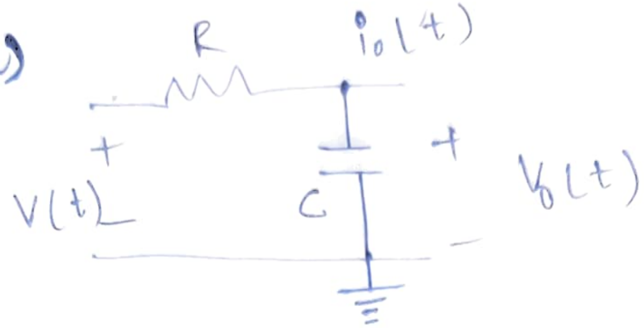
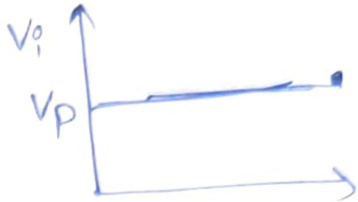
1.1(a)



input Voltage tf



$$\frac{V_o}{V_{in}} = \frac{V_{out}}{V_{in}} = \frac{V_p - iR}{V_p}$$

$Q = CV_o$

$i = C\frac{dV_o}{dt}$

$$V_p - RC\frac{dV_o}{dt} = V_o$$

$$\int_0^t V_p - V_o = \int_0^{V_o} RC\frac{dV_o}{dt}$$

$Q = 0$ at $t = 0$

$\Rightarrow V_o = 0$.

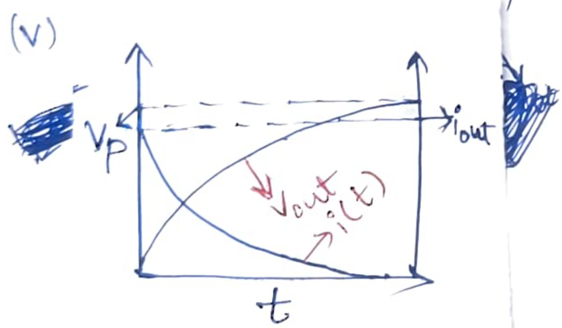
$$\left[\frac{t}{RC}\right]_0^t = -\left[\ln(V_p - V_o)\right]_0^{V_o}$$

$$\frac{-t}{RC} = \ln\left(\frac{V_p - V_o}{V_p}\right) \Rightarrow e^{-t/RC} = 1 - \frac{V_o}{V_p}$$

$$V_o = V_p(1 - e^{-t/RC})$$

Voltage across R = $\frac{V_{out}}{R}$

R



$$= I_{out}$$

$$i_{out} = \frac{V_i - V_o}{R} = \frac{V_i}{R}(e^{-t/RC})$$

Voltage divider

$$i(\omega) = \frac{V_{in}(\omega)}{R + \frac{1}{SC}}$$

$$V_{out}(\omega) = \frac{V_{in}(\omega)\left(\frac{1}{SC}\right)}{R + \frac{1}{SC}}$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{1 + SRC} = H(\omega)$$

Pole:

$H(\omega) = \infty$

$\frac{1}{1+SRC} = \infty$

$0 = 1 + SRC$

$S = \frac{-1}{RC}$,

for $\omega \ll \frac{-1}{RC}$

$1 + SRC \approx 1$

$H(\omega) \approx 1$

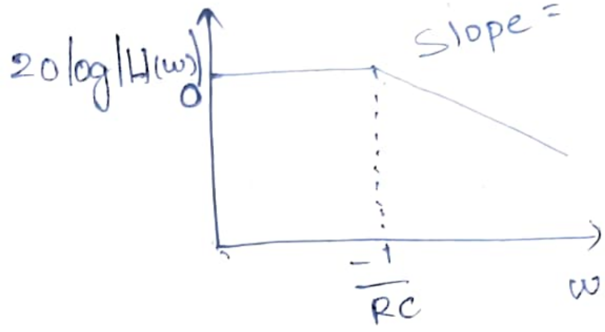
Zero:

$H(\omega) = 0$

$\frac{1}{1+SRC} = 0$

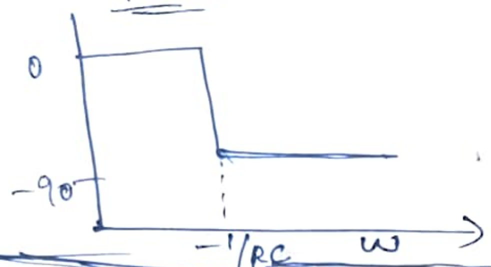
No zeros.

$|H(\omega)| = \frac{1}{\sqrt{1+(SRC)^2}}$

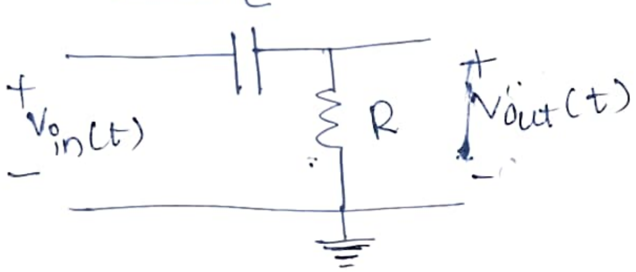


Bodeplot

Phase



b)



$i = \frac{V_{out}}{R} = \frac{V_i}{R}(e^{-t/RC})$

$V_{out} = iR$

$CV_c = Q$

$C(V_i - iR) = Q$

$C(V_i - V_o) = Q$

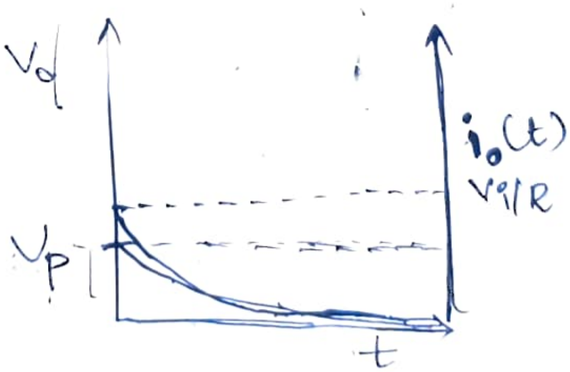
$-C\frac{dV_o}{dt} = i$

$-RC\frac{dV_o}{dt} = iR = V_o$

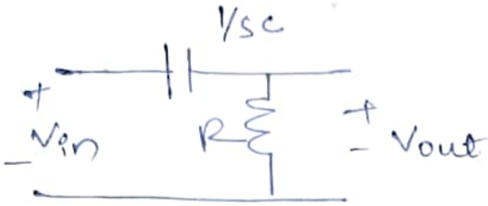
$\frac{dV_o}{V_o} = \frac{dt}{-RC}$

$\ln(V_o) - \ln(V_p) = \frac{t}{-RC}$

$V_o = V_p e^{-t/RC}$



frequencey domain Circuit

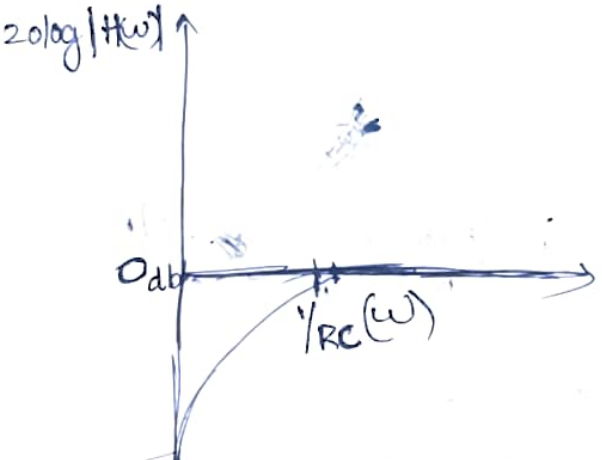


$$V_{out} = \frac{(R)\,V_{in}(\omega)}{R + \frac{1}{sC}}$$

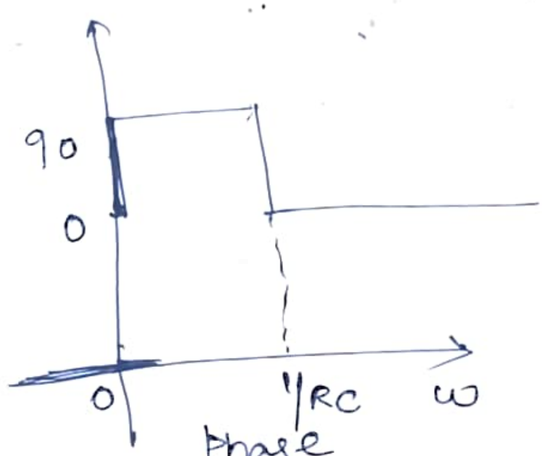
$$\frac{V_{out}}{V_{in}} = H(\omega) = \frac{sRC}{1+sRC}$$

Zeros: (i) $s = 0 \Leftrightarrow (sRC/1+sRC) = 0$

Poles: (ii) $1+sRC = 0 \Rightarrow s = -1/RC$

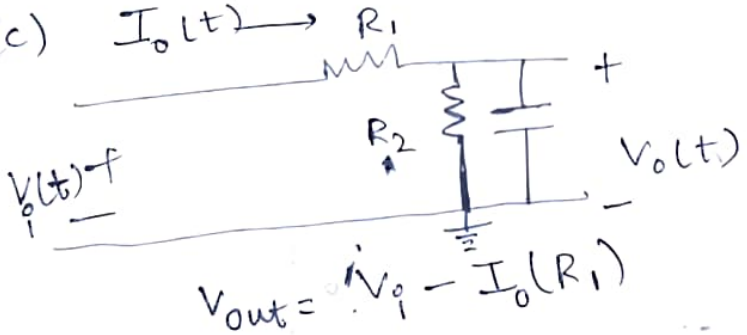


Bode plot



Phase

(c)

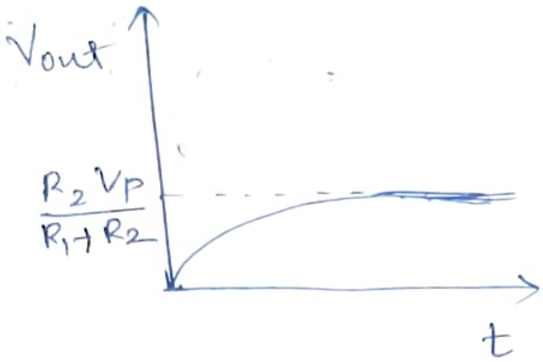


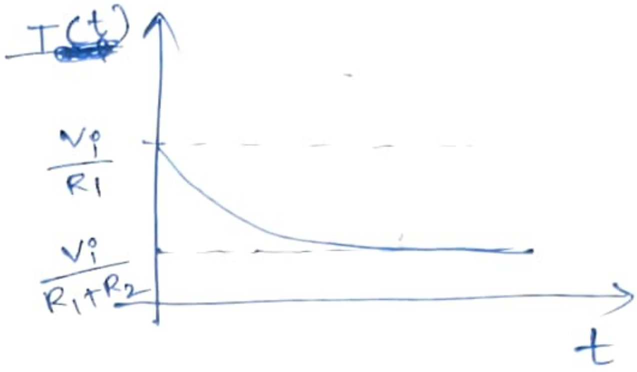
$V_{out} = V_i - I_o(R_1)$

V_{out} at $t=0$ $\quad 0$

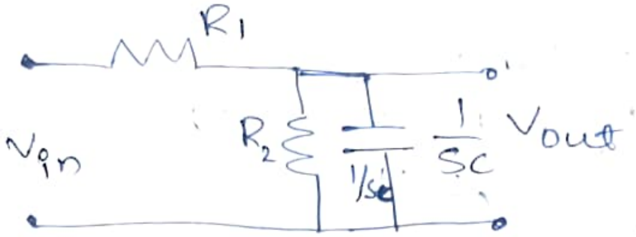
V_{out} at $t=\infty$ $\quad \frac{R_2 \cdot V_p}{R_1+R_2}$

I_{out} at $t=\infty$ $\quad \frac{V_p}{R_1+R_2}$ $\quad$ I_{out} at $t=0$ $\quad \frac{V_i}{R_1}$





f domain ckt



$$\frac{\left(\frac{R_2 \cdot \frac{1}{sc}}{R_2+\frac{1}{sc}}\right) V_p}{\frac{R_2 \frac{1}{sc}}{R_2+\frac{1}{sc}}+R_1} = V_{out}$$

$$\frac{V_{out}}{V_{in}} = \frac{R_2}{R_1+R_2+sR_1R_2C}$$

Poles: $(H(\omega)) = \infty$

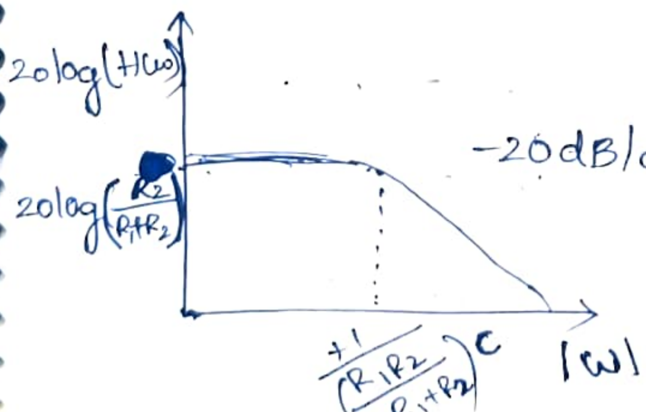
$R_1+R_2+sR_1R_2C=0$

$$s = \frac{-1}{\left(\frac{R_1R_2}{R_1+R_2}\right)C} = \frac{-(R_2+R_1)}{R_1R_2C}$$

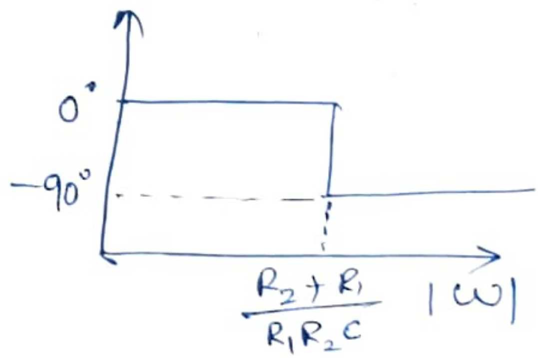
Zeros:

$H(\omega)=0$

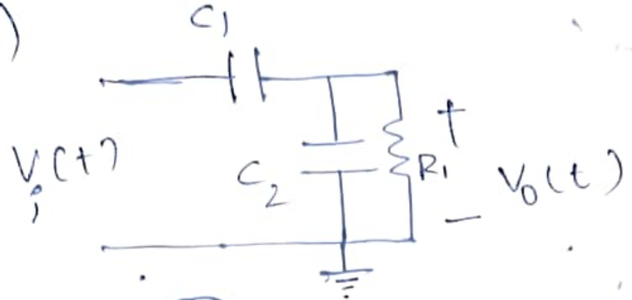
no zeroes.



Phase



d)



$e^{-at}u(t) \Leftarrow \left[\text{in form of } \frac{1}{s+a}\right]$

$\uparrow$

From ①

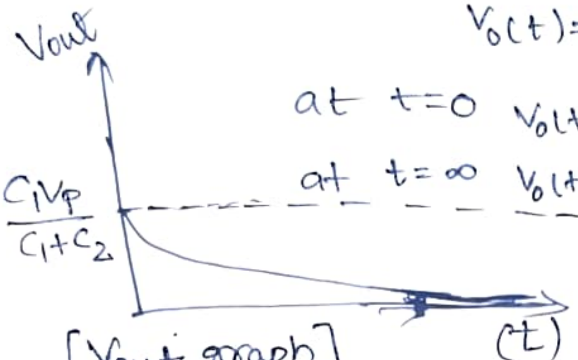
$$V_{out}(s) = \frac{V_p}{\cancel{s}} \frac{R\cancel{s}C_1}{RSC_1+1+RC_2S} = \frac{V_pC_1R}{RSC_1+RSC_2+1} = \frac{\frac{V_pRC_1}{\frac{1}{R(C_1+C_2)}}}{+S}$$

Inverse Laplace

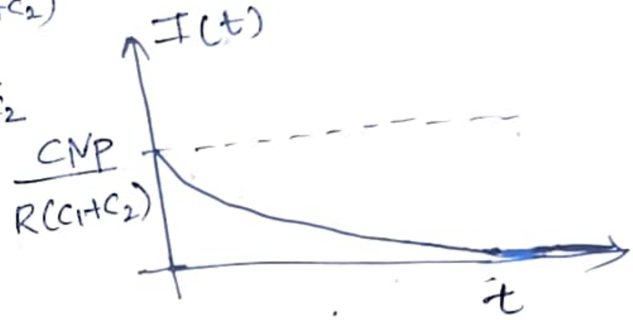
$$V_0(t) = \frac{V_pRC_1}{R(C_1+C_2)} e^{-\frac{t}{R(C_1+C_2)}} \quad -② $$

at $t=0$ $V_0(t) = \frac{C_1V_p}{C_1+C_2}$

at $t=\infty$ $V_0(t) = 0$



[Vout graph]



Applying f-domain ckt

$$V_{out} = V_{in} \cdot \frac{\frac{R/sC_2}{R+1/sC_2}}{\frac{1}{sC_1} + \frac{R/sC_2}{R+1/sC_2}} = V_{in} \cdot \frac{1}{1+\frac{RC_2S+1}{RSC_1}} \quad -①$$

$$\frac{V_{out}}{V_{in}} = \frac{RSC_1}{1+RS(C_1+C_2)} = H(\omega)$$

Zeroes:

$$\frac{RSC_1}{1+RS(C_1+C_2)} = 0$$

$S = 0$

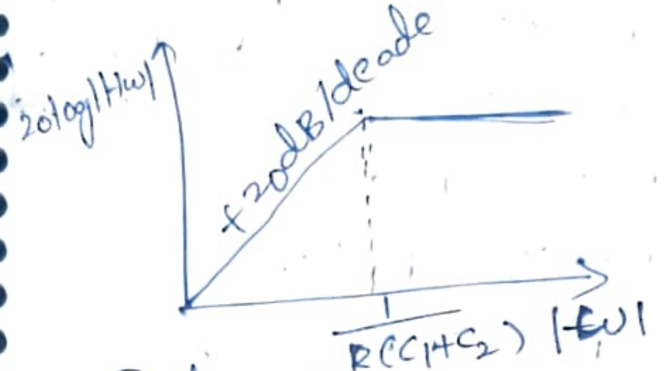
Poles:-

$H(\omega) \longrightarrow \pm\infty$

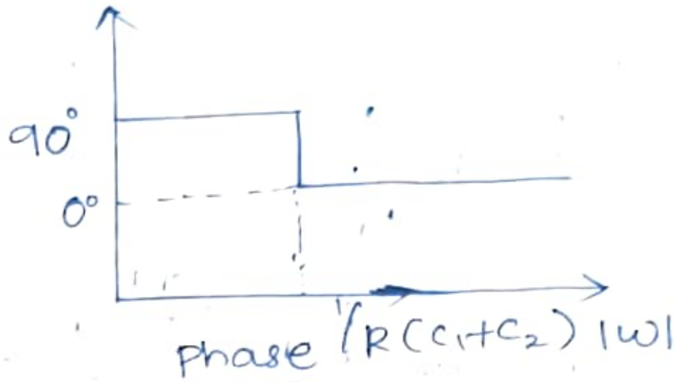
$$\frac{RSC_1}{1+RS(C_1+C_2)} \cong \frac{\infty}{1}$$

$1 + RS(C_1+C_2) = 0$

$$S = \frac{-1}{R(C_1+C_2)}$$

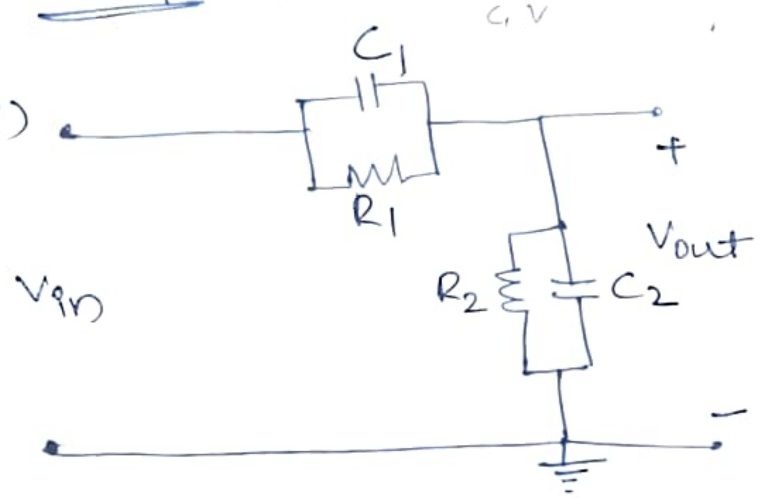


Bodeplot



Phase

(e)



at $t = 0^+$

both capacitors are shorted then there's a path with no resistance, no oppossing path to $e^{\ominus}$ so, huge amount of $e^{\ominus}$ flowed through them and charged instantaneously

So, here charge is conserved bcz. no charges flowed through resistors at the start

$$C_1 V_1 = C_2 V_2$$

$$V_1 + V_2 = V_i$$

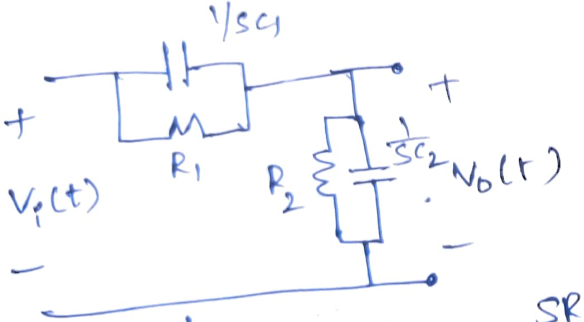
$$V_o = V_2 = \frac{C_1 V_i}{C_1 + C_2} \quad \text{at } t = 0^+$$

$t = \infty$

finally both capacitors charged completely then act as open switches and voltage divided among resistors

$$V_o = \frac{R_2 V_i}{R_1 + R_2}$$

Laplace transformed circuit



$$\frac{V_o}{V_i} = \frac{\dfrac{R_2/sC_2}{R_2+1/sC_2}}{\dfrac{R_2/sC_2}{R_2+1/sC_2} + \dfrac{R_1/sC_1}{R_1+1/sC_1}}$$

$$\boxed{\frac{V_1 R_2}{R_2+R_1} = \frac{V_1 C_1}{C_1+C_2}}$$

$$= \frac{R_2 + sR_1R_2C_1}{R_1+R_2+sR_1R_2(C_1+C_2)}$$

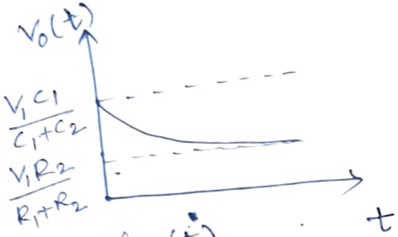
$$H(\omega) = \frac{\dfrac{R_2}{R_1+R_2} + \dfrac{sR_1R_2C_1}{R_1+R_2}}{1 + \dfrac{sR_1R_2(C_1+C_2)}{R_1+R_2}}$$

Zero, $s = \dfrac{-1}{R_1C_1}$

Pole, $s = \dfrac{-(R_1+R_2)}{R_1R_2(C_1+C_2)}$

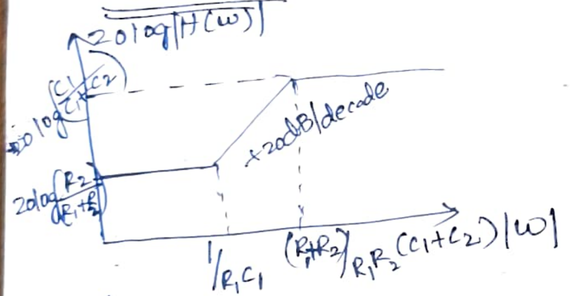
if Voltage is less than initial voltage then capacitors discharged

if $R_1C_1 > R_2C_2$



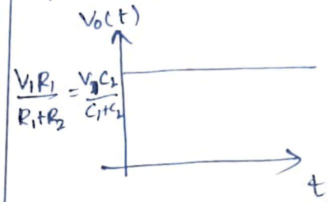
$V_{out}(t)$

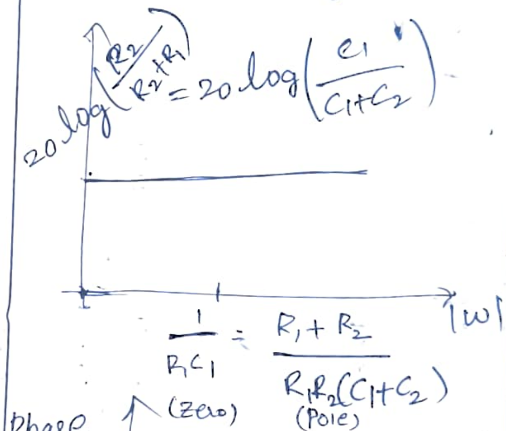
Bode plot

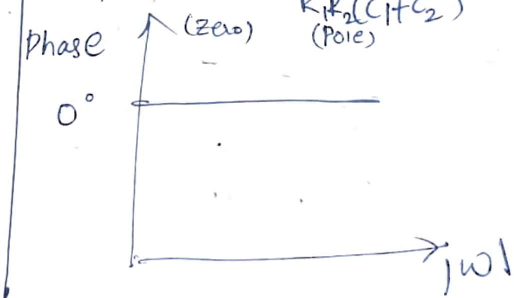


if equal then there was no change in the capacitor' from initial conditions

if $R_1C_1 = R_2C_2$

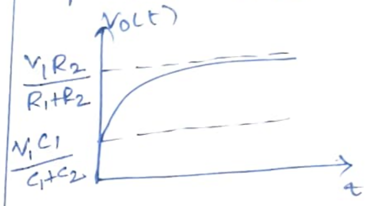


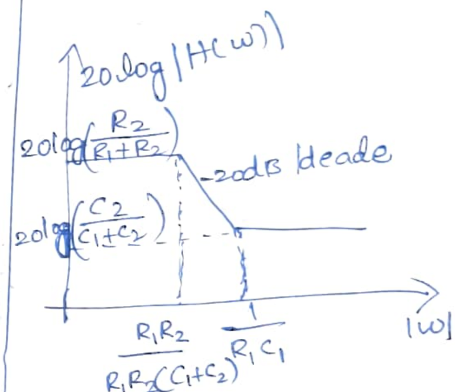


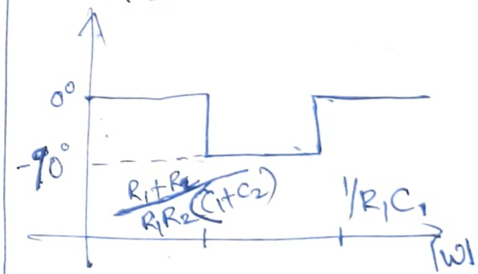


if it was greater then the capacitors have further charged

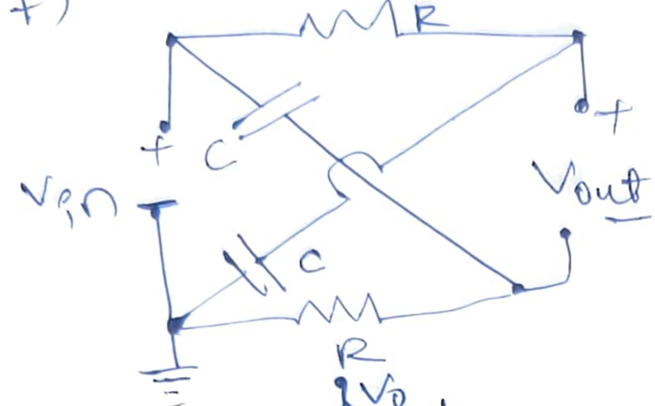
if $R_1C_1 < R_2C_2$

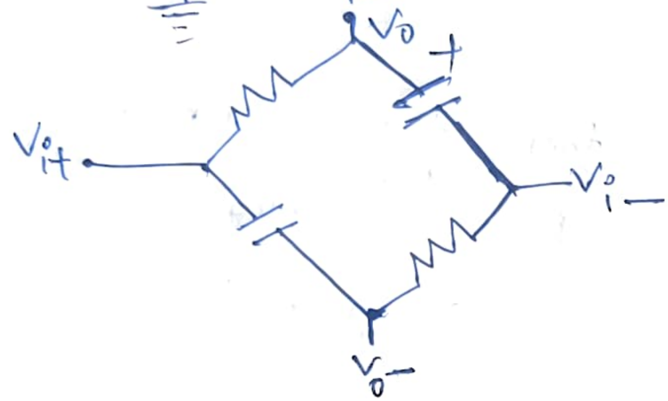


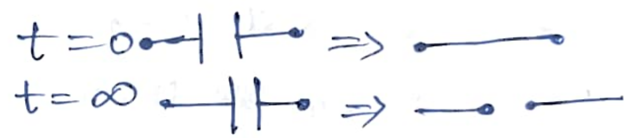




f)





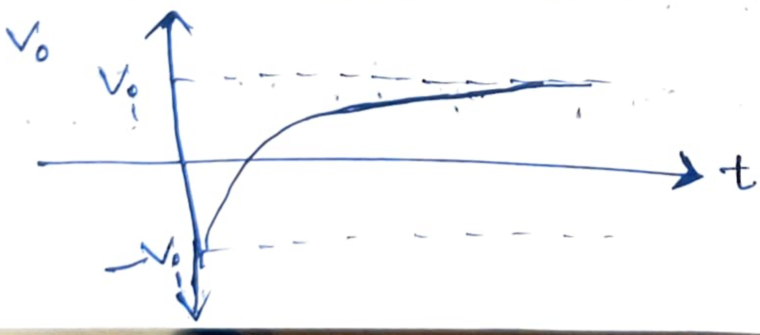


at $t=0^+$ as capacitors they act as closed switches then

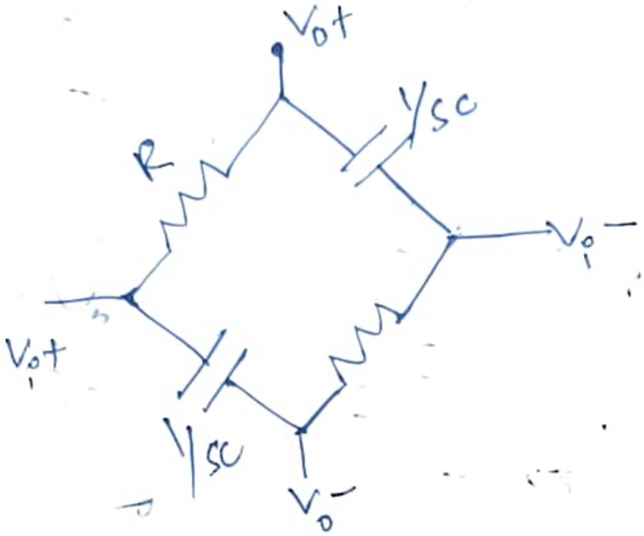
$V_0 = -V_i$ at $t=0^+$

at $t=\infty$

the capacitors are charged and act as open switches then, $V_0 = V_i$ at $t=\infty$



Laplace applied circuit



$$i_{total} = \frac{2V_i}{\left(R+\frac{1}{sC}\right)} = \frac{2V_i}{R+\frac{1}{sC}}$$

[i in one branch
$$i_b = \frac{V_i}{R+\frac{1}{sC}}$$]

$$i\left(\frac{1}{sC}\right) - i(R) = V_o$$

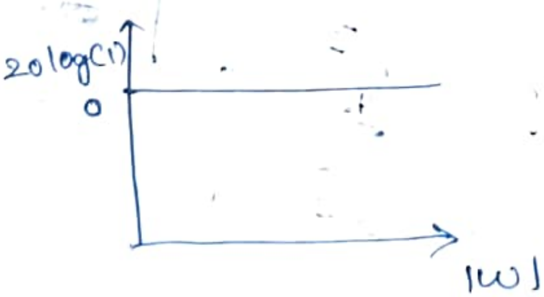
$$\frac{\left(\frac{1}{sC} - R\right)}{\left(\frac{1}{sC} + R\right)} V_i = V_o$$

$$\frac{V_o}{V_i} = \frac{(1-sRC)}{(1+sRC)} = H(\omega).$$

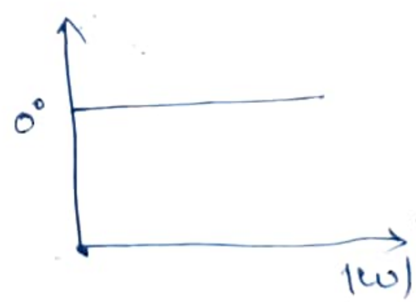
$$\text{Zero} = \frac{1}{RC}, \quad \text{Pole} = \frac{-1}{RC}$$

$$\omega << \frac{1}{RC} \qquad sRC << 1$$

$$H(\omega) = 1$$



Bode plot



. phase

2.1

cut in Voltage:- The voltage at which the diode starts conducting significant amount of current

→ approx 430 mV

knee -voltage :- at which slope of the IV graph increases in the Forward bias, here stronger Conduction starts

⟹ approx
↓
⟹ 600 mV

reverse saturation current:- the small amount of current flown in reverse bias

-2.52 nA

incremental diode resistance:- resistance of the diode from IV graph

$$\frac{\Delta V}{\Delta I} = \frac{690-560}{8.1-0.9} = 18\,\Omega$$

2.2

Half wave rectifier

* given sine wave as input contains both +ve and -ve cycles, the cycle decides the direction of current in circuit

* only passes half of the input wave, according diode orientation with respect to voltage sine and +ve or -ve

2.3

Full wave rectifier

* A Full-wave rectifier converts AC to DC by allowing both halves of the AC input to pass through the same direction. It use two diodes arranged to conduct during both Positive and -ve cycles of the input sine wave

* During the +ve half cycle, diodes conduct and allow current to flow in one direction, during the negative half-cycle, the diodes reverses and still allow current in same direction.

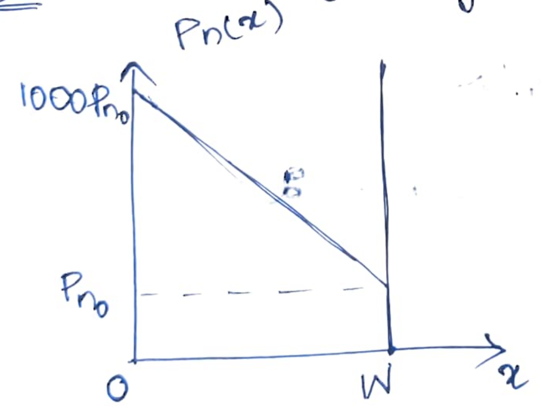
3.1

Yes, During the preparation of doped semi-conductors kirchopf's current law is applicable

KCL is a process of conservation of charge here while in the process of doping. The injected carriers contribute to the current, but total current at the injecting point is remains conserved. because carriers move in thery by produces an output current that is equal to input current

In both n-type and p-type the current associated with the injected carriers is balanced by the current due to other charge carriers, by maintaining the principle of charge conservation.
Hence KCL Remains valid during process of injecting carriers in doping.

3.2



$N_D = 10^{16}/cm^3$ to find. $J_{diff,x}$

$W = 5\mu m$

$n_i = 1.5 \times 10^{10}/cm^3$

$$\frac{dp}{dx} = \frac{(1000-1)P_{no}}{W} = \frac{999P_{no}}{W}$$ from graph

$(N_D)(P_{no}) = n_i^2$ (by book)

$10^{16} \times P_{n0} = 2.25\times10^{20}$

$P_{n0} = 2.25\times10^{4} /cm^3$

$J_{diff} = \frac{I}{A} = D_p \frac{dp}{dx} \cdot q$ $\left[\begin{array}{l} k = 1.38\times10^{-23} JK^{-1} \\ T = 300k, \ q = 1.6\times10^{-19} c \end{array} \right]$

$\frac{D_p}{\mu_p} = \frac{KT}{q}$ (Einstein relation) $\left[\begin{array}{l} \mu_p \text{ in semi-Cond} \\ \text{uctor} = 450 cm^2/v.s \end{array} \right]$

$D_p = (26 mv)(450 cm^2/vs)$

$D_p = 11.6 \ cm^2/s$ $(10 cm^2/s \text{ approx})$

[Converted into SI]

$J = 11.6\times10^{-4} \cdot \frac{(999) \times 2.25\times10^{4}}{5\times10^{-6}} \times 1.6\times10^{-19} \times 10^{+6}$

$J = 8343.6 \times 10^{-4+4+6-19+6} \ A/m^2$

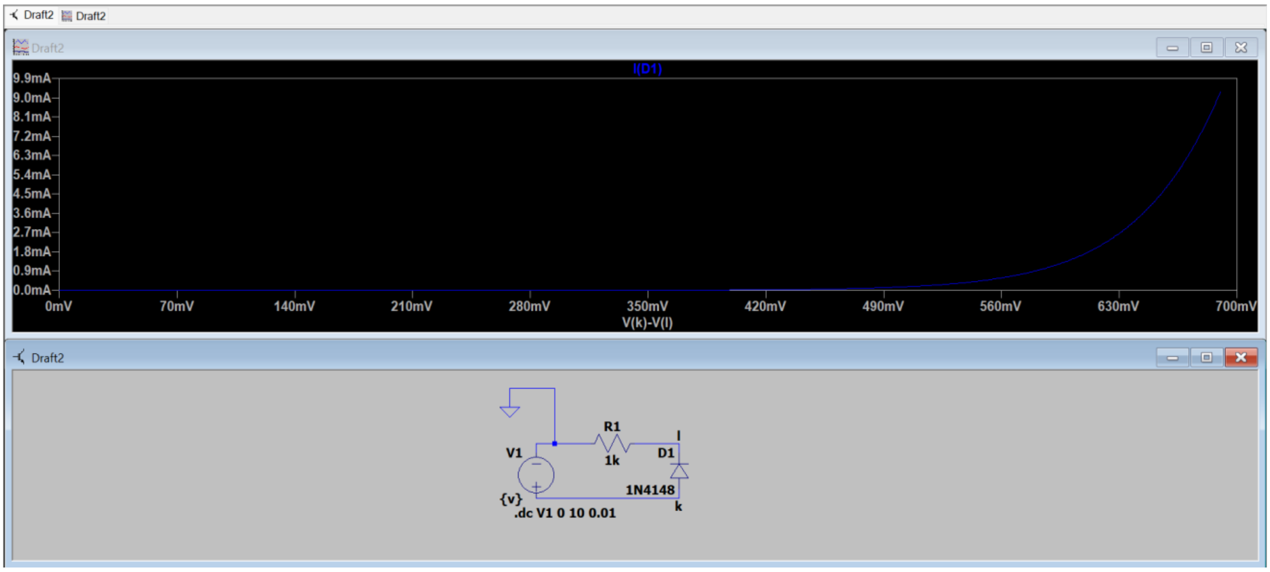
$J = 8343.6 \times 10^{-7}$

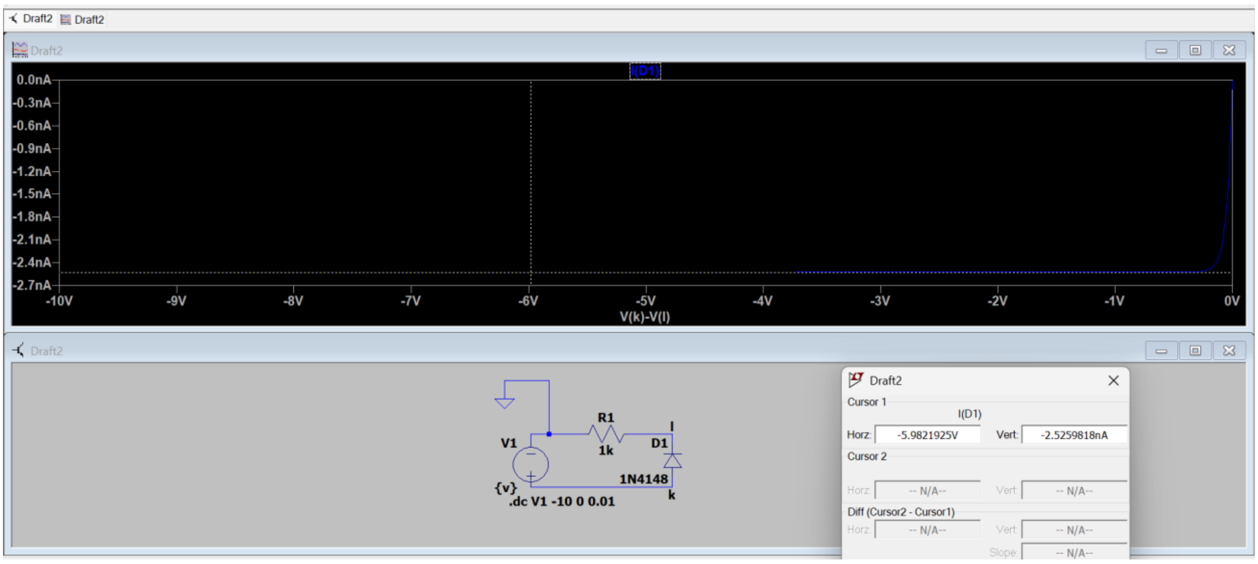
$J = 8.3\times10^{3} \times10^{-7} \times 10^{-4} \ A/cm^2$

$J = 8.3\times10^{-8} \ A/cm^2 = 8.36 \mu A/cm^2$

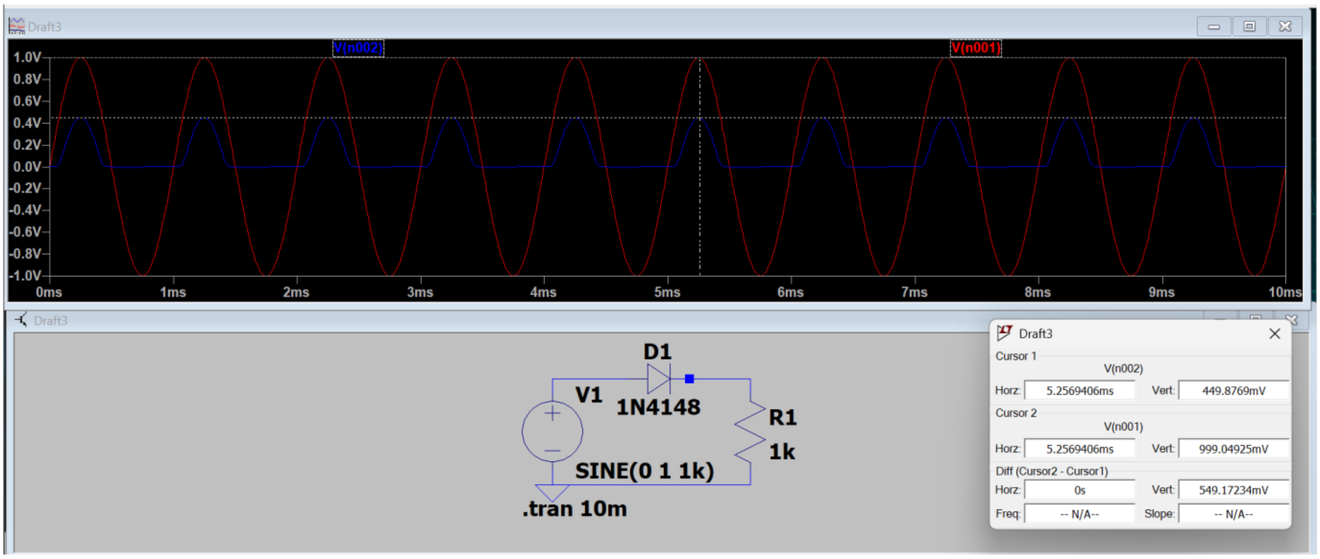
$J = 83.4 nA/cm^2$

2.1

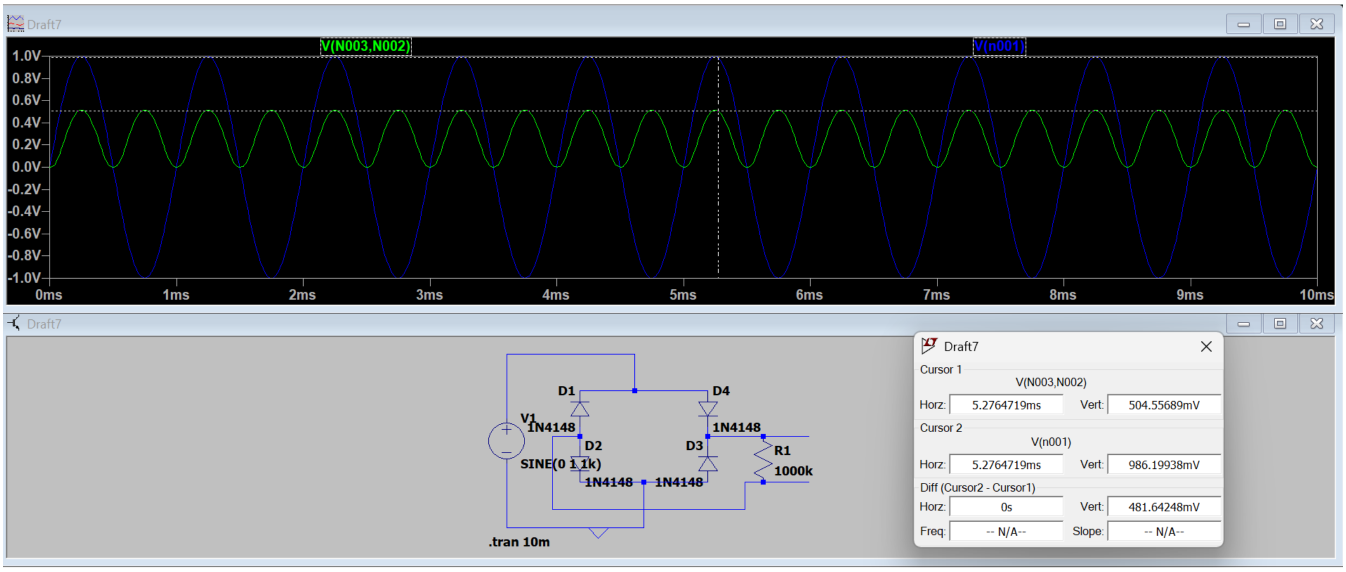

Draft2
I(D1)
9.9mA
9.0mA
8.1mA
7.2mA
6.3mA
5.4mA
4.5mA
3.6mA
2.7mA
1.8mA
0.9mA
0.0mA
0mV
70mV
140mV
210mV
280mV
350mV
420mV
490mV
560mV
630mV
700mV
V(k)-V(l)
R1
1k
V1
D1
1N4148
{v}
.dc V1 0 10 0.01
l
k


Draft2
I(D1)
0.0nA
-0.3nA
-0.6nA
-0.9nA
-1.2nA
-1.5nA
-1.8nA
-2.1nA
-2.4nA
-2.7nA
-10V
-9V
-8V
-7V
-6V
-5V
-4V
-3V
-2V
-1V
0V
V(k)-V(l)
R1
1k
V1
D1
1N4148
{v}
.dc V1 -10 0 0.01
Cursor 1
Horz: -5.9821925V
Vert: -2.5259818nA
Cursor 2
Diff (Cursor2 - Cursor1)
Slope

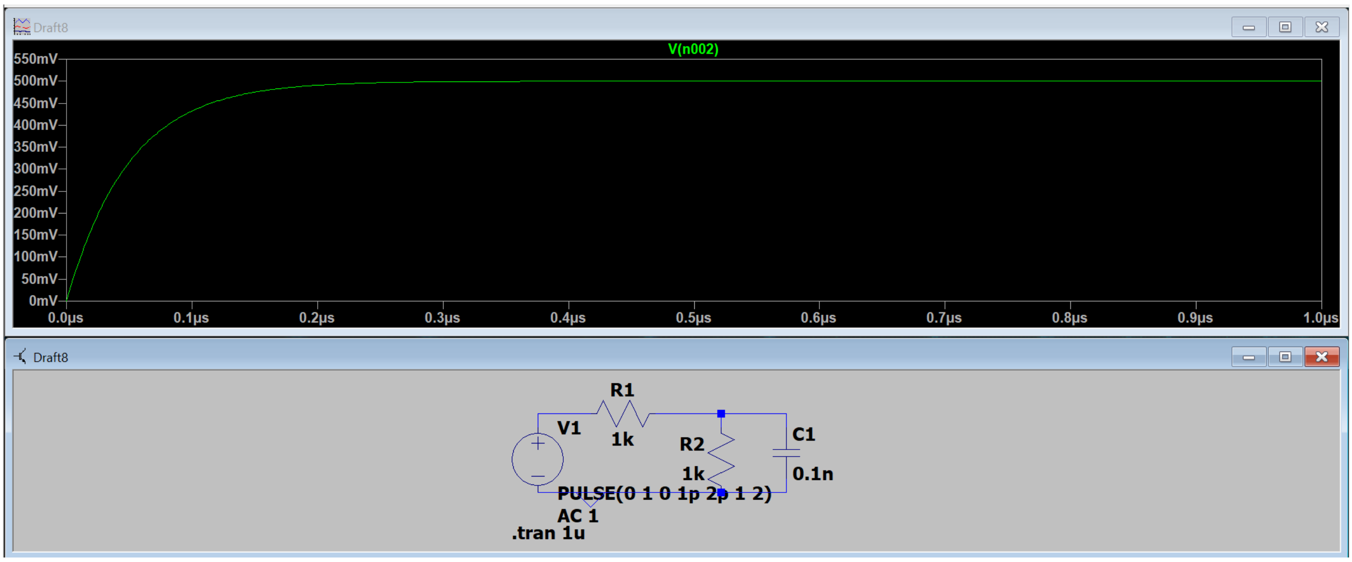
2.2

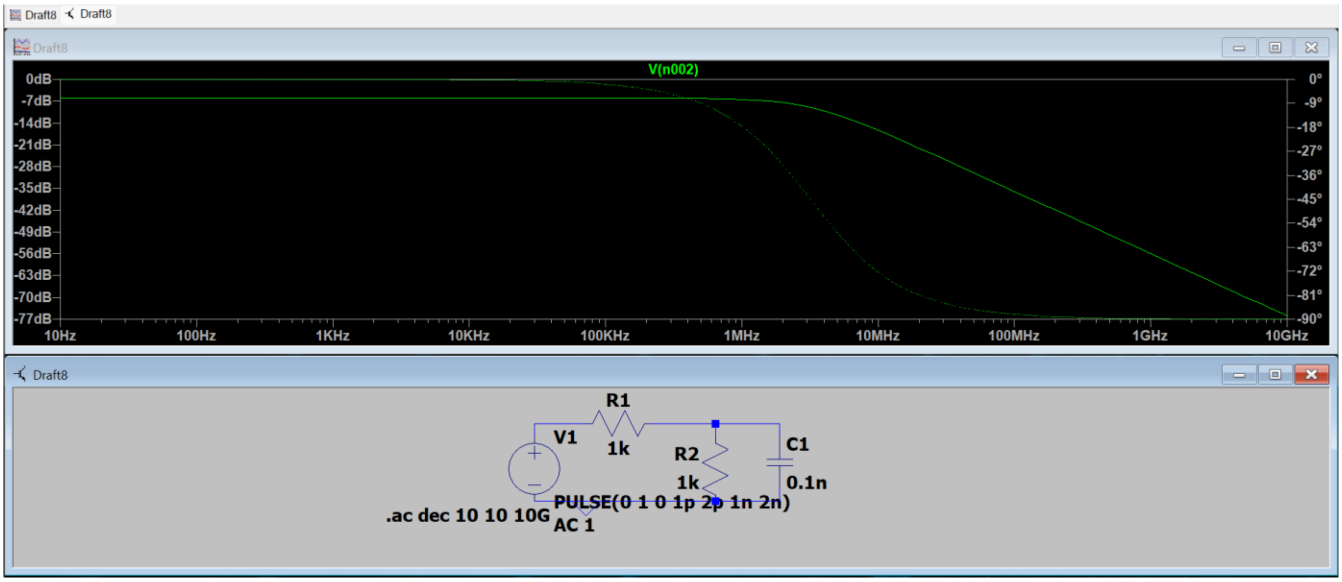

Draft3
V(n002)
V(n001)
1.0V
0.8V
0.6V
0.4V
0.2V
0.0V
-0.2V
-0.4V
-0.6V
-0.8V
-1.0V
0ms
1ms
2ms
3ms
4ms
5ms
6ms
7ms
8ms
9ms
10ms
D1
V1
1N4148
R1
1k
SINE(0 1 1k)
.tran 10m
Cursor 1
Horz: 5.2569406ms
Vert: 449.8769mV
Cursor 2
Horz: 5.2569406ms
Vert: 999.04925mV
Diff (Cursor2 - Cursor1)
Horz: 0s
Vert: 549.17234mV
Freq: -- N/A--
Slope: -- N/A--

2.3


Draft7
V(N003,N002)
V(n001)
1.0V
0.8V
0.6V
0.4V
0.2V
0.0V
-0.2V
-0.4V
-0.6V
-0.8V
-1.0V
0ms
1ms
2ms
3ms
4ms
5ms
6ms
7ms
8ms
9ms
10ms
Draft7
D1
D4
V1
1N4148
1N4148
D2
D3
R1
SINE(0 1 1k)
1000k
1N4148
1N4148
.tran 10m
Draft7
Cursor 1
V(N003,N002)
Horz: 5.2764719ms
Vert: 504.55689mV
Cursor 2
V(n001)
Horz: 5.2764719ms
Vert: 986.19938mV
Diff (Cursor2 - Cursor1)
Horz: 0s
Vert: 481.64248mV
Freq: -- N/A--
Slope: -- N/A--

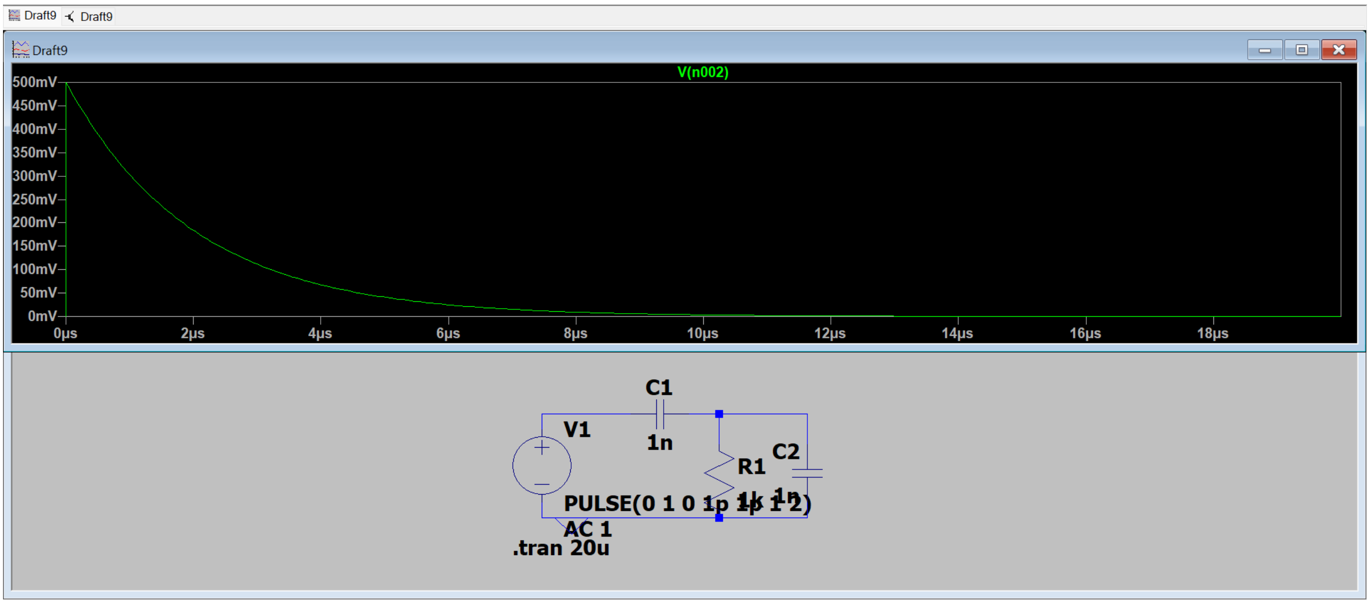
1.2 (c)

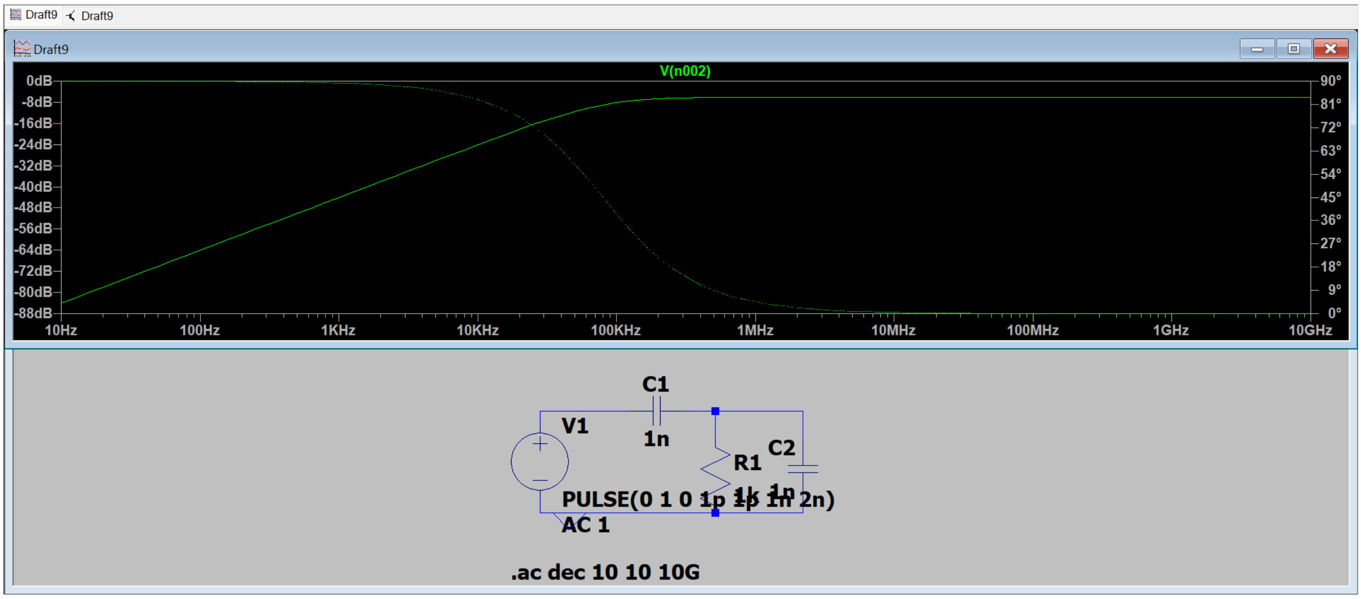

Draft8
V(n002)
550mV
500mV
450mV
400mV
350mV
300mV
250mV
200mV
150mV
100mV
50mV
0mV
0.0µs
0.1µs
0.2µs
0.3µs
0.4µs
0.5µs
0.6µs
0.7µs
0.8µs
0.9µs
1.0µs
Draft8
R1
V1
1k
R2
C1
1k
0.1n
PULSE(0 1 0 1p 2p 1 2)
AC 1
.tran 1u



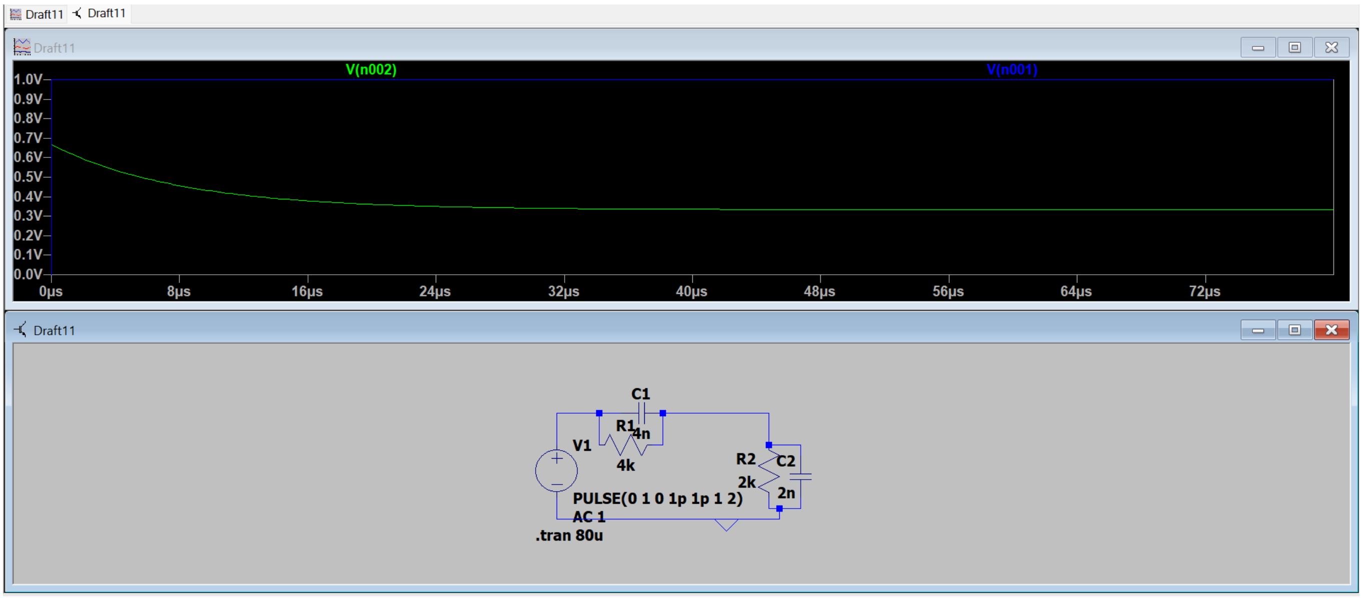
Draft8
Draft8
Draft8
V(n002)
0dB
-7dB
-14dB
-21dB
-28dB
-35dB
-42dB
-49dB
-56dB
-63dB
-70dB
-77dB
0°
-9°
-18°
-27°
-36°
-45°
-54°
-63°
-72°
-81°
-90°
10Hz
100Hz
1KHz
10KHz
100KHz
1MHz
10MHz
100MHz
1GHz
10GHz
Draft8
R1
1k
V1
R2
1k
C1
0.1n
.ac dec 10 10 10G
PULSE(0 1 0 1p 2p 1n 2n)
AC 1

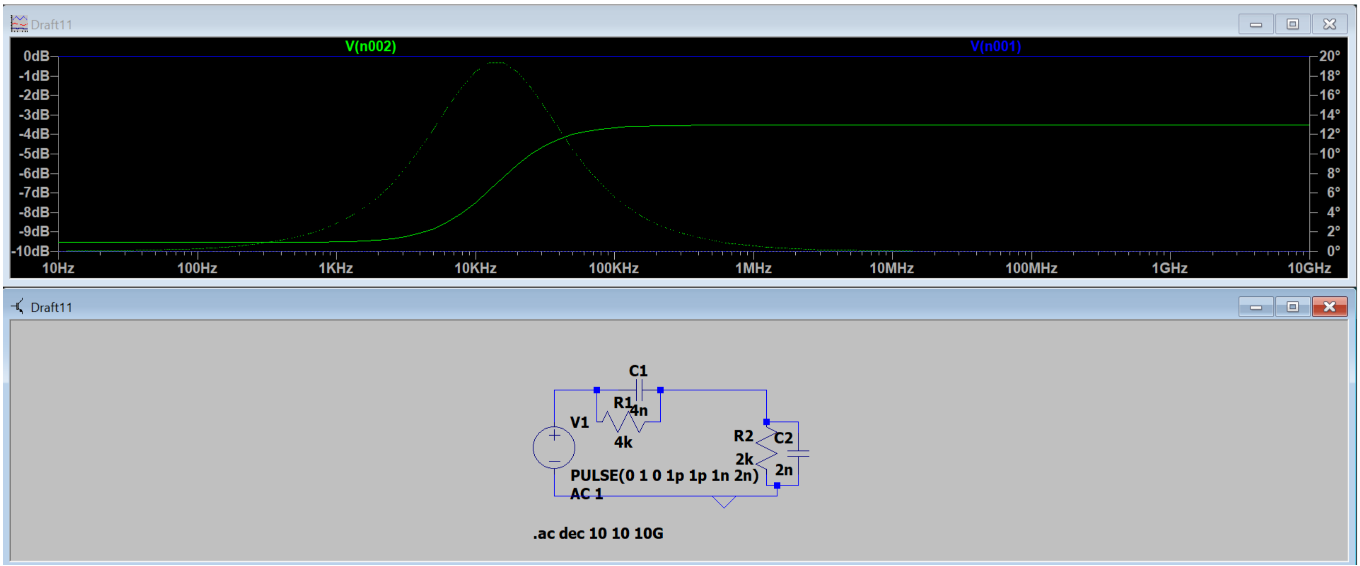
1.2 (d)


Draft9
Draft9
Draft9
V(n002)
500mV
450mV
400mV
350mV
300mV
250mV
200mV
150mV
100mV
50mV
0mV
0µs
2µs
4µs
6µs
8µs
10µs
12µs
14µs
16µs
18µs
C1
1n
V1
R1
C2
PULSE(0 1 0 1p 1p 1 2)
AC 1
.tran 20u

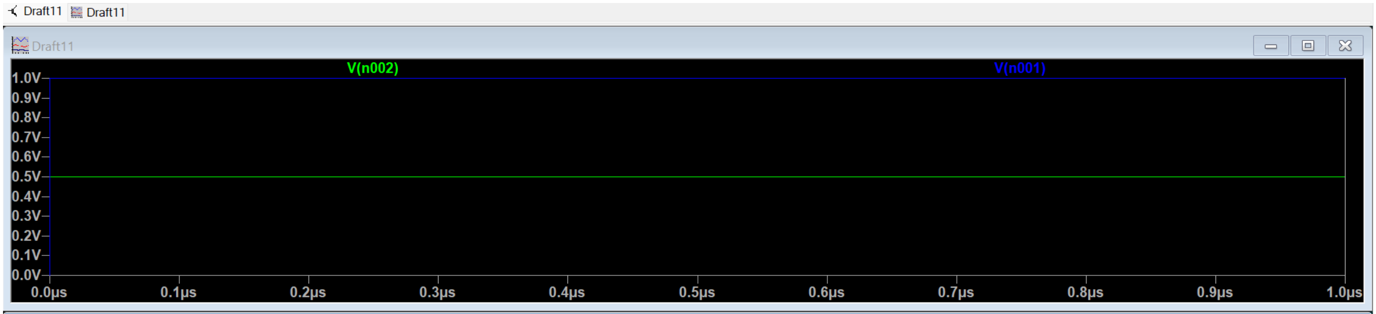

Draft9
Draft9
Draft9
V(n002)
0dB
-8dB
-16dB
-24dB
-32dB
-40dB
-48dB
-56dB
-64dB
-72dB
-80dB
-88dB
90°
81°
72°
63°
54°
45°
36°
27°
18°
9°
0°
10Hz
100Hz
1KHz
10KHz
100KHz
1MHz
10MHz
100MHz
1GHz
10GHz
C1
1n
V1
R1
C2
PULSE(0 1 0 1p 1p 1n 2n)
AC 1
.ac dec 10 10 10G

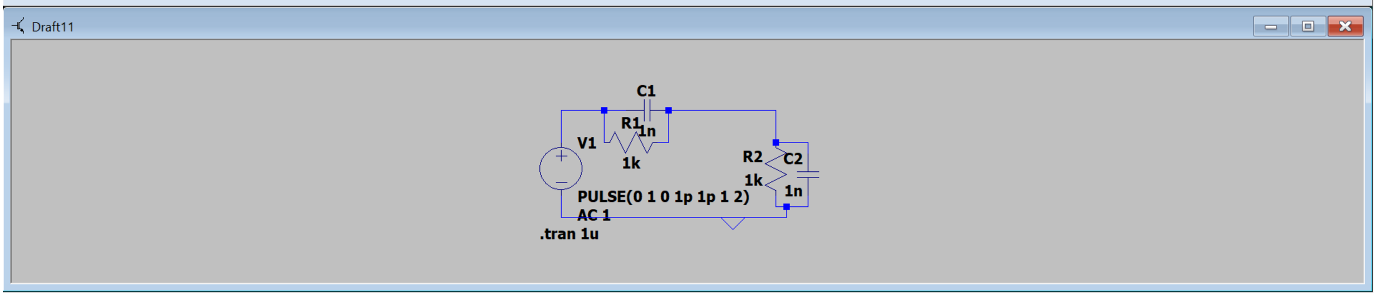
1.2 (e) R1C1>R2C2

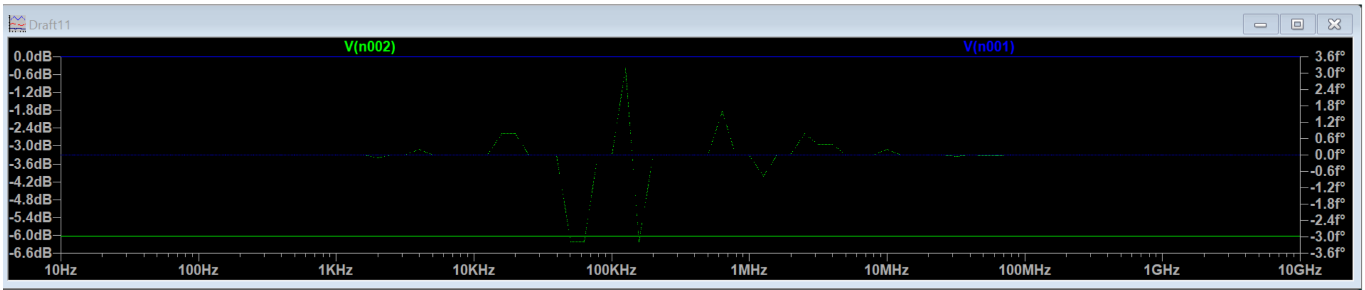


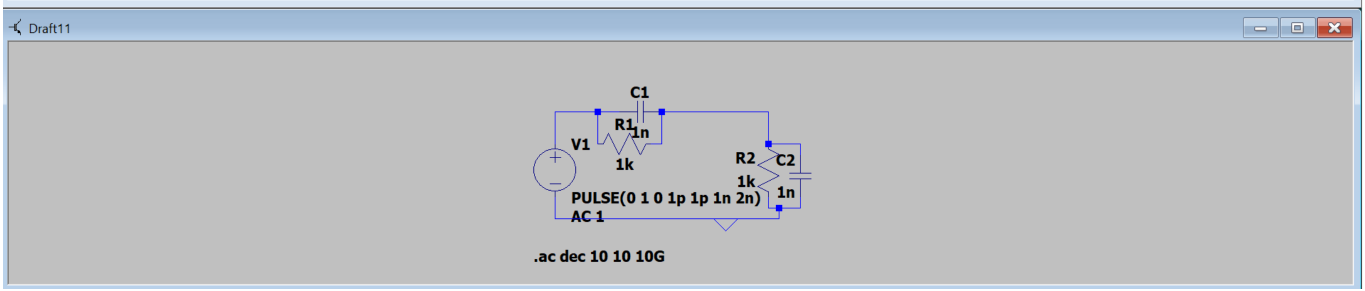


1.2 (e) R1C1=R2C2

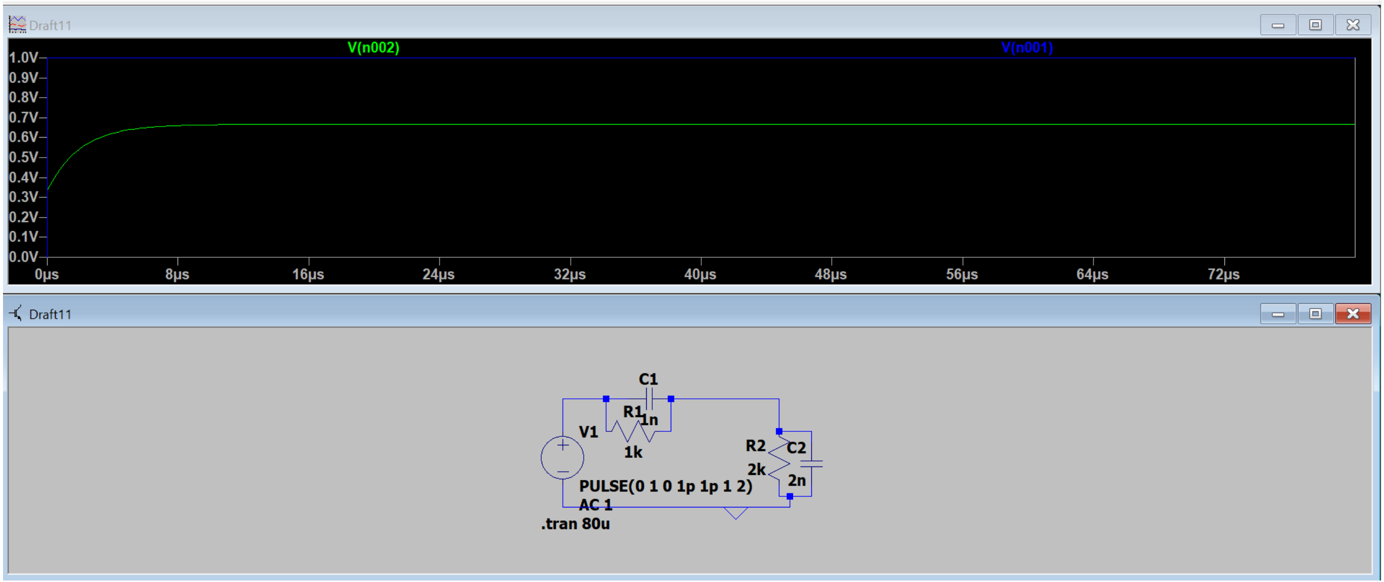


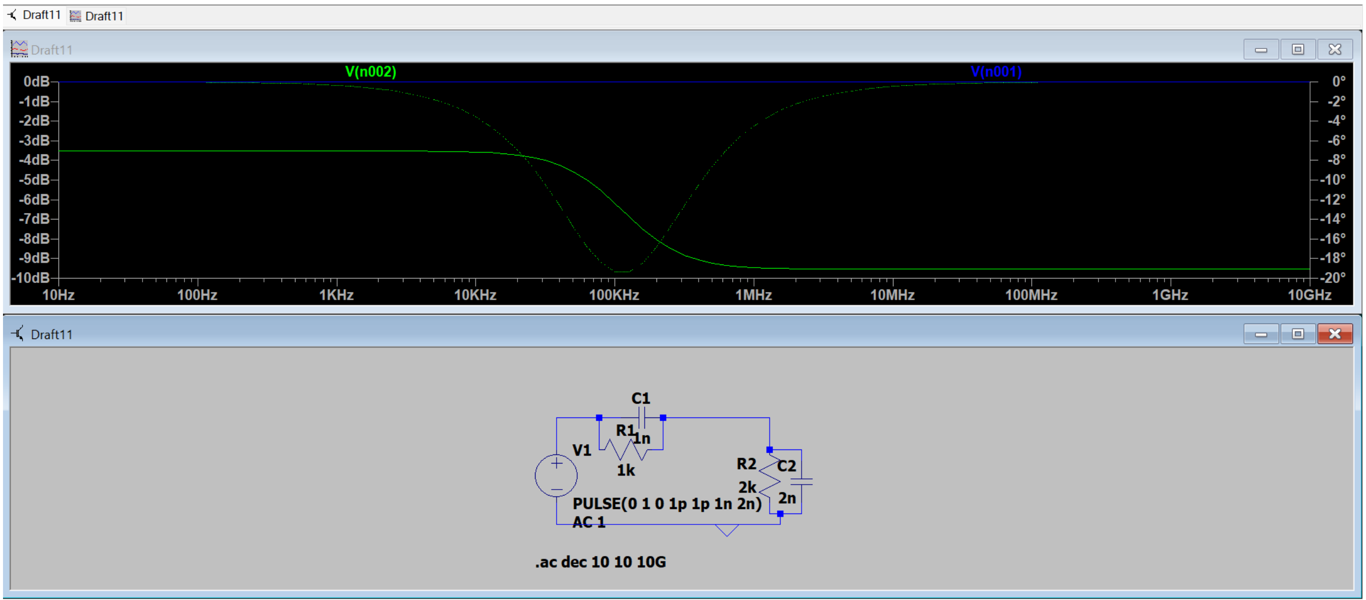




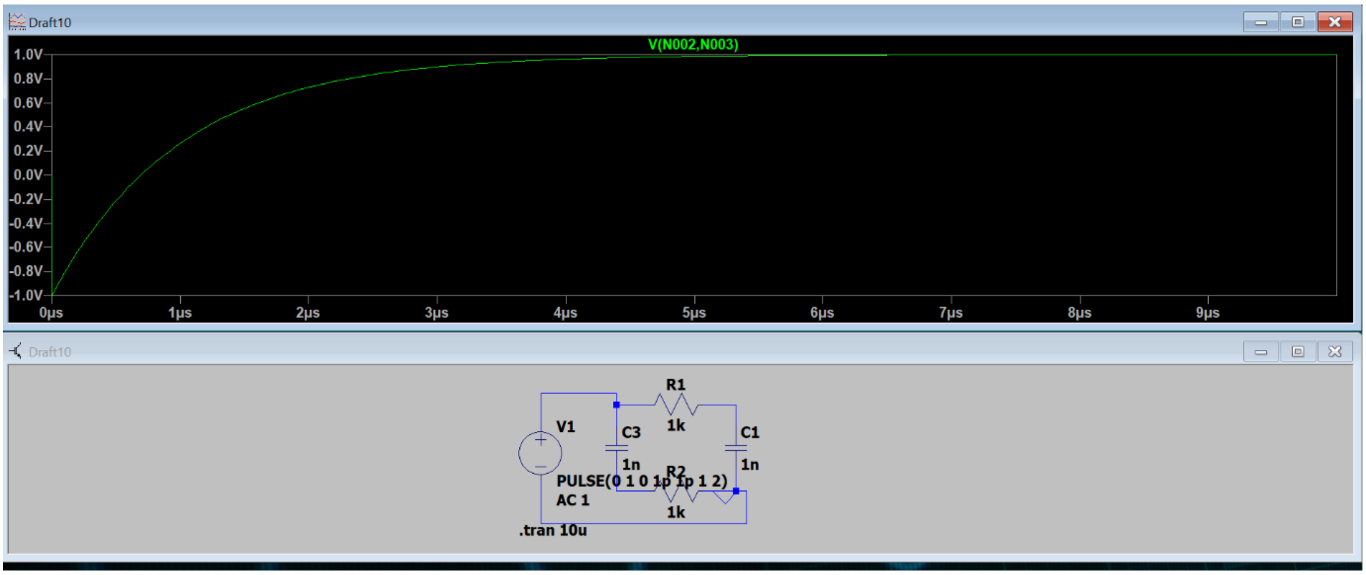


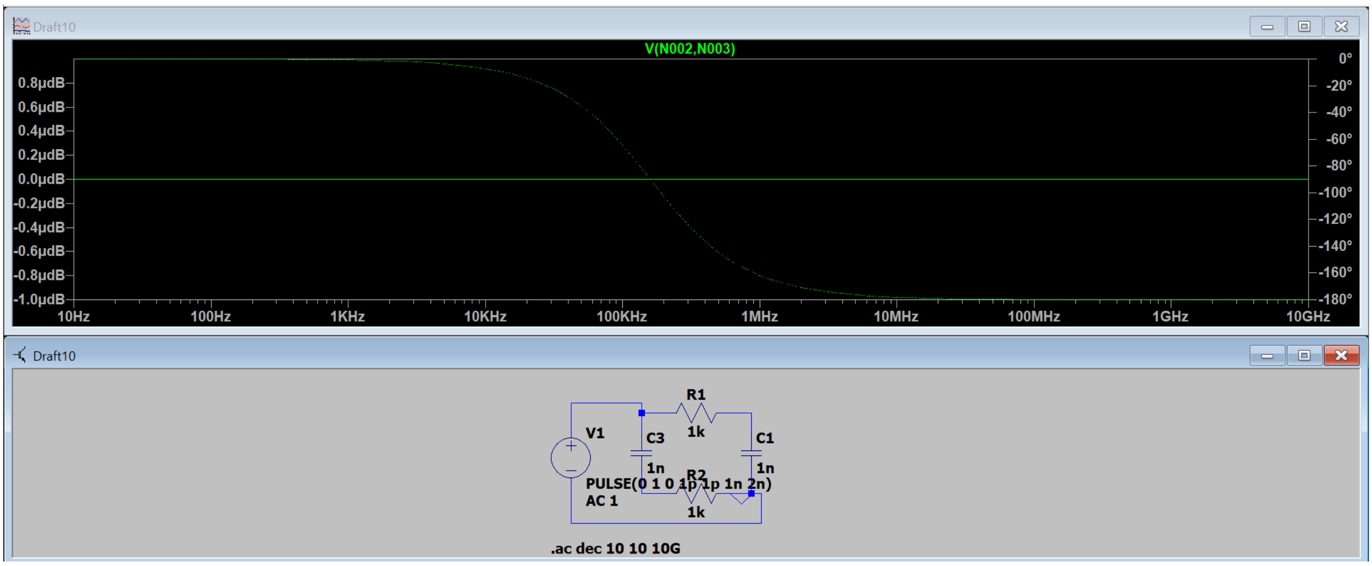
1.2 (e) R1C1<R2C2





1.2 (f)


Draft10
V(N002,N003)
1.0V
0.8V
0.6V
0.4V
0.2V
0.0V
-0.2V
-0.4V
-0.6V
-0.8V
-1.0V
0µs
1µs
2µs
3µs
4µs
5µs
6µs
7µs
8µs
9µs
Draft10
R1
1k
V1
C3
1n
C1
1n
R2
1k
PULSE(0 1 0 1p 1p 1 2)
AC 1
.tran 10u


Draft10
V(N002,N003)
0.8µdB
0.6µdB
0.4µdB
0.2µdB
0.0µdB
-0.2µdB
-0.4µdB
-0.6µdB
-0.8µdB
-1.0µdB
0°
-20°
-40°
-60°
-80°
-100°
-120°
-140°
-160°
-180°
10Hz
100Hz
1KHz
10KHz
100KHz
1MHz
10MHz
100MHz
1GHz
10GHz
Draft10
R1
1k
V1
C3
1n
C1
1n
R2
1k
PULSE(0 1 0 1p 1p 1n 2n)
AC 1
.ac dec 10 10 10G