Solution

National Taiwan Normal University

CSU0007 - Basic Electronics Homework 4

100 points total. Due on 9AM, Monday, 5/25/2020.

Submit your answer via Moodle. Clearly state your analysis to earn full score.

Please tweak your image files to help save some ink! For example, grey-out the background color. Thanks!

請後製影像處理您的作業照片以節省列印墨水! 例如把背景顏色調淡。謝謝!

You may do so by using GIMP (https://www.gimp.org/), Photoshop, etc.

1 (5 points) For the circuit in Figure 1, determine the absolute difference between *the branch current i_{D1} when the switch is ON* and *the branch current i_{D1} when the switch is OFF*.

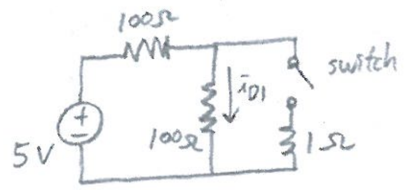


Figure 1

$$i_{D1,ON} = \frac{5}{100+\frac{100\times1}{100+1}} \times \frac{1}{100+1} = 4.9\times10^{-4}\ A$$

$$i_{D1,OFF} = \frac{5}{100+100} = 0.025\ A$$

⇒ the absolute difference is 0.02451 A

2 Signal tracing for MOSFET circuits using the S model:

2.1 (5 points) In Figure 2a, among the eight possible combinations of logical input {A, B, C} (That is, {0,0,0}, {0,0,1}, {0,1,0}, {0,1,1}, {1,0,0}, {1,0,1}, {1,1,0}, {1,1,1}), list all combinations that will make the logical output D equal to 1.

2.2 (5 points) In Figure 2b, suppose the logical input {A, B, C, D} is {1, 0, 0, 0}. Determine the logical output E.

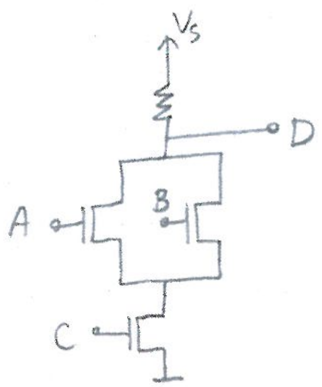


Figure 2a

$\{0,0,0\} \rightarrow 1$

$\{0,0,1\} \rightarrow 1$

$\{0,1,0\} \rightarrow 1$

$\{0,1,1\} \rightarrow 0$

$\{1,0,0\} \rightarrow 1$

$\{1,0,1\} \rightarrow 0$

$\{1,1,0\} \rightarrow 1$

$\{1,1,1\} \rightarrow 0$

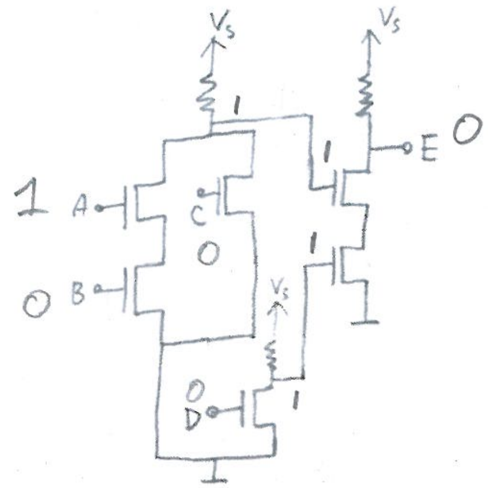


Figure 2b

3 Consider the transfer characteristic of a MOSFET inverter in Figure 3. In each of the following four cases, is the inverter compatible with the specification of the static discipline? Why or why not?

3.1 (5 points) V_{OH}=4.7V, V_{IH}=3V, V_{IL}=2V, V_{OL}=0.6V
3.2 (5 points) V_{OH}=4.5V, V_{IH}=2V, V_{IL}=0.5V, V_{OL}=0.4V
3.3 (5 points) V_{OH}=4.5V, V_{IH}=3.5V, V_{IL}=0.9V, V_{OL}=0.2V
3.4 (5 points) V_{OH}=4.7V, V_{IH}=4V, V_{IL}=0.6V, V_{OL}=0.2V

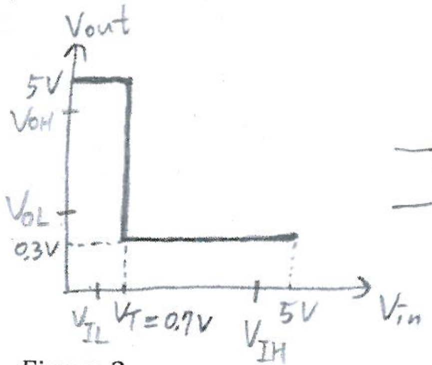


Figure 3

3.1 No $\because V_{IL} > V_T$.

3.2 Yes $\because 0.3 < V_{OL} < V_{OH} < 5$ and $V_{IL} < V_T < V_{IH} < 5$.

3.3 No $\because V_{IL} > V_T$ and $V_{OL} < 0.3$.

3.4 No $\because V_{OL} < 0.3$.

4 Suppose the SR model and the MOSFETs with V_T=2V and R_{ON}=2 kΩ. In the circuit in Figure 4, which of the following configurations can turn ON the MOSFET on the right? If a configuration can achieve that, state your reason; if it cannot, also state your reason.

4.1 (7 points) R_L=18 kΩ, V_{in}=10V ✗
4.2 (7 points) R_L=8 kΩ, V_{in}=10V ✗
4.3 (7 points) R_L=2 kΩ, V_{in}=10V ✓
4.4 (7 points) R_L=8 kΩ, V_{in}=1V ✓

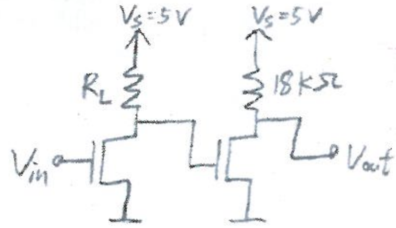


Figure 4

$$V_S \times \frac{R_{ON}}{R_L + R_{ON}} > V_T$$

4.1 $5 \times \frac{2}{18+2} = 0.5 < 2$

4.2 $5 \times \frac{2}{8+2} = 1 < 2$

4.3 $R_L = 2k\Omega \quad V_{in} = 10V$

$\Rightarrow 5 \times \frac{2}{2+2} = 2.5 > 2$

4.4 $R_L = 8k\Omega \quad V_{in} = 1$

$\Rightarrow$ OFF $\Rightarrow V_{out} = 5V > V_T$

5 (10 points) Following Question 4, if R_L= 2 kΩ, can we set V_{in} to turn OFF the MOSFET? If you think the answer is yes, state the appropriate value of V_{in}; if you think the answer is no, state your reason.

No. if $V_{in} < V_T$, V_{out} would be $5V > V_T$

if $V_{in} \geq V_T$, V_{out} would be $5 \times \frac{2}{2+2} = 2.5V$ still $> V_T$.

6 (7 points) Determine the gain of a buffer if V_{OH}=4.2V, V_{IH}=3V, V_{IL}=1.8V, V_{OL}=0.6V

$$gain = \frac{V_{OH} - V_{OL}}{V_{IH} - V_{IL}} = \frac{4.2-0.6}{3-1.8} = \frac{3.6}{1.2} = 3 \quad \#$$

7 Consider both a MOSFET inverter's transfer characteristic and a system's static discipline specification, as shown in the following figure. Using the following modifications, could we make the inverter compatible to the system? Show your analysis. Assume the SR model, and suppose that originally V_S=5V, R_L=23 kΩ, and R_{ON}=1 kΩ

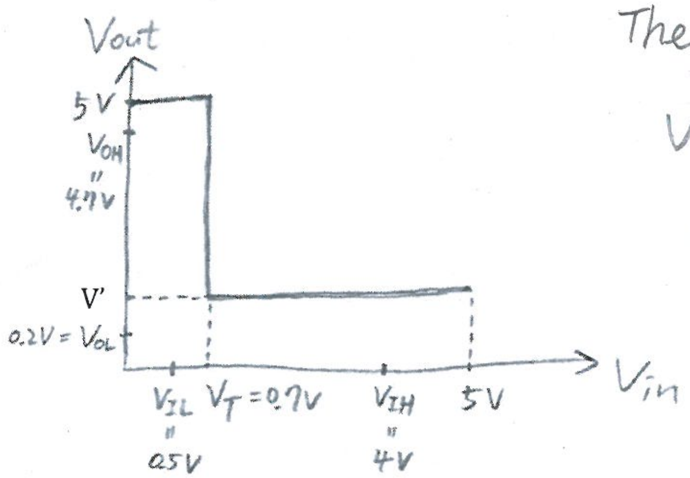
7.1 (5 points) Set V_S=4.1V

7.2 (5 points) Set V_S=4.75V

7.3 (5 points) Set R_L=20 kΩ

7.4 (5 points) Change R_{ON} by setting the W/L sizing for the MOSFET to W/L > 10. Suppose 5 kΩ is the resistance per square of the MOSFET in its ON state. (Review textbook's Section 6.7 and Examples 6.5 and 6.6).

$$V' = 5 \times \frac{1}{23+1} = 0.208 > V_{OL} \overset{\|}{=} 0.2$$



The problem is that the original V' is higher than V_{OL}.

7.1 No, ∵ $V_S < V_{OH}$ violates the static discipline specification.

7.2 Yes.

$$\because V' = 4.75 \times \frac{1}{23+1} = 0.197 < 0.2$$

7.3 No.

$$\because V' = 5 \times \frac{1}{20+1} = 0.23 > 0.2$$

7.4 Yes

$$V' = V_S \times \frac{R_{ON}}{R_L + R_{ON}} < V_{OL} = 0.2$$

$$\Rightarrow 5 \times \frac{R_{ON}}{23k + R_{ON}} < \frac{1}{5}$$

$$23k + R_{ON} > 25\,R_{ON}$$

$$R_{ON} < \frac{23k}{24}$$

$$\| $$

$$5k \times \frac{L}{W} < \frac{23k}{24}$$

$$\Rightarrow \frac{W}{L} > 5 \times \frac{24}{23} = 5.217$$

$\therefore \frac{W}{L} > 10$ can make the inverter compatible to the system.