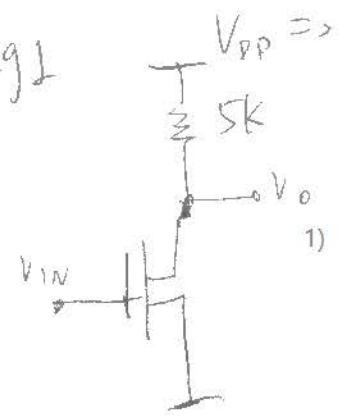
CMOS (P/N)MOS Logic circuits. (delay/static power)

No RLC circuits

NMOS + and/OR diode circuits

+ And/OR Op Amp.

+ And/OR see examples
- RL ⇒ HW 11 Problem 4
- RC ⇒ lecture35 (12-04) Eq. 2

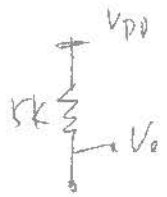
eg1 

=> SR model $R_{on} = 500\Omega$. Vt = 1 V

$V_{IN} = 0$ and 3 V. find V_o and power

1) $V_{IN} = 0$

$V_{GS} = 0$

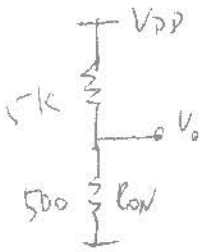


$V_o = V_{DD} = 3V$

i $\quad P = 0$

2) $V_{IN} = 3V$

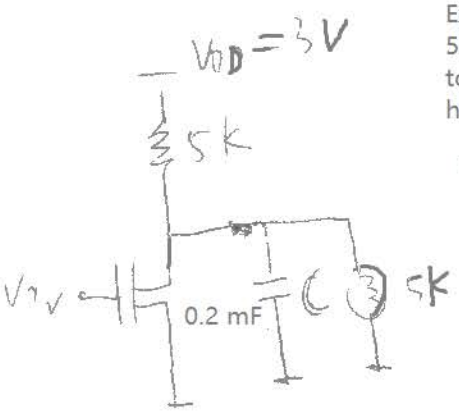
$V_{GS} = V_{IN} - 0 = 3V$ "ON"



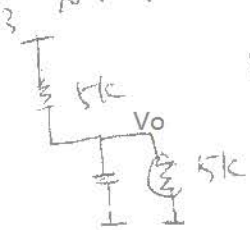
$$V_t = \frac{500}{5k+500} \cdot 3 = \frac{1}{11} 3 = 0.273\,(V)$$

$$P = \frac{V_{DD}^2}{5k+0.5k} = \frac{9}{5.5k\Omega} = 1.64\,mW$$

Extension: A capacitor and lamp are connected. The lamp has internal resistance of 5K and requires a voltage >1 V to light up. Calculate how long it takes for the lamp to change state when the Vin changes from 0 V to 3 V. (Suppose before t =0, Vin has been 0 V for a long time).

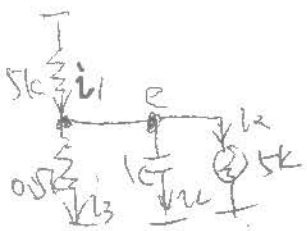


1) At $t < 0$: Vin = 0; VGS = 0; transistor "OFF"



$$V(0+) = \frac{5}{5+5} \times 3 = 1.5\,(V)$$

2) At $t > 0$. Vin = 3 V; VGS = 3 V; transistor "ON" -- Ron = 0.5 K



$i_1 - i_2 - i_c - i_3 = 0$

$$\frac{3-e}{5k} - \frac{e}{5k} - 0.2m\frac{de}{dt} - \frac{e}{0.5k} = 0$$

$$3 - e - e - \frac{de}{dt} - 10e = 0$$

$$\frac{de}{dt} + 12e = 3$$

$$e = \frac{1}{4} + k_1 e^{-12t}$$

Since V(0+) = 1.5, we get K = 1.25

$$e = \frac{1}{4} + 1.25e^{-12t}$$

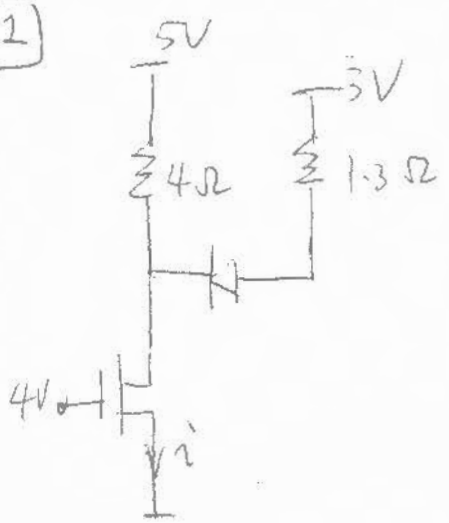
The boundary for lamp state change is e = 1

$$e = \frac{1}{4} + 1.25e^{-12t} = 1$$

$$e^{-12t} = \frac{.75}{1.25} \quad 12t = 0.511$$

$$t = 0.0435$$

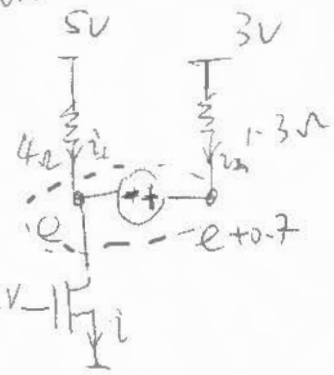
(eg 1)



$V_T = 1\,V$, $k = \frac{1}{8}\,A/V^2$, $V_D = 0.7\,V$

find i.

① Assume D. "ON":



MOS: $V_{GS} = 4 - 0 = 4$ "ON"

Assume MOS = saturation: $i = i_{DS} = \frac{k}{2}(V_{GS} - V_T)^2$

$= \frac{1}{2} \times \frac{1}{8} \times (4-1) = \frac{3}{4}(A)$

Supernode $i_1 + i_2 - i = 0$

$$\frac{5-e}{4} + \frac{3-(e+0.7)}{1.3} - \frac{3}{4} = 0$$

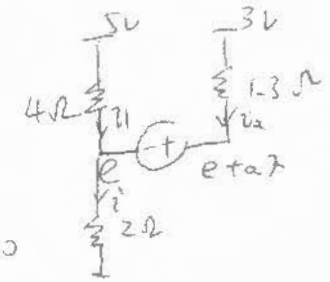
$$6.5 - 1.3e + [12 - 4e - 2.8] - 3 = 0 \Rightarrow 11.8 = 5.3e$$

$$\Rightarrow e = 2.23$$

Check. $V_{DS} = e - 0 = 2.23\,V < V_{GS} - V_T = 4 - 1 = 3\,V$ ✗

Assume MOS = Triode: $k_{ON} = \frac{1}{(V_{GS} - V_T)} = \frac{1}{\frac{1}{8}(4-1)} = \frac{8}{3}$

Supernode. $\frac{5-e}{4} + \frac{3-(e+0.7)}{1.3} - \frac{e}{2} = 0$



$$1.3(5-e) + 4(3 - e - 0.7) - 2.6e = 0$$

$$6.5 - 1.3e + 12 - 4e - 2.8 - 2.6e = 0$$

$$15.7 - 7.9e = 0 \Rightarrow e = 1.99\,(V)$$

Check. $V_{DS} = 1.99 < V_{GS} - V_T = 3\,(V)$ ✓

Check: current passing through the diode id = i2 >0;
assumption of diode being "ON" correct