

EE4803: Homework Assignment 3

Please submit handwritten solutions to this assignment on CANVAS by 23:59 hours on Nov 23, 2025.

Parameter Symbol	Parameter Description	Typical Parameter Value		Units
		n-Channel	p-Channel	
V_{T0}	Threshold voltage ($V_{BS} = 0$)	0.7 ± 0.15	-0.7 ± 0.15	V
K'	Transconductance parameter (in saturation)	$110.0 \pm 10\%$	$50.0 \pm 10\%$	$\mu\text{A}/\text{V}^2$
γ	Bulk threshold parameter	0.4	0.57	$\text{V}^{1/2}$
λ	Channel length modulation parameter	$0.04 (L = 1 \mu\text{m})$ $0.01 (L = 2 \mu\text{m})$	$0.05 (L = 1 \mu\text{m})$ $0.01 (L = 2 \mu\text{m})$	V^{-1}
$2 \phi_F $	Surface potential at strong inversion	0.7	0.8	V

The circuit in Figure 1 depicts a 9-transistor operational transconductance amplifier (referred to as 9T OTA in short). It uses a first stage (M1, M2, M3, M4 and M9) of differential amplifier with MOS diode loads followed by mirroring these currents to the output stage comprising M8 and M9 which gives high gain. **Assume $V_{DD} = 5 \text{ V}$.**

- Find the value of bias voltage V_{nbias} at gate of M9 to create a tail current of $10 \mu\text{A}$.
- Assuming all transistors are in saturation and perfect current mirroring, find the bias currents in all the transistors for $V_1 = V_2$ (i.e. no differential input). Also find the gate voltage V_{G3} , V_{G4} and V_{G6} for this case.

(HINT: Note the current mirroring ratios in M4-M8 and M6-M7)

- For this OTA, which input (V_1 or V_2) is inverting and which one is non-inverting?

(HINT: Find phase shift of V_{out} with respect to V_1 and V_2 one by one).

- Derive the equation for small-signal gain of this 9T OTA in terms of g_m and r_o of the transistors.

- Find the value of ICMR (high and low) and small-signal gain of this 9T OTA. Assuming a load capacitor $C_L = 5 \text{ pF}$ is connected to the output and find the bandwidth of the 9T OTA.

- Suppose the sizes of M7 and M8 are increased to $W/L = 100/5$ (i.e. 5 times current one). Find the new value of gain and bandwidth. To find the new value of λ for this L , use the equation $\lambda = a/L$. Find values of a for NMOS and PMOS from the data points in the Table above by using the equation: $\lambda(\text{avg}) = a/L(\text{avg})$. For example, for NMOS, $\lambda(\text{avg}) = (0.04 + 0.01)/2 = 0.025 \text{ V}^{-1}$ and $L(\text{avg}) = (1 + 2)/2 = 1.5 \mu\text{m}$ based on the table above.

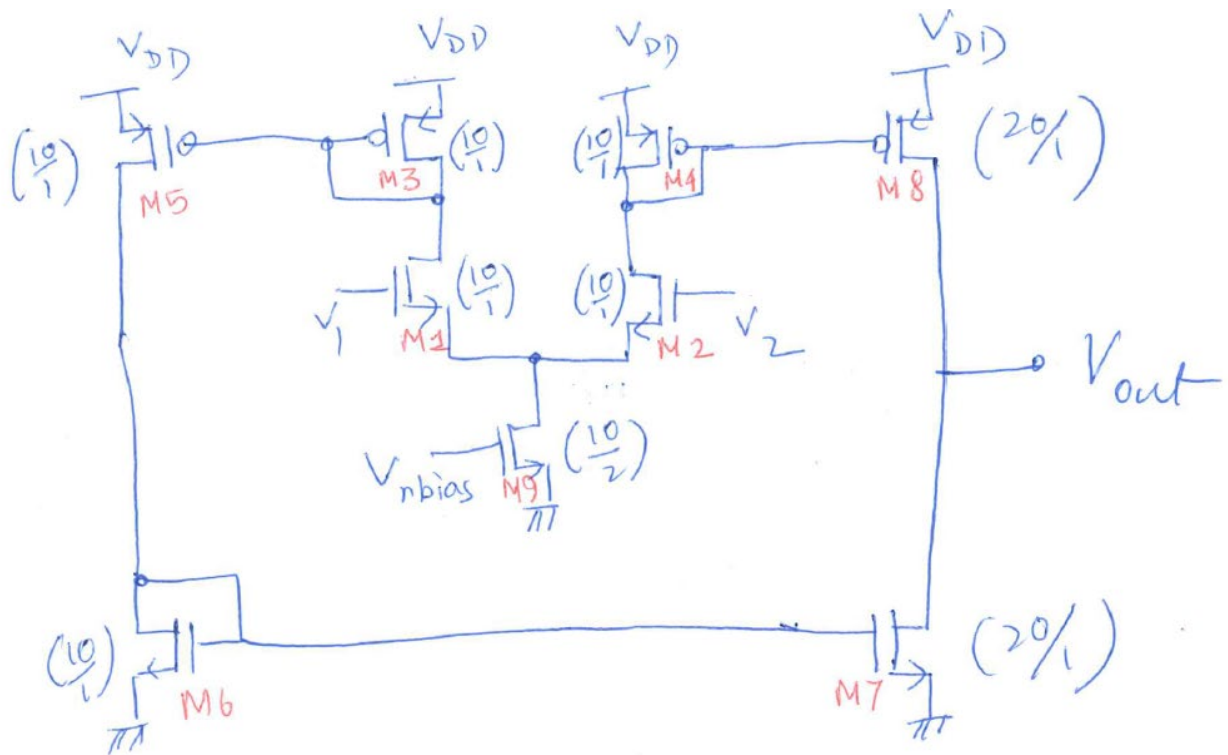


Fig. 1