Self-Exercise 3-11
If $V_{t0} = 0.5$ V, $V_t = 0.59$ V, $\Phi_F = -0.35$ V, and $V_{SB} = 0.8$ V, what is γ?

Answer: $\gamma = 0.232\ \text{V}^{1/2}$.

Self-Exercise 3-12
If $V_{t0} = 0.5$ V, $V_t = 0.675$ V, $N_A = 8 \times 10^{18}$, $\Phi_F = -0.35$ V, and $V_{SB} = 0.8$ V:

(a) What is C_{ox}?
(b) What is T_{ox}?

Answers: **(a)** $C_{ox} = 2.088 \times 10^{-6}\ \dfrac{\text{F}}{\text{cm}^2}$. **(b)** $T_{ox} = 16.5$ Å.

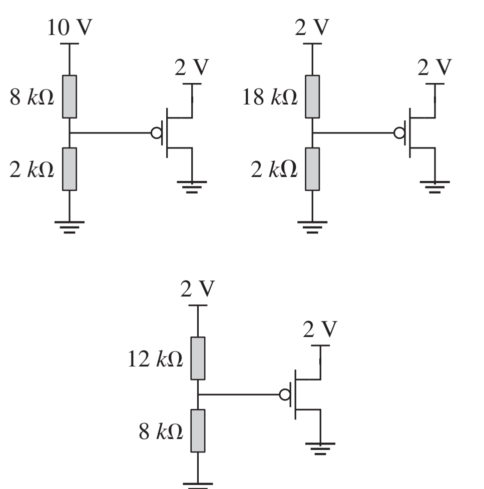
3.7. Summary

The transistor–resistor circuit analysis should become reflexive through the numerous problems in the chapter. Engineers intuitively think in these concepts when designing, debugging, and testing CMOS ICs. The body effect is an important alteration and must be understood. Chapter 5 will combine the *n*MOS and *p*MOS transistors to form the most fundamental logic gate called the inverter.

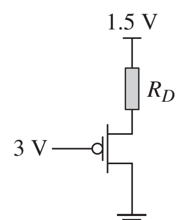
Exercises

nMOSFET Biasing and Current-Voltage Analysis

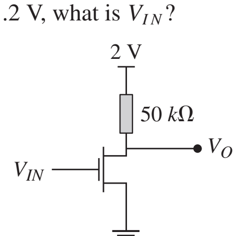
3-1. For the three circuits, **(a)** Give the transistor bias state, **(b)** Write the appropriate model equation, **(c)** Calculate I_D, where $W/L = 2$, $V_{tn} = 0.4$ V and $K_n = 200\ \mu\text{A/V}^2$.



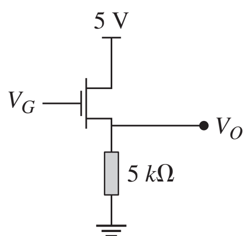
3-2. Given $K_n = 200\ \mu\text{A/V}^2$, $W/L = 4$, $V_{tn} = 0.5$ V, and $V_D = 0.8$ V. Find
(a) Drain current I_D
(b) Find the value of R_D to satisfy these constraints



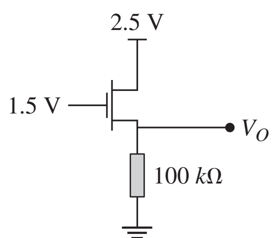
3-3. The transistor parameters in the following circuit are $K_n = 75\ \mu\text{A/V}^2$, and $W/L = 4$. If $V_o = 1.2$ V, what is V_{IN}?



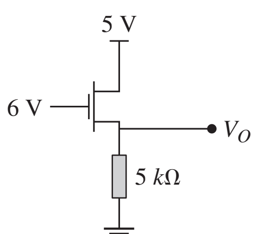
3-4. If $V_{tn} = 0.8$ V, $K_n = 100\ \mu$A/V^2, and $W/L = 4$, calculate V_G so that $I_D = 200\ \mu$A.



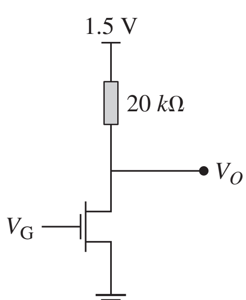
3-5. Given that $W/L = 3$, $V_{tn} = 0.6$ V, and $K_n = 75\mu$A/V^2, calculate V_O and I_D.



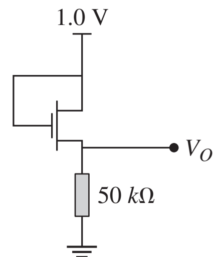
3-6. Given $V_{tn} = 0.8$ V, $K_n = 200\ \mu$A/V^2, and $W/L = 4$, calculate V_O.



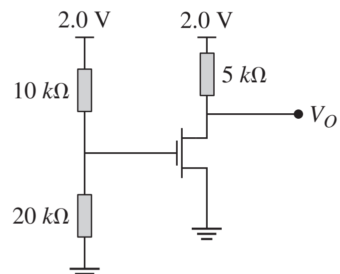
3-7. Given that $W/L = 2$, $V_{tn} = 0.4$ V, and $K_n = 80\ \mu$A/V^2, what value of V_G sets $I_D = 50\ \mu$A?



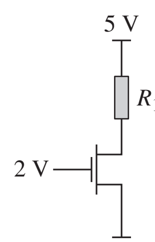
3-8. Given that $W/L = 5$, $V_{tn} = 0.25$ V, and $K_n = 110\ \mu$A/V^2, find V_O and I_D.



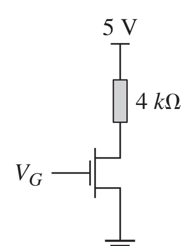
3-9. Given that $W/L = 20$, $V_{tn} = 0.5$ V, and $K_n = 120\ \mu$A/V^2, find V_O and I_D.



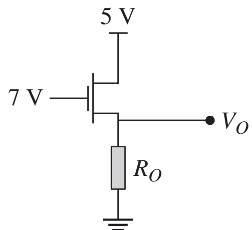
3-10. Given that $K_n = 250\ \mu$A, $V_{tn} = 0.5$ V, and $W/L = 3$, find R_1 so that the transistor is on the saturated/nonsaturated bias boundary.



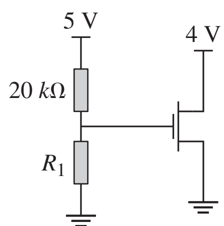
3-11. Given that $K_n = 250\ \mu$A, $V_{tn} = 0.5$ V, and $W/L = 3$, what V_G makes transistor biased at the saturated/nonsaturated boundary?



3-12. Calculate R_O so that $V_O = 2.5$ V, given $K_n = 300\ \mu\text{A/V}^2$, $V_{tn} = 0.7$ V, and $W/L = 2$.



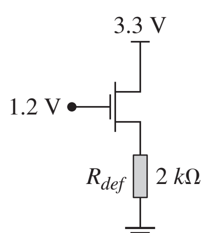
3-13. Adjust R_1 so that M1 is on the saturated/nonsaturated border where $V_{tn} = 0.5$ V.



3-14. Transistors emit light from the drain depletion region when they are in the saturated bias state:

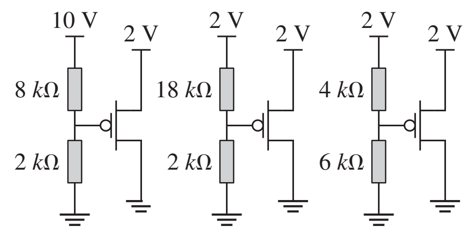
(a) Show whether this useful failure analysis technique will work for the circuit, given that $V_{tn} = 0.6$ V, $K_n = 75\ \mu\text{A/V}^2$, and $W/L = 2$.

(b) Find I_D, V_{GS}, and V_{DS}.

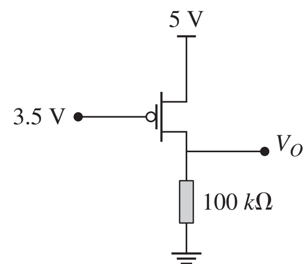


pMOSFET Biasing and Current-Voltage Analysis

3-15. For the three circuits: **(a)** Give the transistor bias state, **(b)** Write the appropriate model equation, **(c)** Calculate I_D, where $V_{tp} = -0.4$ V, $W/L = 4$, and $K_p = 100\ \mu\text{A/V}^2$. The pMOS source is higher voltage than drain.

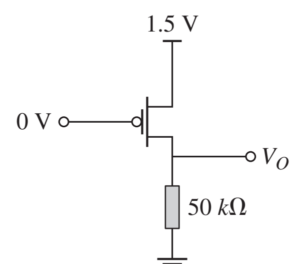


3-16. Calculate I_D and V_O for circuit where $V_{tp} = -0.8$ V, $K_p = 30\ \mu\text{A/V}^2$, and $W/L = 2$.

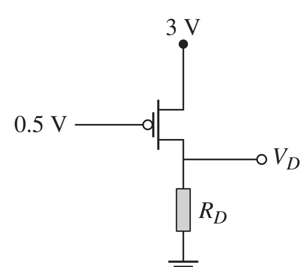


3-17. Repeat Problem 3.16 for $V_G = 1.5$ V.

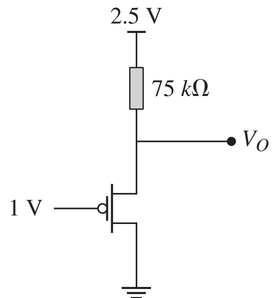
3-18. Given that $W/L = 5$, $V_{tp} = -0.4$ V, and $K_p = 50\ \mu\text{A/V}^2$, calculate V_O and I_D.



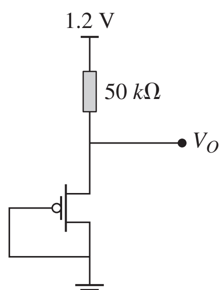
3-19. What value of R_D will place $V_D = 1.5$ V, given $K_p = 25\mu\text{A/V}^2$, $V_{tp} = -0.8$ V, and $W/L = 3$.



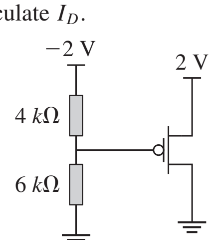
3-20. Given that $W/L = 20$, $V_{tp} = -0.6$ V, and $K_p = 30\ \mu$A/V^2, calculate V_O and I_D.



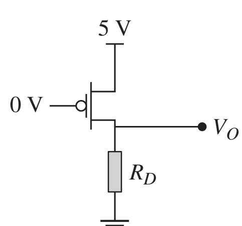
3-21. Given that $W/L = 6$, $V_{tp} = -0.3$ V, and $K_p = 40\ \mu$A/V^2, calculate V_O and I_D.



3-22. Given that $V_{tp} = -0.4$ V, $W/L = 4$, and $K_p = 100\ \mu$A/V^2, **(a)** Give the transistor bias state, **(b)** Calculate I_D.

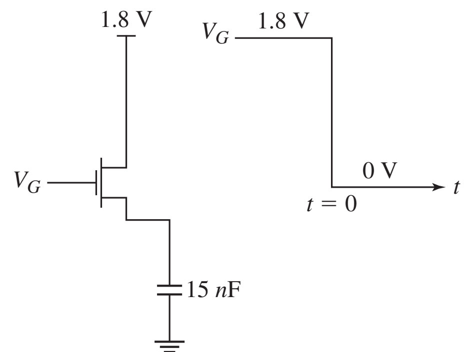


3-23. Given $V_{tp} = -0.8$ V and $K_p = 75\ \mu$A/V^2, what is the required W/L ratio and what is R_D if M1 is to pass 0.25 A and keep $V_{SD} < 0.2$ V.



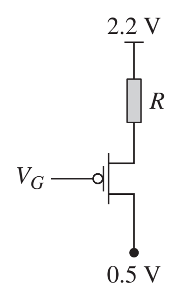
3-24. Given

$K_p = 40\ \mu$A/V^2
$V_{tp} = -0.4$ V
$W/L = 5$



(a) The capacitor is initially uncharged at $t = 0$. At $t = 0^+$ the gate voltage has changed state from 1.8 V to 0 V. What is the initial surge of current at $t = 0^+$.
(b) At $t = \infty$ what is the bias state on the transistor?
(c) How much energy is dissipated in the charge movement, and where does the heat loss occur?

3-25. Given $V_{tp} = -0.4$, $K_p = 50\ \mu$A/V^2, and $W/L = 8$, the transistor is biased at the saturated/nonsaturated boundary. The power in the resistor is 10 μW. What is the value of the resistor R?



Two Resistor MOSFET Circuits

3-26. Given $V_{tp} = -0.6$ V and $K_p = 75\ \mu$A/V^2, and $W/L = 5$, **(a)** Solve for source voltage V_s, **(b)** Solve for drain voltage.