ANALOG CIRCUITS THEORY ASSIGNMENT 1

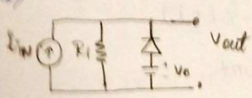
Name: Rahul Mukundhan(IMT2022518)
mail: rahul.mukundhan@iiitb.ac.in

Section 1 – Theory

Analog Circuits - Assignment 2
IMT2022518 - Rahul M

Q1> Vout v/s ~~Vin~~ i_{in}, where diode has V_0 pot.

a>



⇒ Let us assume that the case is reverse bias ($V_{out} - V_B < V_0$)
(V_B shorting)

< always: $\cancel{V_{out}}$ V_{out} $V_B = i_{in} R_1$ > ~~$V_B - V_0$~~

⇒ $V_{out} = (i_{IN}) R_1$

$= \cancel{V_{out} - V_B}$ – ①
$\boxed{V_B - V_0}$

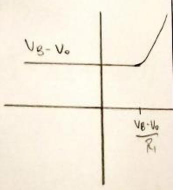
→ Now, for forward bias:

$\cancel{V_{out} - V_B} > V_0$, it conducts, so:
$V_B - V_{out}$
~~$(V_B + V_0 < V_{out})$~~

$V_B > V_{out} + V_0$

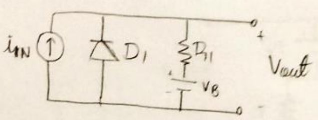
⇒ $V_B - V_0 > (i_{IN} R_1)$

$\frac{V_B - V_0}{R_1} > i_{in}$



⇒ $f(i_{in}) = \begin{cases} V_B - V_0 \; R_1 \text{ (inc.)}, & \text{when } i \geq \frac{V_B - V_0}{R} \\ V_B - V_0 & \end{cases}$

ii) b)



=> ~~If forward bias exists:~~

use KVL:

$$i_{IN} R_1 + V_B + V_0 = 0$$

$$i_{IN} = -\left(\frac{V_B + V_0}{R_1}\right)$$

=> If D_1 is ON:

$$i_{IN} > -\left(\frac{V_B + V_0}{R_1}\right) \quad \text{s.t.}$$

~~$V_B =$~~

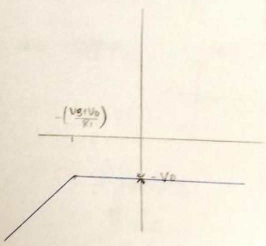
$V_{out} = -V_0$, ~~then~~

=> If D_1 is OFF:

$$i_{IN} < -\left(\frac{V_B + V_0}{R_1}\right)$$

~~$i_{IN} = -\frac{V_B}{R_1}$~~,

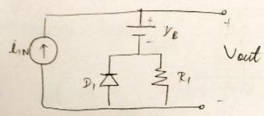
$V_{out} = i_{IN} R_1 + V_B$



Q1>

iii>

c>



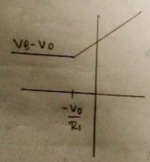
⇒ For diode to be ON:

$(i_{IN} R_1) < -V_0$

$i_{IN} < (-V_0/R_1)$ → forward bias

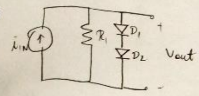
⇒ D_1 is ON: $V_B - V_0 = V_{out}$

D_1 is OFF: $V_{out} = V_B + i_{IN} + R_1$



Q2> R_1's i as a f^n of i_{IN}

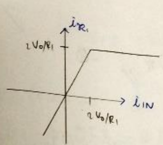
a>



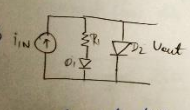
⇒ For OFF DIODES: R_1's $i = i_{IN}$

For ON DIODES: R_1's $i = \frac{2V_0}{R_1}$

⇒



b>



→ when both diodes are OFF, as $i_{IN} < 0$:

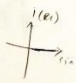
$(i)_{R_1} = 0$

→ $(i)_{IN} > 0$: both diodes are ON:

$i_{IN} > 0$

→ $V_{out} = V_0$

→ $(i)_{R_1}(R_1) + V_0 = V_0$ ∴ $(i)_{R_1} = 0$, $R_1 \neq 0$

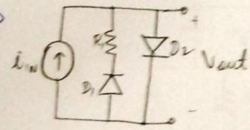


∴ No current in R_1 as it gets shorted

$\boxed{(0, \text{always})}$

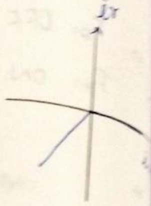
Q2>

c>



→ when $i_{IN} < 0$: D_2 is OFF

⇒ D_1 is ON

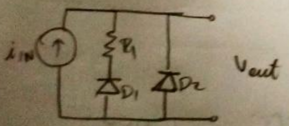


$(i_{IN}R_1) - V_o = 0$

$\frac{V_o}{R_1} = i_{IN} = i_R$ — ①

⇒ $i_{in} > 0$: D_1 is OFF, no path, so $(i)_{R_1} = 0$

d>



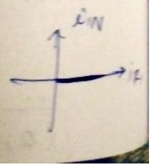
If $i_{IN} > 0$: both diodes are OFF: $(i)_{R_1} = 0$

If $(i_{IN}) < 0$: both diodes are ON:

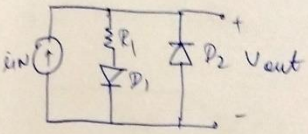
$V_{out} = D_2 = -V_o$

⇒ $-V_o = (i_{R_1}) R_1 - V_o$: $i_{R_1} = 0$

∴ $\boxed{\text{Like in b> , always 0}}$



Q1) a)



⇒ when ($i_{IN}>0$) : D2 is off : $V_{out}=0$

⇒ D1 is ON

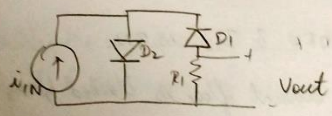
⇒ $\cancel{i_{IN}}$ $(i_{R_1}) R_1 = V_0$

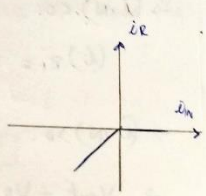
$(i)_{R_1} = V_0/R_1$

⇒ For (i_{IN}) <0 : D2 is ON, $V_{out} = V_0$

⇒ D1 is OFF, $(i)_{R_1}=0$, as there is no path of current flow due to OFF D1

Q2) a)





⇒ $i_{IN}<0$: D2 is OFF, D1 is ON

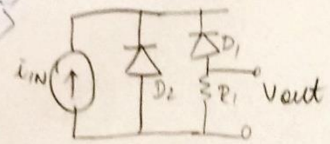
⇒ $V_{out}+V_0=0$

⇒ $V_{out}=-V_0$, $(i)_{R_1} = -V_0/R_1 = i_{in}$

⇒ $i_{IN}>0$: D1 is OFF, D2 is ON, $(i)_{R_1}=0$, due to D1 being OFF

Q2>

g>



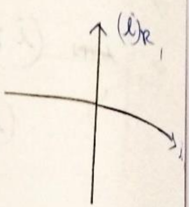
-> D_1, D_2 are OFF when $(i_{IN}) < 0$: $(i)_{R1} > 0$

-> D_1, D_2 are ON, when $(i_{IN}) > 0$:

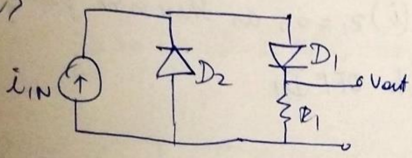
$V_{out} + V_D = V_0$

-> $V_{out} = V_0$, $(i_{R1}) R_1 = 0$

$(i)_{R1} = 0$



h>



-> $(i_{IN}) < 0$: D_1 is OFF & D_2 is ON:

$(i)_{R1} = 0$, as current flow is blocked by R_1

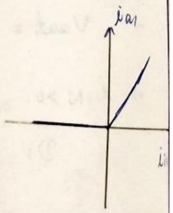
-> $(i_{IN}) > 0$: D_2 is OFF, D_1 is ON.

-> $V_{out} + V_0 = 0$

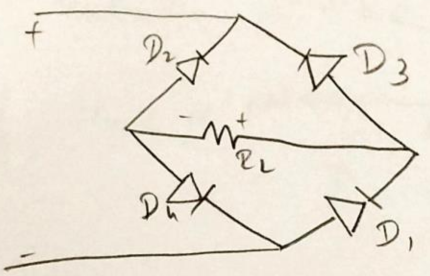
$V_{out} = -V_0$

-> $(i_{R1}) R_1 = -V_0$

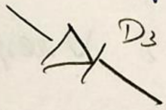
$(i)_{R1} = -V_0/R_1 = i_{IN}$



Q3> Full-wave Rectifier



=> Problem: connection of D_3



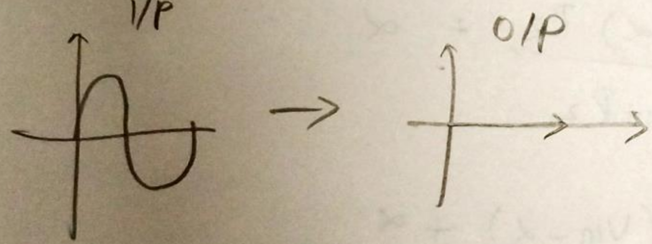
, but reversed here

=> During the positive half cycle, D_2 & D_3 will be reverse biased

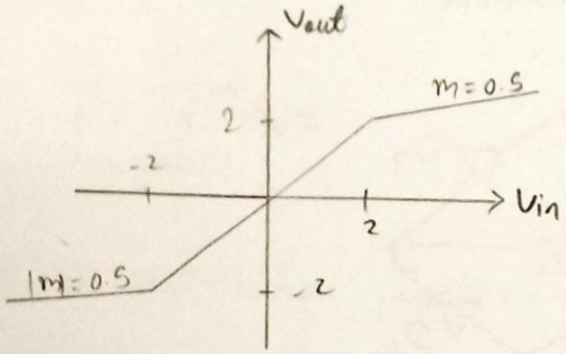
=> $V_{out} = 0$, due to i in $R_L = 0$

=> During the negative half cycle, D_1 & D_3 are ON, short the input & once again, no current via R_L.

=> No rectification, V_{out} is always $\boxed{0}$

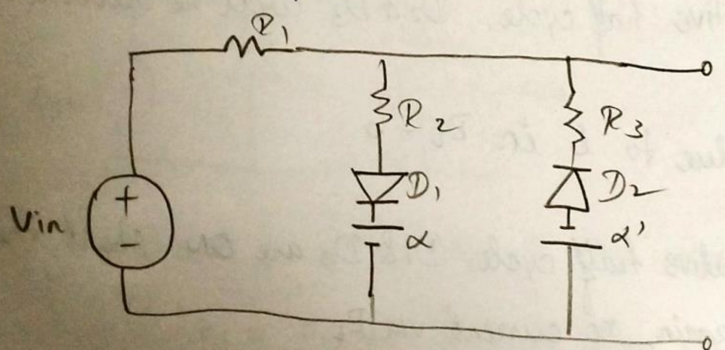


Q4>



Given: 1kΩ resistor, diodes ($V_0 = 0$), other components

⇒ Take α, α' as 2, -2 V respectively, as:
m goes from 1 to ½
(m: slope)



$R_1 = 1k\Omega$
$R_2 = 1k\Omega$
$R_3 = 1k\Omega$

⇒ If $V_{in} > \alpha$, D_2 is OFF
D_1 is ON

$$V_{out} = \frac{(V_{in} - \alpha) R_2}{R_1 + R_2} + \alpha$$

$$= \frac{1}{2}(V_{in} - \alpha) + \alpha$$

$$= \frac{V_{in}}{2} + 1$$

Q4) $\alpha' < V_{in} < \alpha$: D_1 & D_2 are OFF

$\therefore$ $V_{out} = V_{in}$, as $i = 0$

if $V_{in} < \alpha'$: D_1 is OFF
D_2 is ON

$$V_{out} = -2 + \frac{(V_{in} + |\alpha'|) R_3}{R_1 + R_3}$$

$$= -2 + \frac{(V_{in} + 2) R_3}{R_1 + R_3}$$

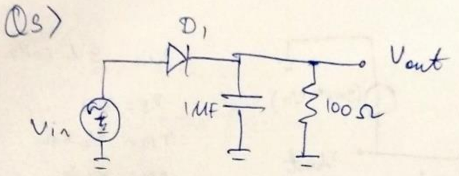
$$= -2 + 1/2 \, (V_{in} + 2)$$

$$= V_{in}/2 - 1$$

< $V_{in}/2$ comes when $R_1 = R_2 = R_3 = 1 k\Omega$ >

Section 2- LTSPICE

Q5>



Vin: 60Hz, 5V

a> p-p ripple

$$\Rightarrow \text{p-p} = \frac{V_{in}}{fRC}, \quad f = 60\ Hz,\ R = 100\,\Omega,\ C = 1\,\mu F$$

$$= \frac{5}{10^{-6} \times 100 \times 60} = \frac{5}{6 \times 10^{-3}}$$

$$= \frac{5}{6} \times 1000 = \frac{5000}{6}$$

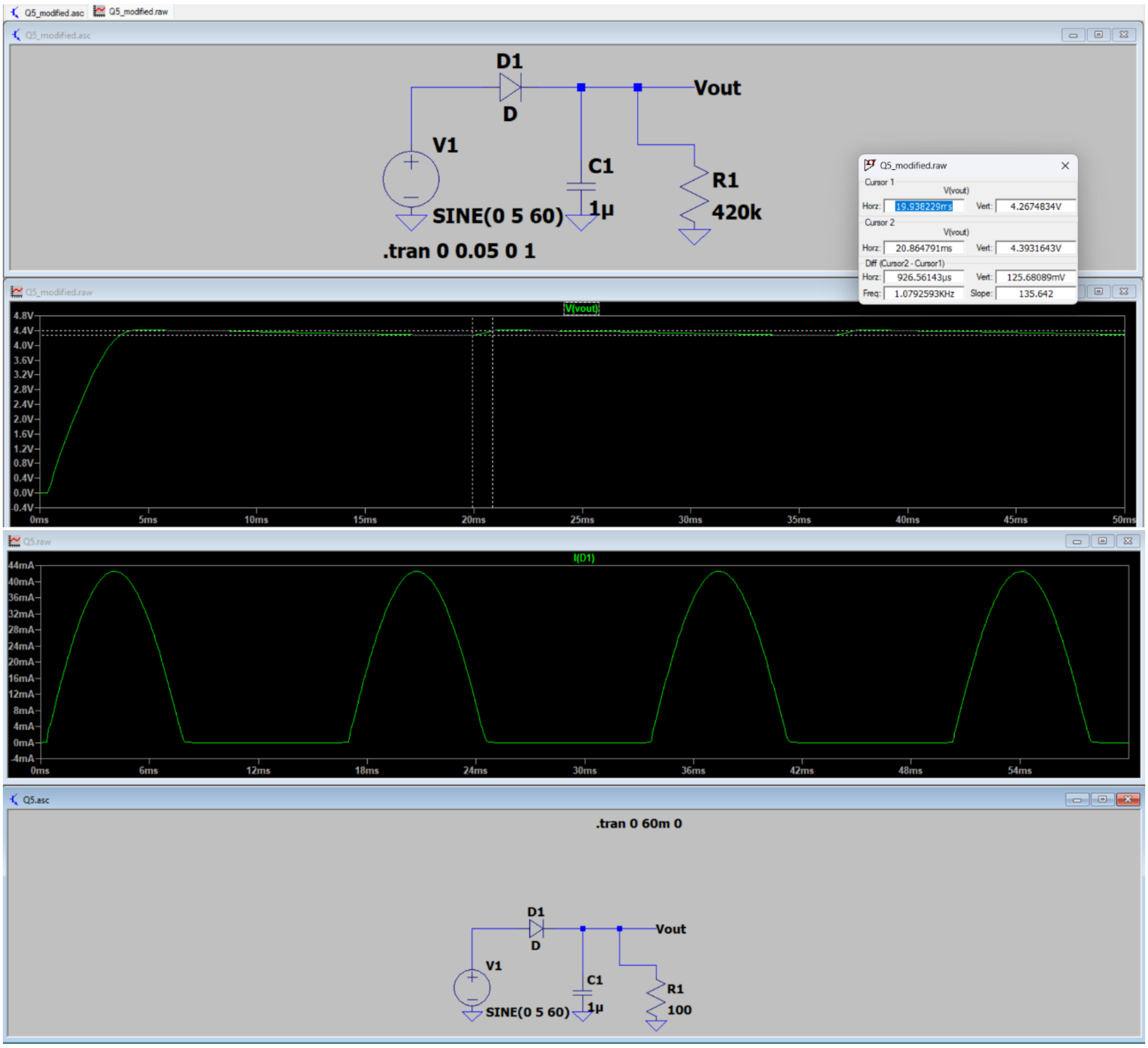
Q5>

a> p-p ripple: $\boxed{V_p \approx 4.245191\,V}$, so $\cancel{\boxed{V_p = 0V}}$

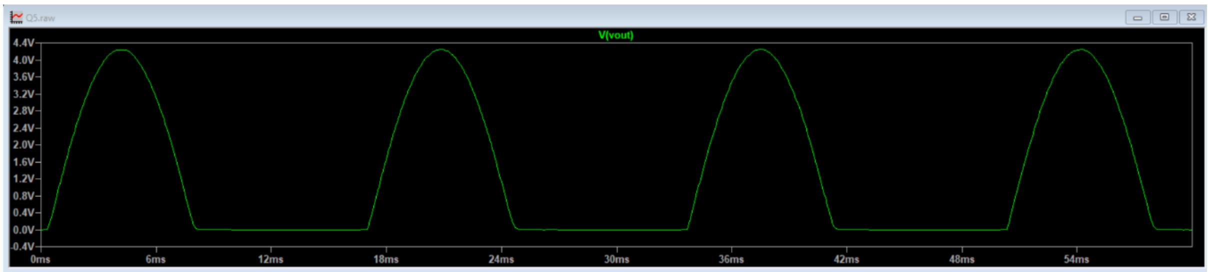
b) peak current

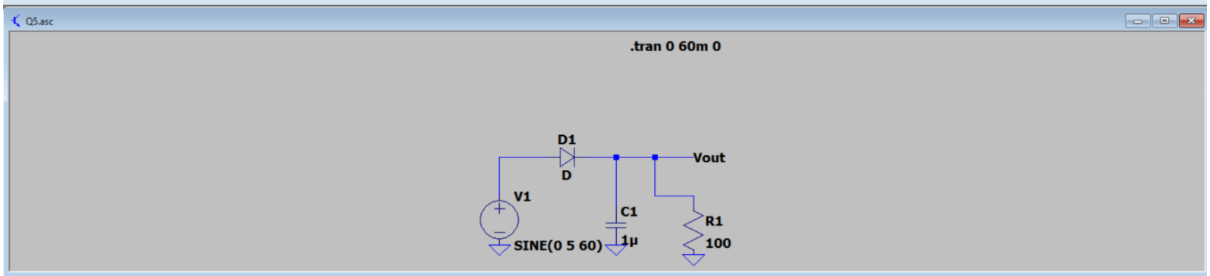
↳ $\boxed{42.48\,mA}$

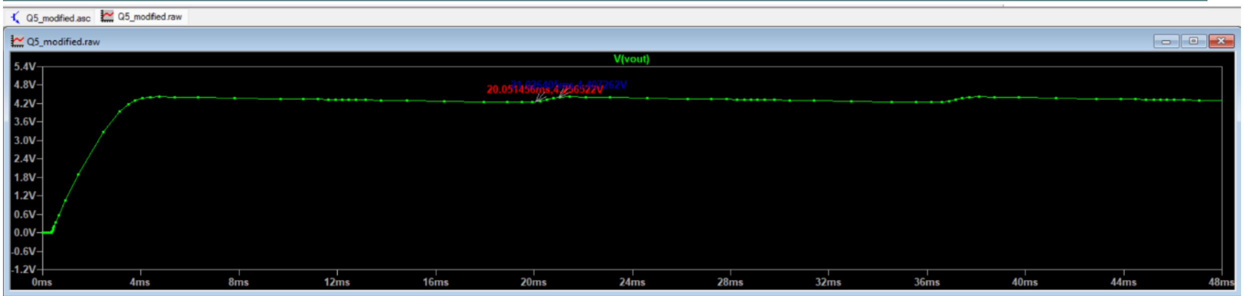
(graphical observations)

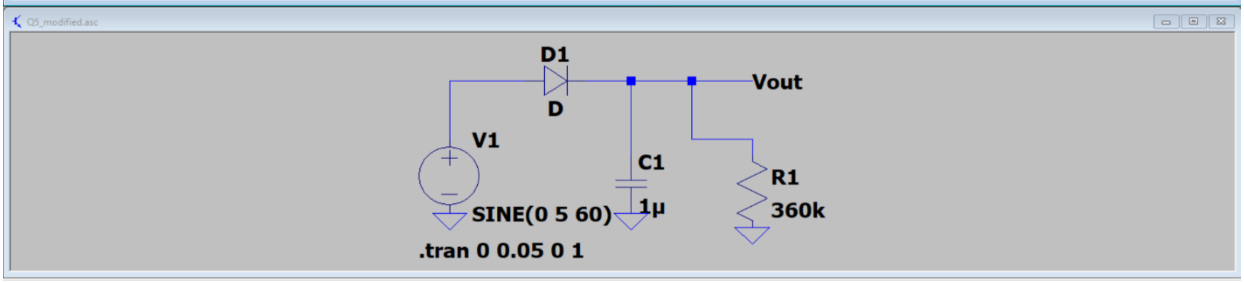


Q5_modified.asc
Q5_modified.raw
D1
D
Vout
V1
C1
1µ
R1
420k
SINE(0 5 60)
.tran 0 0.05 0 1
Cursor 1
V(vout)
Horz: 19.938229ms
Vert: 4.2674834V
Cursor 2
Horz: 20.864791ms
Vert: 4.3931643V
Diff (Cursor2 - Cursor1)
Horz: 926.56143µs
Vert: 125.68089mV
Freq: 1.0792593KHz
Slope: 135.642
V(vout)
I(D1)
Q5.raw
Q5.asc
.tran 0 60m 0
100


Q5.raw
V(vout)
4.4V
4.0V
3.6V
3.2V
2.8V
2.4V
2.0V
1.6V
1.2V
0.8V
0.4V
0.0V
-0.4V
0ms
6ms
12ms
18ms
24ms
30ms
36ms
42ms
48ms
54ms


Q5.asc
.tran 0 60m 0
D1
D
Vout
V1
C1
1µ
R1
100
SINE(0 5 60)


Q5_modified.asc
Q5_modified.raw
Q5_modified.raw
V(vout)
20.051456ms,4.2355322V
5.4V
4.8V
4.2V
3.6V
3.0V
2.4V
1.8V
1.2V
0.6V
0.0V
-0.6V
-1.2V
0ms
4ms
8ms
12ms
16ms
20ms
24ms
28ms
32ms
36ms
40ms
44ms
48ms


Q5_modified.asc
D1
D
Vout
V1
C1
1µ
R1
360k
SINE(0 5 60)
.tran 0 0.05 0 1

Q3)
c) ⇒ For this, let value of —/\/\/\— be R

→ $200\,mV \geq \frac{V_p}{fRC}$ (here $V_o = 0\,V$)

→ $0.2 \geq \frac{5}{60 \times R \times 10^{-6}}$

→ $R \geq \frac{5}{0.2 \times 60 \times 10^{-6}}$

→ $R \geq \frac{5 \times 10^{6} \times 5}{60}$

→ $R \geq \frac{25}{60} \times 10^{6}$

$R \geq \frac{5}{12} \times 10^{6}$

$R \geq 416,666.67\,\Omega$

$R \geq \approx 417\,k\Omega$

< Take $R = 420\,k\Omega$ >

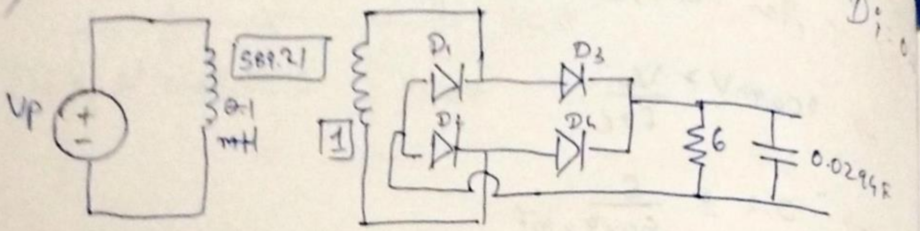
If $V_o = 0.76\,V$, $V_p = 4.24\,V$.

→ $R \geq \frac{4.24}{0.2 \times 60 \times 10^{-6}}$

$R \geq 353,333\,\Omega$

$R \approx 353\,k\Omega$ (≥)

Q6)



$V_p = 230 \times \sqrt{2}$ (Vpeak)

$\rightarrow \dfrac{V_p}{13.4} = \dfrac{n_1}{n_2}$ (@ o/p of $\overset{12}{\cancel{13.4}}$V, transformer should have $12 + 0.7 \times 2$ V)

$\rightarrow \dfrac{V_p}{13.4} = \dfrac{325.3}{13.4} = 24.27382$

$\therefore \dfrac{L_1}{L_2} \propto \left(\dfrac{n_1}{n_2}\right)^2$

$\therefore \dfrac{L_1}{L_2} = 589.21809 \rightarrow 589$

$\Rightarrow \dfrac{V_r}{V_p} = 0.05$ (Given)

$\because$ DC component goes only in R, $i = 2A$, $V = 12V$

$\therefore R = 6\Omega$

$\rightarrow \dfrac{V_p - 2V_0}{2fRC(V_p)} = \dfrac{1}{20}$

$\dfrac{(V_p)fRC}{V_p - 2V_0} = 10 \rightarrow \dfrac{(13.4)(50)(6)C}{12} = 10$

$\rightarrow \boxed{C = 0.0294F}$

PIV: $V_S - V_0$

$= 12.7V$

~~i_{avg}~~

$$i_{max} = i_L \left(1 + 2\pi \sqrt{\frac{V_p}{2V_r}}\right)$$

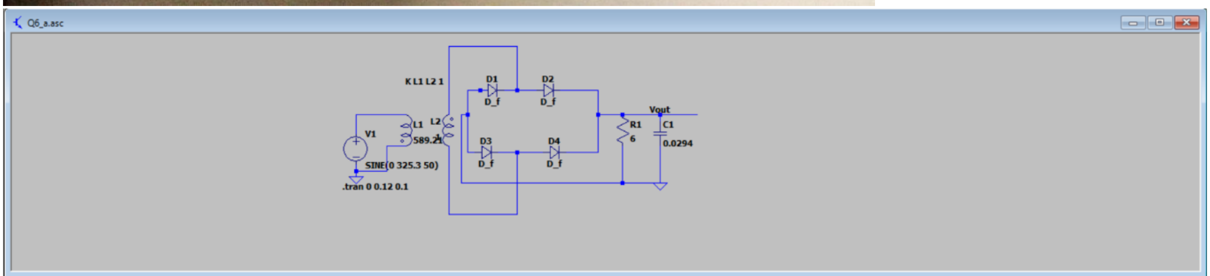
$$= 2\left(1 + 2\pi\sqrt{\frac{20}{2}}\right)$$

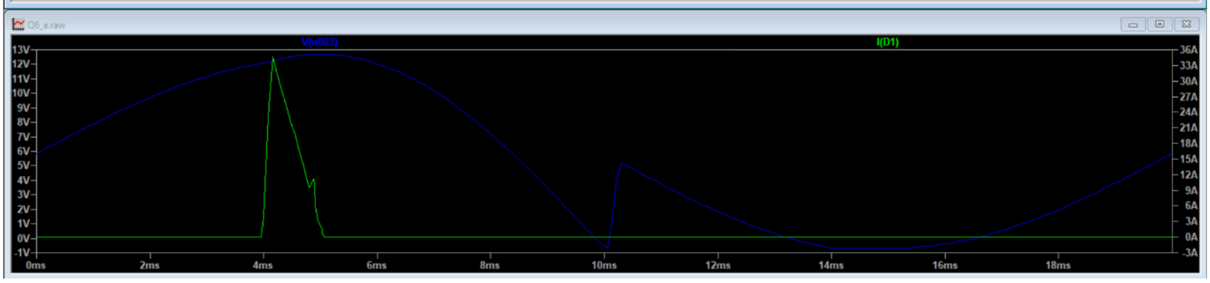
$$= 2\left(1 + 2\pi\sqrt{10}\right)$$

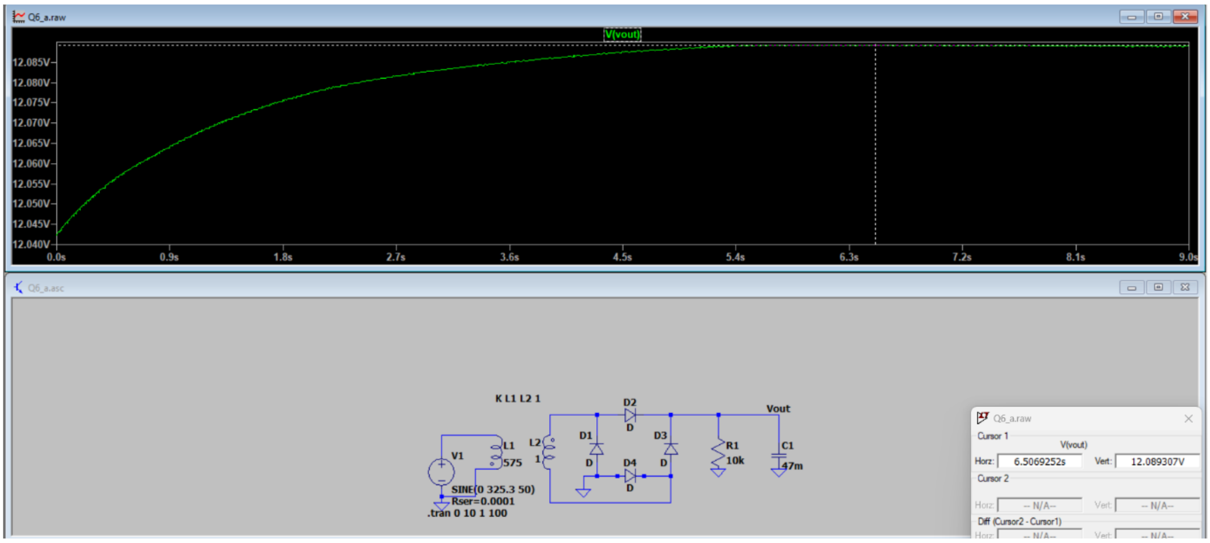
$$\boxed{i_{max} = 2\left(1 + 2\pi\sqrt{10}\right) \approx 41.74A}$$

~~i_{avg}~~

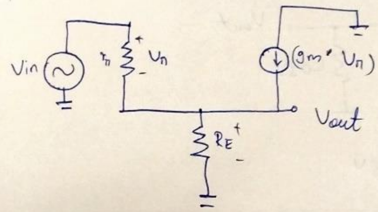
From graph, we can infer that $\boxed{PIV = 12.73V}$ and $i_{avg} = \boxed{956.48\ mA}$







Q7)



V_{in} : 5V, 60Hz

$R_E = 50\,\Omega$

$r_\pi = 5/2\ k\Omega$

$g_m = 0.1\ S$

∴ we know that

$$A_v = \frac{R_E(1+g_m r_\pi)}{r_\pi + R_E(1+g_m r_\pi)}, \quad V_{out} = (A_v)\,V_{in}$$

$$\Rightarrow 1+g_m r_\pi = 1 + 0.1 \times 5/2 \times 10^3$$

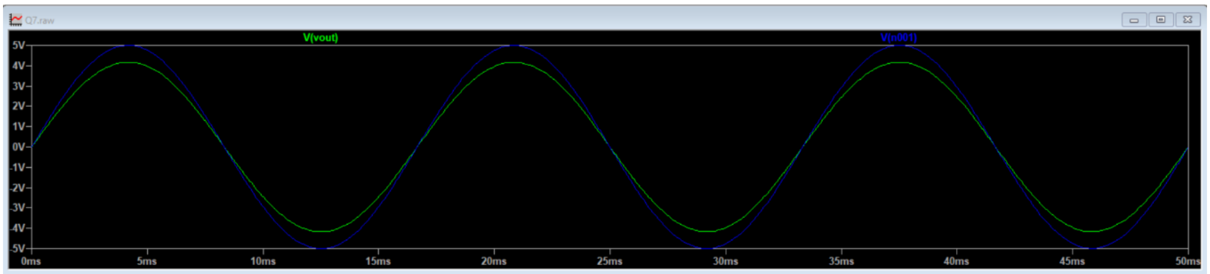
$$= 1 + \frac{1}{10} \times \frac{25}{10} \times 10\times10\times10 = 251$$

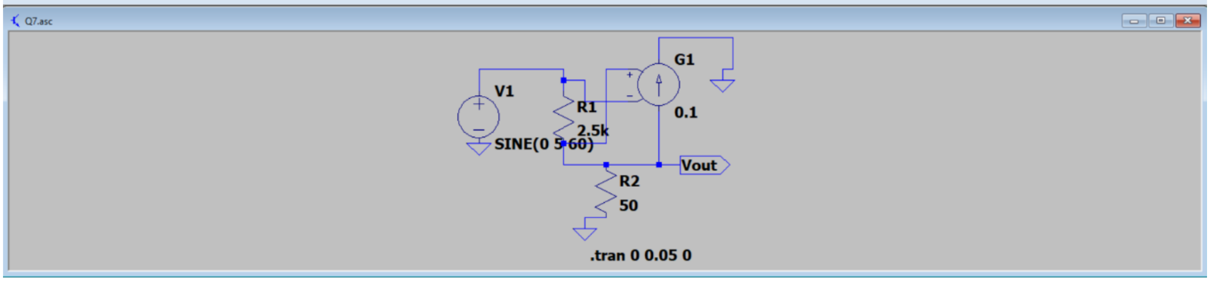
$$A_v = \frac{50(251)}{\frac{5}{2}\times10^3 + 50(251)} = \frac{50(251)}{50(251) + \frac{5\times10^5}{2}\times 100}$$

$$= \frac{50(251)}{50(251) + 25\times100}$$

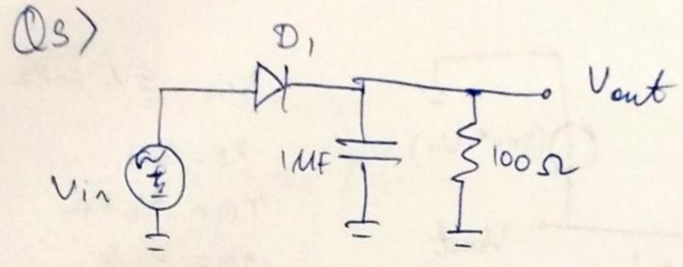
$$A_v = \frac{50(251)}{50(251) + 25\times50\times2} = \frac{251}{251+25\times2} = \frac{251}{301}$$

$$\Rightarrow V_{out} = \left(\frac{251}{301}\right) V_{in} \approx \frac{5}{6}\times 5 \approx \frac{25}{6} \rightarrow 4\ V$$ approx.


Q7.raw
V(vout)
V(n001)
5V
4V
3V
2V
1V
0V
-1V
-2V
-3V
-4V
-5V
0ms
5ms
10ms
15ms
20ms
25ms
30ms
35ms
40ms
45ms
50ms


Q7.asc
G1
V1
R1
2.5k
0.1
SINE(0 5 60)
Vout
R2
50
.tran 0 0.05 0

Q5>



Vin: 60 Hz, 5V

~~a> p-p ripple~~

~~$\Rightarrow$ p-p $= \frac{V_{in}}{fRC}$, $f = 60$ Hz, $R = 100\,\Omega$, $C = 1\mu F$~~

~~$= \frac{5}{10^{-6} \times 100 \times 60} = \frac{5}{6 \times 10^{-3}}$~~

~~$= \frac{5}{6} \times 1000 = \frac{5000}{6}$~~

Q5>

a> p-p ripple: $\boxed{V_r \approx 4.245191\,V}$, so ~~$V_p = 0V$~~

b> peak current

$\hookrightarrow \boxed{42.48\,mA}$

(graphical observations)