu_p C_{ox}$	$50\mu\ A/V^2$
V_{th}	0.3 V
W_1/L_1	300
W_2/L_2	300
W_5/L_5	250
W_6/L_6	300
W_7/L_7	125
W_8/L_8	10
W_9/L_9	25

Q_3 and Q_4 are matched and their currents must be half of the current in Q_5.

$$\frac{I_{SD5}}{I_{SD9}} \approx \frac{W_5/L_5}{W_9/L_9} \Rightarrow I_{SD5} = 10\, I_{SD9} = 10\, I_{DS8} \Rightarrow I_{DS3} = 5\, I_{DS8}$$

$$\frac{I_{DS3}}{I_{DS8}} = \frac{W_3/L_3}{W_8/L_8} = 5 \Rightarrow \frac{W_3}{L_3} = \frac{W_4}{L_4} = 50$$

* Q8 and Q9 are operating in saturation:

$$\begin{cases} I_{DS8} = \frac{1}{2}\mu_n C_{ox}\frac{W_8}{L_8}(V_{GS8}-V_{th})^2[1+\lambda V_{th}] \\ I_{SD9} = \frac{1}{2}\mu_p C_{ox}\frac{W_9}{L_9}(V_{SG9}-V_{th})^2[1+\lambda V_{th}] \\ I_{SD9} = I_{DS8} \\ V_{dd} = V_{SG9} + R_b . I_{DS8} + V_{GS8} \end{cases}$$

$$\Rightarrow 50\mu \times 25 \times (V_{SG9}-0.3)^2 = 125\mu \times 10 \times (V_{GS8}-0.3)^2$$

$$\Rightarrow V_{SG9} - 0.3 = \pm(V_{GS8}-0.3)$$

$$\Rightarrow \begin{cases} V_{SG9} = V_{GS8} \\ V_{SG9} = -V_{GS8} + 0.6 \quad \text{(not acceptable)} \end{cases}$$

$$\Rightarrow 1.5 = 2V_{GS8} + 62.5\times10^{-3}\times 10 \times (V_{GS8}-0.3)^2 \times 1.003$$

$$\Rightarrow .627(V_{GS8}^2 - 0.6V_{GS8} + 0.09) + 2V_{GS8} - 1.5 = 0$$

$$\Rightarrow V_{GS9}^2 + 2.59V_{GS9} - 2.3 = 0 \Rightarrow V_{GS8} = 0.7V$$

$$\Rightarrow V_{SG9} = 0.7V \quad \text{and} \quad I_{DS8} = 100\mu A$$

* Q_5 and Q_9 are current mirrors.

$$I_{bias} \approx I_{SD9} \cdot \frac{W_5}{W_9} = 100\mu \times \frac{250}{25} = 1mA$$

* Q_7 and Q_9 are also current mirrors.

$$I_{SD7} = I_{SD9} \frac{W_7}{W_9} = 100\mu \times \frac{125}{25} = 0.5\,mA$$

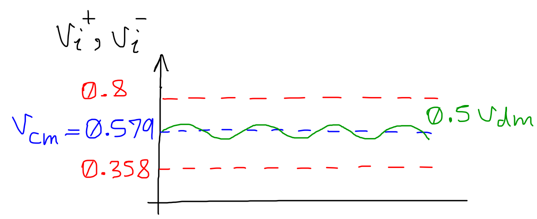
$$P_{diss} = V_{dd}\left(I_{SD9} + I_{bias} + 2I_{SD7}\right) = 1.5 \times 2.1_m = 3.15_{mW}$$

$$\begin{cases} r_{ds} = \dfrac{1}{\lambda I_{DS}} \\ g_m = \mu_n C_{ox} \dfrac{W}{L}(V_{GS} - V_{th}) = \dfrac{2I_{DS}}{V_{GS} - V_{th}} = \sqrt{2I_{DS}\mu C_{ox}\dfrac{W}{L}} \\ V_{eff} = \dfrac{2I_{DS}}{g_m} \end{cases}$$

	Q_1, Q_2	Q_3, Q_4	Q_5	Q_6	Q_7
I_{DS}	0.5mA	0.5mA	1mA	0.5mA	0.5mA
g_m	3.87mA/V	2.5mA/V	5mA/V	6.12mA/V	2.5mA/V
r_{ds}	200kΩ	200kΩ	100kΩ	200kΩ	200kΩ
V_{eff}	0.258V	0.4V	0.4V	0.163V	0.4V

$$V_{cm\text{-}max} < V_{dd} - V_{eff5} - V_{th1} \Rightarrow V_{cm\text{-}max} < 0.8\,V$$

$$V_{cm\text{-}min} > V_{eff3} + V_{eff1} - V_{th1} \Rightarrow V_{cm\text{-}min} > 0.358\,V$$



$$V_{o\text{-}max} < V_{dd} - V_{eff7} \Rightarrow V_{o\text{-}max} < 1.1\,V$$

$$V_{o\text{-}min} > V_{eff6} \Rightarrow V_{o\text{-}min} > 0.163\,V$$