EE230: Homework 1
Familiarization with NGSpice Circuit Simulator

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1 Overview of the experiment

1.1 Aim of the experiment

Familiarization with the basic functions of NGSpice, by creating and simulating the following examples:

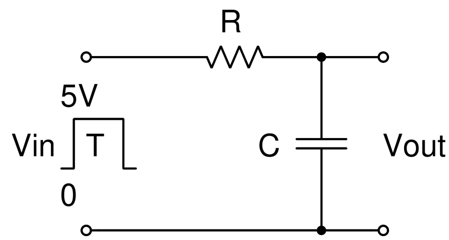
- RC Integrator
- RC Differentiator
- RC Lowpass Filter
- RC Highpass Filter
- RC Bandpass Filter
- RLC Bandpass Filter

1.2 Methods

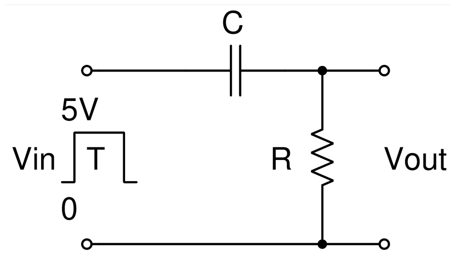
The circuit diagrams for the above examples were provided in the lab handout, using which I created and simulated them in NGSpice

2 Design

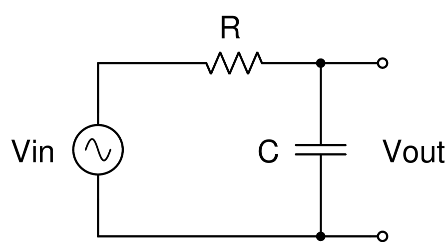
1. **RC Integrator**



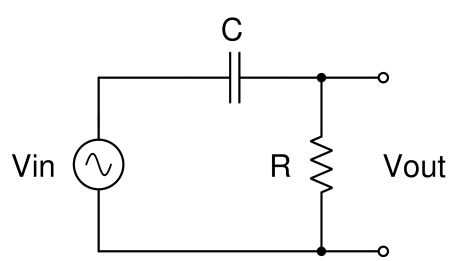
2. **RC Differentiator**



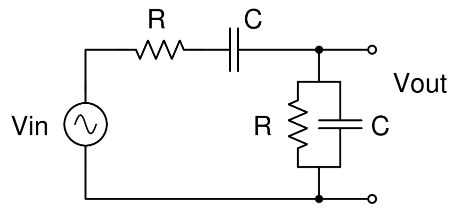
3. **RC Lowpass Filter**



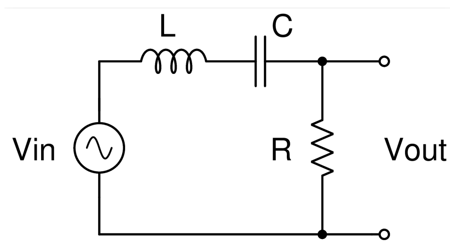
4. **RC Highpass Filter**



5. **RC Bandpass Filter**



6. **RLC Bandpass Filter**



3 Simulation results

3.1 RC Integrator

3.1.1 Code snippet

```
RC Integrator
*Connections as mentioned in the figure
R 1 2 10k
C 2 0 0.1u
*Input Pulse
Vin 1 0 pulse(0 5 0 0 0 10m 20m)
*Transient Analysis
.tran 0.02m 60m
.control
run
*Plotting Vin and Vout
plot v(1) v(2)
print v(1) v(2)
.endc
```

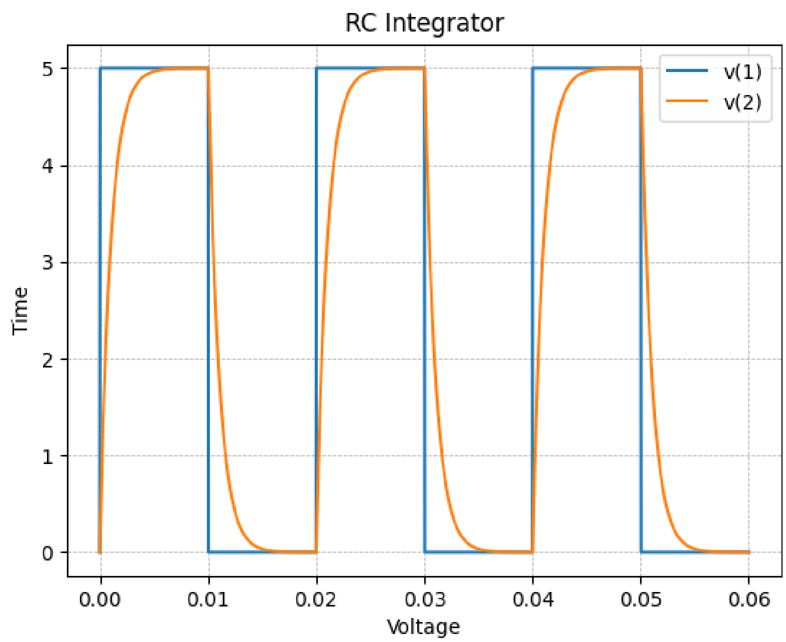
.end

3.1.2 Simulation results

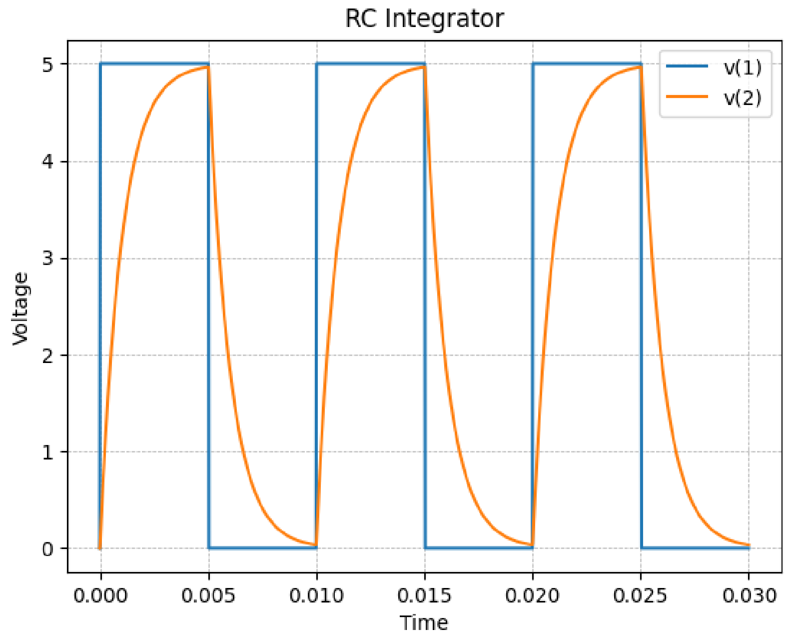
Given below are the plots and reasoning for the 5 cases given for an RC Integrator.

Cases:

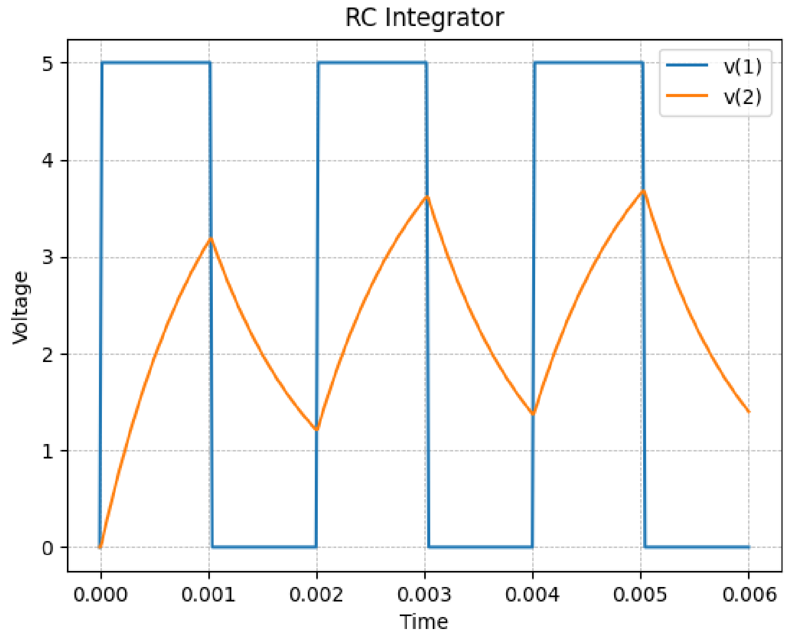
1. $T = 10\tau$



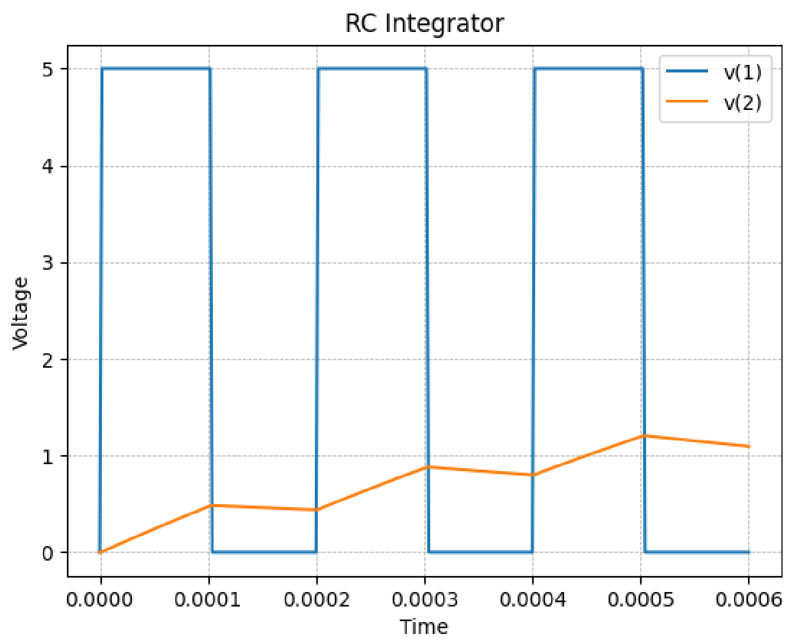
2. $T = 5\tau$


RC Integrator
Voltage
Time
v(1)
v(2)
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0
1
2
3
4
5

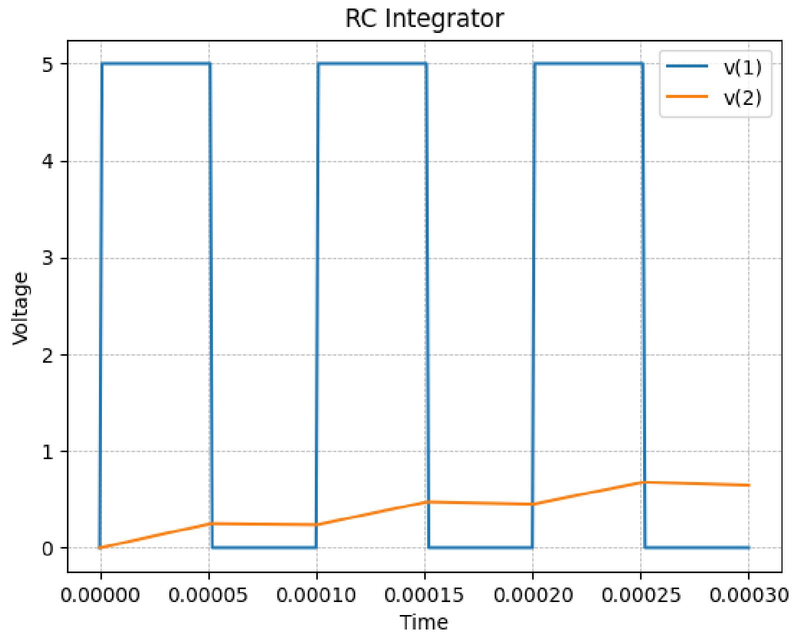
3. $T = \tau$


RC Integrator
Voltage
Time
v(1)
v(2)
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0
1
2
3
4
5

4. $T = 0.1\tau$



5. $T = 0.05\tau$



As the Pulse Width to Time Constant ratio decreases, the Capacitor does not get enough time to charge fully and thus we get a lower V_{out} and a reasonably linear curve. Similarly, for the Discharge cycle, the Capacitor does not get enough time to discharge completely and V_{out} decreases almost linearly.

3.2 RC Differentiator

3.2.1 Code snippet

```
RC Differentiator
*Connections as mentioned in the figure
C 1 2 0.1u
R 2 0 10k
*Input Pulse
Vin 1 0 pulse(0 5 0 0 0 10m 20m)
*Transient analysis
.tran 0.02m 60m
.control
run
```

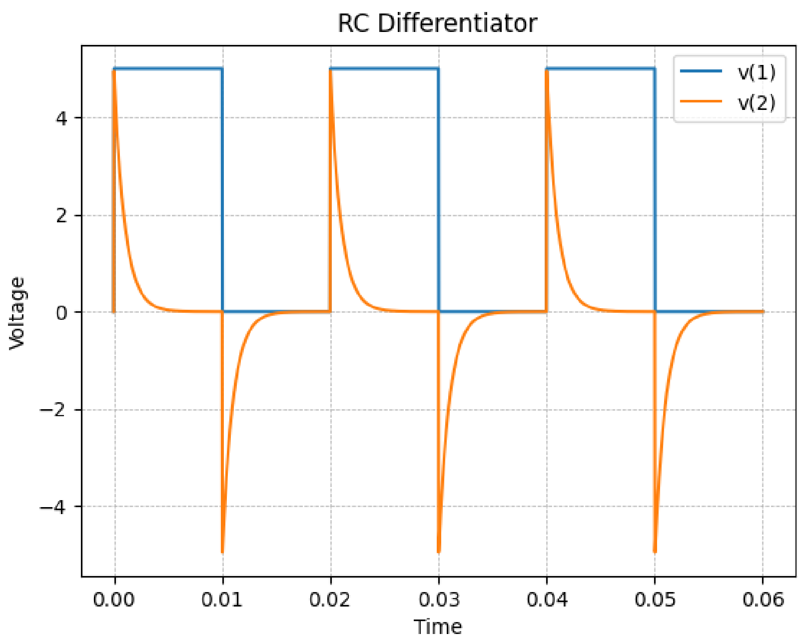
```
*Plotting Vin and Vout
plot v(1) v(2)
print v(1) v(2)
.endc
.end
```

3.2.2 Simulation results

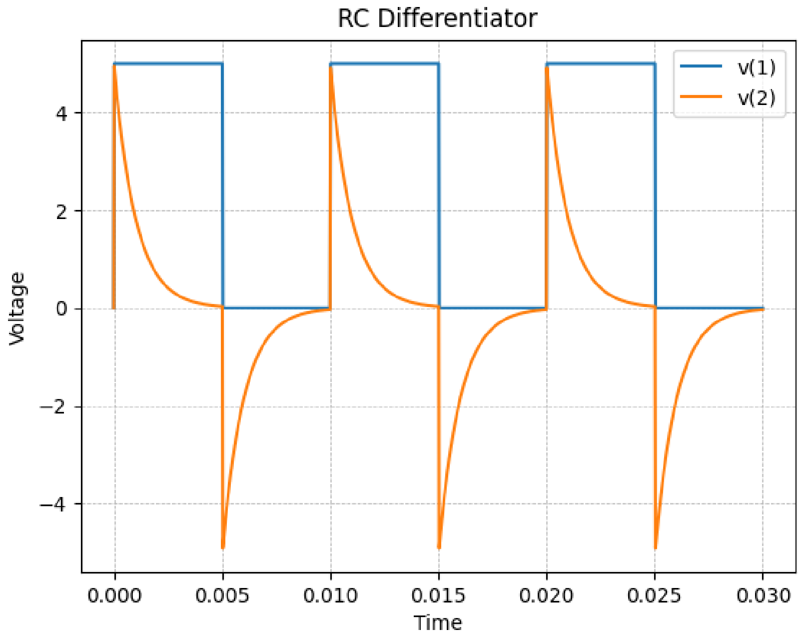
Given below are the plots and reasoning for the 5 cases given for an RC Differentiator.

Cases:

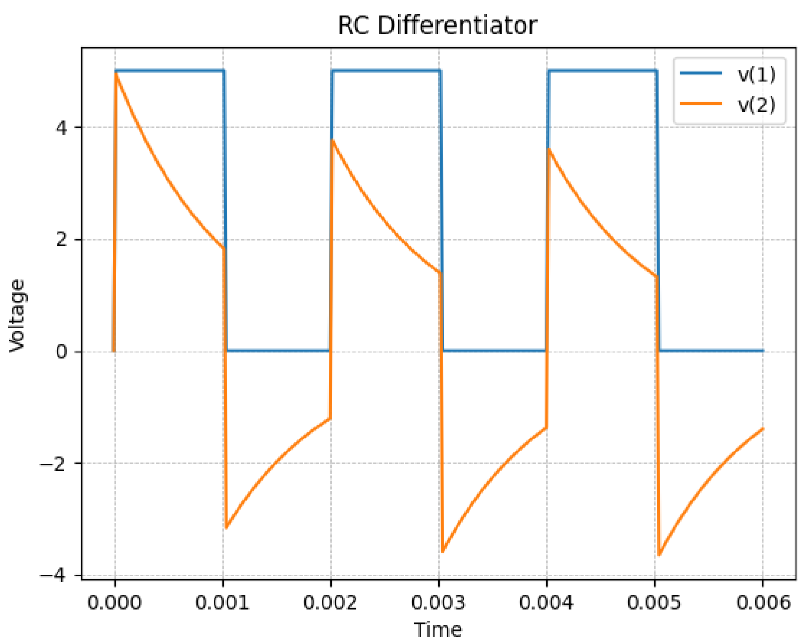
1. $T = 10\tau$



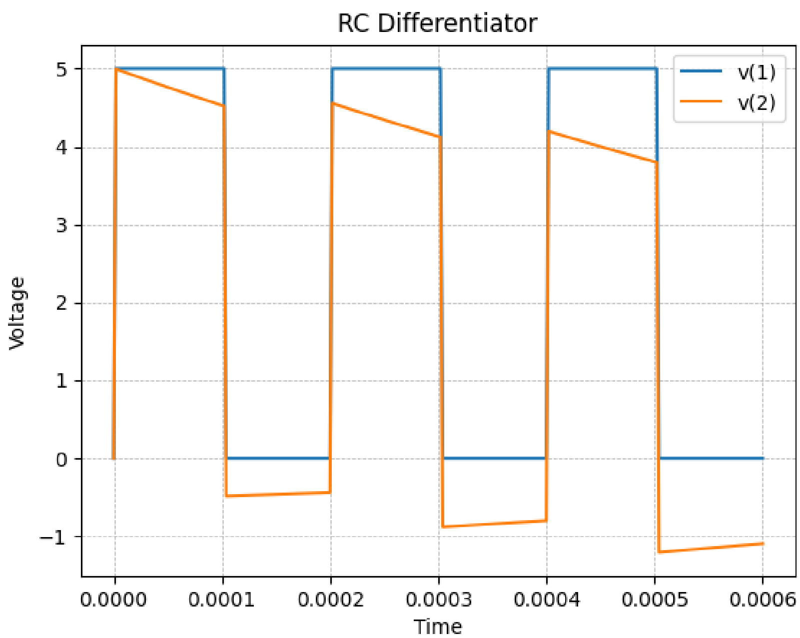
2. $T = 5\tau$


RC Differentiator
v(1)
v(2)
Voltage
Time
4
2
0
−2
−4
0.000
0.005
0.010
0.015
0.020
0.025
0.030

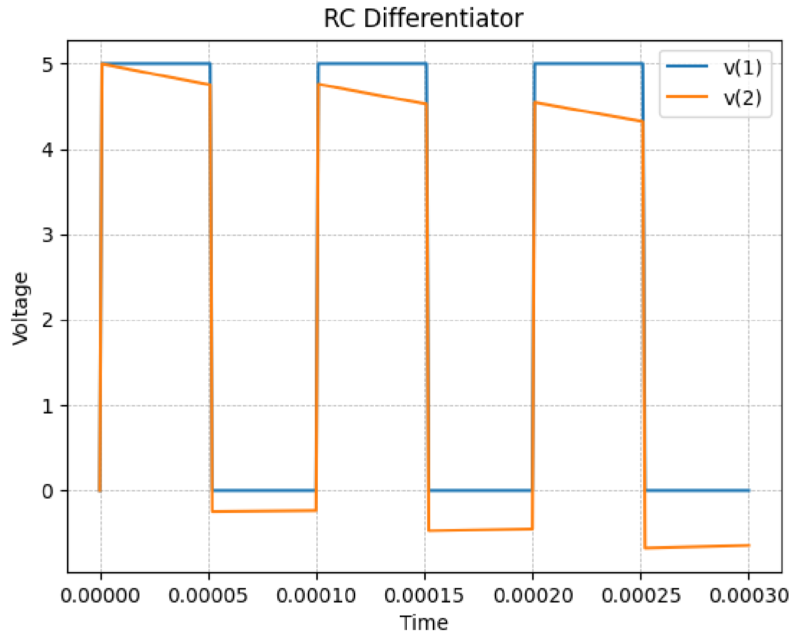
3. $T = \tau$


RC Differentiator
v(1)
v(2)
Voltage
Time
4
2
0
−2
−4
0.000
0.001
0.002
0.003
0.004
0.005
0.006

4. $T = 0.1\tau$



5. $T = 0.05\tau$



As the Pulse Width to Time Constant ratio decreases, the Capacitor does not get enough time to charge fully and thus we get a large Voltage across the Resistor and a reasonably linear decrease in V_{out}. Similarly, for the Discharge cycle, the Capacitor does not get enough time to discharge fully and V_{out} increases almost linearly.

3.3 RC Lowpass Filter

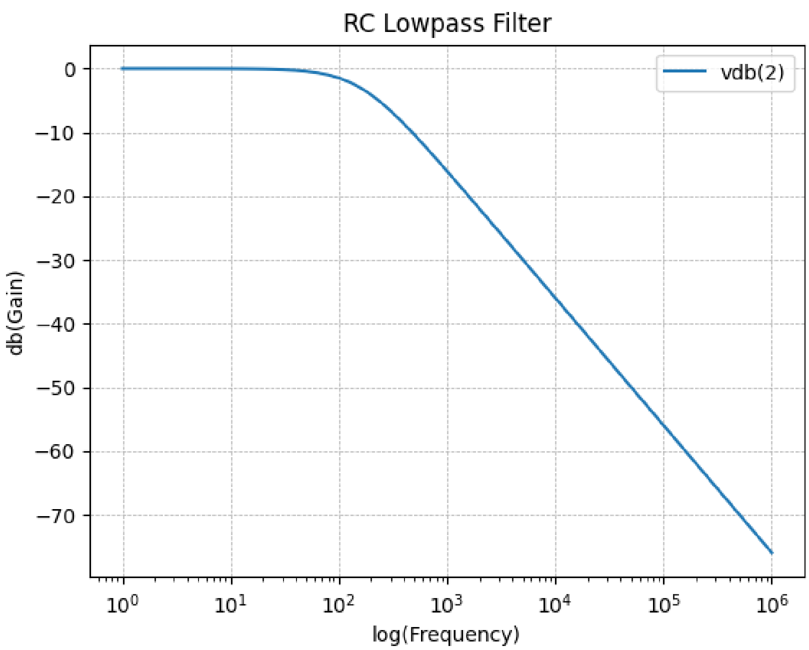
3.3.1 Code snippet

```
RC Lowpass Filter
*Connections as mentioned in the figure
R 1 2 10k
C 2 0 0.1u
*AC Input
Vin 1 0 dc 0 ac 1
*AC analysis
.ac dec 10 1 1Meg
.control
```

```
run
*Amplitude Bode Plot
plot vdb(2)
print vdb(2)
.endc
.end
```

3.3.2 Simulation results

Given below is the plot and reasoning for an RC Lowpass Filter.



The filter given above has a 3dB frequency of 158.49 Hz.

3.4 RC Highpass Filter

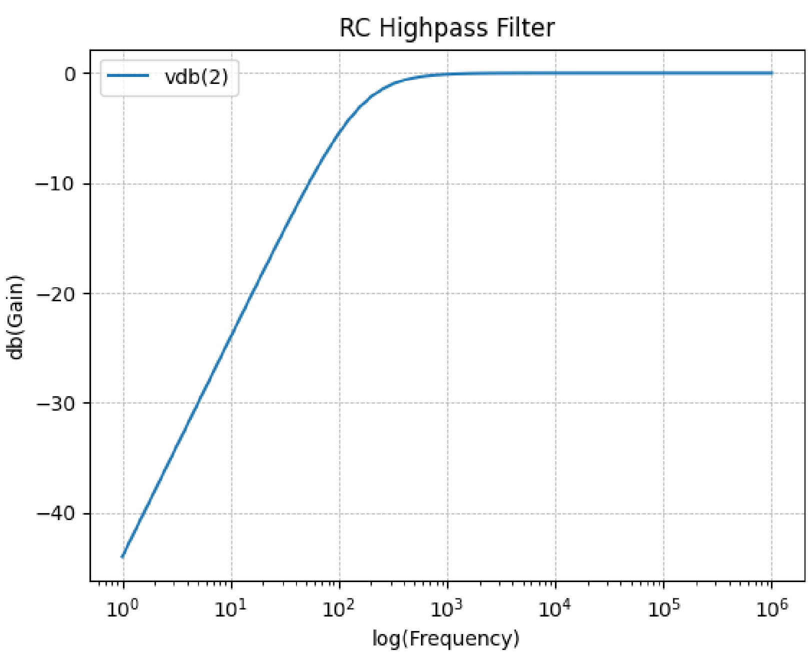
3.4.1 Code snippet

```
RC Highpass Filter
*Connections as mentioned in the figure
C 1 2 0.1u
R 2 0 10k
```

```
*AC input
Vin 1 0 dc 0 ac 1
*AC analysis
.ac dec 10 1 1Meg
.control
run
*Amplitude Bode Plot
plot vdb(2)
print vdb(2)
.endc
.end
```

3.4.2 Simulation results

Given below is the plot and reasoning for an RC Highpass Filter.



The filter given above has a 3dB frequency of 158.49 Hz.

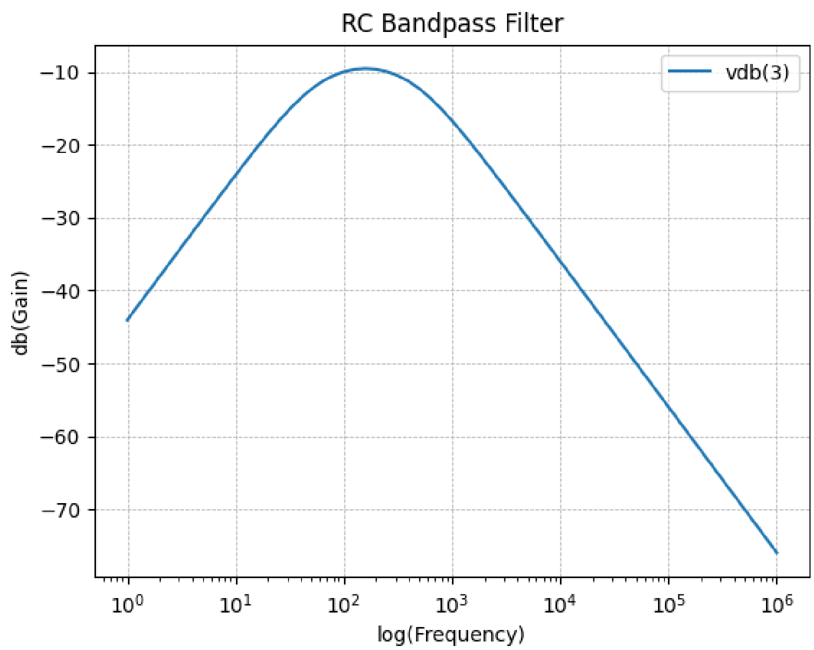
3.5 RC Bandpass Filter

3.5.1 Code snippet

```
RC Bandpass Filter
*Connections as mentioned in the figure
R1 1 2 10k
C1 2 3 0.1u
R2 3 0 10k
C2 3 0 0.1u
*AC input
Vin 1 0 dc 0 ac 1
*AC analysis
.ac dec 10 1 1Meg
.control
run
*Amplitude Bode Plot
plot vdb(3)
print vdb(3)
.endc
.end
```

3.5.2 Simulation results

Given below is the plot and reasoning for an RC Bandpass Filter.



- **Centre Frequency** (f_0)
  Theoretical: $\frac{1}{2\pi RC} = 159.15$ Hz
  Simulation: 158.49 Hz

- **Lower -3dB point** (f_L)
  Theoretical: 48.31 Hz
  Simulation: 48.306 Hz

- **Higher -3dB point** (f_H)
  Theoretical: 524.7 Hz
  Simulation: 524.81 Hz

3.6 RLC Bandpass Filter

3.6.1 Code snippet

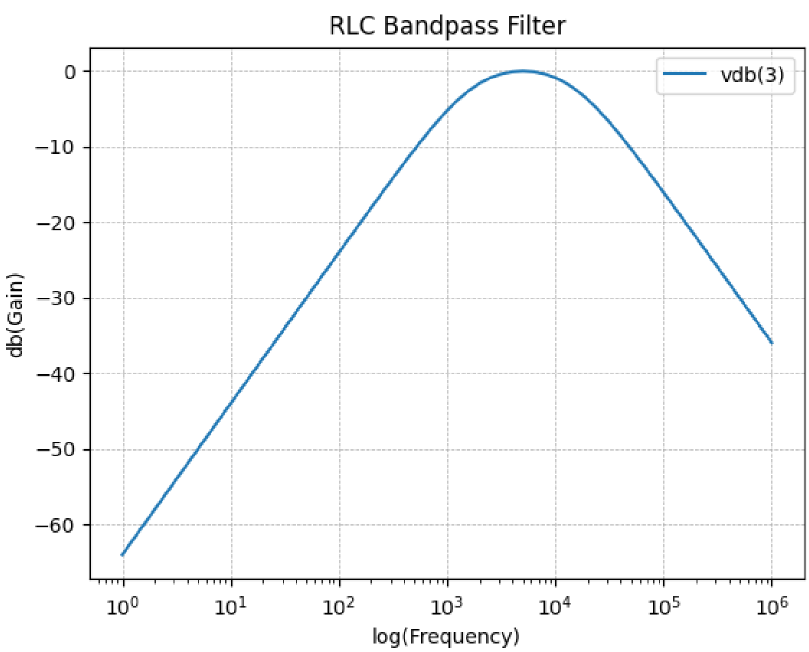
```
RLC Bandpass Filter

*Connections as mentioned in the figure
L 1 2 10m
```

```
C 2 3 0.1u
R 3 0 1k
*AC input
Vin 1 0 dc 0 ac 1
*AC analysis
.ac dec 10 1 1Meg
.control
run
*Amplitude Bode Plot
plot vdb(3)
print vdb(3)
.endc
.end
```

3.6.2 Simulation results

Given below is the plot and reasoning for an RLC Bandpass Filter.



- **Centre Frequency** (f_0)
  Theoretical: $\frac{1}{2\pi\sqrt{LC}} = 5.033$ kHz

Simulation: 5.012 kHz

- **Lower -3dB point** (f_L)
  Theoretical: $\sqrt{\frac{R}{2L}^2 + \frac{1}{LC}} - \frac{R}{2L} = 1.458$ kHz
  Simulation: 1.445 kHz

- **Higher -3dB point** (f_H)
  Theoretical: $\sqrt{\frac{R}{2L}^2 + \frac{1}{LC}} + \frac{R}{2L} = 17.373$ kHz
  Simulation: 17.378 kHz

4 Experimental results

4.1 RC Integrator

Results of the 5 cases for an RC Integrator are as follows:

Cases:

1. $T = 10\tau$

Sr. No.	Time	v(1)	v(2)
1	1.196400e-02	0.000000e+00	7.227096e-01
2	2.370065e-02	5.000000e+00	4.875239e+00
3	3.518400e-02	0.000000e+00	2.887281e-02
4	4.776065e-02	5.000000e+00	4.997848e+00
5	5.924400e-02	0.000000e+00	4.979602e-04

2. $T = 5\tau$

Sr. No.	Time	v(1)	v(2)
1	1.228400e-02	0.000000e+00	3.512221e-03
2	2.369112e-02	5.000000e+00	4.874040e+00
3	3.632400e-02	0.000000e+00	6.179789e-05
4	4.760400e-02	0.000000e+00	3.785714e-01
5	5.920400e-02	0.000000e+00	3.468677e-06

3. $T = \tau$

Sr. No.	Time	v(1)	v(2)
1	1.228400e-02	0.000000e+00	4.139834e-05
2	2.356400e-02	0.000000e+00	2.536046e-01
3	3.632400e-02	0.000000e+00	7.284082e-07
4	4.760400e-02	0.000000e+00	4.462199e-03
5	5.920400e-02	0.000000e+00	4.088510e-08

4. $T = 0.1\tau$

Sr. No.	Time	v(1)	v(2)
1	1.228400e-02	0.000000e+00	2.974361e-06
2	2.356400e-02	0.000000e+00	1.822089e-02
3	3.516400e-02	0.000000e+00	1.669497e-07
4	4.760400e-02	0.000000e+00	3.205984e-04
5	5.920400e-02	0.000000e+00	2.937497e-09

5. $T = 0.05\tau$

Sr. No.	Time	v(1)	v(2)
1	1.227400e-02	0.000000e+00	1.707494e-06
2	2.351400e-02	0.000000e+00	1.088698e-02
3	3.627400e-02	0.000000e+00	3.126979e-08
4	4.751400e-02	0.000000e+00	1.993754e-04
5	5.911400e-02	0.000000e+00	1.826786e-09

4.2 RC Differentiator

Results of the 5 cases for an RC Differentiator are as follows:

Cases:

1. $T = 10\tau$

Sr. No.	Time	v(1)	v(2)
1	1.228400e-02	0.000000e+00	-5.24789e-01
2	2.370065e-02	5.000000e+00	1.247605e-01
3	3.402400e-02	0.000000e+00	-9.21059e-02
4	4.776065e-02	5.000000e+00	2.151705e-03
5	5.924400e-02	0.000000e+00	-4.97960e-04

2. $T = 5\tau$

Sr. No.	Time	v(1)	v(2)
1	1.228400e-02	0.000000e+00	-3.51222e-03
2	2.369112e-02	5.000000e+00	1.259603e-01
3	3.632400e-02	0.000000e+00	-6.17979e-05
4	4.760400e-02	0.000000e+00	-3.78571e-01
5	5.920400e-02	0.000000e+00	-3.46868e-06

3. $T = \tau$

Sr. No.	Time	v(1)	v(2)
1	1.228400e-02	0.000000e+00	-4.13983e-05
2	2.356400e-02	0.000000e+00	-2.536046e-01
3	3.632400e-02	0.000000e+00	-7.284082e-07
4	4.760400e-02	0.000000e+00	-4.462199e-03
5	5.920400e-02	0.000000e+00	-4.088510e-08

4. $T = 0.1\tau$

Sr. No.	Time	v(1)	v(2)
1	1.228400e-02	0.000000e+00	-2.974361e-06
2	2.356400e-02	0.000000e+00	-1.822089e-02
3	3.516400e-02	0.000000e+00	-1.669497e-07
4	4.760400e-02	0.000000e+00	-3.205984e-04
5	5.920400e-02	0.000000e+00	2.937497e-09

5. $T = 0.05\tau$

Sr. No.	Time	v(1)	v(2)
1	1.227400e-02	0.000000e+00	-1.70749e-06
2	2.351400e-02	0.000000e+00	-1.08870e-02
3	3.627400e-02	0.000000e+00	-9.97524e-08
4	4.751400e-02	0.000000e+00	-1.99375e-04
5	5.911400e-02	0.000000e+00	-1.82679e-09

4.3 RC Lowpass Filter

Results of the given RC Lowpass Filter are as follows:

Sr. No.	Frequency	vdb(2)
1	1.584893e+00	-4.30648e-04
2	1.584893e+02	-2.99214e+00
3	1.995262e+03	-2.19911e+01
4	2.511886e+04	-4.39638e+01
5	3.162278e+05	-6.59636e+01

4.4 RC Highpass Filter

Results of the given RC Highpass Filter are as follows:

Sr. No.	Frequency	vdb(2)
1	1.258925e+01	-2.20635e+01
2	1.584893e+02	-3.02854e+00
3	1.995262e+03	-2.75452e-02
4	2.511886e+04	-1.74348e-04
5	3.162278e+05	-1.10008e-06

4.5 RC Bandpass Filter

Results of the given RC Bandpass Filter are as follows:

Sr. No.	Frequency	vdb(2)
1	1.258925e+01	-2.22227e+01
2	1.584893e+02	-9.54246e+00
3	1.995262e+03	-2.21530e+01
4	2.511886e+04	-4.39648e+01
5	3.162278e+05	-6.59636e+01

4.6 RLC Bandpass Filter

Results of the given RLC Bandpass Filter are as follows:

Sr. No.	Frequency	vdb(3)
1	1.258925e+01	-4.20366e+01
2	1.584893e+02	-2.00707e+01
3	1.995262e+03	-1.61962e+00
4	2.511886e+04	-5.17847e+00
5	3.162278e+05	-2.59724e+01