EE330 Fall 2018 HW10 Solutions TA: Robert Buckley

Problem 1:

$$A_V = -\frac{2I_{DQ}R}{V_{EB}} = -\frac{40000I_{DQ}}{0.25}$$

with preset variables $R = 20k$, $V_{EB} = (1 - 0.5) = 0.5$

$$A_V = -\frac{40000I_{DQ}}{0.5} = -4 \rightarrow I_{DQ} = 0.1mA$$

$$V_{outq} = 1 - 20000I_{DQ} = 0V$$

So this I_{DQ} works for both constraints, setting $L = 1\mu$

$$I_{DQ} = 350e - 6 * \left(\frac{W}{2}\right)0.25 = 0.0001$$

$$W = 2.28\mu, l = 1\mu$$

Problem 2:

Choose $V_{GTMax} = 0.9\ V$ (at 0^oC) and $I_{GT} = 200\ \mu A$

$\rightarrow\ R_{GG} = \frac{15 - 0.9}{200\ \mu} = 70.5k\Omega$

b) $I_{Fmax} = \frac{80-1.6}{40} = 1.96\ A, V_F = 1.6 \rightarrow P = IV = 1.96 * 1.6 = 3.136W$

c) $V_{GT} = .8,\ I_G = \frac{15-0.8}{70.5k} = 201.4\ \mu A \rightarrow P = 161.13\ \mu W$

Problem 3:

a)

Upper portion of potentiometer = 500*(1 - 0.1) = 450
Lower portion of potentiometer = 500*0.1 = 50

$$V_{TM} = 1.6\,V, \;\; V_{GT} = V_{AC}\left(\frac{50}{500*2}\right) = 3\sin(2\pi*60*t)$$

$$\rightarrow V_F = \begin{cases} 1.6V & t_0 < t < t_1,\; t_2 < t < t_3 \\ V_{AC} & otherwise \end{cases}$$

where $t_3 = 602\pi n, t_1 = 60\pi n$ and

$V_g = 2.5 = 4\sin(60*2\pi t_0)$

$\frac{2.5}{4} = \sin(60*2\pi t_0)$

$60*2\pi t_0 = \sin^{-1}\left(\frac{2.5}{4}\right)$

$$t_0 = \frac{\sin^{-1}\left(\frac{2.5}{4}\right)}{120\pi}$$

Then it is simple to see that

$$t_3 = \frac{\sin^{-1}\left(-\frac{2.5}{4}\right)}{120\pi}$$

b)

$$V_{RMS} = \frac{80-1.6}{\sqrt{2}} = 55.43, \rightarrow \;\; I_L = \frac{V_{RMS}}{R_L} = 2772\,A_{RMS}$$

$$P = V*I_L = 1.6*2.065 = 3.304\,W_{RMS}$$

c)

Quadrants 1 and 3

Problem 4:

Turn on voltage is 0.8 V so at 2π/8 we need, $0.8 = \frac{R_1}{R_1+10000}*170\sin\left(\frac{\pi}{4}\right) \rightarrow R_1 = 67\,\Omega$

Problem 5

$$V_{GS} = 0 \; and \; V_{DS} > V_{GS} - V_P \rightarrow V_{out} = I_{DSS}*6k = 0.6\,V$$

Problem 6:

a)

$V_{GSH} = 20\ mV, assume\ V_{DS} > V_{GS} - V_P$

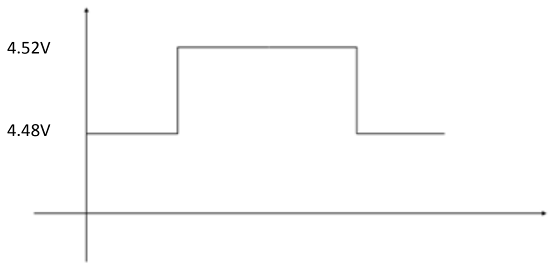
$$V_{out1} = 5 - I_D * 5k = 5 - I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 * 5k = 4.482$$

$Verify \rightarrow V_{DS} > V_{GS} - V_P \rightarrow 4.48 > 1.025$

$V_{GSL} = -20\ mV, assume\ V_{DS} > V_{GS} - V_P$

$$V_{out1} = 5 - I_D * 5k = 5 - I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 * 5k = 4.519$$

$Verify \rightarrow V_{DS} > V_{GS} - V_P \rightarrow 4.52 > 1.025$



b) $V_{in} < V_{GSMax} =$ $0.3\ V$ (From lecture slides)

Problem 7:

$$I = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)(V_G - V_{out} - V_{TN})^2 = I_{DSS} * \left(1 - \frac{V_{in}}{V_P}\right)^2$$

$$\rightarrow \frac{350 * 10^{-6}}{2} * \left(\frac{W}{12}\right)(5 - 3 - 0.75)^2 = 350 * 10^{-6} * \left(1 - \frac{-0.5}{-1}\right)^2 \rightarrow W = 3.84\ \mu m$$

Problem 7:

$$g_m = \frac{\partial I_D}{\partial V_{GS}} = -2 * \frac{I_{DSSP}}{-V_P}\left(1 - \frac{V_{GS}}{V_P}\right)(1 - \lambda V_{DS}) \approx = 2 * \frac{I_{DSSP0}}{V_P}\left(\frac{W}{L}\right)\left(1 - \frac{V_{GS}}{V_P}\right)$$

$$g_o = \frac{\partial I_D}{\partial V_{DS}} = \lambda * I_{DSSP}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

Problem 8:

$$I_{DQ} = \frac{30\mu * 10}{15} * \left(1 - \frac{0}{1}\right)^2 = \frac{V_{outQ} - (-5)}{50k} \rightarrow V_{outQ} = -4\,V, I_{DQ} = 20\,\mu A$$

$$g_m = \frac{2}{V_P}\frac{I_{DQ}}{\left(1 - \frac{V_{GS}}{V_P}\right)} \rightarrow A_V = \frac{V_{out}}{V_{in}} = -g_m * 50k = 2\,V/V$$

Problem 9

Guess Saturation

$$I_{DQ} = I_{DSS_{p0}}\frac{W}{L}\left(1 - \frac{V_{GS}}{VP}\right)^2 = 30e - 6\left(\frac{10}{15}\right)\left(1 - \frac{0}{1}\right) = 20\mu A$$

$$V_{DS} = -5 + 20 * 10^{-6} * 50000 = -4V$$

$$A_V = -g_m * 50000 = \frac{2}{1}\left(\frac{20e-6}{1-\frac{0}{1}}\right)50000 = 2\frac{V}{V}$$

Problem 10

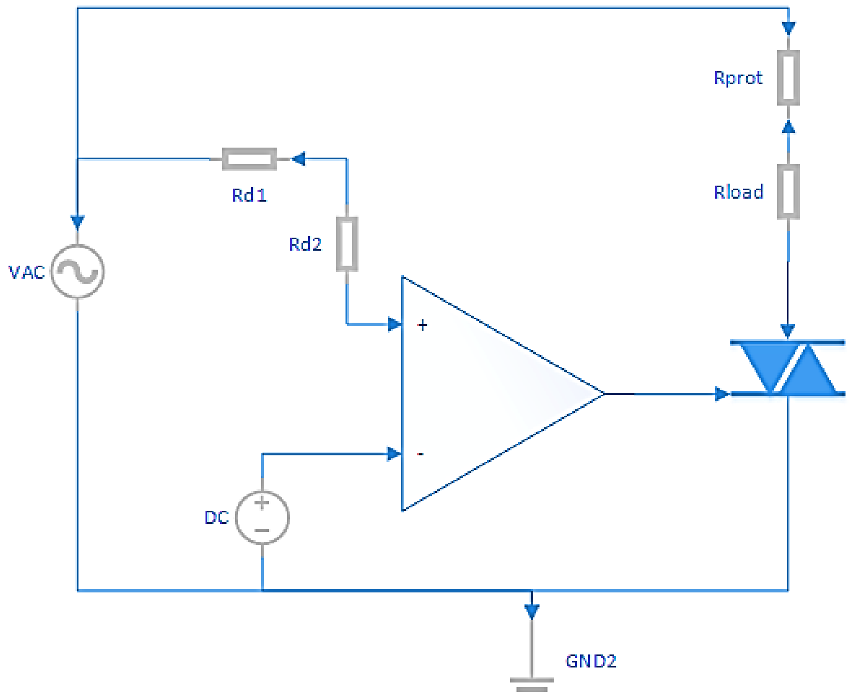
a) $A_V = \left(\frac{R_{in1}}{R_{impede}+R_{in1}}\right)A_{V1}\left(\frac{R_{in2}}{R_{o1}+R_{in2}}\right)A_{V2}\left(\frac{R_{load}}{R_{o2}+R_{load}}\right) = \left(\frac{4}{4+2}\right)(-10)\left(\frac{20}{20+0.5}\right)(-20)\left(\frac{0.5}{5+0.5}\right) = 11.83$

b) $A_V = \left(\frac{R_{in2}}{R_{impede}+R_{in2}}\right)A_{V2}\left(\frac{R_{in1}}{R_{o2}+R_{in1}}\right)A_{V1}\left(\frac{R_{load}}{R_{o1}+R_{load}}\right) = \left(\frac{20}{20+2}\right)(-20)\left(\frac{4}{4+5}\right)(-10)\left(\frac{0.5}{0.5+0.5}\right) = 40.4$

Problem 11

a) $R_{in} = R_{in1} = 4k\Omega,\ A_{VR} = 0,\ R_{out} = R_{o2} = 5k\Omega$
   $A_V = A_{V1}\left(\frac{R_{in2}}{R_{o1}+R_{in2}}\right)A_{V2} = -10\left(\frac{20}{20+0.5}\right)(-20) = 195.12$
b) Adding in the source input impedance and load,
   $A_V = \left(\frac{R_{in}}{R_{in}+R_{impede}}\right)A_V\left(\frac{R_{load}}{R_{out}+R_{load}}\right) = \left(\frac{4}{4+2}\right)(195.12)\left(\frac{0.5}{5+0.5}\right) = 11.83$
   Yes, they match.

Problem 12:



The above is one design. R_{prot} would protect R_{load} by keeping $I_{MAX} < I_{safe}$, whatever I_{safe} is by taking $\frac{V_{MAX}}{(R_{prot}+R_{load})} < I_{safe}$.

R_{d1} and R_{d2} create a voltage divider so $V_{gateMax} = V_{GT} = 0.8V$, since we have $120V_{AC}$, we need

$$\frac{R_{d2}}{R_{d2}+R_{d1}}(120) = 0.8$$

$$\frac{R_{d2}}{R_{d2}+R_{d1}} = \frac{1}{150}$$

so I will use $R_{d2} = 10\Omega$, $R_{d2} = 1.49k\Omega$

Then the adder causes this to cross V_{GT} when turned on, until the wave is always greater that V_{GT} at $DC = 5V$