EE230: Homework 1
Homework 1 : Familiarization with NGSPICE Circuit Simulator and Lab Equipment

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1 Overview of the experiment

1.1 Aim of the experiment

- To get familiar with NGSpice by simulation of various RC and RLC Circuits
- To get familiar with the lab equipment.

1.2 Methods

To get acquainted with NGSpice, we simulated 6 different RC and RLC circuits (RC Integrator, RC Differentiator, RC Lowpass Filter, RC Highpass Filter, RC Bandpass Filter and RLC Bandpass Filter). We further analyzed various parameters of the circuit by plotting graphs.

2 Design

2.1 RC Integrator

- A resistor and a capacitor are connected in series.
- The voltage input is a square pulse with different width and time period for 5 different cases.

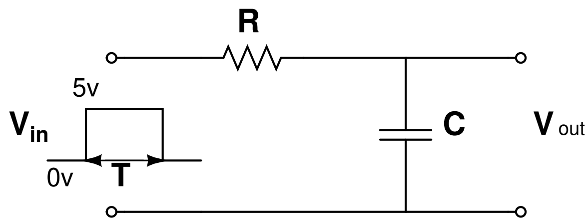
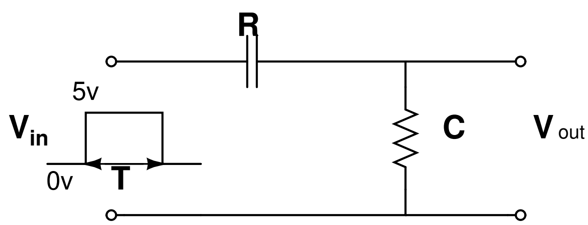


Figure 1: RC Integrator

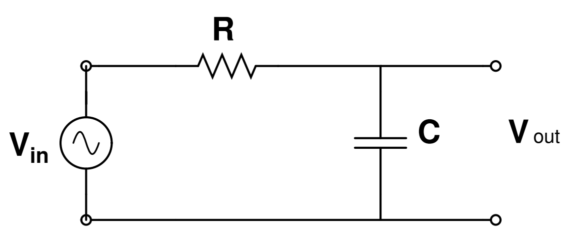
- The output voltage is measured across the capacitor.

2.2 RC Differentiator



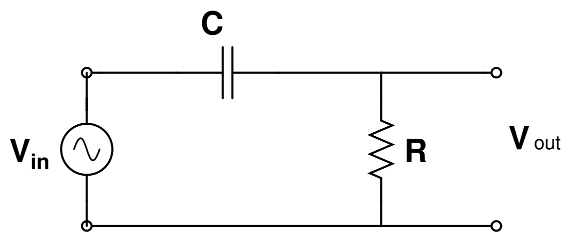
- A resistor and a capacitor are connected in series.
- The voltage input is a square pulse with different width and time period for 6 different cases.
- The output voltage is measured across the resistor.

2.3 RC Lowpass filter



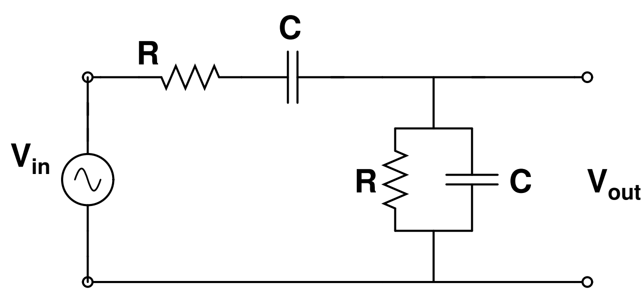
- A resistor and a capacitor are connected in series.
- The voltage input is a sin wave.
- The output voltage is measured across the capacitor.

2.4 RC Highpass filter



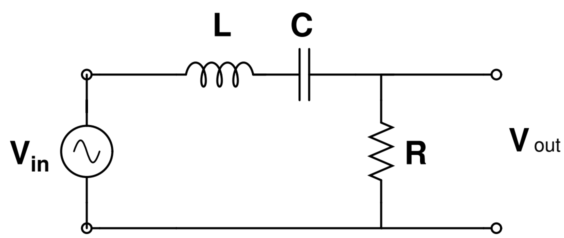
- A resistor and a capacitor are connected in series.
- The voltage input is a sin wave.
- The output voltage is measured across the resistor.

2.5 RC Bandpass filter



- A resistor, a capacitor and a resistor with a capacitor in parallel, are connected in series.
- The voltage input is a sin wave.
- The output voltage is measured across the parallel combination.

2.6 RLC Highpass filter



- A resistor, a capacitor and an inductor are connected in series.
- The voltage input is a sin wave.
- The output voltage is measured across the resistor.

3 Simulation results

3.1 Code snippet

3.1.1 B1 - RC Integrator

```
HW1 B1 RC Integrator Case 1
*Specifying the components
r1 1 2 10k
c1 2 0 0.1u
* Specifying the input voltage
*Case 1
vin 1 0 pulse(0 5 0 0 0 10ms 20ms)
.tran 0.01ms 100ms
*Case 2
*vin 1 0 pulse(0 5 0 0 0 5ms 10ms) )
*.tran 0.01ms 100ms
*Case 3
*vin 1 0 pulse(0 5 0 0 0 1ms 2ms)
*.tran 0.01ms 10ms
*Case 4
*vin 1 0 pulse(0 5 0 0 0 0.1ms 0.2ms)
```

```
*.tran 0.01ms 20ms
*Case 5
*vin 1 0 pulse(0 5 0 0 0 0.05ms 0.1ms)
*.tran 0.01ms 6ms
.control
run
plot v(1) v(2)
.endc
.end
```

3.1.2 B2 - RC Differentiator

```
HW1 B2 RC Differentiator Case 1
* Specifying the components
c1 1 2 0.1u
r1 2 0 10k
* Specifying the input voltage
* Case 1
vin 1 0 pulse(0 5 0 0 0 10ms 20ms)
.tran 0.01ms 100ms
* Case 2
*vin 1 0 pulse(0 5 0 0 0 5ms 10ms)
*.tran 0.01ms 100ms
* Case 3
*vin 1 0 pulse(0 5 0 0 0 1ms 2ms))
*.tran 0.01ms 70ms
* Case 4
*vin 1 0 pulse(0 5 0 0 0 0.5ms 1ms)
*.tran 0.01ms 40ms
* Case 5
*vin 1 0 pulse(0 5 0 0 0 0.1ms 0.2ms)
*.tran 0.01ms 10ms
* Case 6
*vin 1 0 pulse(0 5 0 0 0 0.05ms 0.1ms)
*.tran 0.01ms 10ms
.control
run
```

```
plot v(1) v(2)
.endc
.end
```

3.1.3 B3 - RC Lowpass Filter

```
HW1 B3 RC Lowpass filter
* Specifying the components
r1 1 2 10k
c1 2 0 0.1u
* Specifying the input voltage
vin 1 0 dc 0 ac 1
.ac dec 10 1 1Meg
.control
run
* Plotting amplitude frequency reponse (amplitude Bode plot)
plot vdb(2) xlog
.endc
.end
```

3.1.4 B4 - RC Highpass Filter

```
HW1 B4 RC Highpass filter
* Specifying the components
c1 1 2 0.1u
r1 2 0 10k
* Specifying the input voltage
vin 1 0 dc 0 ac 1
.ac dec 10 1 1Meg
.control
run
* Plot Amplitude frequency response
plot vdb(2) xlog
.endc
.end
```

3.1.5 B5 - RC Bandpass Filter

```
HW1 B5 RC Bandpass filter
* Specifying the components
r1 1 2 10k
c1 2 3 0.1u
r2 3 0 10k
c2 3 0 0.1u
* Specifying the input voltage
vin 1 0 dc 0 ac 1
.ac dec 10 1 1Meg
.control
run
* Plot Amplitude frequency response
plot vdb(3) xlog
.endc
.end
```

3.1.6 B6 - RLC Bandpass Filter

```
HW1 B6 RLC Bandpass filter
* Specifying the components
l1 1 2 10m
c1 2 3 0.1u
r1 3 0 1k
* Specifying the input voltage
vin 1 0 dc 0 ac 1
.ac dec 10 1 1Meg
.control
run
* Plot amplitude frequency response
plot vdb(3) xlog
.endc
.end
```

3.2 Simulation results

The following are the output voltage plots and Bode plots of the RC and RLC Circuits mentioned above.

3.2.1 RC Integrator

RC Integrator : **Case 1**

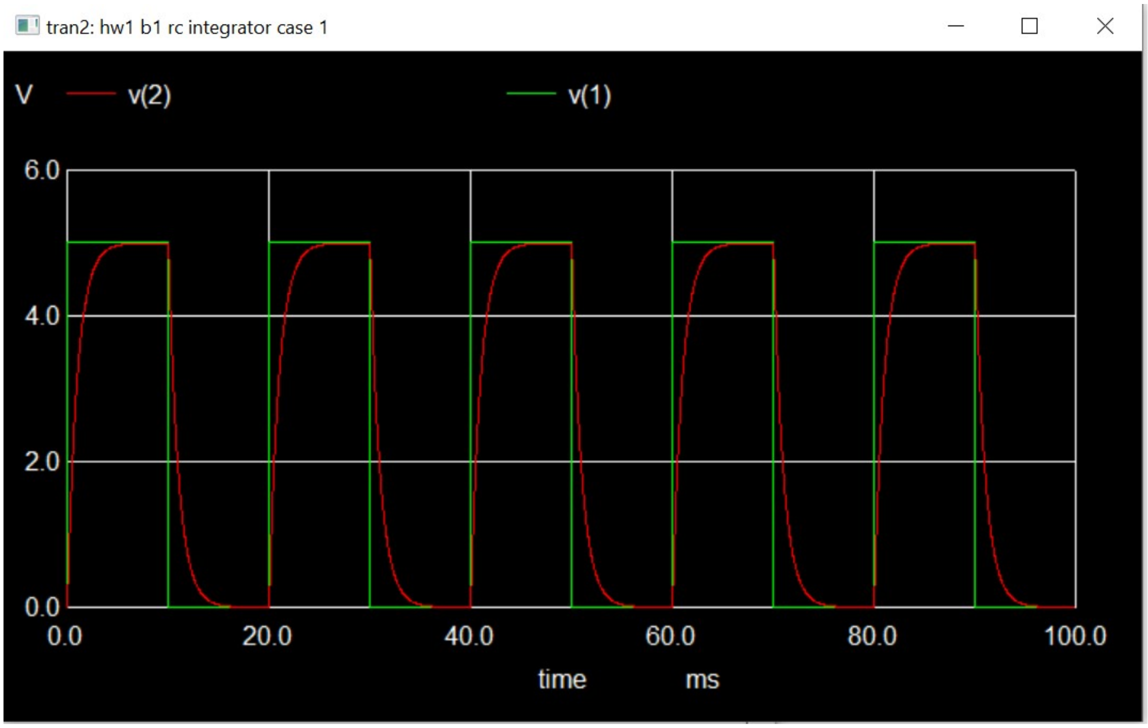


Figure 2: RC Integrator : Case 1

RC Integrator : **Case 2**

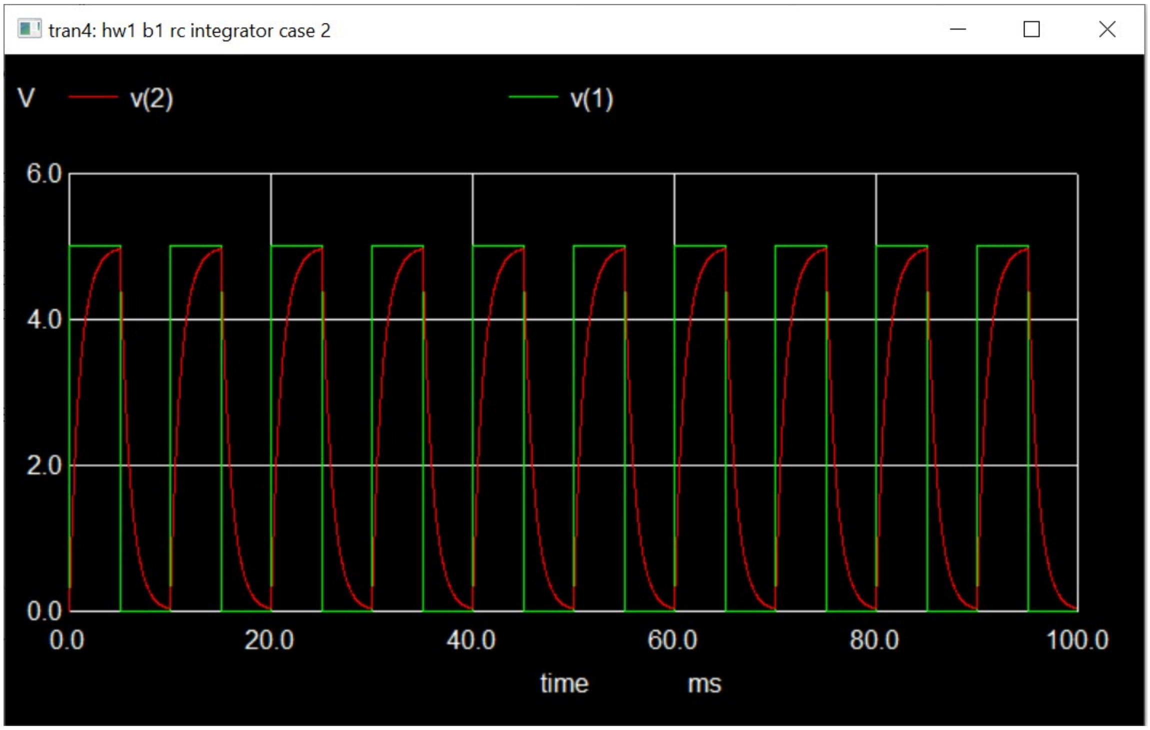


Figure 3: RC Integrator : Case 2

RC Integrator : **Case 3**

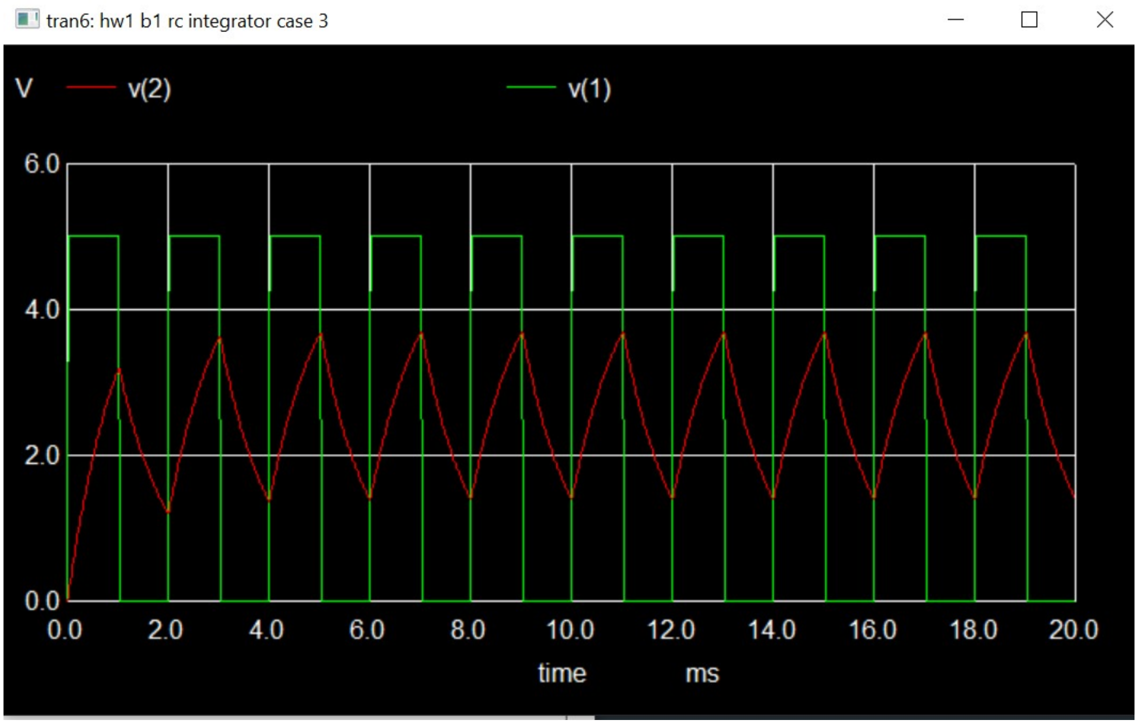


Figure 4: RC Integrator : Case 3

RC Integrator : **Case 4**

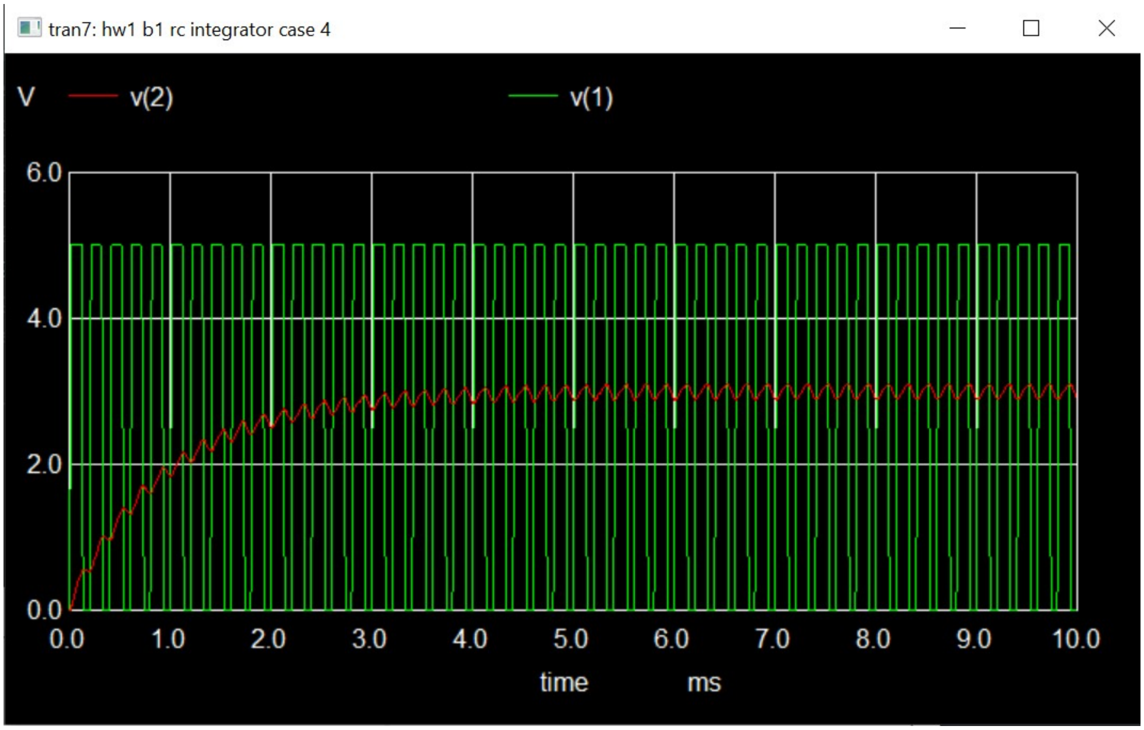


Figure 5: RC Integrator : Case 4

RC Integrator : **Case 5**

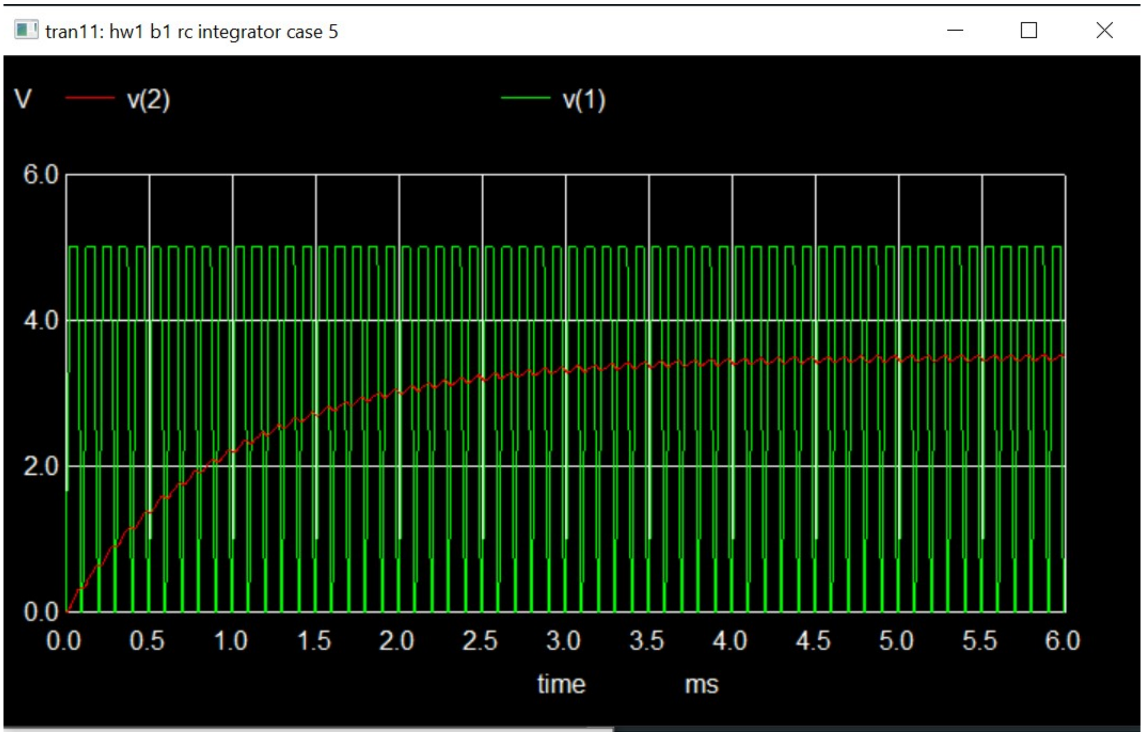


Figure 6: RC Integrator : Case 5

3.2.2 RC Differentiator

RC Differentiator : **Case 1**

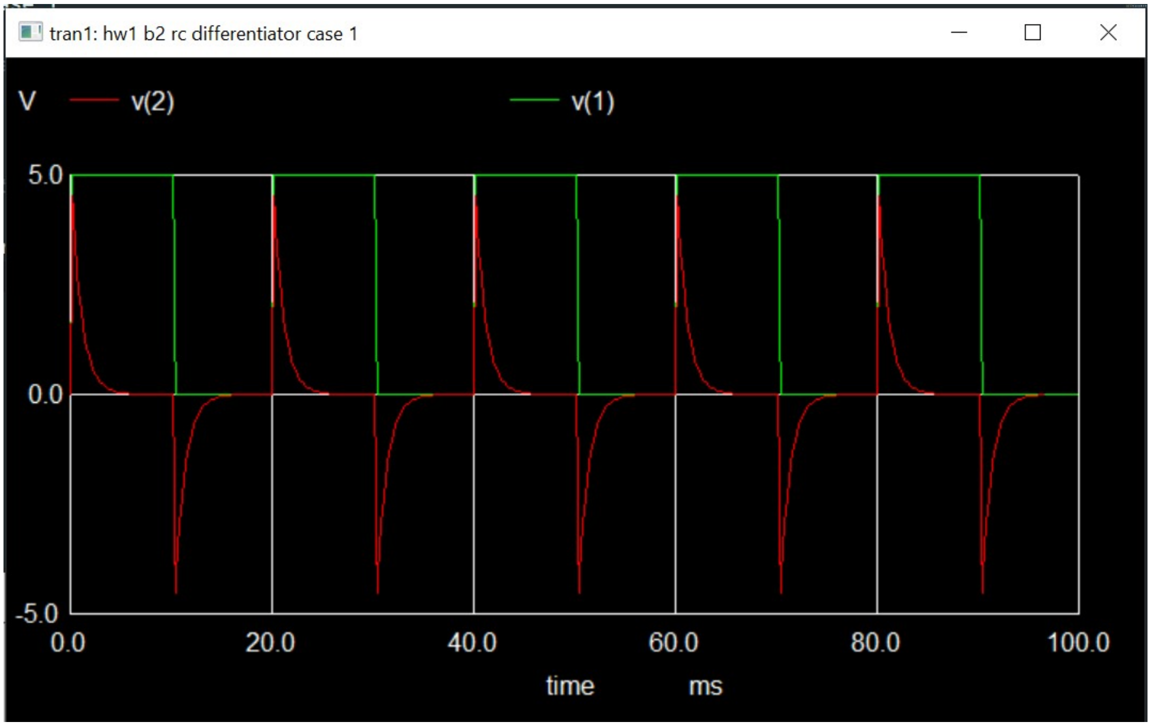


Figure 7: RC Differentiator : Case 1

RC Differentiator : **Case 2**

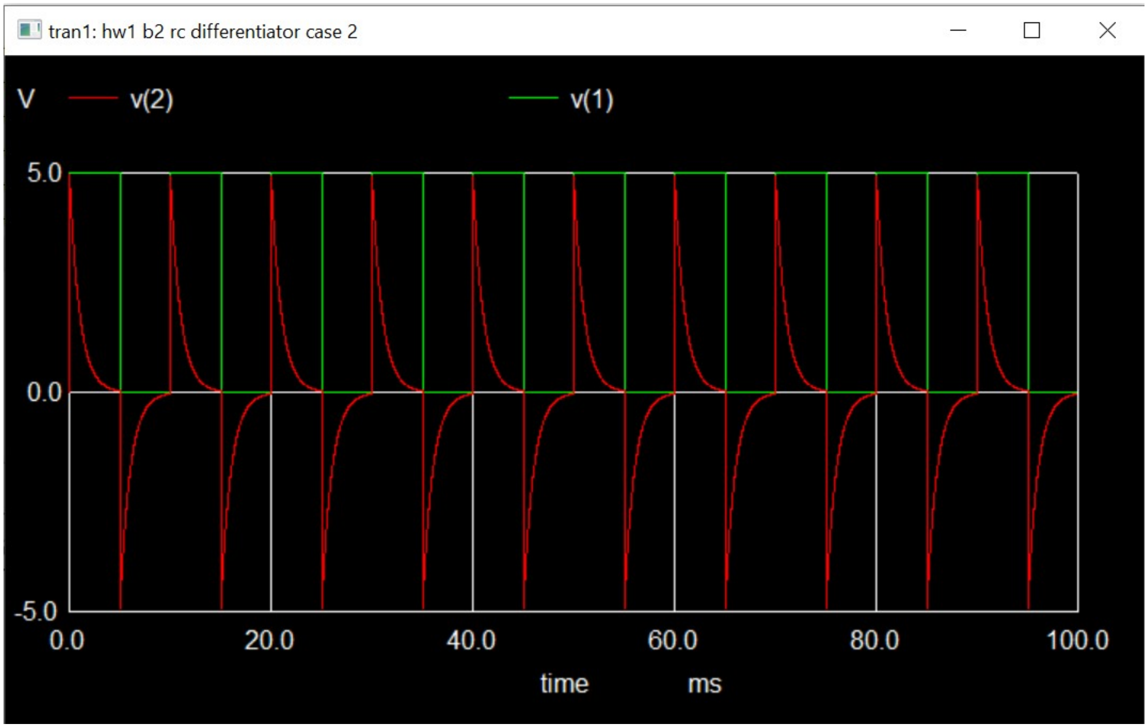


Figure 8: RC Differentiator : Case 2

RC Differentiator : **Case 3**

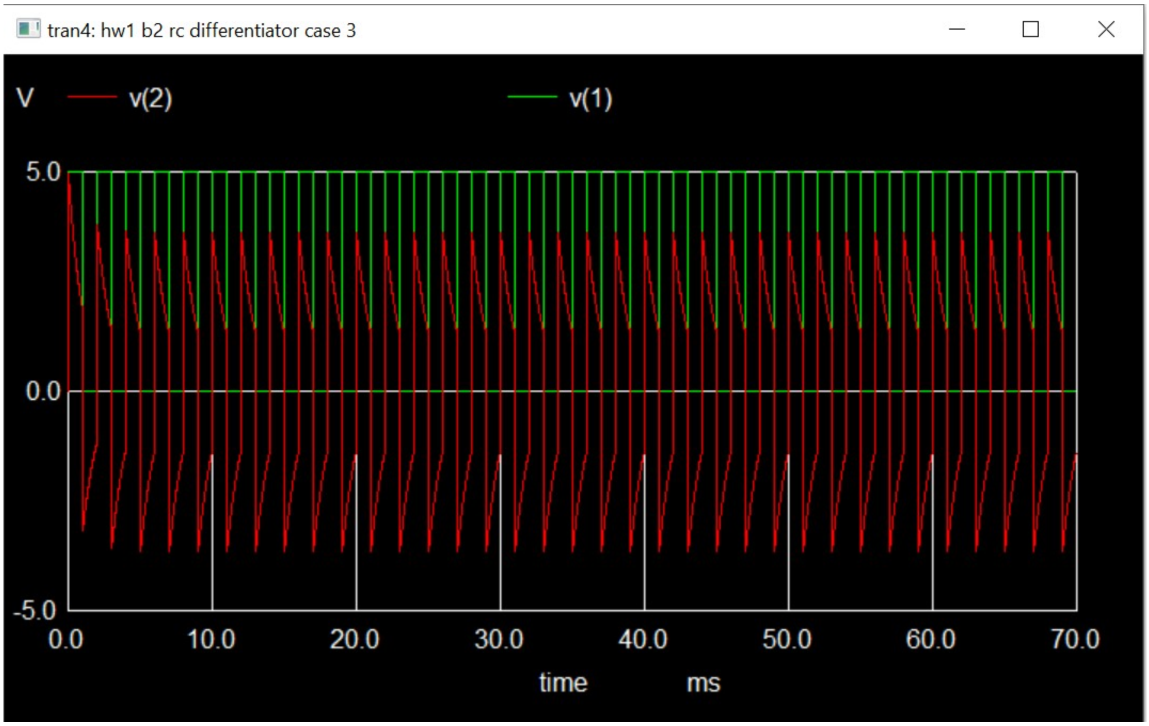


Figure 9: RC Differentiator : Case 3

RC Differentiator : **Case 4**

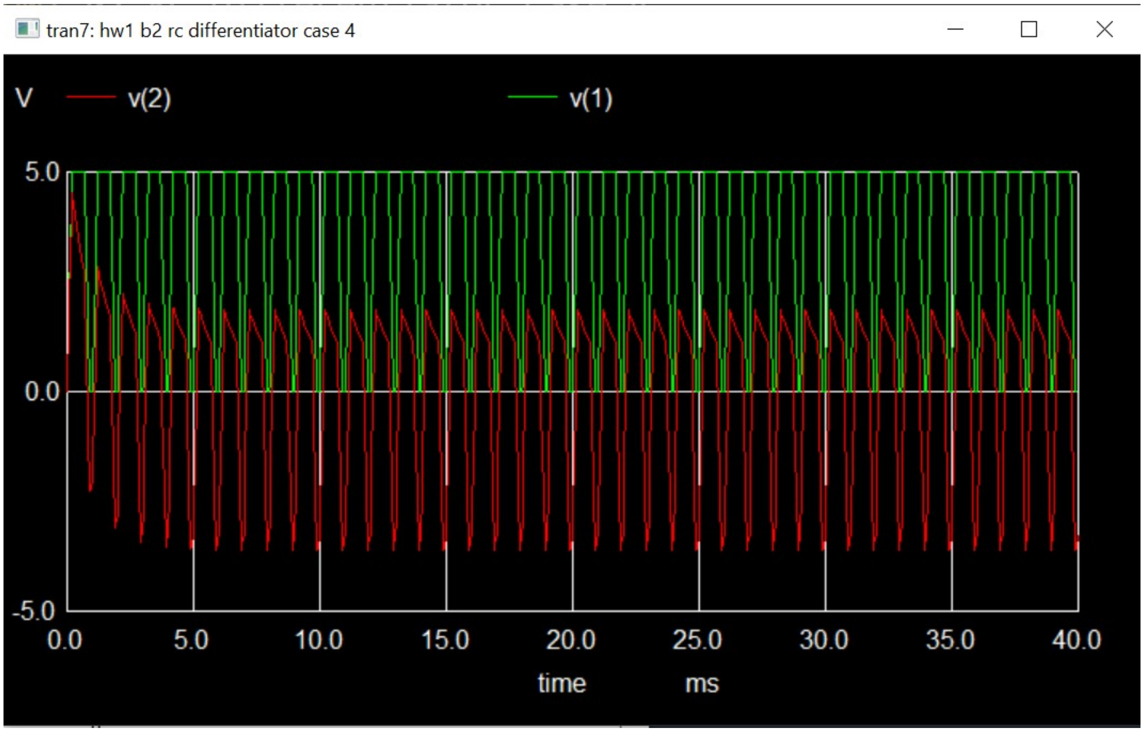


Figure 10: RC Differentiator : Case 4

RC Differentiator : **Case 5**

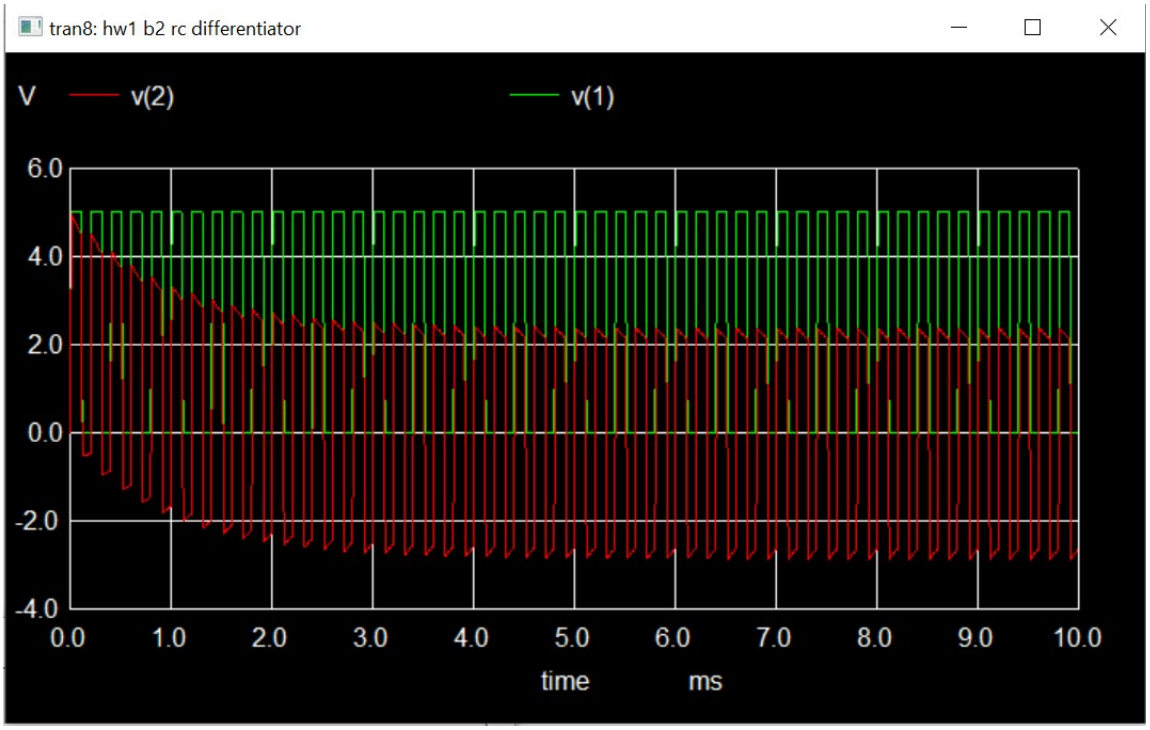


Figure 11: RC Differentiator : Case 5

RC Differentiator : **Case 6**

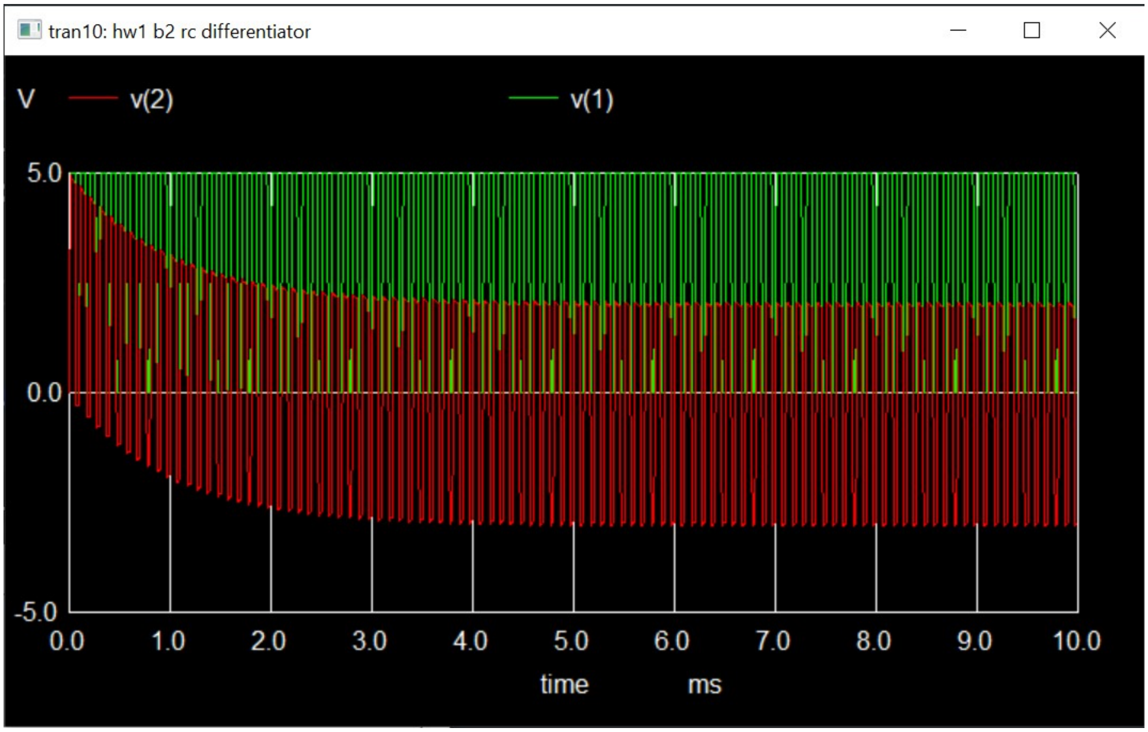


Figure 12: RC Differentiator : Case 6

3.2.3 RC Lowpass Filter

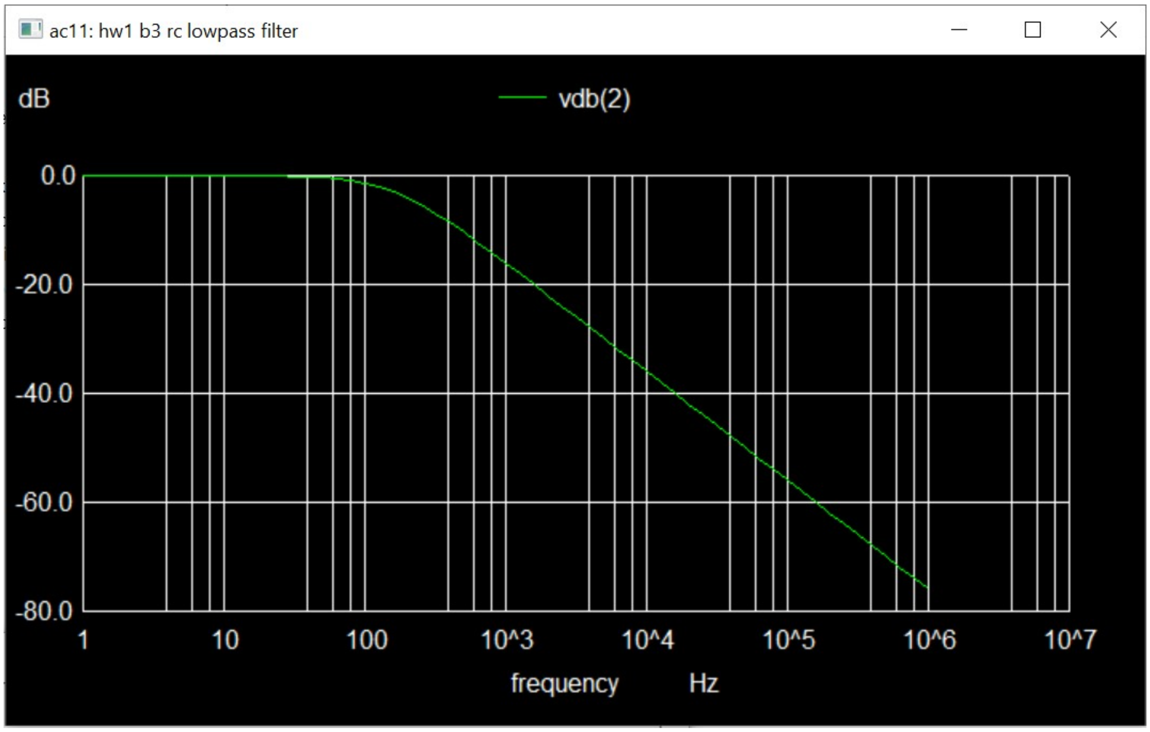


Figure 13: RC Lowpass Filter

3.2.4 RC Highpass Filter

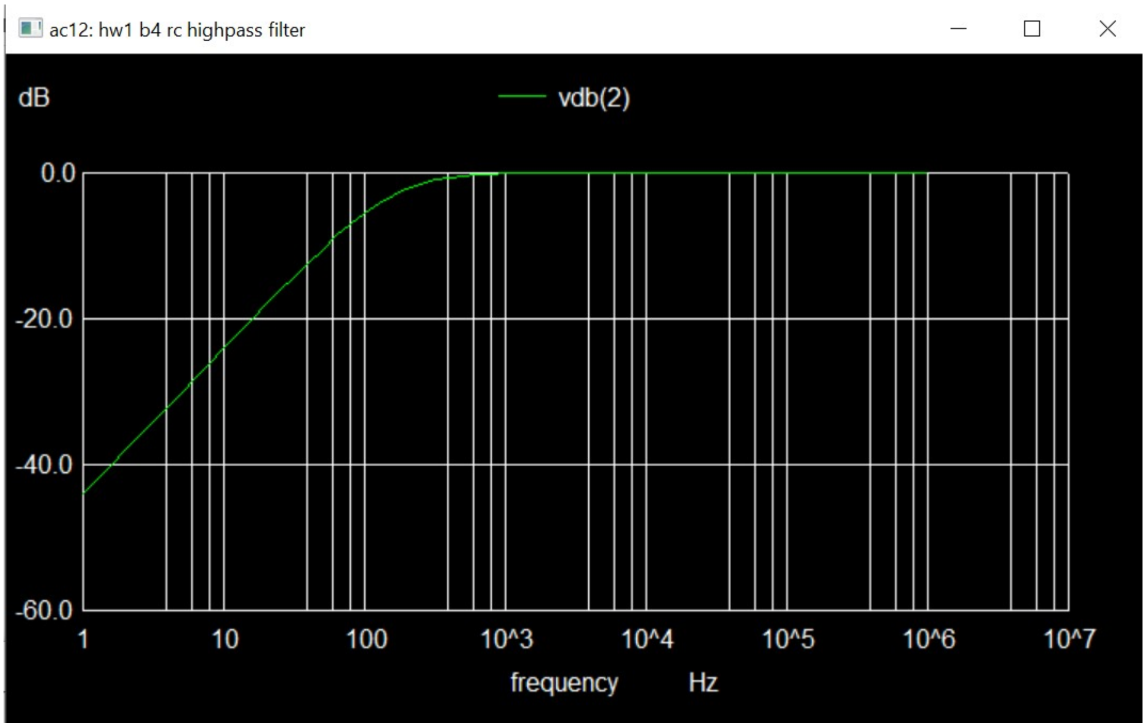


Figure 14: RC Highpass Filter Bode plot

3.2.5 RC Bandpass Filter

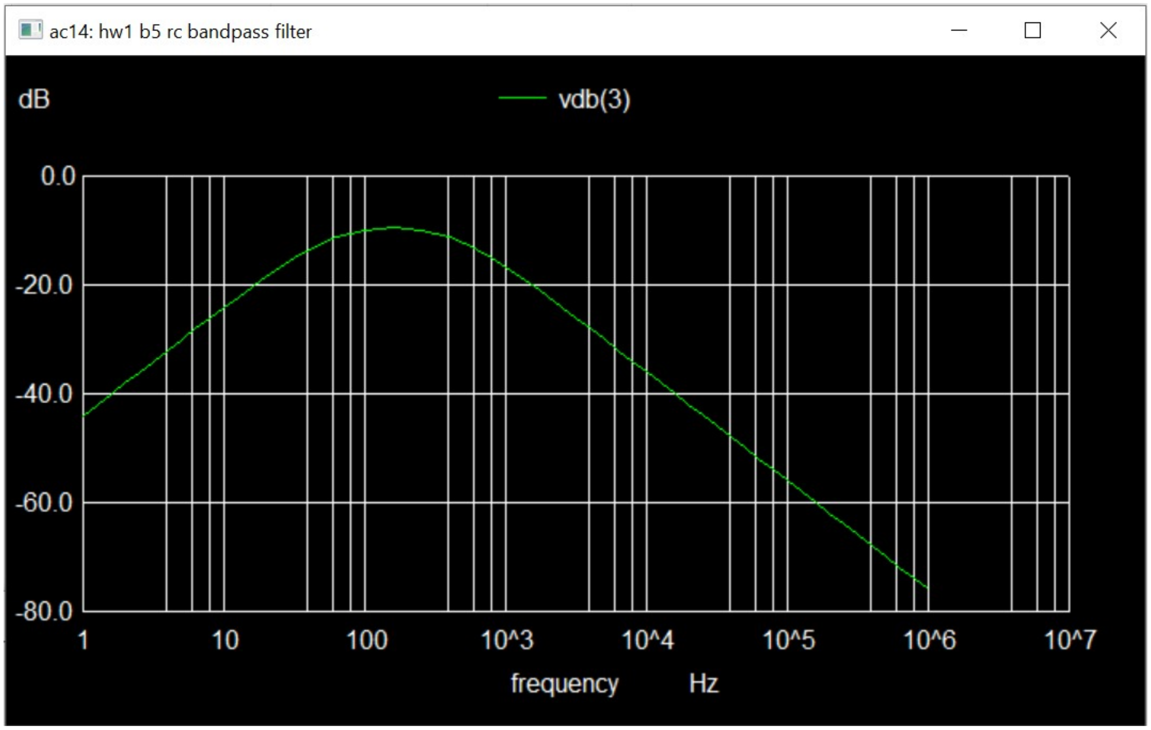


Figure 15: RC Bandpass Filter Bode plot

The **peak amplitude** of the plot is : -9.4 dB
The **centre frequency** (f0) is : 160 hz
The **lower frequency** (fL) is : 50.6 hz
The **upper frequency** (fH) is : 493 hz

From theory, we know that, the **transfer function** for the RC Bandpass filter is :

$$\left|\frac{V_{out}}{V_{in}}\right| = \left|\frac{R}{\sqrt{9R^2 + (\omega R^2 C - \frac{1}{\omega C})}}\right|$$

To maximize the amplitude,

$$\omega R^2 C = \frac{1}{\omega C}$$

$$\therefore \omega^2 = \frac{1}{R^2C^2}$$

$$\therefore \omega = \frac{1}{RC}$$

$$\therefore f_0 = \frac{1}{2\pi RC}$$

$$\therefore f_0 = \frac{1000}{2\pi} = 159.1hz \approx 160hz$$

The above result can be confirmed from the result :

$$f_0 = \sqrt{f_L * f_H}$$

$$\therefore f_0 = \sqrt{50.6 * 493} = \sqrt{24945.8} = 158hz \approx 160hz$$

To obtain the lower and upper frequencies, we equate the magnitude of the transfer function with 0.707*(peak of the magnitude) and solve the quadratic equation.

Therefore, our simulation results align with our theoretical results.

3.2.6 RLC Bandpass Filter

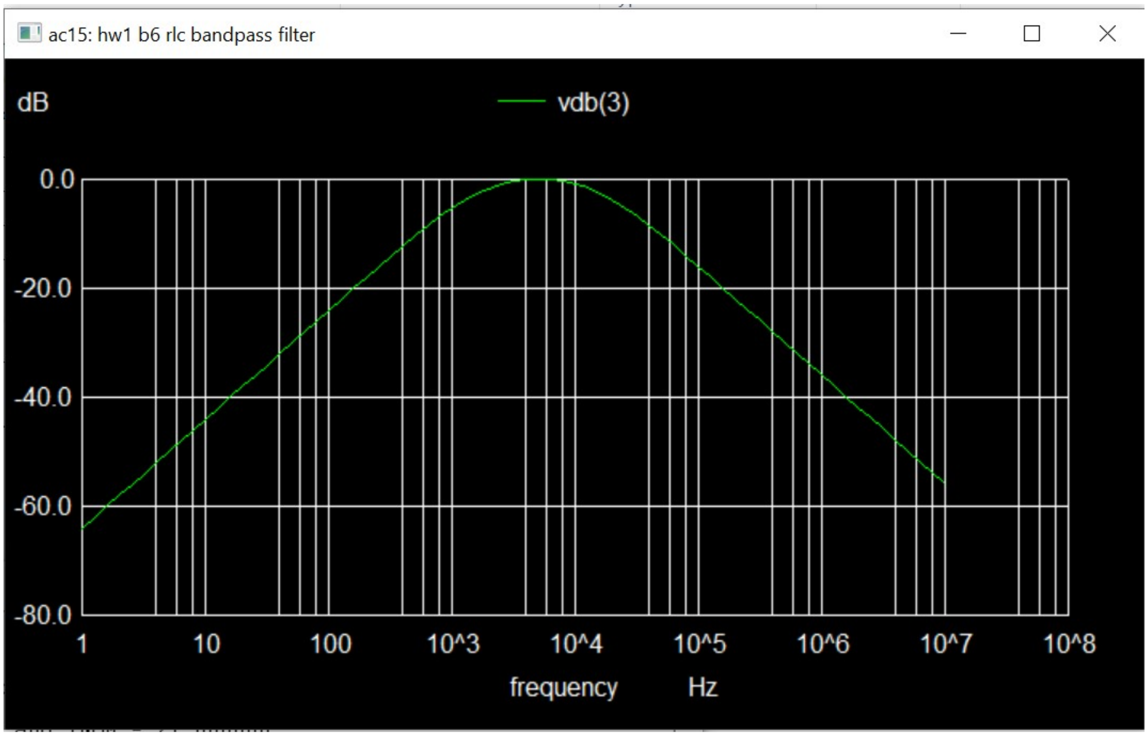


Figure 16: RLC Bandpass Filter Bode plot

The **peak amplitude** of the plot is : 0 dB
The **centre frequency** (f0) is : 5179 hz
The **lower frequency** (fL) is : 1431 hz
The **upper frequency** (fH) is : 17850 hz

From theory, we know that, the **transfer function** for the RLC Bandpass filter is :

$$\left|\frac{V_{out}}{V_{in}}\right| = \left|\frac{R}{\sqrt{R^2 + (\omega L - \frac{1}{\omega C})}}\right|$$

To maximize the amplitude,

$$\omega L = \frac{1}{\omega C}$$

$$\therefore \omega^2 = \frac{1}{LC}$$

$$\therefore \omega = \frac{1}{\sqrt{LC}}$$

$$\therefore f_0 = \frac{1}{2\pi\sqrt{RC}}$$

$$\therefore f_0 = \frac{\sqrt{10^9}}{2\pi}$$

$$\therefore f_0 = 5032hz \approx 5179hz$$

The above result can be confirmed from the result :

$$f_0 = \sqrt{f_L * f_H}$$

$$\therefore f_0 = \sqrt{1431 * 17850} = \sqrt{25543350} = 5054hz \approx 5179hz$$

To obtain the lower and upper frequencies, we equate the magnitude of the transfer function with 0.707*(peak of the magnitude) and solve the quadratic equation.

Therefore, our simulation results align with our theoretical results.