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Due date: Fri Nov 4 03:00:00 pm 2016 (CDT)

An nMOS transistor, in the active mode, has a drain current given by \( I_D = k(V_{GS} - V_{TH})^2 \). Assume for this problem that the transistor will always remain in the active region. According to the datasheet, \( V_{TH} \) is 1 V.

Initially, \( V_{GS} \) is 6 V. What happens when \( V_{GS} \) is decreased to 3.5 V?

**Comment:** Focus on what changes in the formula. The numbers are simple enough that you should be able to do this problem without a calculator!

A. \( I_D \) quadruples.
B. \( I_D \) doubles.
C. \( I_D \) is cut in half.
D. \( I_D \) is reduced to 1/4 of its original value.
E. There is not enough information to tell.

---

Let \( V_{DS} \) be the voltage drop from the Drain to the Source of the MOSFET above. Which of the following equations is equivalent to the right-side KVL of an nMOS transistor configured as shown above?

A. \( I_D = k(V_{DD} - V_{DS})/R_D \)
B. \( I_D = (V_{DD} - V_{DS})/(k R_D) \)
C. \( I_D = (V_{DD} - V_{DS})/R_D \)
D. \( I_D = k(V_{DD} + V_{DS})/R_D \)

---

**Tries 0/2**
For this problem, we will assume a piecewise continuous nMOS model (as drawn above) in which

\[ I_D = k(V_{GS} - V_{TH})V_{DS} \]

in the Ohmic region

and that

\[ I_D = k(V_{GS} - V_{TH})^2 \]

in the active region.
If $I_1 = 0.005 \text{ A}$ what is $k$?

\[ k = \frac{\text{A}}{\text{V}^2} \]

*tries 0/8*

If $V_{TH} = 2 \text{ V}$, $V_{GS} = 3 \text{ V}$, $V_{DD} = 5 \text{ V}$ and $R_D = 100 \Omega$, then use the intersection of the IV curve above with the load line to determine the operating point $I_D$ and $V_{DS}$.

\[ I_D = \frac{\text{A}}{} \]

\[ V_{DS} = \frac{\text{V}}{} \]

*tries 0/8*
For this problem, we will assume a piecewise continuous nMOS model (as drawn above) in which

\[ I_D = k(V_{GS} - V_{TH})V_{DS} \]

in the Ohmic region

and that

\[ I_D = k(V_{GS} - V_{TH})^2 \]

in the active region.
If \( I_1 = 0.004 \text{ A} \) what is \( k \)?

\[
k = \text{ } \text{A/V}^2
\]

_Tries 0/8_

If \( V_{TH} = 2 \text{ V} \), \( V_{GS} = 6 \text{ V} \), \( V_{DD} = 8 \text{ V} \) and \( R_D = 200 \Omega \), then use the intersection of the IV curve above with the load line to determine the operating point \( I_D \) and \( V_{DS} \).

\[
I_D = \text{ } \text{A}
\]

\[
V_{DS} = \text{ } \text{V}
\]

_Tries 0/8_
For this problem, we will assume a piecewise continuous nMOS model (as drawn above) in which

\[ I_D = k(V_{GS} - V_{TH})V_{DS} \] in the Ohmic region

and that

\[ I_D = k(V_{GS} - V_{TH})^2 \] in the active region.

If \( V_{TH} = 1 \) V, \( V_{GS} = 4 \) V, \( V_{DD} = 7 \) V, \( V_{DS} = 2.25 \) V, and \( k = 0.001 \) A/V\(^2\), then determine \( R_D \).
For the given circuit complete the truth table:
Logical 1 represents an applied voltage of 5V and a 0 represents an applied voltage of 0V. Give your answers as logical 0 or logical 1.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>Z</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td></td>
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<tr>
<td>1</td>
<td>0</td>
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<tr>
<td>1</td>
<td>1</td>
<td></td>
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</tbody>
</table>

Tries 0/8
For the given circuit complete the truth table:
(1 represents a voltage of 5V and a 0 represents a voltage of 0V). The same circuit is redrawn on the right using logic symbols for clarity.
This part will help you think logically about the circuit above. 'IFF' means 'If and Only If' below. If the left side is true, then the right side must be also true. If the right side is true, then the left side must also be true.

For all statements below,

Choices: True, False.

• (V₀ is 1) IFF [(V₁ is 1) OR (V₂ is 1) OR (V₃ is 1)]
• (V₀ is 1) IFF [(V₁ is 0) OR (V₂ is 0) OR (V₃ is 0)]
• (V₀ is 0) IFF [(V₁ is 1) AND (V₂ is 1) AND (V₃ is 1)]
• (V₀ is 0) IFF [(V₁ is 0) AND (V₂ is 0) AND (V₃ is 0)]

Tries 0/8
For the given circuit complete the truth table:
(1 represents a voltage of 5V and a 0 represents a voltage of 0V). On the right, this same figure is shown using logic symbols!
This part will help you think logically about the circuit above. "IFF" means 'If and Only If" below. For the given circuit, which statements are correct?

Choices: **True, False.**

- [V0 is 1] IFF [(V3 is 0) OR (V2 is 0 AND V1 is 0)]
- [V0 is 1] IFF [(V3 is 1) AND (V2 is 1 OR V1 is 1)]
- [V0 is 0] IFF [(V3 is 1) OR (V2 is 1 AND V1 is 1)]
- [V0 is 0] IFF [(V3 is 0) OR (V2 is 0 AND V1 is 0)]
- [V0 is 0] IFF [(V3 is 1) AND (V2 is 1 OR V1 is 1)]
- [V0 is 1] IFF [(V3 is 0) AND (V2 is 0 OR V1 is 0)]

Tries 0/8

Comment: There is an "H-bridge" IC in your Lab Kit and a module that describes how to use it. If you dream of making your car do more interesting things by reversing the direction the wheels turn, you should work through the module!

The 'bridge' circuit below can be used to electronically change the direction of current in a DC motor (i_m > 0 for forward, or i_m < 0 for reverse) or to stop the motor (i_m = 0).

The motor is connected between the outputs of two CMOS inverters. Notice that (T1) and (T3) are pMOS transistors, and (T2) and (T4) are nMOS transistors.

The two digital control voltages V1 and V2 are input voltages and can be either 0V or 5V. **Assume the output voltages V_A and V_B will either be 0V or 5V.**

Assume that V1 = 0 V, and V2 = 5 V.
a) Indicate all conducting Transistors:

Choices: True, False.
- T1
- T2
- T3
- T4

Tries 0/8

b) Use the results from part a) to give the numerical value for $V_A$ below:

$V_A = \underline{\quad} \text{ (in Volts)}$

Tries 0/8

c) Use the results from part a) to give the numerical value for $V_B$ below:

$V_B = \underline{\quad} \text{ (in Volts)}$

Tries 0/8

d) Check the one correct answer:

46. A $i_m > 0$  B $i_m < 0$  C $i_m = 0$

Tries 0/8

How much energy is stored in a 60 pF capacitor charged to 3 V? Give your answer in picojoules (pJ).

$\underline{\quad} \text{ pJ}$

Tries 0/8

Assume that it requires twice this amount of energy to charge the capacitor ($E_{\text{input}}=E_{\text{useful}}+E_{\text{waste}}; E_{\text{waste}}=E_{\text{useful}}$). Stated more simply, it requires $CV^2$ Joules to charge a capacitor of capacitance $C$ to voltage $V$. While $0.5CV^2$ is stored in the capacitor, $0.5CV^2$ is wasted in the typical charging process.

How much power is consumed from the source when the capacitor is charged and discharged 65 million times per second? Give your answer in milliwatts (mW).

HINT: No power is consumed from the source when the capacitor is discharging.

$\underline{\quad} \text{ mW}$

Tries 0/8

If it requires $CV^2$ Joules to charge a capacitor of capacitance $C$ to voltage $V$, how many 9 fF caps are switched at 3.3 V every ns to dissipate 80 W?

$\underline{\quad} \text{ capacitors}$

Tries 0/8

If an IC has 1 billion transistors, what is its activity factor (as a percentage) if it produces the same 80 W?

$\underline{\quad} \%$

Tries 0/8