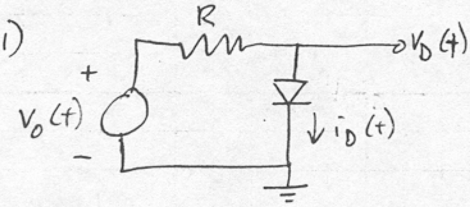
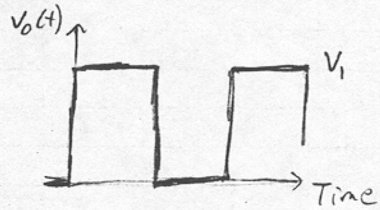
EE40 Problem Set 8

1)





$R = 10k\Omega$
$V_1 = 15V$

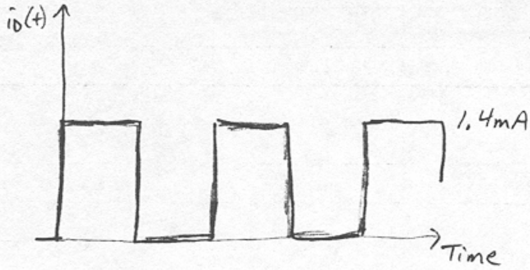
Current through resistor = Current through diode

$$\frac{V_0(t) - V_D(t)}{R} = I_S\left(e^{\frac{V_D(t)q}{KT}} - 1\right) \qquad I_S = 10^{-13}A$$

When $V_0(t) = 0$, current $= 0$

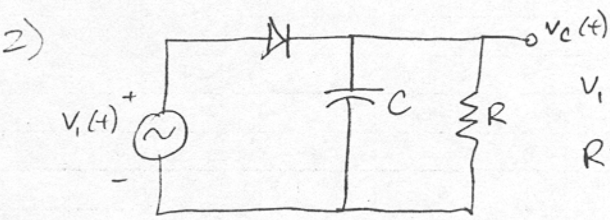
When $V_0(t) = 15V$, $\frac{15 - V_D}{10k\Omega} - 10^{-13}\left(e^{V_D/26mV} - 1\right) = 0$

$\Rightarrow V_D = .608V$ current $= 1.4mA$



Current graph has the same shape as the voltage graph

2)

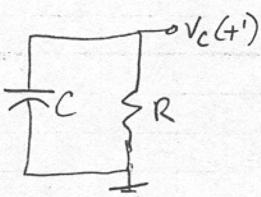


$V_1(t) = 165 \sin 60\cdot(2\pi)t$ V

$R = 1k\Omega$

Remember that we assume the capacitor is fully charged when $V_1(t) = 165V$ (time $= t_1$). Current in the circuit may be very high, but finite.

During the discharge cycle (which starts at $t' = 0$), the load behaves like:



$$V_C(t') = 165\, e^{-t'/RC}$$

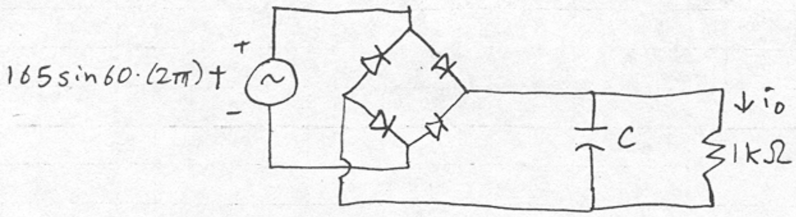
We want voltage to drop 0.5V in $\frac{1}{60}$ s:

$$164.5 = 165\, e^{-\frac{1}{60RC}}$$

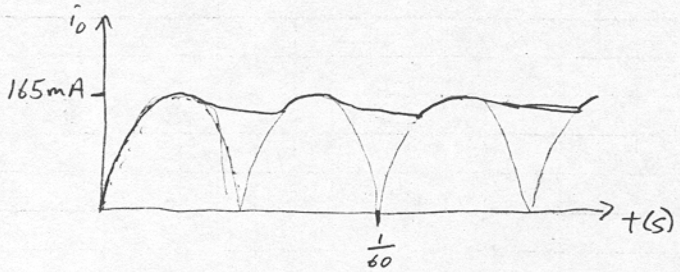
$$\ln\left(\frac{164.5}{165}\right) = -\frac{1}{60RC}$$

$C = 5.5mF$ ← that's BIG!

3)



Current through the resistor (with and without filter cap) looks like this:

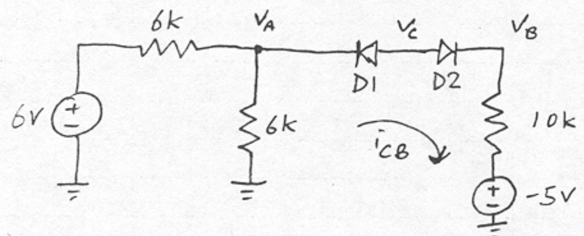


Compare this with Fig 13.15 in the book

This is really the same as the previous problem, except the discharge cycle last $\approx \frac{1}{120}$ s.

$$\ln\left(\frac{164.5}{165}\right) = -\frac{1}{120RC} \quad \Rightarrow \quad C = 2.75\text{mF}$$ (half the previous answer)

4)



a) if the diodes are <u>perfect</u> rectifiers. current can only flow in the direction of the diode arrow. By KCL, no current flows through either diode. Hence

$$V_A = 6V \frac{6k}{6k+6k} = 3V \qquad V_B = -5V$$

V_C is anywhere between $-5V$ and $3V$ (inclusive)

b) Again using KCL, the upper bound on $|i_{CB}| = I_S = 10^{-16} A \approx 0$ since current must flow against a diode arrow either way. ($i_{CB} = +I_S$, assuming $V_A > V_B$)

So again, $V_A = 3V$ and $V_B = -5V$ since the current through the diodo is small. V_C, however, isn't arbitrary. We need:

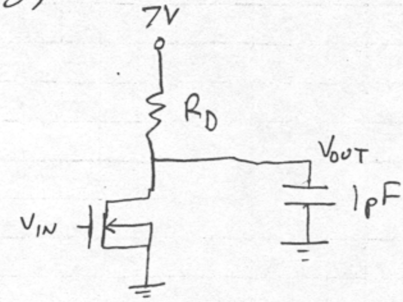
$$I_S\left(e^{\frac{V_C-3}{.026}} - 1\right) + I_S\left(e^{\frac{V_C-(-5)}{.026}} - 1\right) = 0$$

$$\Rightarrow V_C = -5 + .026 \ln 2 = -4.982$$

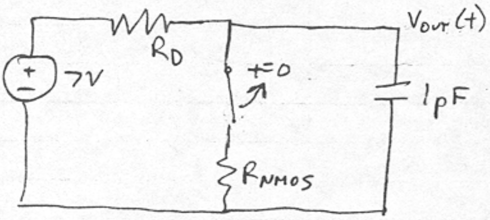
5) (ignoring load capacitance)

When $V_{IN} = 7V$, $V_{OUT} = 0.6V$

$V_{IN} = 0V$, $V_{OUT} = 7V$



We can draw an equivalent switch circuit, modelling the MOS as a switch plus resistor.



$V_{out}(0) = 0.6V$

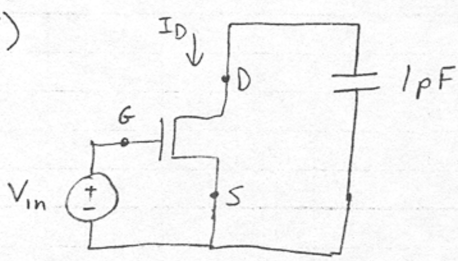
$V_{OUT}(\infty) = 7V$

$V_{OUT}(t) = 7 - 6.4e^{-t/RC}$ $R_D = 23k\Omega$, $C = 1pF$

$= 3.8V \Rightarrow t = 15.9ns$

When the input is 7V, there is 0.275mA flowing from V_{DD} to ground (through the resistor and NMOS transistor), so power $= 0.275mV \times 7V = 1.925mW$

6)

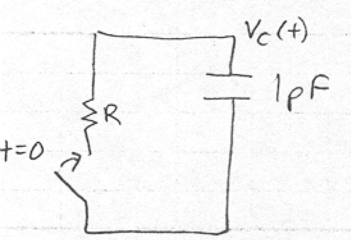


a) $i_D = C\frac{\partial v_c}{\partial t}$

$V_c(t)$ is linear with a slope of $\frac{i_D}{C} = 2E9\ V/s$

b) $\Delta t = \frac{C}{i_D}\Delta V = \frac{1s}{2E9V} \cdot 1V = 500ps$

Using a switch model:



c) Here $V_C(t)$ is a decaying exponential from 2V to 0V

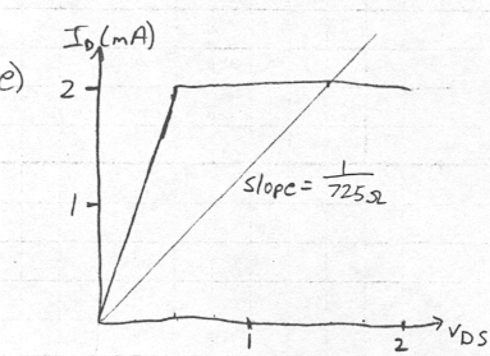
$V_c(t) = 2e^{-t/RC}$

$= 1 \Rightarrow t = 0.69RC$

d) $500ps = 0.69 \cdot R \cdot 1pF \Rightarrow R = 725\Omega$

Remember that the V_c curves look different in parts (a) and (c), but coincide at $t=0$ and $t=500ps$. That's all we want.

e)



The two plots cross at $V = 1.45V$, which is roughly the average of 1V and 2V.

(Additional comments)

4b) This question *could* be solved using nodal analysis:

$$\frac{6-V_A}{6k} + \frac{0-V_A}{6k} + I_s\left(e^{\frac{V_C-V_A}{.026}}-1\right) = 0$$

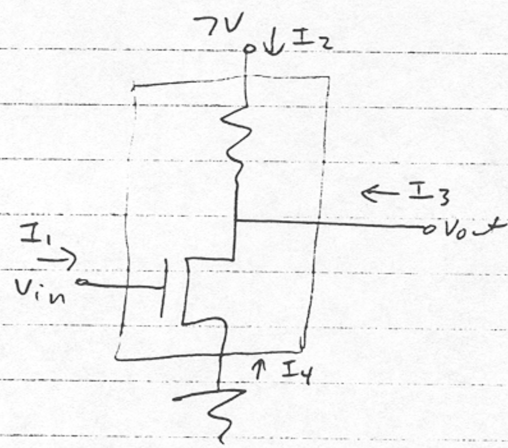
$$I_s\left(e^{\frac{V_C-V_B}{.026}}-1\right) + \frac{V_B+5}{10k} = 0$$

$$I_s\left(e^{\frac{V_C-V_B}{.026}}-1\right) + I_s\left(e^{\frac{V_C-V_A}{.026}}-1\right) = 0$$

but involves solving a bunch of nonlinear equations (*not* fun).

Also, V_A is not *exactly* 3V and V_B is not *exactly* −5V, but *very* close (to the 12th decimal place).

5b) The inverter is just another "box" with ports:



$$\text{Power} = I_1(V_{in}-0) + I_2(7V-0) + I_3(V_{out}-0) + I_4(0-0)$$

We know that $I_1 = 0$. I_3 is also 0. (if we still have our load capacitor, I_3 will also eventually be 0. In this case we are solving for "static" power dissipation)

$$\text{So Power} = 0\cdot(7-0) + I_2(7V) + 0(0.6-0) + I_4(0)$$

$$= I_2 \cdot 7V = .275\text{mW} \cdot 7V = 1.925\text{mW}$$