Discussion 1A

For this discussion, Note 1 is helpful for background in transistors and RC circuits.

1. NAND Circuit

Let us consider a NAND logic gate. This circuit implements the boolean function $\overline{(A \cdot B)}$. The $\cdot$ stands for the AND operation, and the $\overline{}$ stands for NOT; combining them, we get NAND!

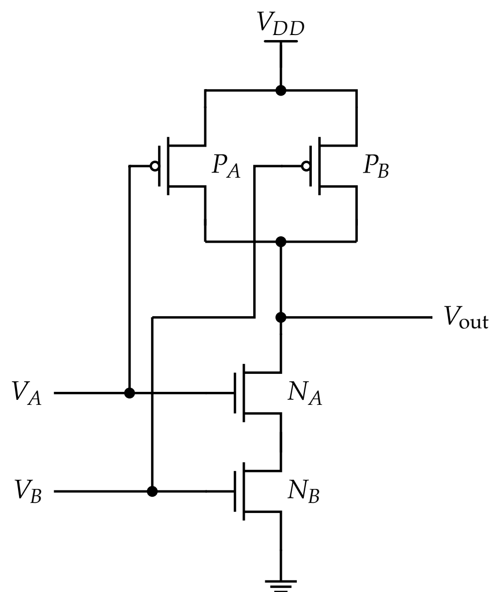

Figure 1: NAND gate transistor-level implementation.

V_{tn} and V_{tp} are the threshold voltages for the NMOS and PMOS transistors, respectively. Assume that $V_{DD} > V_{tn}, |V_{tp}| > 0$.

(a) **Label the gate, source, and drain nodes for the NMOS and PMOS transistors above.**

(b) If $V_A = V_{DD}$ and $V_B = V_{DD}$, **which transistors act like open switches? Which transistors act like closed switches? What is V_{out}?**

(c) **If $V_A = 0V$ and $V_B = V_{DD}$, what is V_{out}?**

(d) **If $V_A = V_{DD}$ and $V_B = 0V$, what is V_{out}?**

(e) **If $V_A = 0V$ and $V_B = 0V$, what is V_{out}?**

(f) **Write out the truth table for this circuit.**

V_A	V_B	V_{out}
0	0	
0	V_{DD}	
V_{DD}	0	
V_{DD}	V_{DD}	

2. RC Circuits - Part I

In this problem, we will find the voltage across a capacitor over time in an RC circuit. We set up our problem by first defining four functions over time: $I(t)$ is the current at time t, $V(t)$ is the voltage across the circuit at time t, $V_R(t)$ is the voltage across the resistor at time t, and $V_C(t)$ is the voltage across the capacitor at time t.

Recall from 16A that the voltage across a resistor is defined as $V_R = RI_R$ where I_R is the current across the resistor, and the voltage across a capacitor is defined as $V_C = \frac{Q}{C}$ where Q is the charge across the capacitor.

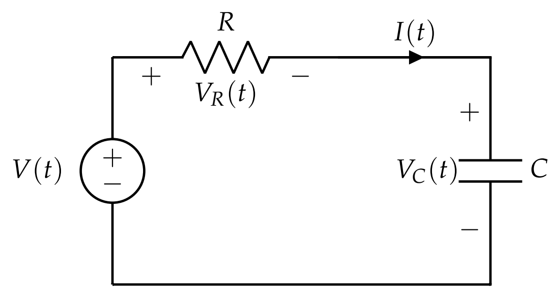

Figure 2: Example Circuit

(a) Starting from the given charge-voltage relation for a capacitor, **find an equation that relates the current across the capacitor** $I(t)$ **with the voltage across the capacitor** $V_C(t)$.

(b) Analyzing the circuit, **write an equation that relates the functions** $I(t)$**,** $V_C(t)$**, and** $V(t)$.

(c) So far, we have an equation that involves both $I(t)$ and $V_C(t)$. To solve this equation, we can remove $I(t)$ (one of the unknowns) using what we found in part 2.a. **Rewrite the previous equation in part 2.b in the form of a differential equation.** You will pick up with this in the next discussion.

Contributors:

- Neelesh Ramachandran.
- Kumar Krishna Agrawal.
- Lev Tauz.
- Varun Mishra.
- Regina Eckert.

