PMOS I/V Characteristics and Applications

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The Problem Statement

In this experiment, we will do the following:

* Measure its output and transfer characteristics
* Investigate the effect of body bias on the characteristics of a PMOS transistor

Background Information

* The MOSFET is one of the most commonly used transistor.
* It has four terminals- Gate (G), Drain (D), Source (S) and Body (B).
* The device working principle is that the voltage applied between its gate and source terminal controls the current through the source and drain terminals.
* The body terminal of an PMOS is connected to **the highest voltage** in the circuit i.e, V_{DD} while that of a NMOS is connected to **ground**
* For the transistor to be ON, the applied gate to source voltage must be **less** than the threshold voltage i.e. $V_{GS} < V_T$. The conditions for different operating regions of a PMOS are

$$\begin{aligned} V_{GS} - V_T &< V_{DS} \qquad \text{(Linear Region)} \\ V_{GS} - V_T &> V_{DS} \qquad \text{(Saturation Region)} \end{aligned} \tag{1}$$

Background Information (cont'd...)

Some information and conventions which we use:

* The threshold voltage V_{TP} of an PMOS is negative, while that of a NMOS, V_{TN} is positive.

* The parameter k in current eq. is as k_p and k_n for PMOS and NMOS respectively, and is given as

$$k = \mu C_{ox} \left(\frac{W}{L} \right) \tag{2}$$

Where;
μ- mobility of charge carriers (electrons/holes) in the channel of the MOSFET.

C_{ox}- per unit area capacitance between the gate and body.

W, L- width and length of the channel respectively.

Part 1- I_D-V_{DS} Characteristics

1. Write ngspice netlist to plot the I_D-V_{DS} characteristics of PMOS with the voltage V_{GS} varied from -2.5 V to -4 V in steps of -0.5 V. You may vary V_{DS} from 0 V to -5 V.(show all 4 curves on a single plot)
2. From these characteristics, obtain r_{DS} (linear region) for each value of V_{GS}. Also, find "Early voltage" and r_0 in saturation region(considering channel length modulation).

Part 2- I_D-V_{GS} Characteristics in different regions

1. Estimate the value of threshold voltage and transconductance g_m in **linear region**:
   - Bias the transistor in linear region by keeping V_{DS} = -200 mV
   - Now write ngspice netlist to plot I_D v/s V_{GS} characteristics by varying V_{GS} from -5 to 0 V
   - From this characteristic, obtain V_T and g_m
2. Estimate the value of threshold voltage and transconductance g_m in **saturation region**:
   - Bias the transistor in saturation region by keeping V_{DS} = -5 V
   - Now write ngspice netlist to plot I_D v/s V_{GS} characteristics by varying V_{GS} from -5 to 0 V
   - From this characteristic, obtain V_T and g_m
   - Also, plot $\sqrt{I_D}$ v/s V_{GS} to find parameter K(mention its unit)

Part 3- Effect of Body Bias

1. Bias the transistor in linear region by keeping V_{DS} = -200 mV.
2. Now write ngspice netlist to plot I_D v/s V_{GS} characteristics by varying V_{GS} from -5 to 0 V for V_{SB}= 0 V. (which is already asked in part 2)
3. Repeat the above step to get four more sets of I_D v/s V_{GS} characteristics for V_{SB} = -1, -2, -3, and -4 V.
4. Show all five I_D v/s V_{GS} characteristics on the same plot
5. Obtain the value of threshold voltage from each plot
6. Plot V_T v/s V_{SB} and Obtain body effect coefficient (γ) using below equation. comment on dependence of V_T on V_{SB}.

   $V_T = V_{T0} + \gamma(\sqrt{\phi_s + V_{BS}} - \sqrt{\phi_s})$

   where ϕ_s is Surface Potential = 0.8 V for ALD1107 PMOS model, Threshold voltage (V_T) = V_{T0} when V_{BS} = 0 V