Full resolution photo on my Instagram @feenafoto

1

ECOR1043: Circuits

Passive Filters

Capacitor and Inductor Based Filters

4

First Order RC Filters (Lowpass & Highpass)

5

RC Low-pass Filter

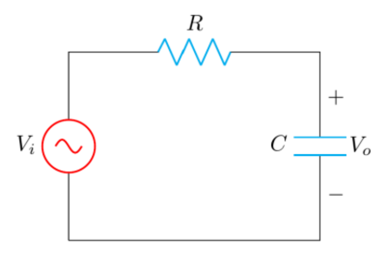
- RC Low-pass filter
  - The Transfer function H

$$\mathbf{V}_o = \frac{\mathbf{Z}_c}{R + \mathbf{Z}_c} \times \mathbf{V}_i$$

(using simple voltage divider)

$$\mathbf{H} = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{\mathbf{Z}_c}{R + \mathbf{Z}_c}$$

where $\mathbf{Z}_c = \frac{1}{j\omega C} = \frac{1}{j2\pi f C} = \frac{-j}{2\pi f C}$



  - Magnitude

$$H = \frac{X_c}{\sqrt{R^2 + X_c^2}}$$

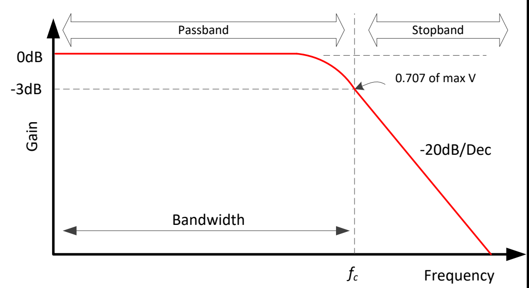
where $X_c = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

  - Cut-off frequency

$$f_c = \frac{1}{2\pi RC}$$

  - Bandwidth

$BW = 0\ Hz\ to\ f_c$



6

RC Low-pass Filter

- Example 1a: Find the transfer function ($H=V_0/V_i$) of the given RC LPF

$$\mathbf{H} = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{\mathbf{Z}_c}{R + \mathbf{Z}_c}$$

1) Find Z_c

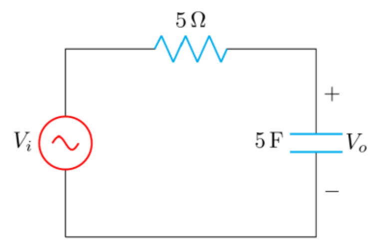
$R = 5\Omega$

$$\mathbf{Z}_c = \frac{1}{j\omega C}$$

$$\mathbf{Z}_c = \frac{1}{j\omega(5F)}$$

$$\mathbf{Z}_c = \frac{1}{j5\omega}$$

$$\mathbf{Z}_c = -\frac{j}{5\omega}$$



7

7

RC Low-pass Filter

- Example 1a: Find the transfer function ($H=V_0/V_i$) of the given RC LPF (cont.)

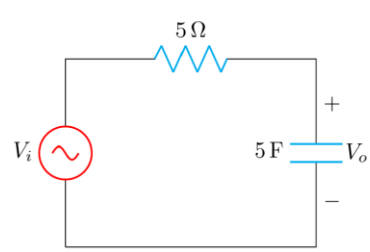
1) Find H $= \frac{V_0}{V_i}$

$Z_c = -\frac{j}{5\omega}$

$R = 5\Omega$

$$\mathbf{H} = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{\mathbf{Z}_c}{R + \mathbf{Z}_c}$$

$$\mathbf{H} = \frac{\mathbf{V_0}}{\mathbf{V}_i} = \left(\frac{-\frac{j}{5\omega}}{5 - \frac{j}{5\omega}} \right)$$



8

8

RC Low-pass Filter

- Example 1b: Create the Bode plot for the **magnitude** of given transfer function. Use $\boldsymbol{\omega}$ = 0.2, 1, 10 rad/s

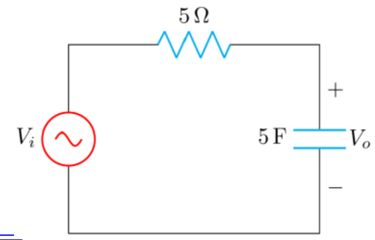
3) Solve for the magnitude of $\omega = 0.2$

$$\mathbf{H} = \frac{\mathbf{V_0}}{\mathbf{V_i}} = \left(\frac{-\frac{j}{5\omega}}{5\ -\frac{j}{5\omega}}\right)$$

$$H = \frac{V_0}{V_i} = \frac{1/5\omega}{\sqrt{5^2 + \left(\frac{1}{5\omega}\right)^2}}$$

$$H = \frac{V_0}{V_i} = \frac{1/1}{\sqrt{5^2 + \left(\frac{1}{1}\right)^2}}$$

$$H = \frac{V_0}{V_i} = \frac{1}{\sqrt{26}} = 0.2$$



Magnitude $H = \frac{X_c}{\sqrt{R^2 + X_c^2}}$

Where $X_c = \frac{1}{\omega C}$

9

RC Low-pass Filter

- Example 1b: Create the Bode plot for the magnitude of given transfer function. Use $\boldsymbol{\omega}$ = 0.2, 1, 10 rad/s

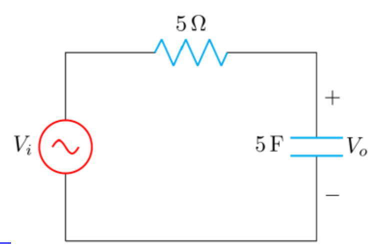
3) Solve for the magnitude of $\omega = 1$

$$\mathbf{H} = \frac{\mathbf{V_0}}{\mathbf{V_i}} = \left(\frac{-\frac{j}{5\omega}}{5\ -\frac{j}{5\omega}}\right)$$

$$H = \frac{V_0}{V_i} = \frac{1/5\omega}{\sqrt{5^2 + \left(\frac{1}{5\omega}\right)^2}}$$

$$H = \frac{V_0}{V_i} = \frac{1/5}{\sqrt{5^2 + \left(\frac{1}{5}\right)^2}}$$

$$H = \frac{V_0}{V_i} = \frac{0.2}{\sqrt{25.04}} = 0.04$$



Magnitude $H = \frac{X_c}{\sqrt{R^2 + X_c^2}}$

Where $X_c = \frac{1}{\omega C}$

10

RC Low-pass Filter

- Example 1b: Create the Bode plot for the magnitude of given transfer function. Use $\boldsymbol{\omega}$ = 0.2, 1, $\boxed{10}$ rad/s

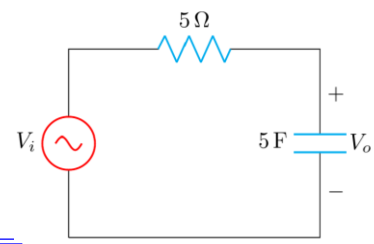
3) Solve for the magnitude of $\omega = 10$

$$\mathbf{H} = \frac{\mathbf{V_0}}{\mathbf{V}_i} = \left(\frac{-\frac{j}{5\omega}}{5 - \frac{j}{5\omega}}\right)$$

$$H = \frac{V_0}{V_i} = \frac{1/5\omega}{\sqrt{5^2 + \left(\frac{1}{5\omega}\right)^2}}$$

$$H = \frac{V_0}{V_i} = \frac{1/50}{\sqrt{5^2 + \left(\frac{1}{50}\right)^2}}$$

$$H = \frac{V_0}{V_i} = \frac{0.02}{\sqrt{25.0004}} = 0.004$$



Magnitude $H = \frac{X_c}{\sqrt{R^2 + X_c^2}}$

Where $X_c = \frac{1}{\omega C}$

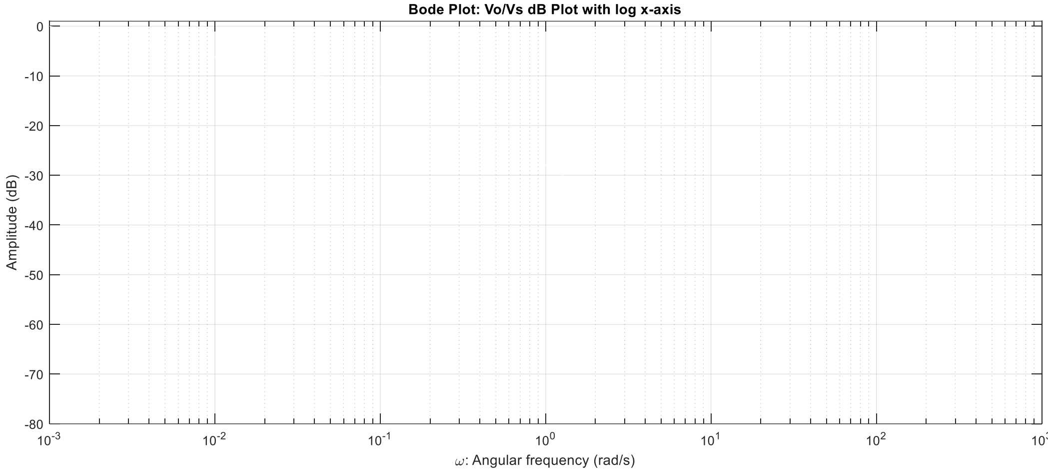
RC Low-pass Filter

6) Convert values into dB

Frequency (rad/s)	Amplitude [V/V]	Amplitude dB [$20\log_{10}$(V/V)]
0.2	0.2	-14
1	0.04	-28
10	0.004	-48

RC Low-pass Filter

Frequency (rad/s)	Amplitude [V/V]	Amplitude dB [$20\log_{10}(V/V)$]
.001	1	0
0.2	0.2	-14
1	0.04	-28
10	0.004	-48

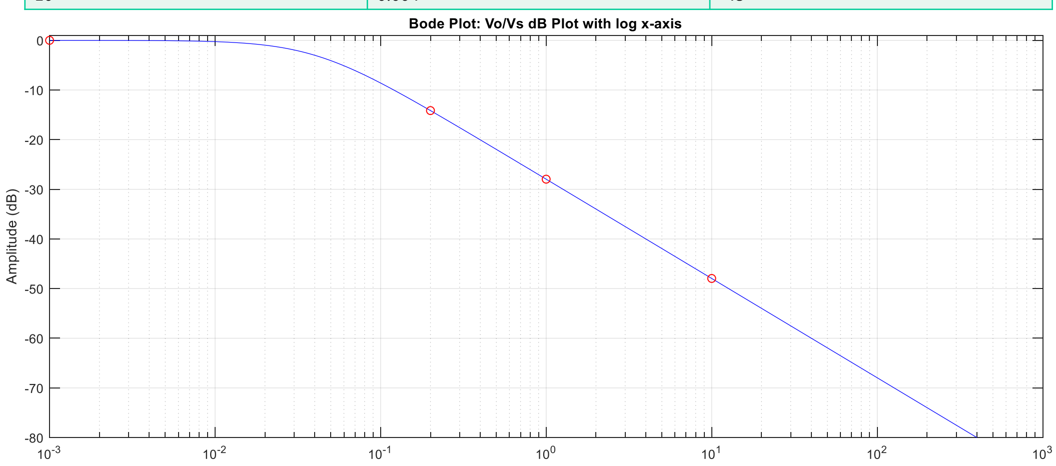


13

13

RC Low-pass Filter

Frequency (rad/s)	Amplitude [V/V]	Amplitude dB [$20\log_{10}(V/V)$]
.001	1	0
0.2	0.2	-14
1	0.04	-28
10	0.004	-48



14

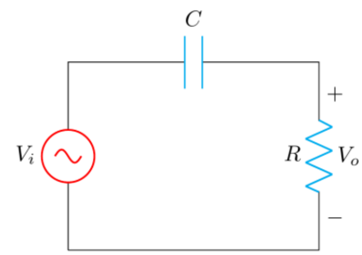
14

RC High-pass Filter

- RC High-pass filter
  - The Transfer function

$$\mathbf{V}_o = \frac{R}{R + \mathbf{Z}_c} \times \mathbf{V}_i$$ (using simple voltage divider)

$$\mathbf{H} = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{R}{R + \mathbf{Z}_c}$$ where $\mathbf{Z}_c = \frac{1}{j\omega C} = \frac{1}{j2\pi f C} = \frac{-j}{2\pi f C}$



  - And magnitude

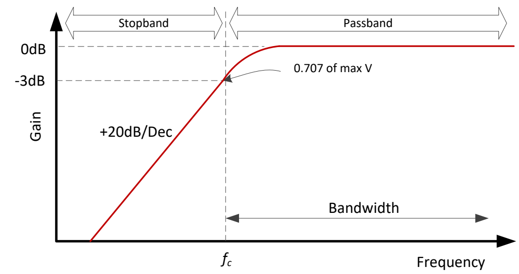
$$H = \frac{R}{\sqrt{R^2 + X_c^2}}$$ where $X_c = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

  - Cut-off frequency

$$f_c = \frac{1}{2\pi RC}$$

  - Bandwidth

$$BW = f_c \; to \; \infty \text{ (ideally)}$$



15

15

First Order
RL Filters
(Lowpass & Highpass)

16

16

RL High-pass Filter

- RL High-pass filter
  - Transfer function

$$\mathbf{V}_o = \frac{\boldsymbol{Z_L}}{R+\mathbf{Z}_L} \times \mathbf{V}_i$$

(using simple voltage divider)

$$\mathbf{H} = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{\boldsymbol{Z_L}}{R+\mathbf{Z}_L}$$

where $\mathbf{Z}_L = j\omega L = j2\pi f L$

  - Magnitude

$$H = \frac{X_L}{\sqrt{R^2 + X_L^2}}$$

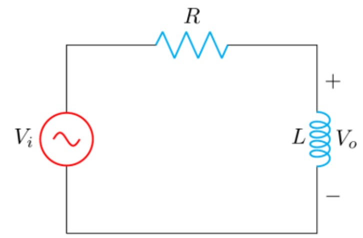
where $X_L = \omega L = 2\pi f L$

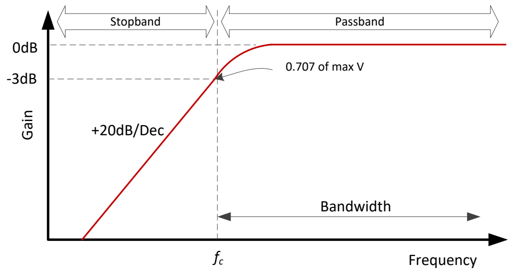
  - Cut-off frequency

$$f_c = \frac{R}{2\pi L}$$

  - Bandwidth

$$BW = f_c \; to \; \infty \; (\text{ideally})$$





17

RL High-pass Filter

- Example 2a: Find the transfer function (V_0/V_i) of given RL HPF circuit

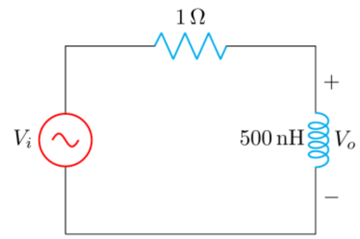
$$\mathbf{H} = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{\boldsymbol{Z_L}}{R+\mathbf{Z}_L}$$

1) Find Z_L

$R = 1\Omega$

$Z_L = j\omega L$

$Z_L = j\omega(500\ n)\ \Omega$



18

RL High-pass Filter

- Example 2a: Find the transfer function (V_0/V_i) of given RL HPF circuit (cont.)

2) Find $\frac{V_0}{V_i}$

$Z_L = j\omega(500\,n)$

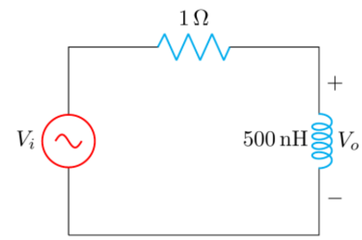
$R = 1\Omega$

$$\mathbf{H} = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{\boldsymbol{Z}_L}{R + \mathbf{Z}_L}$$

$$\mathbf{H} = \frac{\boldsymbol{V_0}}{\boldsymbol{V_i}} = \left(\frac{j\omega(500n)}{1\ + j\omega(500n)}\right)$$

$$\frac{\boldsymbol{V_0}}{\boldsymbol{V_i}} = \left(\frac{j2\pi f(500n)}{1\ + j2\pi f(500n)}\right)$$

What if I tell you to find its magnitude?



RL High-pass Filter

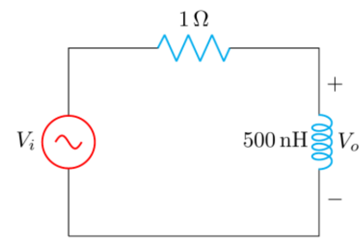
- Example 2b: Find f_c of the RL high-pass filter

3) Find f_c

$$f_c = \frac{R}{2\pi L}$$

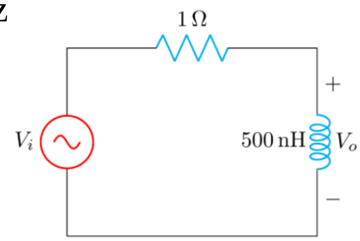
$$f_c = \frac{1\Omega}{2\pi(500x10^{-9}\ H)}$$

$$f_c == 318.3\ kHz$$



RL High-pass Filter

- Example 2c: Using the magnitude of transfer function (V_0/V_i), create a bode plot using f = $\boxed{\text{100 Hz}}$, f_c, and 1 MHz



4) Solve for the magnitude at $f = 100\ Hz$

$$\frac{\mathbf{V_0}}{\mathbf{V_i}} = \left(\frac{j2\pi f(500n)}{1\ + j2\pi f(500n)}\right)$$

$$H = \frac{V_0}{V_i} = \frac{2\pi f(500n)}{\sqrt{1^2 + (2 \times \pi \times f \times 500n)^2}}$$

Magnitude $H = \dfrac{V_o}{V_i} = \dfrac{Z_L}{\sqrt{R^2 + X_L^2}}$

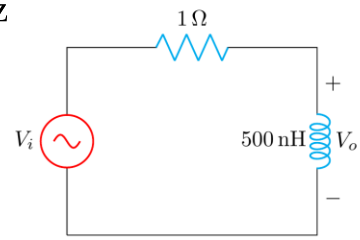
where $X_L = \omega L = 2\pi f L$

$$H = \frac{V_0}{V_i} = \frac{2\pi 100(500n)}{\sqrt{1^2 + (2 \times \pi \times 100 \times 500n)^2}}$$

$$H = \frac{V_0}{V_i} = 0.000314$$

RL High-pass Filter

- Example 2c: Using the magnitude of transfer function (V_0/V_i), create a bode plot using f = 100 Hz, $\boxed{f_c,}$ and 1 MHz



4) Solve for the magnitude at $f_c = 318.3\ kHz$

$$\frac{\mathbf{V_0}}{\mathbf{V_i}} = \left(\frac{j2\pi f(500n)}{1\ + j2\pi f(500n)}\right)$$

$$H = \frac{V_0}{V_i} = \frac{2\pi f(500n)}{\sqrt{1^2 + (2 \times \pi \times f \times 500n)^2}}$$

Magnitude $H = \dfrac{V_o}{V_s} = \dfrac{Z_L}{\sqrt{R^2 + X_L^2}}$

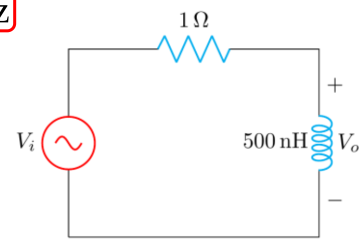
where $X_L = \omega L = 2\pi f L$

$$H = \frac{V_0}{V_i} = \frac{2\pi \times 318.3k \times (500n)}{\sqrt{1^2 + (2 \times \pi \times 318.3k \times 500n)^2}}$$

$$H = \frac{V_0}{V_i} = 0.7071$$

RL High-pass Filter

- Example 2c: Using the magnitude of transfer function (V_0/V_i), create a bode plot using f = 100 Hz, f_c, and $\boxed{1\text{ MHz}}$



4) Solve for the magnitude at $f = 1\ MHz$

$$\frac{\mathbf{V_0}}{\mathbf{V_i}} = \left(\frac{j2\pi f(500n)}{1 + j2\pi f(500n)}\right)$$

$$H = \frac{V_0}{V_i} = \frac{2\pi f(500n)}{\sqrt{1^2 + (2 \times \pi \times f \times 500n)^2}}$$

$$H = \frac{V_0}{V_i} = \frac{2\pi \times 1M \times (500n)}{\sqrt{1^2 + (2 \times \pi \times 1M \times 500n)^2}}$$

$$H = \frac{V_0}{V_i} = .953$$

Magnitude $H = \frac{V_o}{V_s} = \frac{Z_L}{\sqrt{R^2 + X_L^2}}$

where $X_L = \omega L = 2\pi f L$

23

RL High-pass Filter

- Example 2c: Plot the Bode plot for the following frequencies

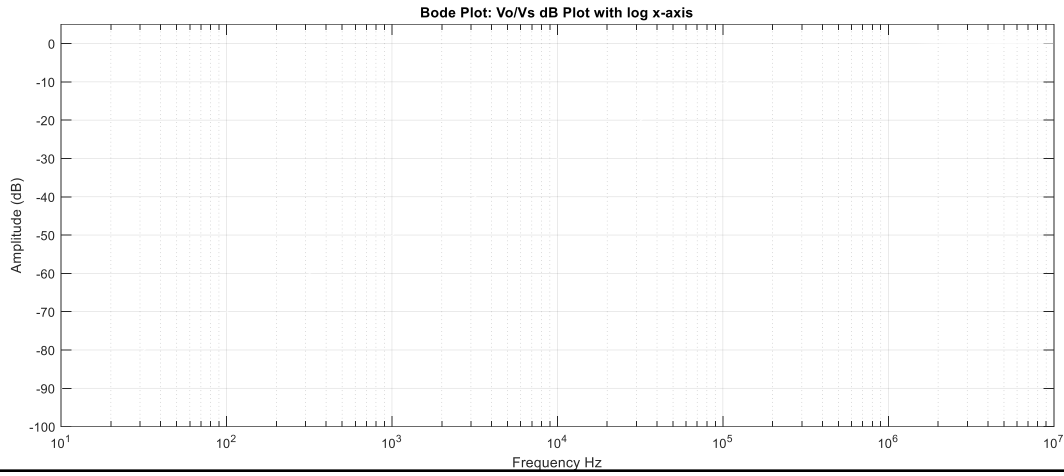
$$\frac{V_0}{V_i} = \left(\frac{(2\pi f)(500\ nH)}{1\ \Omega + j(2\pi f)(500\ nH)}\right)$$

Frequency (Hz)	**Amplitude [V/V]**	**Amplitude dB [20log$_{10}$(V/V)]**
100	0.000314	-70
318.3k	0.7071	-3.01
1M	0.953	-0.42

24

RL High-pass Filter

Frequency (Hz)	Amplitude [V/V]	Amplitude dB [$20\log_{10}$(V/V)]
100	0.000314	-70
318.3k	0.7071	-3.01
1M	0.953	-0.42

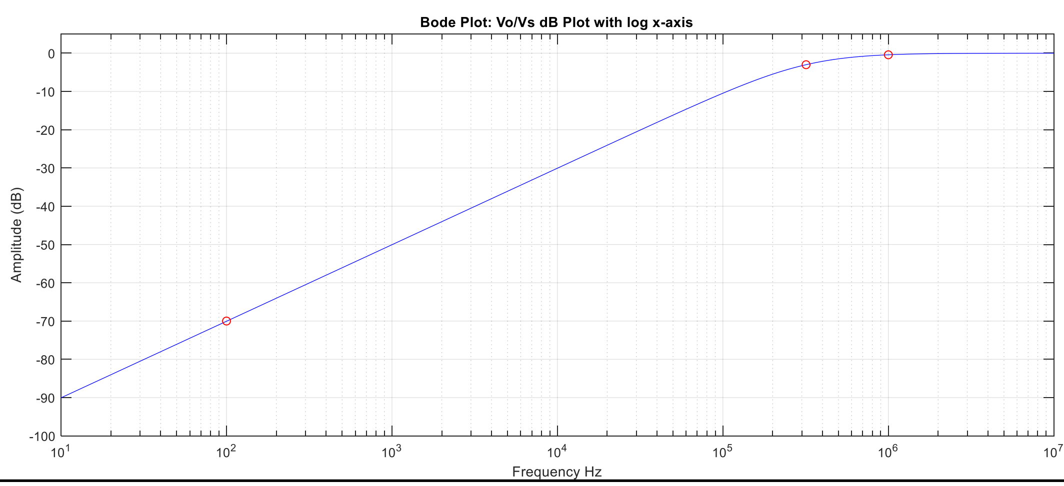


25

25

RL High-pass Filter

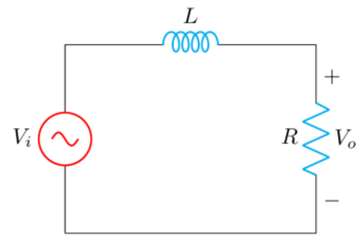
Frequency (Hz)	Amplitude [V/V]	Amplitude dB [$20\log_{10}$(V/V)]
100	0.000314	-70
318.3k	0.7071	-3.01
1M	0.953	-0.42



26

26

RL Low-pass Filter



- RL Low-pass filter
  - Transfer function

$$\mathbf{V}_o = \frac{R}{R + \mathbf{Z}_L} \times \mathbf{V}_i$$

$$\mathbf{H} = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{R}{R + \mathbf{Z}_L}$$

where $\mathbf{Z}_L = j\omega L = j2\pi f L$

  - Magnitude

$$H = \frac{R}{\sqrt{R^2 + X_L^2}}$$

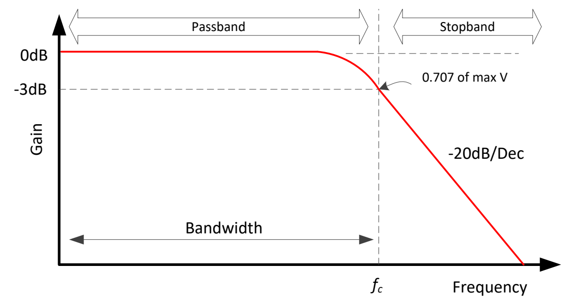
where $X_L = \omega L = 2\pi f L$

  - Cut-off frequency

$$f_c = \frac{R}{2\pi L}$$

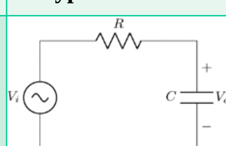
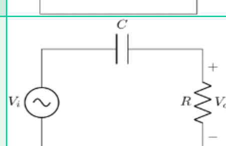
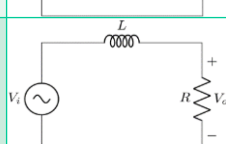
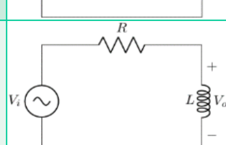
  - The bandwidth

$$BW = 0\ Hz\ to\ f_c$$



27

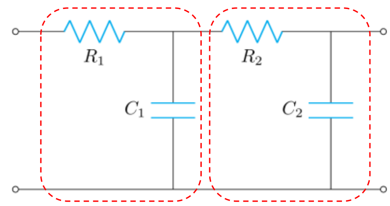
Alternative Low/High-pass Filters

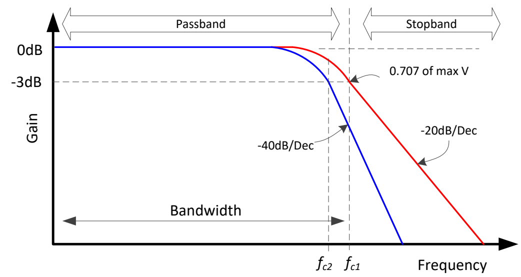
Filter Type	Typical Circuit	Transfer Function	Cut-off Frequency	Bandwidth
RC LPF		$\mathbf{H} = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{\mathbf{Z}_c}{R + \mathbf{Z}_c}$	$f_c = \frac{1}{2\pi RC}$	$BW = 0$ Hz to f_c
RC HPF		$\mathbf{H} = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{R}{R + \mathbf{Z}_c}$	$f_c = \frac{1}{2\pi RC}$	$BW = f_c$ to ∞
RL LPF		$\mathbf{H} = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{R}{R + \mathbf{Z}_L}$	$f_c = \frac{R}{2\pi L}$	$BW = 0$ Hz to f_c
RL HPF		$\mathbf{H} = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{\mathbf{Z}_L}{R + \mathbf{Z}_L}$	$f_c = \frac{R}{2\pi L}$	$BW = f_c$ to ∞

28

Higher Order RC Filters

- Higher order filters
  - Sometimes the roll-off of -20dB/decade may not be enough to remove unwanted signals
  - There we can use multiple stages of filtering to increase our roll-off rate
  - First order filters are cascaded (arranged in series) to get higher order filters which increase the roll-off rate
  - There is a limit to how many filters we can cascade (more in next lecture)





29

Practice Problems

30

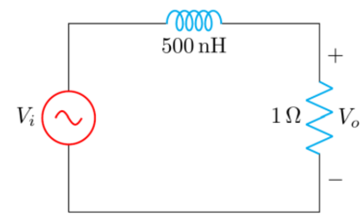
RL Low-pass Filter

- Problem 1a: Find the transfer magnitude function (V_0/V_i) of the circuit below

1) Find Z_L

$Z_L = j\omega L$

$Z_L = j\omega(500\ nH)$



31

31

RL Low-pass Filter

- Problem 1a: Find the transfer magnitude function (V_0/V_i) of the circuit below

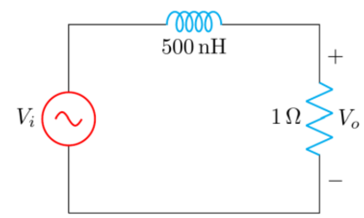
2) Find $\frac{V_0}{V_i}$

$Z_L = j\omega(500\ n)$

$$\mathbf{H} = \frac{\mathbf{V_0}}{\mathbf{V_i}} = \left(\frac{R}{R + \boldsymbol{Z_L}}\right)$$

$$\mathbf{H} = \frac{\mathbf{V_0}}{\mathbf{V_i}} = \left(\frac{1}{1 + j\omega(500n)}\right)$$

$$\frac{\mathbf{V_0}}{\mathbf{V_i}} = \left(\frac{1}{1 + j2\pi f(500n)}\right)$$



32

32

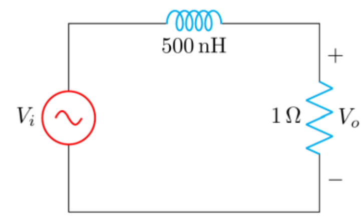
RL Low-pass Filter

- Problem 1b: Find f_c of the RL low-pass filter

3) Find f_c

$$f_c = \frac{R}{2\pi L}$$

$$f_c = \frac{R}{2\pi L} = \frac{1\Omega}{2\pi(500x10^{-9}\ H)} = 318.3\ kHz$$



RL Low-pass Filter

- Problem 1c: Using the magnitude of transfer function (V_0/V_i), create a bode plot using f = 1 Hz, 10 kHz , f_c, and 500 kHz

4) Solve for the magnitude at $f = 1\ Hz$

$$\mathbf{H} = \frac{\mathbf{V_0}}{\mathbf{V_i}} = \left(\frac{1}{1\ + j2\pi f(500n)}\right)$$

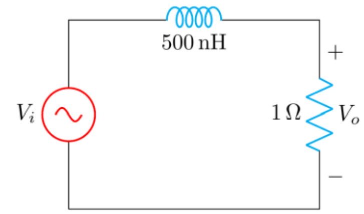
$$H = \frac{V_0}{V_i} = \frac{1}{\sqrt{1^2 + (2 \times \pi \times f \times 500n)^2}}$$

Magnitude $H = \frac{V_o}{V_i} = \frac{R}{\sqrt{R^2 + X_L^2}}$

where $X_L = \omega L = 2\pi f L$

$$H = \frac{V_0}{V_i} = \frac{1}{\sqrt{1^2 + (2 \times \pi \times 1 \times 500n)^2}}$$

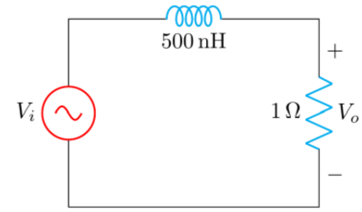
$$H = \frac{V_0}{V_i} = \frac{1}{1} = 1$$



RL Low-pass Filter

- Problem 1c: Using the magnitude of transfer function (V_0/V_i), create a bode plot using f = 1 Hz, 10 kHz , f_c, and 500 kHz

4) Solve for the magnitude at $f = 10\ Hz$



$$\mathbf{H} = \frac{\mathbf{V_0}}{\mathbf{V_i}} = \left(\frac{1}{1\ + j2\pi f(500n)}\right)$$

$$H = \frac{V_0}{V_i} = \frac{1}{\sqrt{1^2 + (2 \times \pi \times f \times 500n)^2}}$$

Magnitude $H = \frac{V_o}{V_i} = \frac{R}{\sqrt{R^2 + X_L^2}}$

where $X_L = \omega L = 2\pi f L$

$$H = \frac{V_0}{V_i} = \frac{1}{\sqrt{1^2 + (2 \times \pi \times 10k \times 500n)^2}}$$

$$H = \frac{V_0}{V_i} = \frac{1}{1.0005} = 0.9995 = 1$$

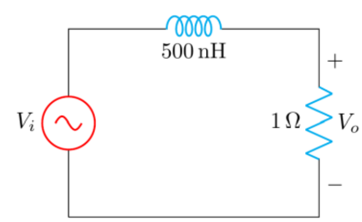
35

35

RL Low-pass Filter

- Problem 1c: Using the magnitude of transfer function (V_0/V_i), create a bode plot using f = 1 Hz, 10 kHz , f_c, and 500 kHz

4) Solve for the magnitude at $f = 318.3\ kHz$



$$\mathbf{H} = \frac{\mathbf{V_0}}{\mathbf{V_i}} = \left(\frac{1}{1\ + j2\pi f(500n)}\right)$$

$$H = \frac{V_0}{V_i} = \frac{1}{\sqrt{1^2 + (2 \times \pi \times f \times 500n)^2}}$$

$$H = \frac{V_0}{V_i} = \frac{1}{\sqrt{1^2 + (2 \times \pi \times 318.3k \times 500n)^2}}$$

$$H = \frac{V_0}{V_i} = \frac{1}{1.414} = 0.70712$$

36

36

RL Low-pass Filter

- Problem 1c: Using the magnitude of transfer function (V_0/V_i), create a bode plot using f = 1 Hz, 10 kHz , f_c, and 500 kHz

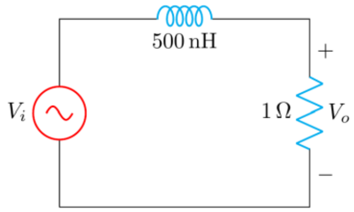
4) Solve for the magnitude at $f = 500\ kHz$

$$\mathbf{H} = \frac{\mathbf{V_0}}{\mathbf{V_i}} = \left(\frac{1}{1 + j2\pi f(500n)}\right)$$

$$H = \frac{V_0}{V_i} = \frac{1}{\sqrt{1^2 + (2 \times \pi \times f \times 500n)^2}}$$

$$H = \frac{V_0}{V_i} = \frac{1}{\sqrt{1^2 + (2 \times \pi \times 500k \times 500n)^2}}$$

$$H = \frac{V_0}{V_i} = \frac{1}{1.862} = 0.537$$



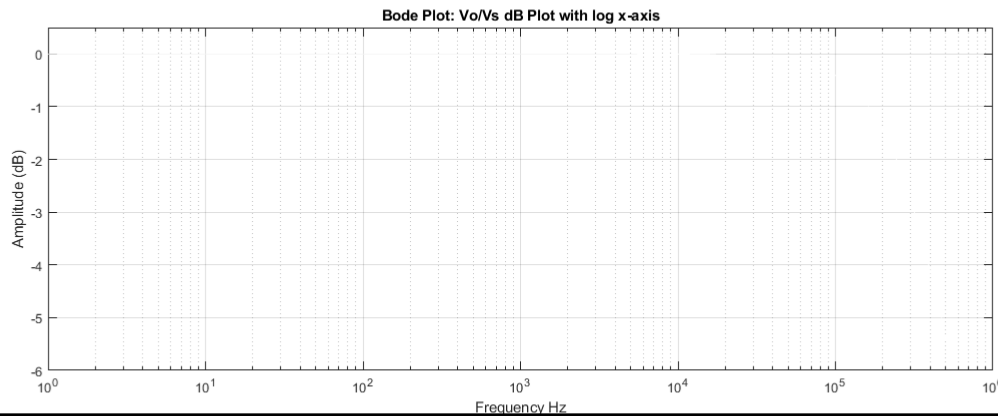
RL Low-pass Filter

8) Convert values into dB

Frequency (Hz)	**Amplitude [V/V]**	**Amplitude dB [20log$_{10}$(V/V)]**
1	1	0
10k	0.9995	-0.004
318.3k	0.70712	-3.01
500k	0.537	-5.4

RL Low-pass Filter

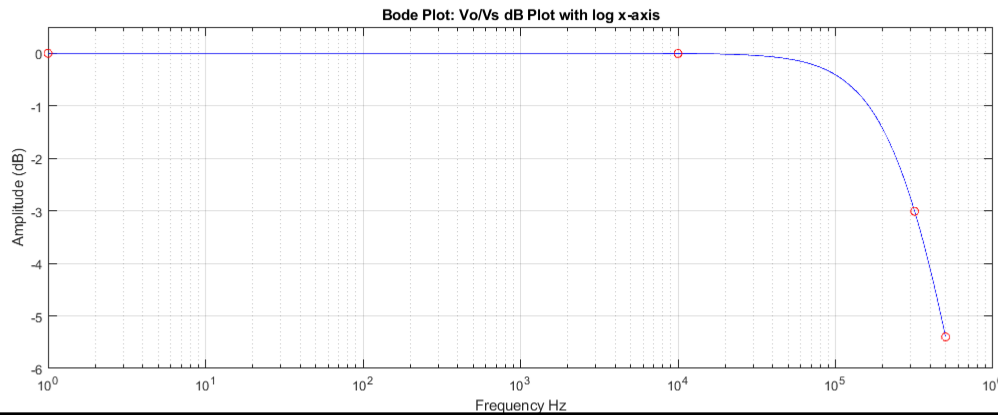
Frequency (Hz)	Amplitude [V/V]	Amplitude dB [$20\log_{10}$(V/V)]
1	1	0
10k	0.9995	-0.004
318.3k	0.70712	-3.01
500k	0.537	-5.4



39

RL Low-pass Filter

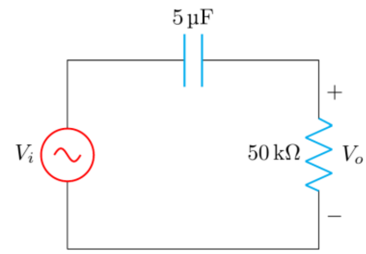
Frequency (Hz)	Amplitude [V/V]	Amplitude dB [$20\log_{10}$(V/V)]
1	1	0
10k	0.9995	-0.004
318.3k	0.70712	-3.01
500k	0.537	-5.4



40

RC High-pass Filter

- Problem 2a: Find the transfer function (H= V_0/V_i) of circuit



1) Find Z_c

$$Z_c = \frac{1}{j\omega C}$$

$$Z_c = \frac{1}{j\omega(5\mu F)}$$

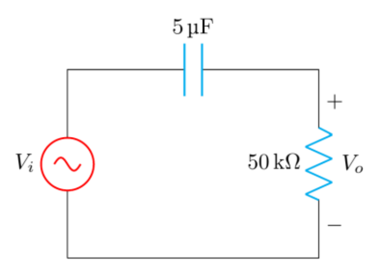
$$Z_c = -\frac{j}{\omega(5\mu)}$$

$$Z_c = -\frac{j}{2\pi f(5\mu)}$$

41

RC High-pass Filter

- Problem 2a: Find the transfer function (H= V_0/V_i) of circuit



1) Find $\frac{V_0}{V_i}$

$$Z_c = -\frac{j}{(5\mu)2\pi f}$$

$$\mathbf{H} = \frac{\mathbf{V_0}}{\mathbf{V_i}} = \left(\frac{R}{R + \mathbf{Z_c}}\right)$$

Remember the voltage divider?

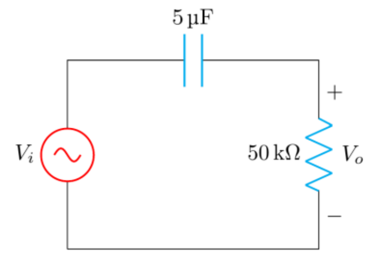
$$\mathbf{H} = \frac{\mathbf{V_0}}{\mathbf{V_i}} = \left(\frac{50k}{50k + Z_c}\right)$$

$$\mathbf{H} = \frac{\mathbf{V_0}}{\mathbf{V_i}} = \left(\frac{50k}{50k - \frac{j}{(5\mu)2\pi f}}\right)$$

42

RC High-pass Filter

- Problem 2b: Create the Bode plot for the magnitude of given transfer function using f = 0.01, f_c, 100 Hz



3) Solve for the magnitude of f = 0.01

$$\mathbf{H} = \frac{\mathbf{V_0}}{\mathbf{V_i}} = \left(\frac{50k}{50k - \frac{j}{(5\mu)2\pi f}}\right)$$

$$\mathrm{H} = \frac{V_0}{V_i} = \frac{50k}{\sqrt{(50k)^2 + \left(\frac{1}{(5\mu)2\pi f}\right)^2}}$$

Magnitude $H = \frac{R}{\sqrt{R^2 + X_c^2}}$ where $X_c = \frac{1}{\omega C}$

$$\mathrm{H} = \frac{V_0}{V_i} = \frac{50k}{\sqrt{(50k)^2 + \left(\frac{1}{(5\mu)2\pi \times .01}\right)^2}}$$

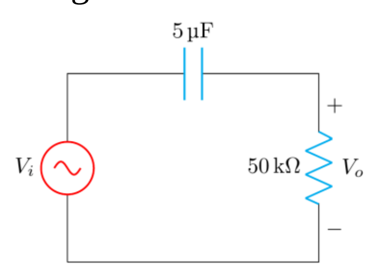
$$H = \frac{V_0}{V_i} = \frac{50k}{\sqrt{(50k)^2 + (3183098)^2}}$$

$$H = \frac{V_0}{V_i} = 0.0157$$

43

RC High-pass Filter

- Problem 2b: Create the Bode plot for the magnitude of given transfer function using f = 0.01, f_c, 100 Hz



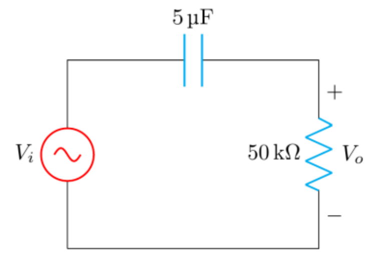
4) Find f_c

$$f_c = \frac{1}{2\pi RC}$$

$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi(50K \times 5 \times 10^{-6})} = 0.6366\ Hz$$

RC High-pass Filter

- Problem 2b: Create the Bode plot for the magnitude of given transfer function using f = 0.01, f_c, 100 Hz



3) Solve for the magnitude of f_c = 0.6366

$$\mathbf{H} = \frac{\mathbf{V_0}}{\mathbf{V}_i} = \left(\frac{50k}{50k - \frac{j}{(5\mu)2\pi f}}\right)$$

$$H = \frac{V_0}{V_i} = \frac{50k}{\sqrt{(50k)^2 + \left(\frac{1}{(5\mu)2\pi \times 0.6366}\right)^2}}$$

Magnitude $H = \frac{R}{\sqrt{R^2 + X_c^2}}$ where $X_c = \frac{1}{\omega C}$

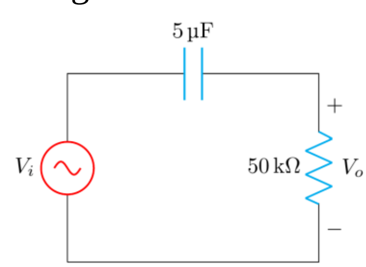
$$H = \frac{V_0}{V_i} = \frac{50k}{\sqrt{(50k)^2 + (50002)^2}}$$

$$H = \frac{V_0}{V_i} = 0.7071$$

45

RC High-pass Filter

- Problem 2b: Create the Bode plot for the magnitude of given transfer function using f = 0.01, f_c, 100 Hz



3) Solve for the magnitude of f = 100

$$\mathbf{H} = \frac{\mathbf{V_0}}{\mathbf{V}_i} = \left(\frac{50k}{50k - \frac{j}{(5\mu)2\pi f}}\right)$$

$$H = \frac{V_0}{V_i} = \frac{50k}{\sqrt{(50k)^2 + \left(\frac{1}{(5\mu)2\pi \times 100}\right)^2}}$$

Magnitude $H = \frac{R}{\sqrt{R^2 + X_c^2}}$ where $X_c = \frac{1}{\omega C}$

$$H = \frac{V_0}{V_i} = \frac{50k}{\sqrt{(50k)^2 + (318.31)^2}}$$

$$H = \frac{V_0}{V_i} = 0.99998$$

46

RC High-pass Filter

7) Convert values into dB

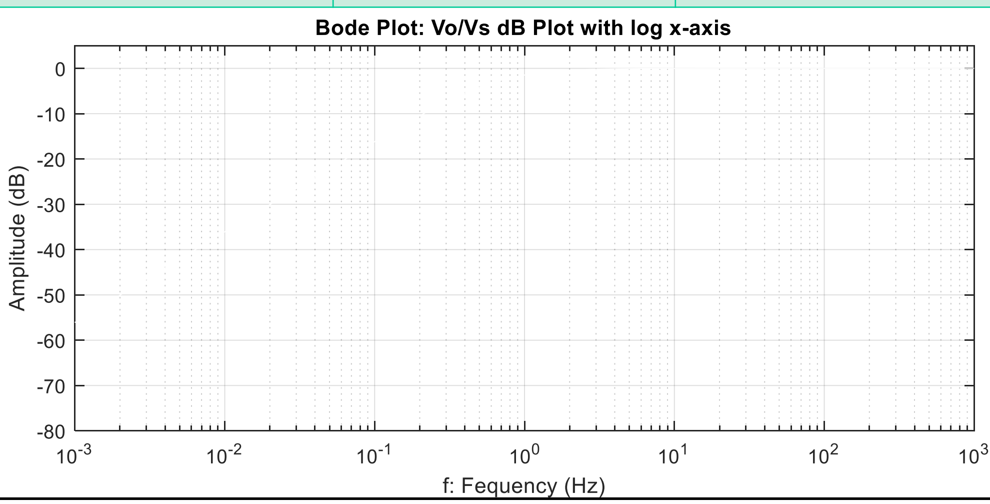
Frequency (Hz)	**Amplitude [V/V]**	**Amplitude dB [$20\log_{10}$(V/V)]**
0.01	0.0157	-36.08
0.637	0.7071	-3.01
100	0.99998	-0.00017

47

47

RC High-pass Filter

Frequency (Hz)	**Amplitude [V/V]**	**Amplitude dB [$20\log_{10}$(V/V)]**
0.01	0.0157	-36.08
0.637	0.7071	-3.01
100	0.99998	-0.00017

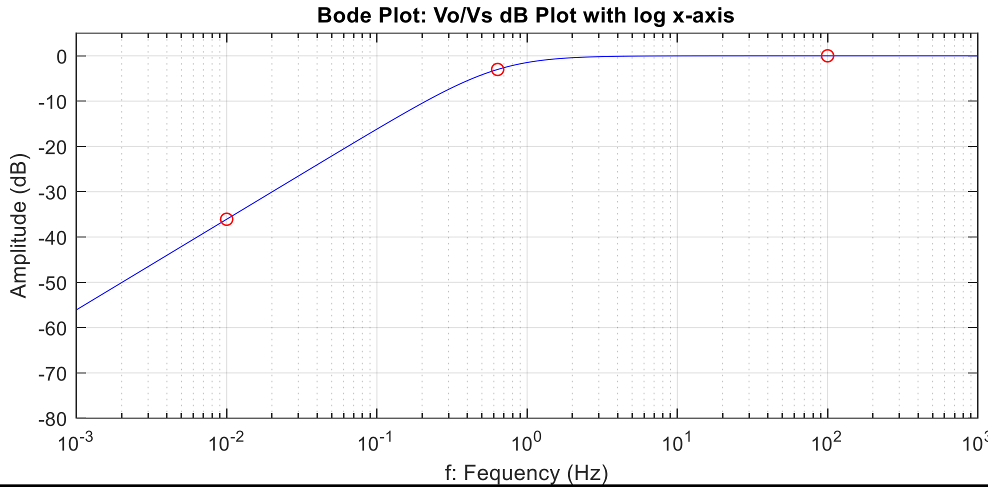


48

48

RC High-pass Filter

Frequency (Hz)	Amplitude [V/V]	Amplitude dB [$20\log_{10}$(V/V)]
0.01	0.0157	-36.08
0.637	0.7071	-3.01
100	0.99998	-0.00017



49