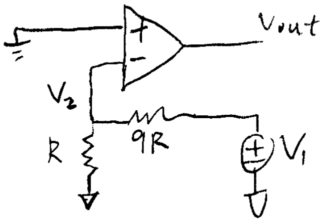
EECS 311 - fall08 - HW3 sol'ns

P3.1 $A(s)=\frac{10^6}{1+s}$ for all parts

a)



$$B(s)=\frac{V_2}{V_1}=\frac{1}{10}$$

$$\boxed{1/B(s)=10}$$

$$\frac{V_{out}}{V_{in}}=\frac{A(s)}{1+A(s)B(s)}=\frac{\frac{10^6}{1+s}}{\frac{1+s+10^5}{1+s}}=\boxed{\frac{10^6}{s+(10^5+1)}}$$

b)
$$B(s)=\frac{R+\frac{1}{sC}}{10R+\frac{1}{sC}}=\boxed{\frac{1+sRC}{1+10sRC}}$$

$$\frac{V_{out}}{V_{in}}=\boxed{\frac{10^6/(1+s)}{1+\frac{10^6}{1+s}\,\frac{1+sRC}{1+10sRC}}}$$

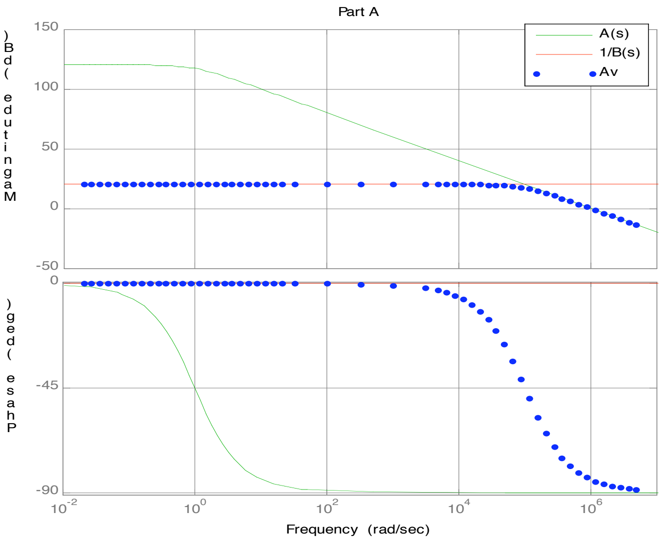
c)
$$B(s)=\frac{R}{R+(9R/\!/\frac{1}{sC})}=\frac{R}{R+\frac{9R/sC}{9R+1/sC}}=\frac{1}{1+\frac{9}{1+9sRC}}=\boxed{\frac{1+9sRC}{10+9sRC}}$$

$$\frac{V_{out}}{V_{in}}=\boxed{\frac{10^6/(1+s)}{1+\frac{10^6}{1+s}\,\frac{1+9sRC}{10+9sRC}}}$$

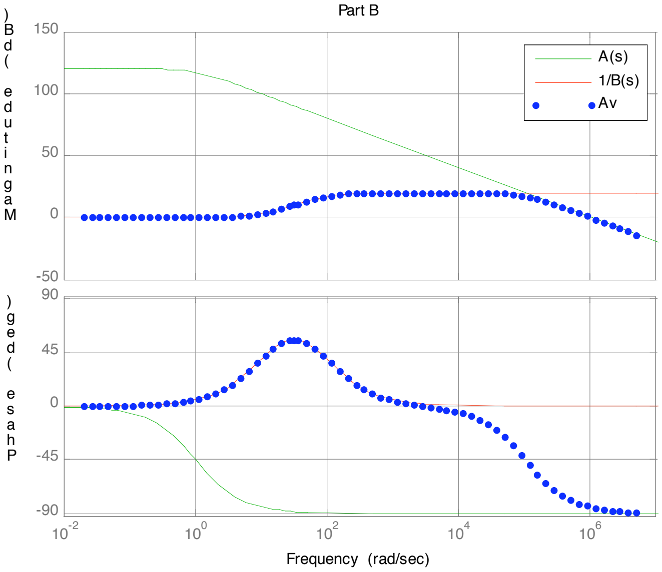
d)
$$\beta(s)=\frac{R}{sL+1/sC+R}=\boxed{\frac{sRC}{s^2LC+sRC+1}}$$

$$\frac{V_{out}}{V_{in}}=\boxed{\frac{10^6/(1+s)}{1+\frac{10^6}{1+s}\cdot\frac{sRC}{s^2LC+sRC+1}}}$$

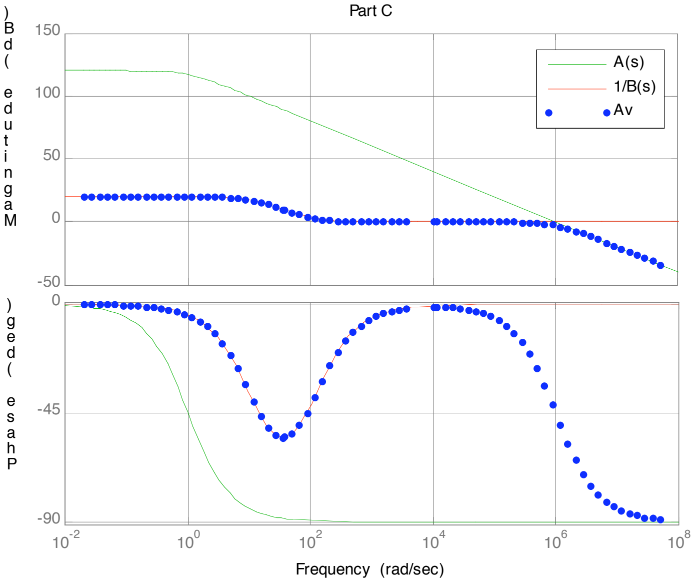
(over for plots)



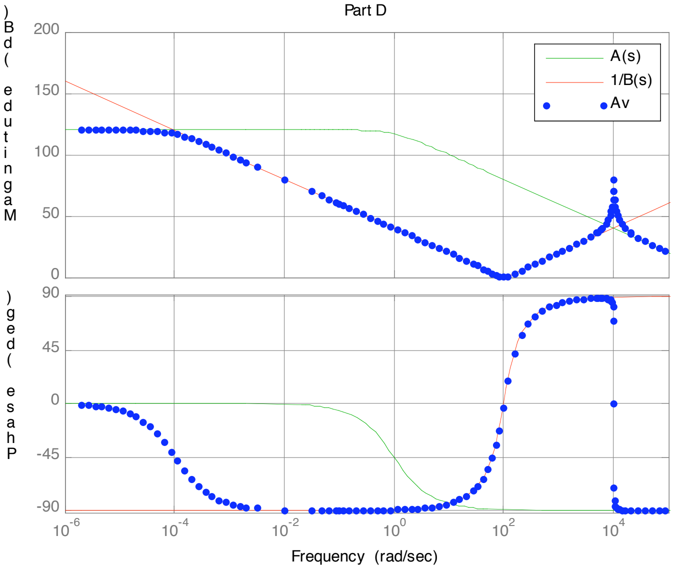
```
%%% Example Matlab Code for P3.1
close all; clear;
s=tf('s');
% Amplifier A(s)
A_s = 1e6/(1+s);
% This is an example Beta B(s),
substitute for other B(s)
B_s = 0.1*s/s;
% Vout/Vin = A(s)/(1+B(s)*A(s))
vout_vin = A_s/(1+B_s*A_s);
% Plot A(s), 1/B(s), and Vout/Vin
figure;
bode(A_s,'g:',1/B_s,'r-',vout_vin,'b.');
title('Part A');
legend('A(s)','1/B(s)','Av');
grid on;
```



`B_s = (1+0.01*s)/(1+0.1*s);`
(Is the only difference)



`B_s = (1+0.09*s)/(10+0.09*s);`
(Is the only difference)



`B_s = (0.01*s)/((0.0001*s^2) + (0.01*s) + 1);`
(Is the only difference)

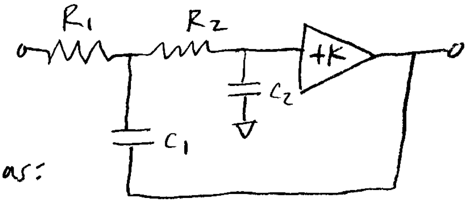
P3.2 $H(s) = \dfrac{K|P_1||P_2|}{(s-P_1)(s-P_2)}$

a) $P_1 = -100$, $P_2 = -10{,}000$, $\boxed{K=2}$

$$H(s) = \frac{2\times10^6}{(s+100)(s+10^4)} = \frac{2\times10^6}{s^2+10100s+10^6} = \frac{2}{\underset{\overset{\uparrow}{\omega_n}}{\left(\frac{s}{1000}\right)^2} + \underbrace{\frac{10100}{1000}}_{d}\frac{s}{1000}+1}$$

$\boxed{d = 10.1}$ $\boxed{\omega_n = 1000\ \frac{rad}{s}}$

$\Downarrow$



$T_1 T_2 = 1$

group IV formulas:

$\gamma_{min} = \dfrac{d^2-4(1-K)}{4} \approx 26.5$ pick $\gamma = 26.5$

$K_{min} = \dfrac{4(1+\gamma)-d^2}{4} \approx 2$ satisfied.

assuming we picked γ, use group IV formulas:

$d = \frac{1}{T_1} + T_1(1+\gamma-K)$

$10.1 = \frac{1}{T_1} + T_1(1+\gamma-2) \Rightarrow T_1 \approx \underset{= 1/5.1}{0.196078}$ or 0.2

group II formulas:

$d = \dfrac{(1+\gamma-K)}{T_2} + T_2 \Rightarrow T_2 = 5.1$ or 5

pick $\boxed{T_1 = 0.2 \quad T_2 = 5}$

group I formulas:

$d = \dfrac{(1-K)}{T_2} + T_2(1+\rho) \Rightarrow \rho = 1.06$

$\therefore$ $T_1 = R_1C_1\omega_n = 0.2 \Rightarrow R_1C_1 = 2\times10^{-4}$

$T_2 = R_2C_2\omega_n = 5 \Rightarrow R_2C_2 = 5\times10^{-3}$

$\gamma = C_2/C_1 = 26.5$

$\rho = R_1/R_2 = 1.06$

pick $C_1 = 1nF$

solve $\Rightarrow$

$C_2 \approx 26.5\,nF$

$R_1 \approx 200\,k\Omega$

$R_2 \approx 188.6\ k\Omega$

3.2

b)

$$H(s) = \frac{K|P_1||P_2|}{(s-P_1)(s-P_2)} \qquad P_1 = -\frac{1000}{\sqrt{2}} + j\frac{1000}{\sqrt{2}} \qquad P_2 = -\frac{1000}{\sqrt{2}} - j\frac{1000}{\sqrt{2}} \qquad K=1$$

$$\Downarrow$$

$$|P_1| = 1000 = |P_2|$$

$$H(s) = \frac{10^6}{\left[s+\left(\frac{1000}{\sqrt{2}} - j\frac{1000}{\sqrt{2}}\right)\right]\left[s+\left(\frac{1000}{\sqrt{2}} + j\frac{1000}{\sqrt{2}}\right)\right]} = \frac{10^6}{s^2 + 1000\sqrt{2}\,s + \left(\frac{10^6}{2} + \frac{10^6}{2}\right)}$$

$$= \frac{1}{\left(\frac{s}{1000}\right)^2 + \sqrt{2}\left(\frac{s}{1000}\right) + 1} \Rightarrow \boxed{\begin{matrix} \omega_n = 1000 \\ d = \sqrt{2} \end{matrix}} \quad \boxed{K=1}$$

group IV formulas:

$$\gamma_{min} = \frac{d^2 - 4(1-K)}{4} = \frac{1}{2}$$

$$K_{min} = \frac{4(1+\gamma) - d^2}{4} \leq K = 1 \Rightarrow \gamma \leq 1/2$$

∴ we must use $\gamma = 1/2$

$$d = \frac{1}{T_1} + T_1(1+\gamma-K) \Rightarrow T_1 \approx 1.4142135623 7 = \boxed{\sqrt{2} = T_1}$$

$$T_2 = \frac{1}{T_1} = \boxed{\frac{1}{\sqrt{2}} = T_2}$$

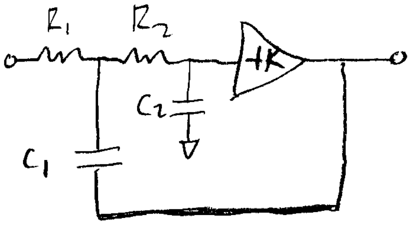
using group III formulas:

$$d = \frac{(1+\rho)}{T_1} + T_1(1-K) \Rightarrow \rho = 1$$

$$\left.\begin{aligned} \therefore\ R_1C_1 &= \frac{\sqrt{2}}{1000} \\ R_2C_2 &= \frac{1}{1000\sqrt{2}} \\ R_1/R_2 &= 1 \\ C_2/C_1 &= 1/2 \end{aligned}\right\} \text{pick } C_1 = 1nF \Rightarrow \text{solve}$$

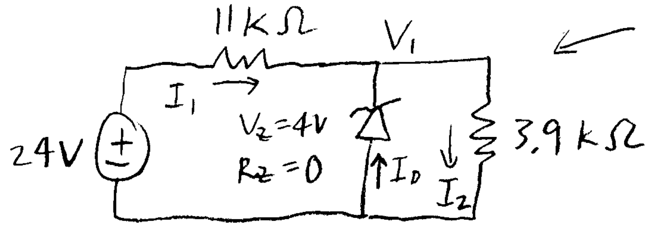
$$\Downarrow$$

$$\boxed{\begin{matrix} C_1 = 1nF \quad C_2 = 0.5nF \\ R_1 = R_2 = 1.41\ M\Omega \end{matrix}}$$



P3.3

3.78)



← this is a basic shunt regulator!

w/o the zener, $V_1 = \frac{3.9}{14.9} 24 = 6.28 V > V_z$

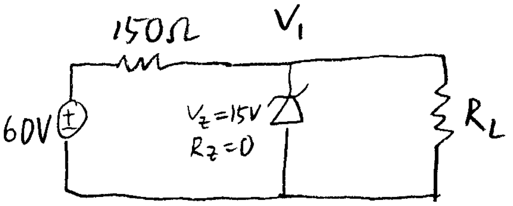
∴ w/ the zener, $V_1 = 4V$

$$I_1 = I_z - I_D \Rightarrow \frac{24-4}{11k} = \frac{4}{3.9k} - I_D$$

$$\boxed{I_D \approx -792.\ \mu A}$$

$$\boxed{V_D = -4V}$$

3.83)



a) $R_L = 100$

w/o zener, $V_1 = \frac{100}{250} 60 = 24 V > V_z$

∴ w/ zener, $V_1 = V_z = 15 V$

$$\left.\begin{array}{l} \\ I_D = \frac{60-15}{150} - \frac{15}{100} = 0.15 A \end{array}\right\} P_{diode} = V_D I_D = 15(0.15) = \boxed{2.25 W}$$

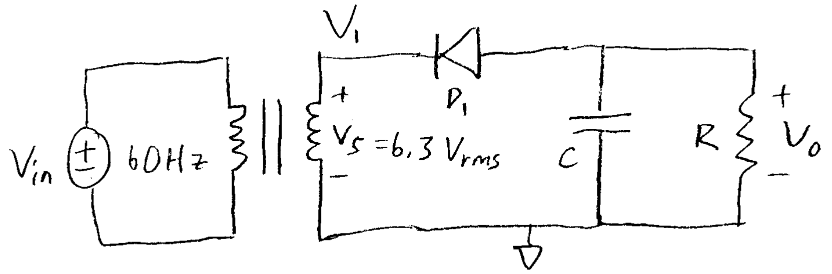
b) $R_L = \infty$ then the diode clamps $V_1 = 15V$

$$I_D = \frac{60 - V_1}{150} = 0.3 A$$

$$P_{diode} = 15(0.3) = \boxed{4.5 W}$$

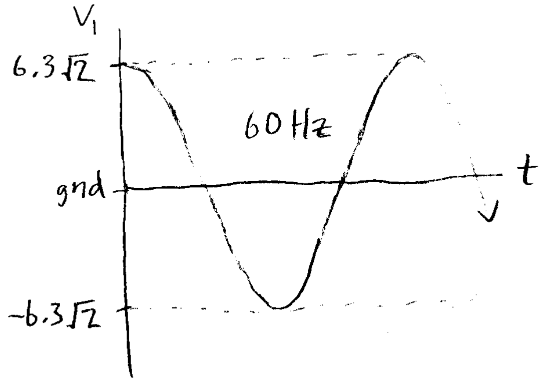
P3.4

3.91



a)

a plot of V_1 would look like:



assuming C is discharged, D_1 is off for $V_1 > 0$, and begins to conduct when $V_1 < -V_{D,on} = -1$

as $V_1 \downarrow$ to $-6.3\sqrt{2}$ V, V_o tracks V_1 through D_1 where $V_o = V_1(t) + \cancel{V_D}\ 1$

$\therefore V_o \to -6.3\sqrt{2}+1$ as $V_1 \to -6.3\sqrt{2}$

assuming R is big and V_o is restored to $-6.3\sqrt{2}+1$ before C can lose too much charge every ½ cycle,

$$V_{o,DC} = -6.3\sqrt{2}+1 \approx \boxed{-7.91\ V}$$

b) $R = 0.5\Omega$, find C_{min} for which $V_{out,ripple} \leq 0.25V$

$$V_r = (V_p - V_{on})\left[1 - e^{-\frac{T-\Delta T}{RC}}\right]$$

$V_p = 6.3\sqrt{2}$

$V_{on} = 1$

$R = 0.2$

$T = \frac{1}{f} = \frac{1}{60}$

$$\Delta T \approx \frac{1}{\omega}\sqrt{\frac{2T}{RC}\frac{(V_p - V_{on})}{V_p}}$$

$$\approx \frac{6.45314\times10^{-4}}{\sqrt{C}}$$

or

ΔT also $\approx \frac{1}{\omega}\sqrt{\frac{2V_r}{V_p}}$ for $\Delta T << T$ & $RC >> T - \Delta T$

$$0.25 = (6.3\sqrt{2} - 1)\left[1 - e^{-\frac{\frac{1}{60} - \Delta T}{0.5C}}\right]$$

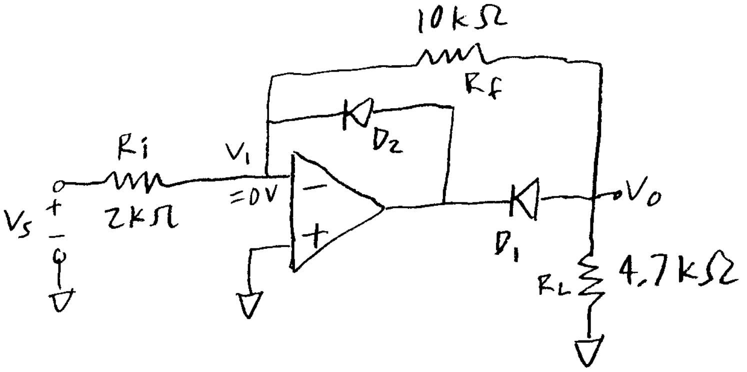
$$C_{min} \approx \boxed{1.0\ F}$$

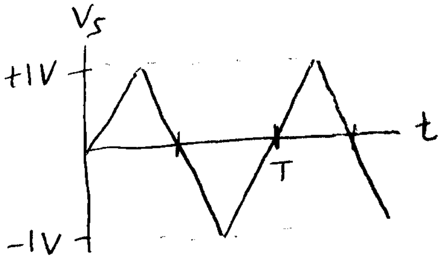
$\Rightarrow \Delta T << T$ ✓

$T - \Delta T \approx 1.602e-2 << RC$ ✓

P3.5

11.91



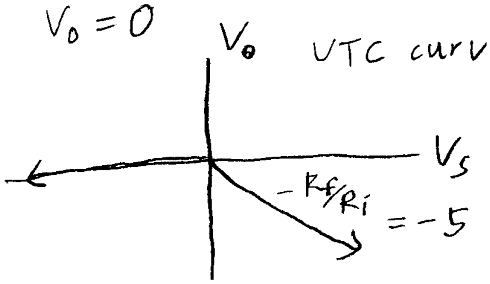


for $V_s > 0 \Rightarrow D_2$ off & D_1 on

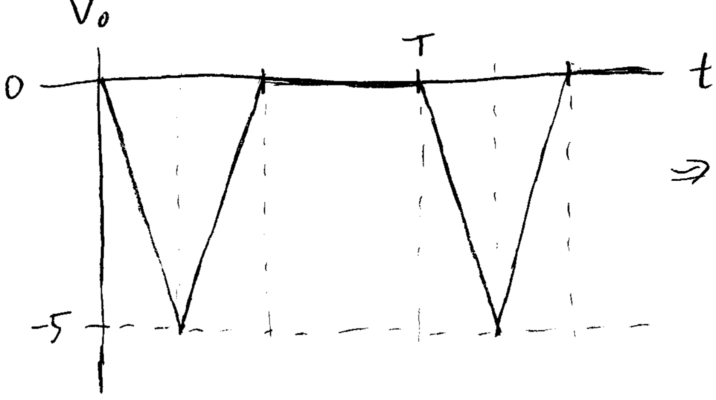
$$\frac{V_1 - V_s}{R_i} = \frac{V_o - V_1}{R_f} \Rightarrow \frac{V_o}{V_s} = -\frac{R_f}{R_i}$$

for $V_s < 0 \Rightarrow D_1$ off & D_2 on

$V_o = 0$



UTC curve



⇒ etc...