ESc201 : Introduction to Electronics

Frequency Domain Response

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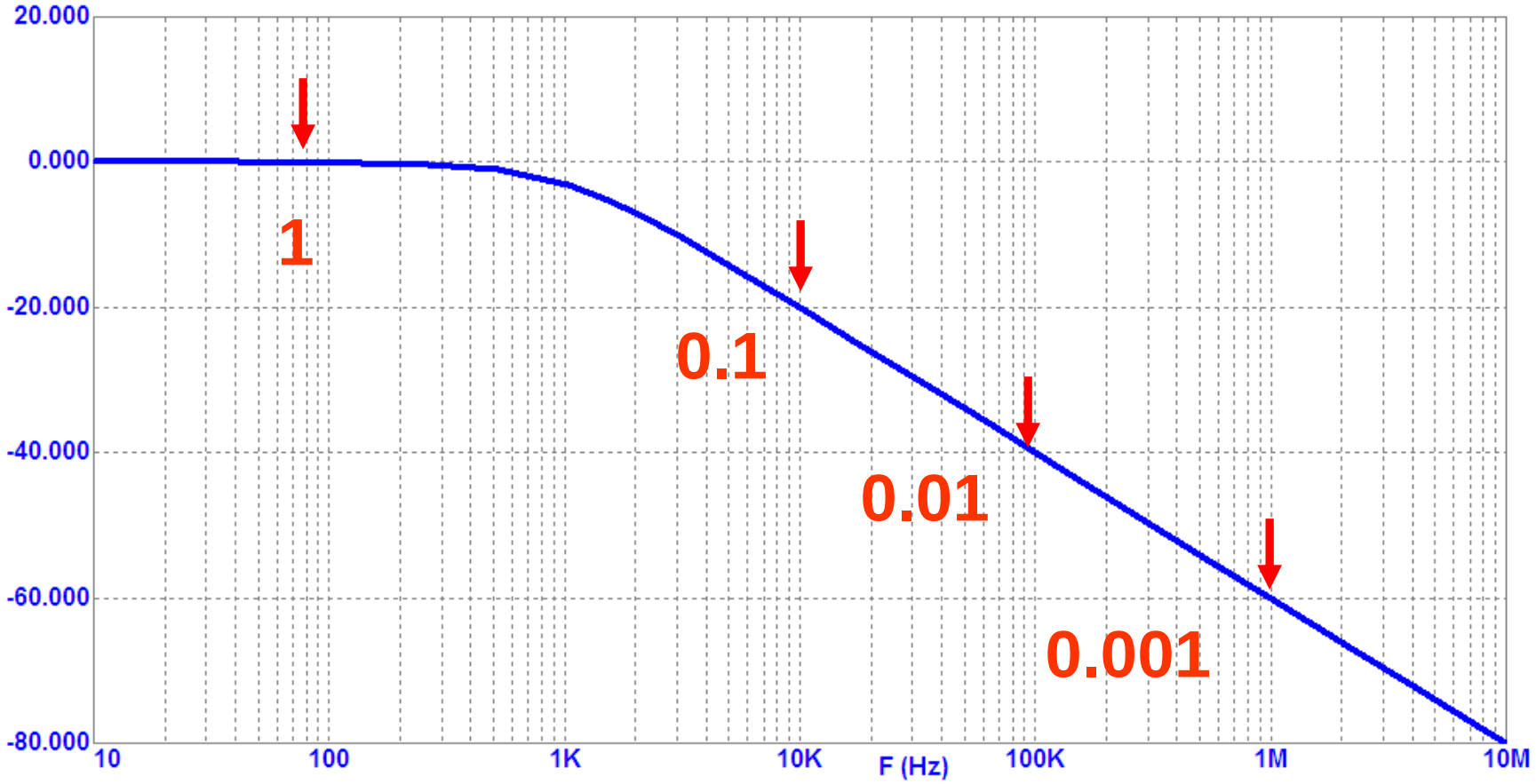
Bode plot (recap)



A plot of the decibel magnitude of transfer function versus frequency using a logarihmic scale for frequency is called a **Bode plot**

Example Bode Plot (magnitude)

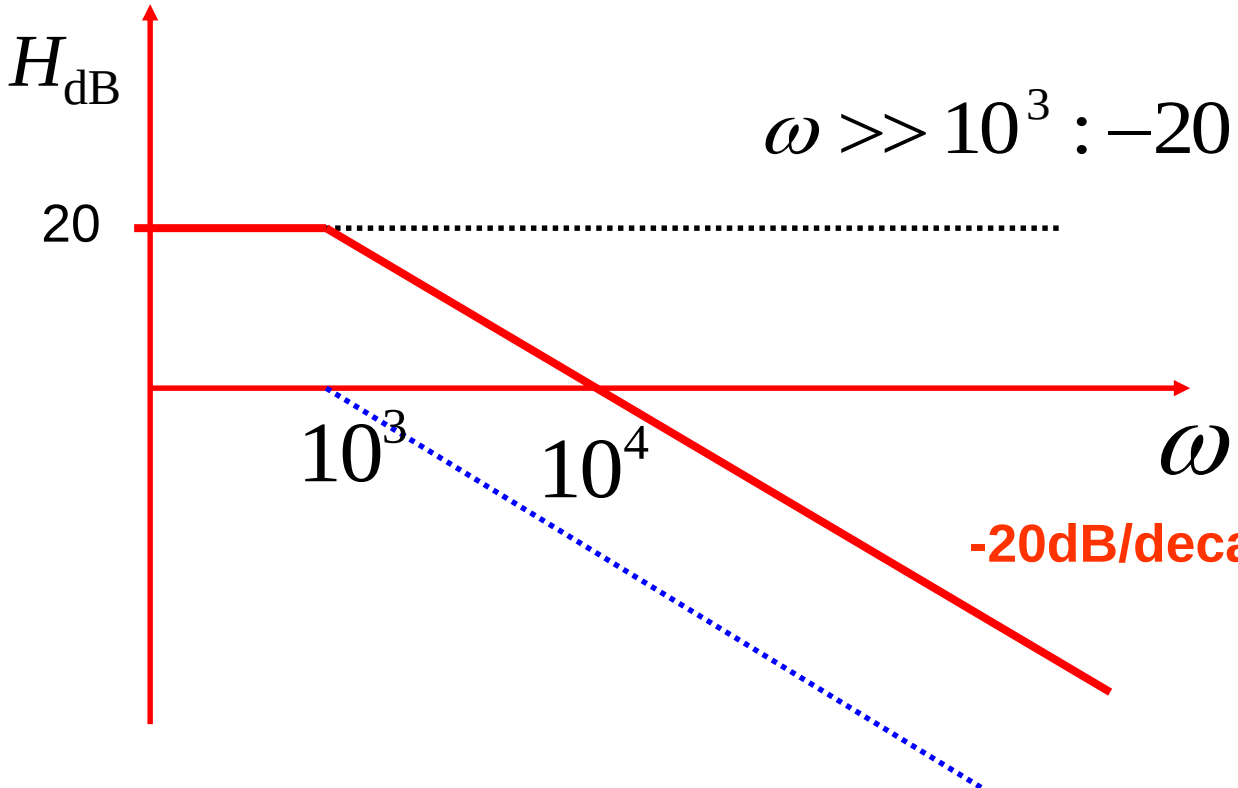
$$H(j\omega) = \frac{10}{1 + j\omega 10^{-3}}$$

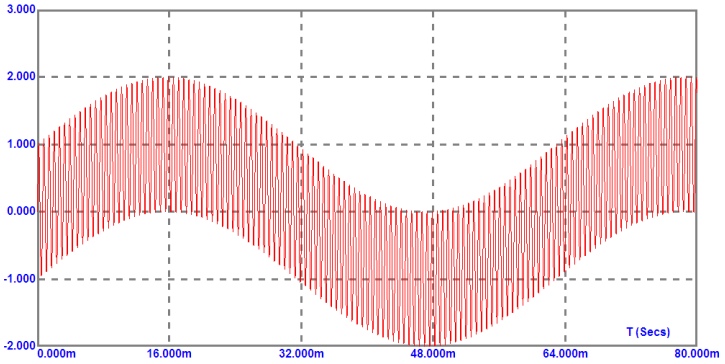
$$\omega_{3dB} = 10^3$$

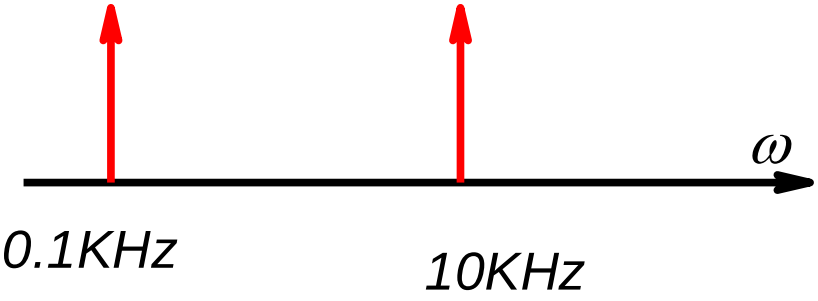
$$H_{dB} = 20 - 20\log_{10}\sqrt{1 + \left(\frac{\omega}{10^3}\right)^2}$$

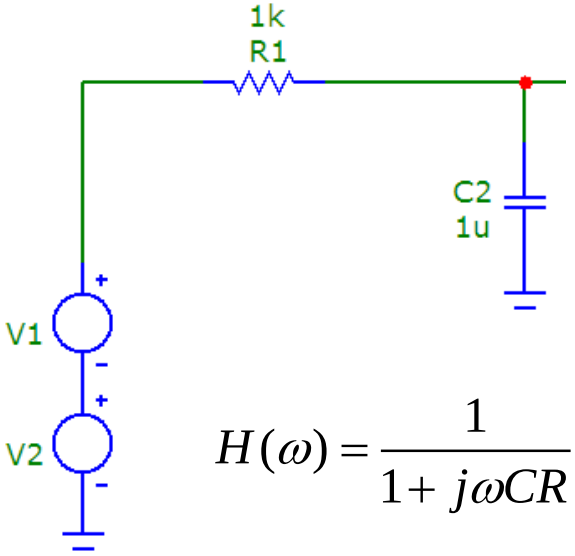
$$\omega << 10^3 : 0dB$$

$$\omega >> 10^3 : -20\log_{10}\frac{\omega}{10^3}$$



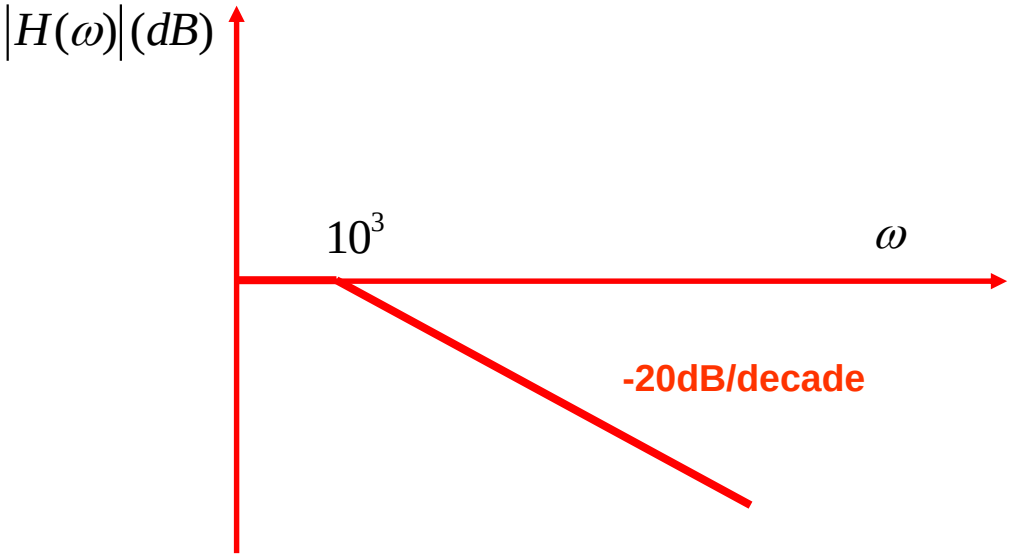




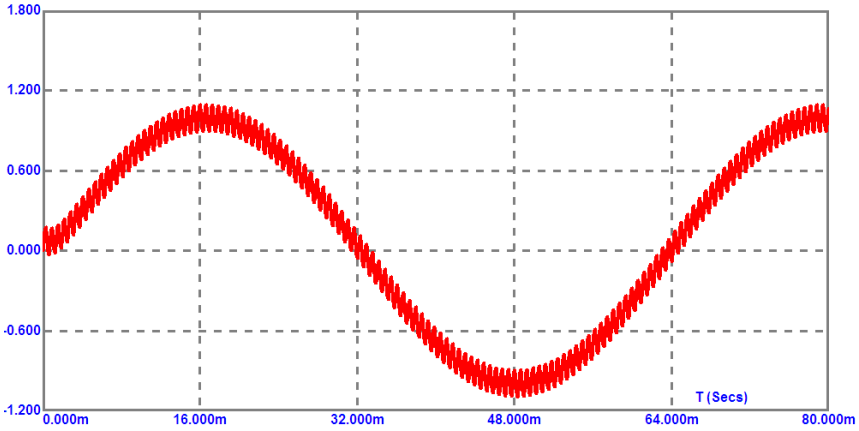


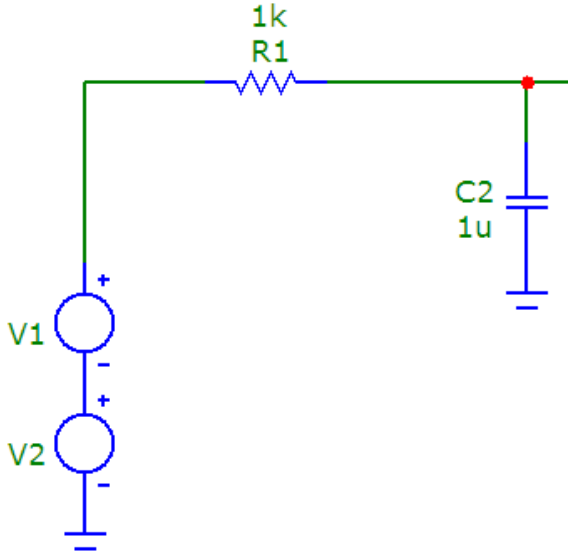
$$H(\omega) = \frac{1}{1 + j\omega CR}$$

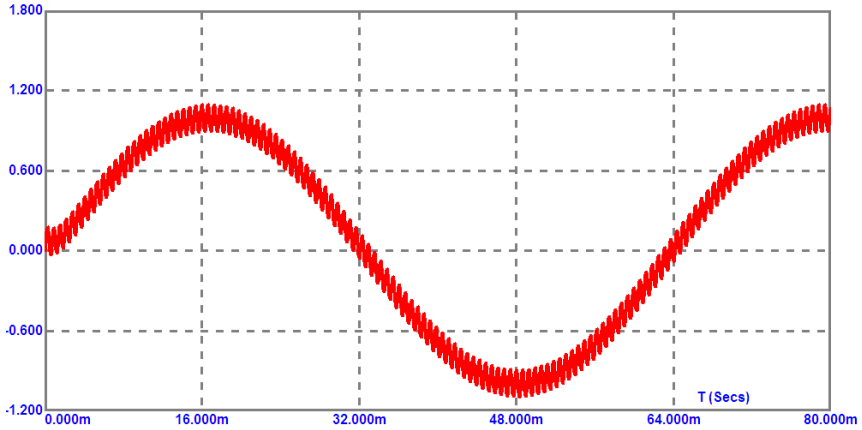
$$H(\omega) = \frac{1}{1 + j\omega 10^{-3}} = \frac{1}{1 + j\dfrac{\omega}{10^3}}$$

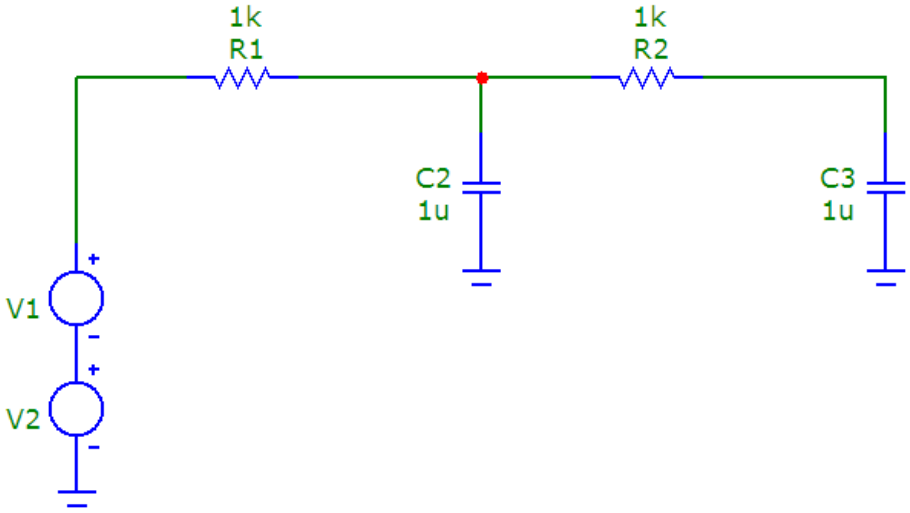


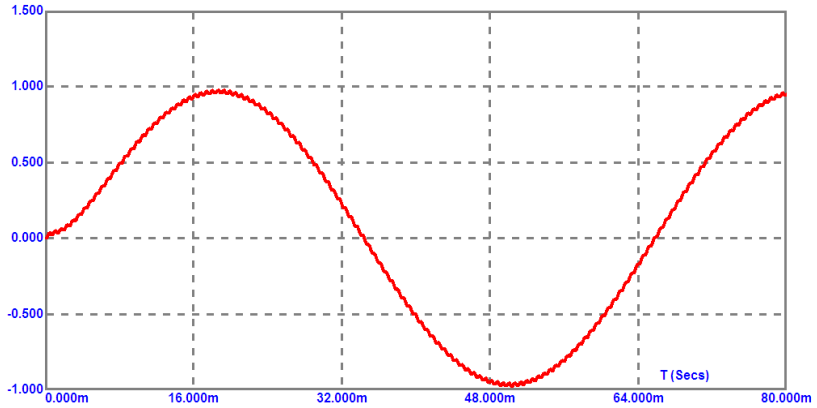
$$V_O(t) = 1Sin(100t) + 0.1Sin(10^4 t)$$

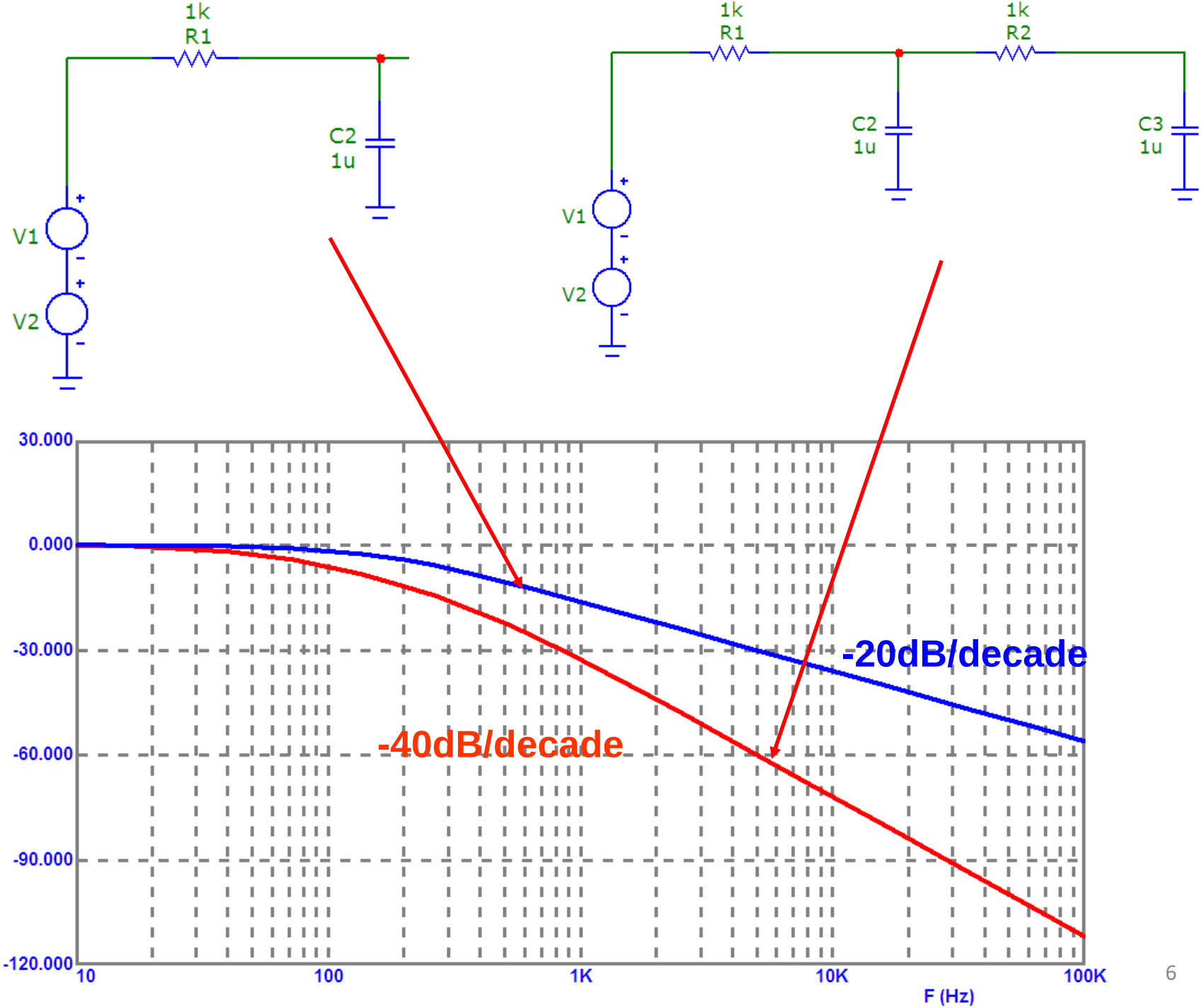



1k
R1
C2
1u
V1
V2

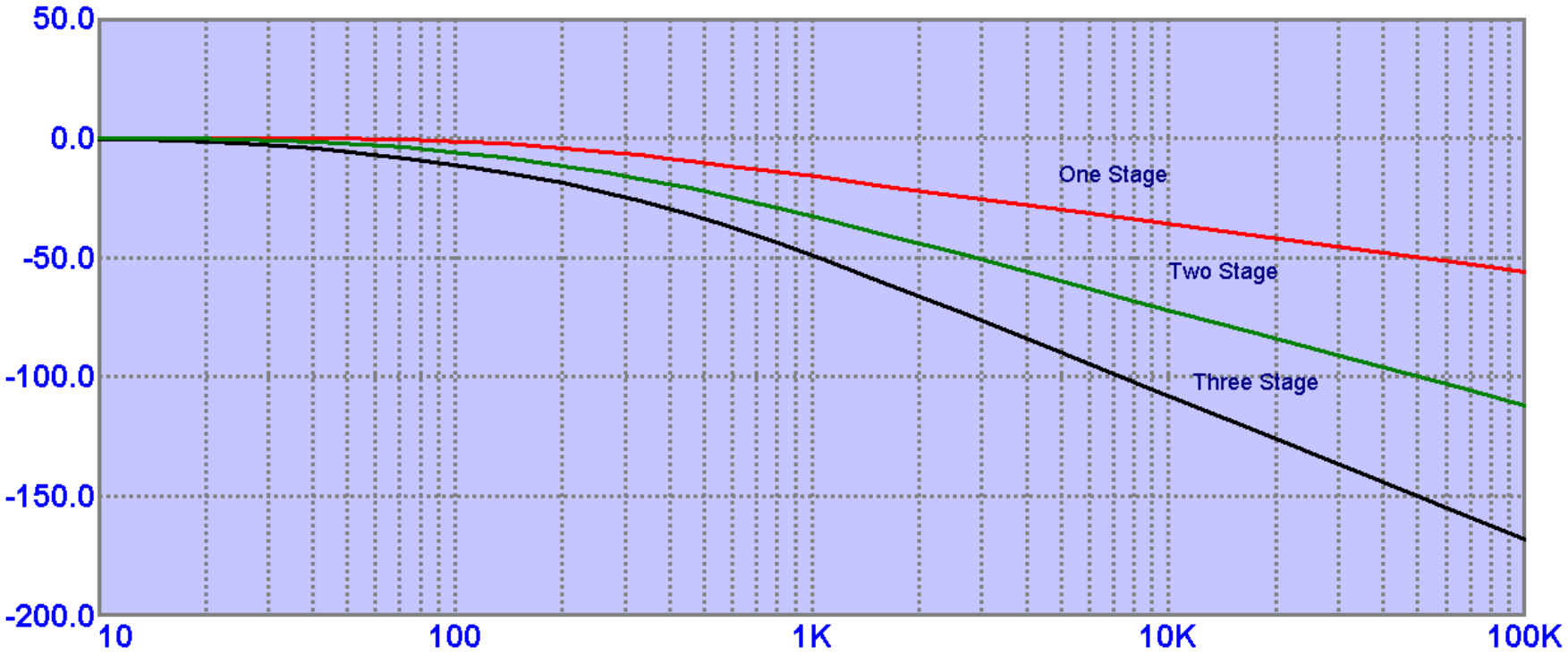

1.800
1.200
0.600
0.000
-0.600
-1.200
0.000m
16.000m
32.000m
48.000m
64.000m
80.000m
T (Secs)


1k
R1
1k
R2
C2
1u
C3
1u
V1
V2


1.500
1.000
0.500
0.000
-0.500
-1.000
0.000m
16.000m
32.000m
48.000m
64.000m
80.000m
T (Secs)


1k
R1
C2
1u
V1
V2
1k
R1
1k
R2
C2
1u
C3
1u
V1
V2
30.000
0.000
-30.000
-60.000
-90.000
-120.000
10
100
1K
10K
100K
F (Hz)
-20dB/decade
-40dB/decade

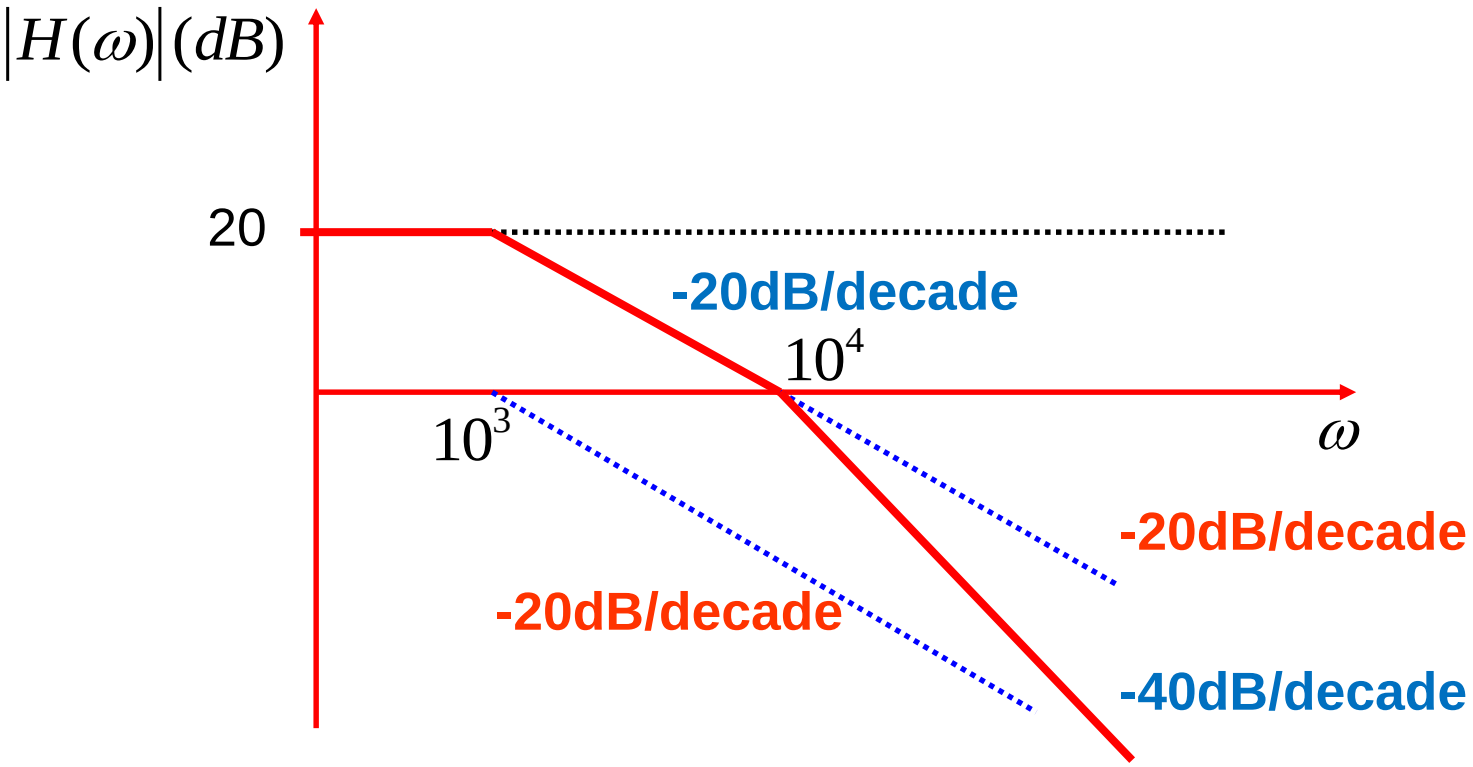
Adding more RC stages, makes the characteristics sharper



Sketching of Transfer function:
Bode Magnitude Plot

$$H(\omega) = \frac{10}{1 + j\frac{\omega}{10^3}} \times \frac{1}{1 + j\frac{\omega}{10^4}}$$

$$20\text{Log}_{10}(|H(\omega)|) = 20 - 20Log_{10}\sqrt{(1+(\frac{\omega}{10^3})^2)} - 20Log_{10}\sqrt{(1+(\frac{\omega}{10^4})^2)}$$

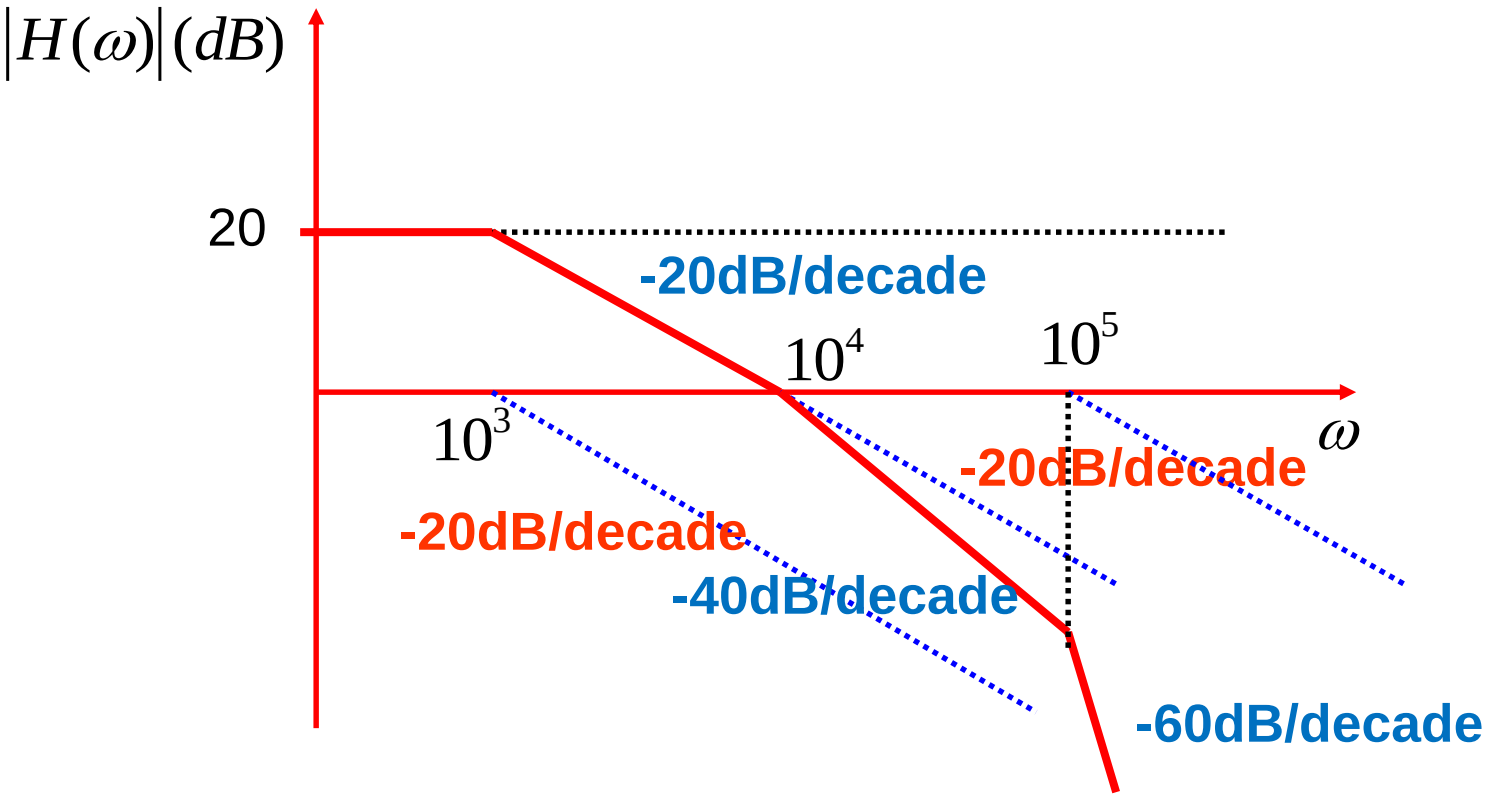


Sketching of Transfer function

Bode Magnitude Plot

$$H(\omega)=\frac{10}{1+j\frac{\omega}{10^3}}\times\frac{1}{1+j\frac{\omega}{10^4}}\times\frac{1}{1+j\frac{\omega}{10^5}}$$

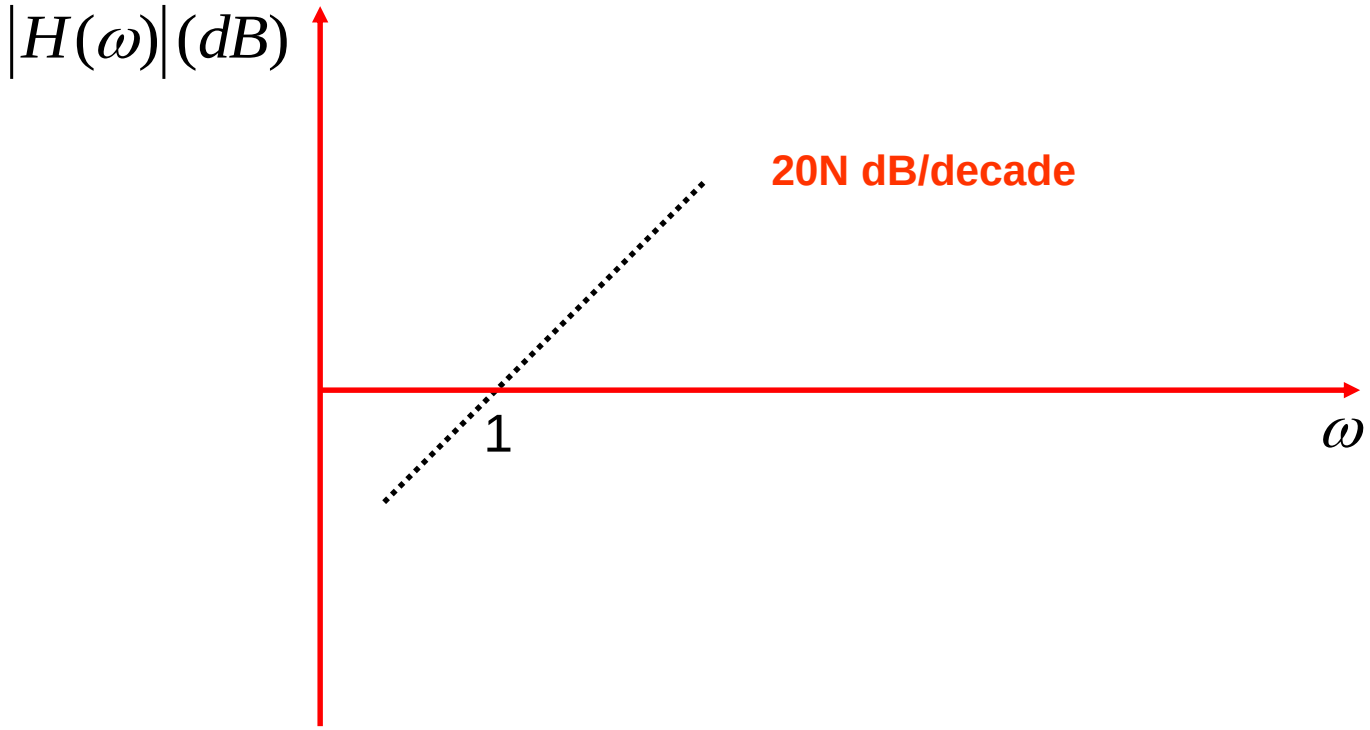
$$20\text{Log}_{10}(|H(\omega)|)=20-20Log_{10}\sqrt{(1+(\frac{\omega}{10^3})^2)}-20Log_{10}\sqrt{(1+(\frac{\omega}{10^4})^2)}-20Log_{10}\sqrt{(1+(\frac{\omega}{10^5})^2)}$$



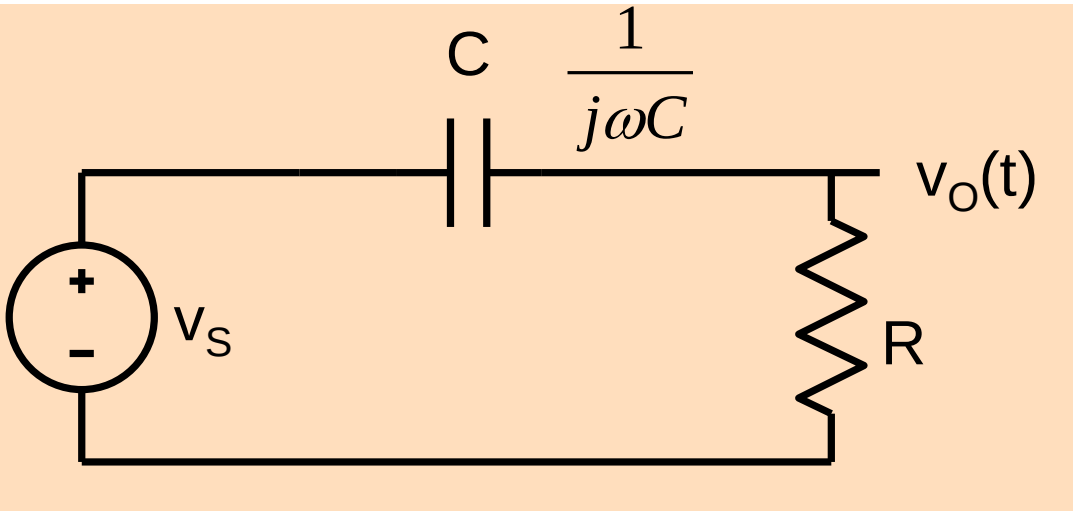
Bode Magnitude Plot

$$H(\omega) = (j\omega)^N$$

$$20\text{Log}_{10}(|H(\omega)|) = 20N \times Log_{10}(\omega)$$



Determine transfer function?



$$H(\omega) = \frac{V_O(\omega)}{V_S(\omega)}$$

$$H(\omega) = \frac{j\omega CR}{1 + j\omega CR}$$

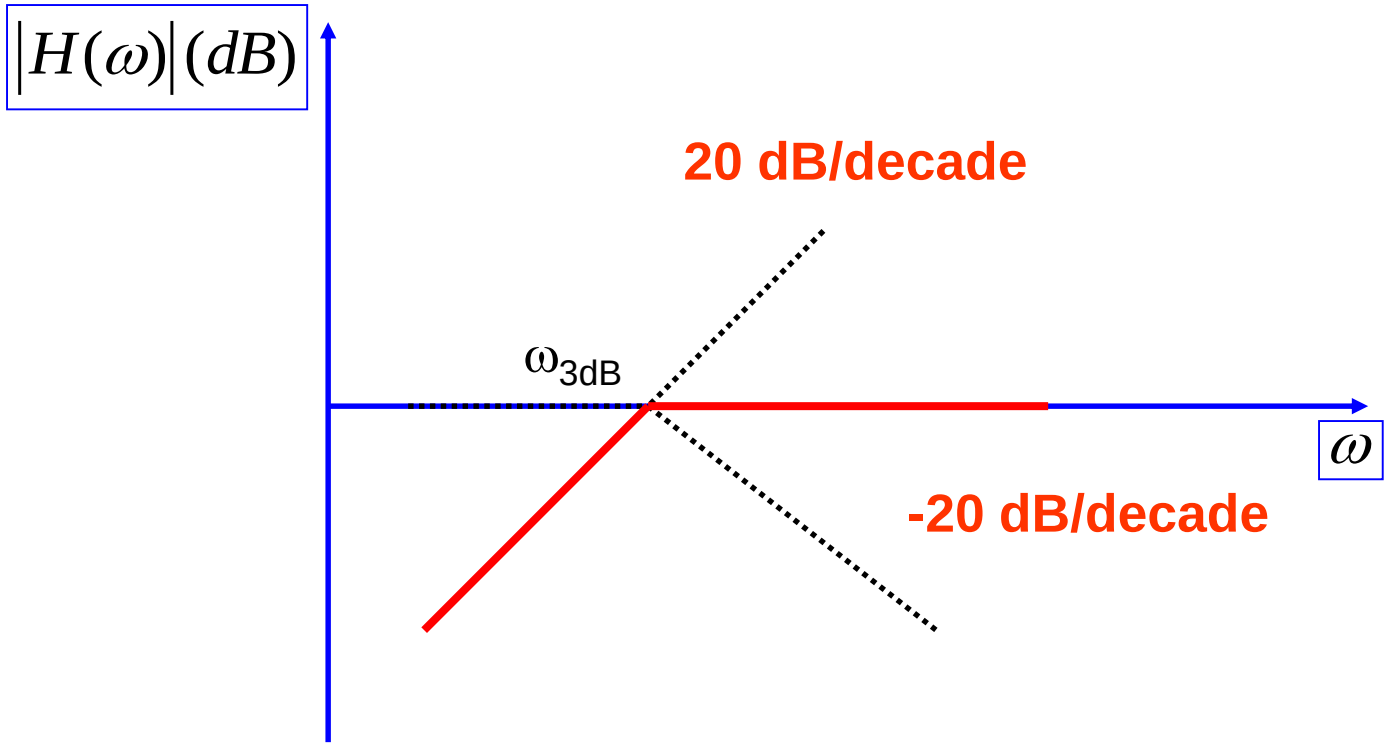
$$H(\omega) = \frac{j(\omega/\omega_{3dB})}{1 + j(\omega/\omega_{3dB})}$$

$$\omega_{3\text{dB}} = \frac{1}{\text{RC}} \; ; \; \text{f}_{3\text{dB}} = \frac{1}{2\pi\text{RC}}$$

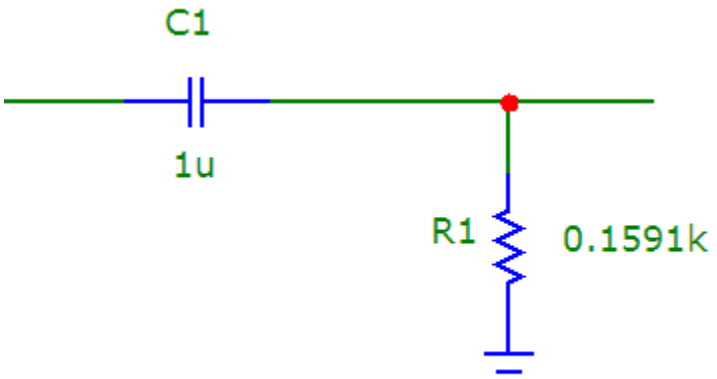
$$20\text{Log}_{10}(|H(\omega)|) = 20log_{10}(\frac{\omega}{\omega_{3dB}}) - 20log_{10}\sqrt{(1+(\frac{\omega}{\omega_{3dB}})^2)}$$

Bode Magnitude Plot

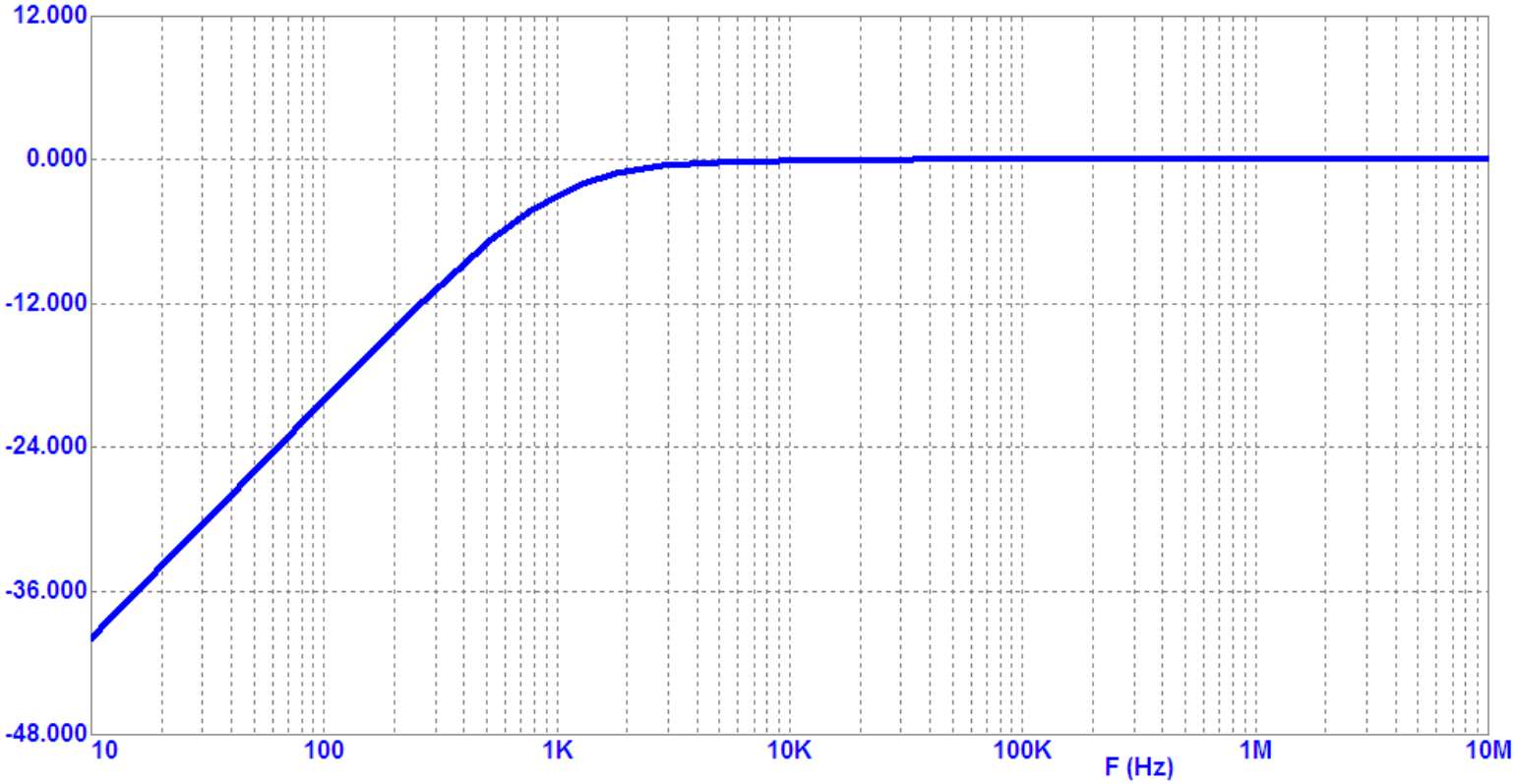
$$20\mathrm{Log}_{10}(|H(\omega)|) = 20log_{10}(\frac{\omega}{\omega_{3dB}}) - 20log_{10}\sqrt{(1+(\frac{\omega}{\omega_{3dB}})^2)}$$



High Pass Filter



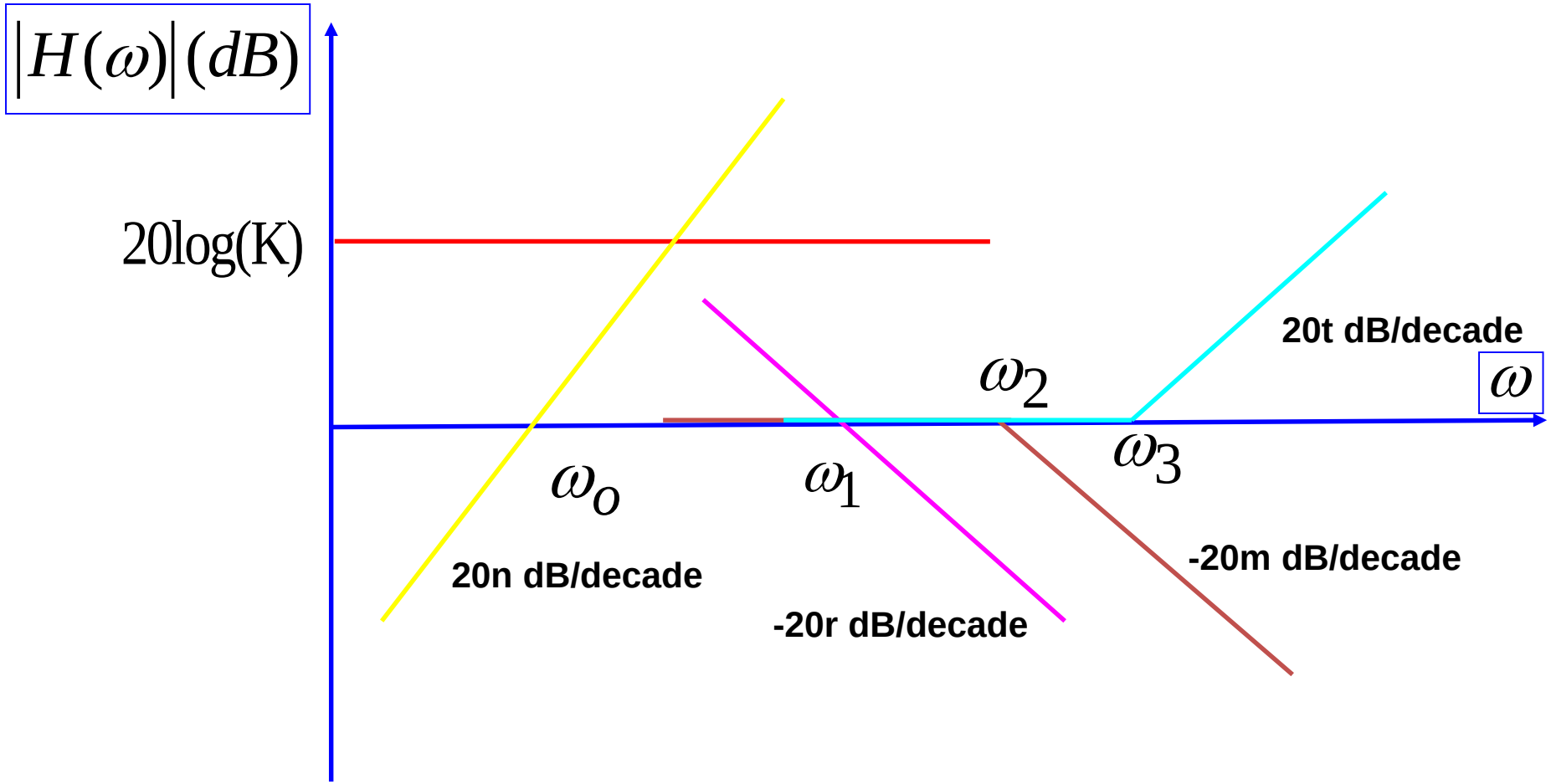
$$f_{3dB} = \frac{1}{2\pi RC} = 10^3\, Hz$$



High Pass Filter

Bode Plot segments

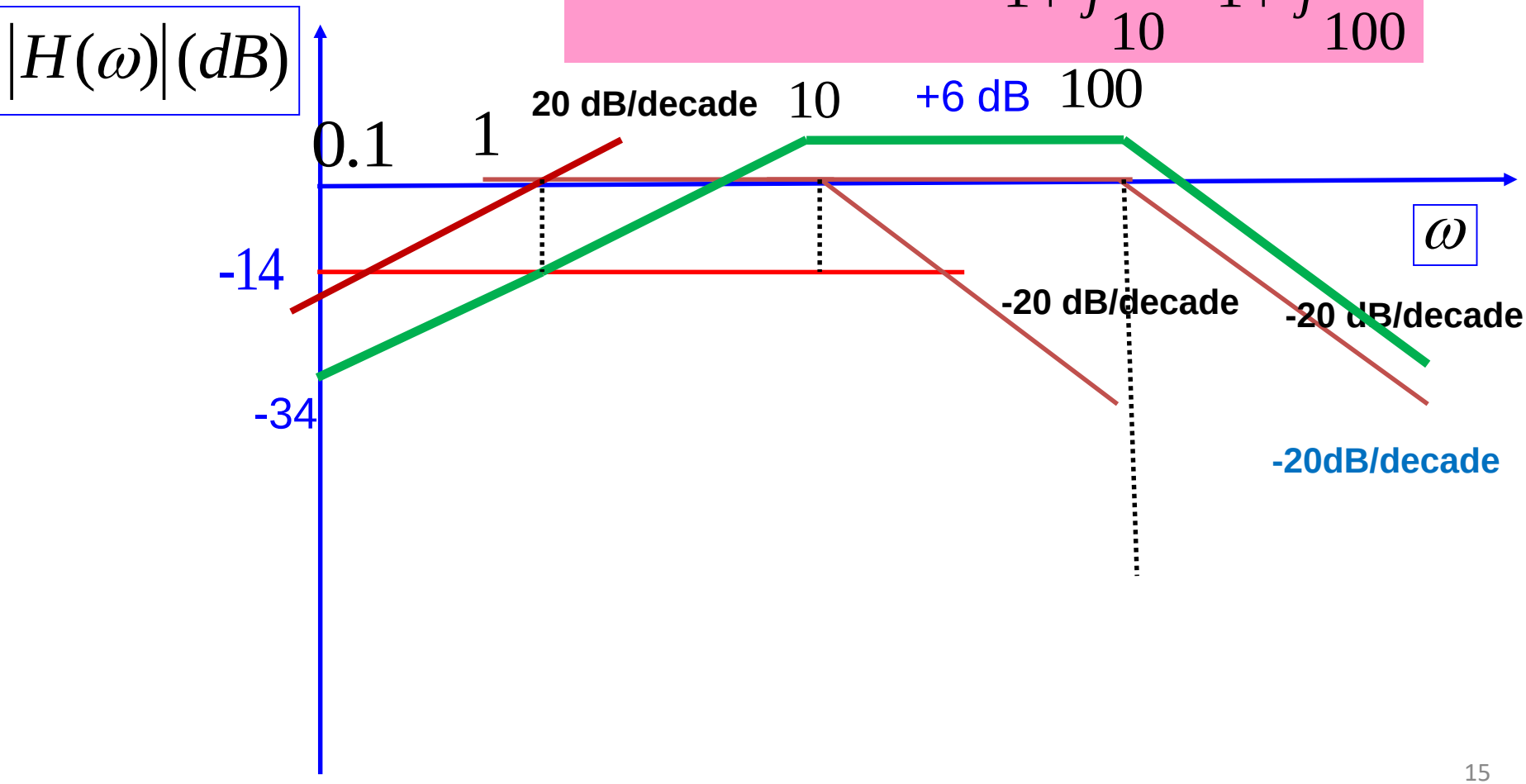
$$H(\omega) = K \times j(\omega/\omega_o)^n \times \frac{1}{j(\omega/\omega_1)^r} \times \frac{1}{\{1+j(\omega/\omega_2)\}^m} \times \{1+j(\omega/\omega_3)\}^t$$



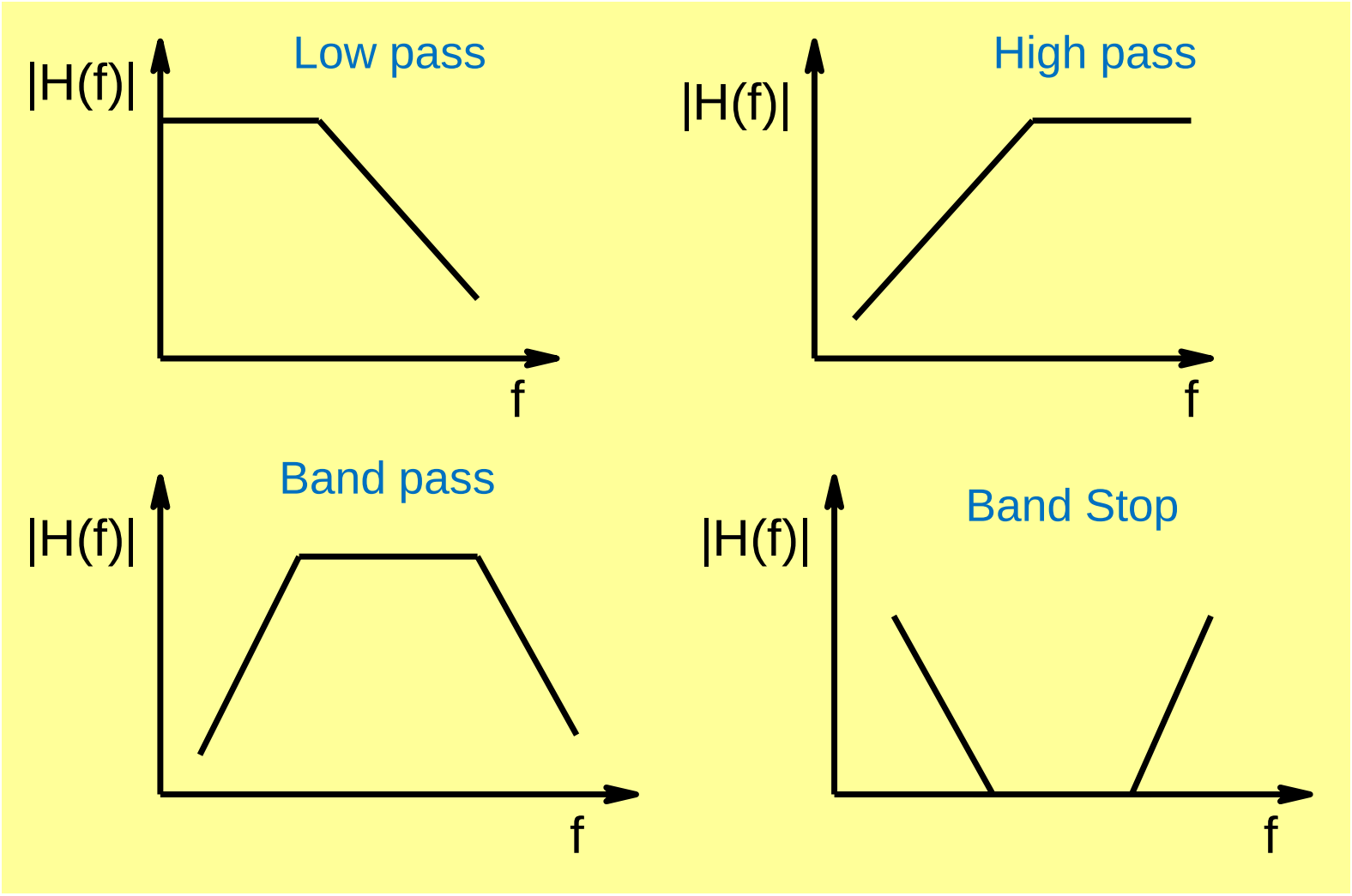
Example:

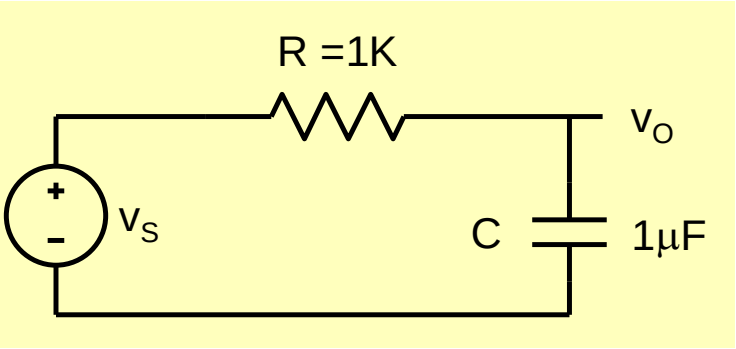
$$H(\omega) = 200 \times j\omega \times \frac{1}{10 + j\omega} \times \frac{1}{100 + j\omega}$$

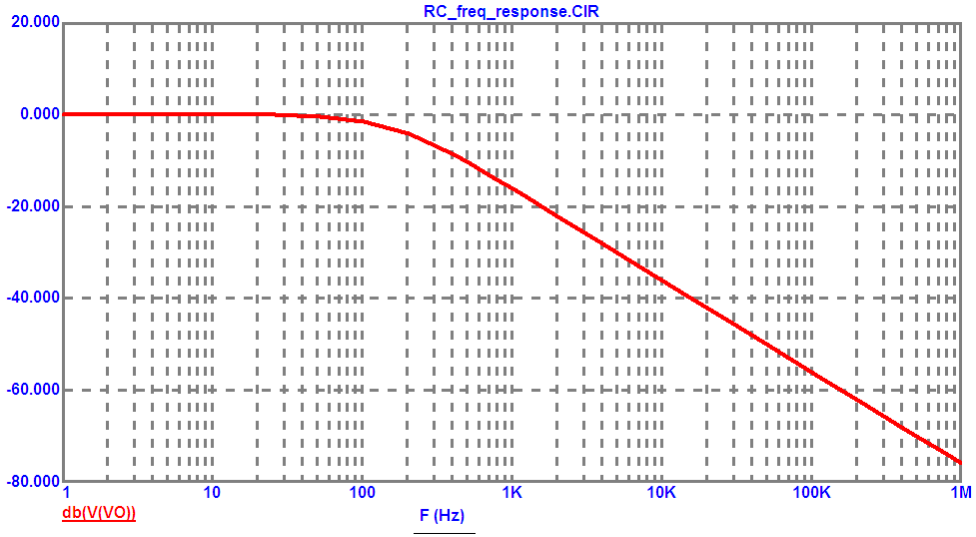
$$H(\omega) = 0.2 \times j\omega \times \frac{1}{1 + j\frac{\omega}{10}} \times \frac{1}{1 + j\frac{\omega}{100}}$$

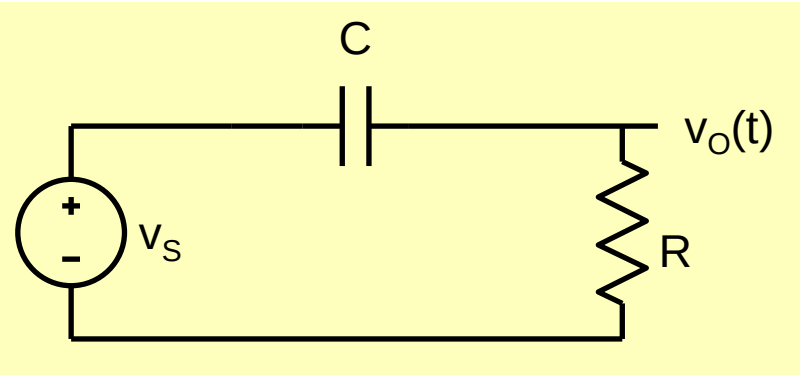


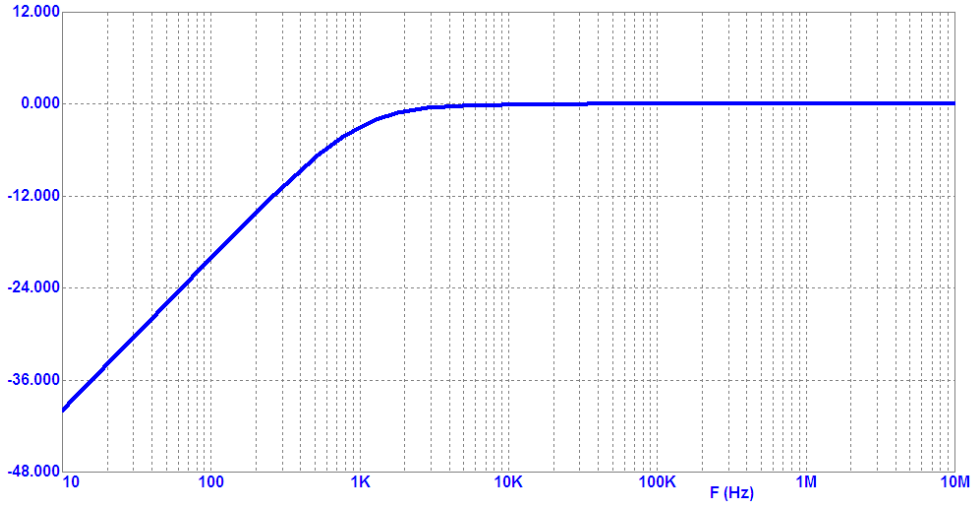
Filter -pass a band of frequency and reject the remaining



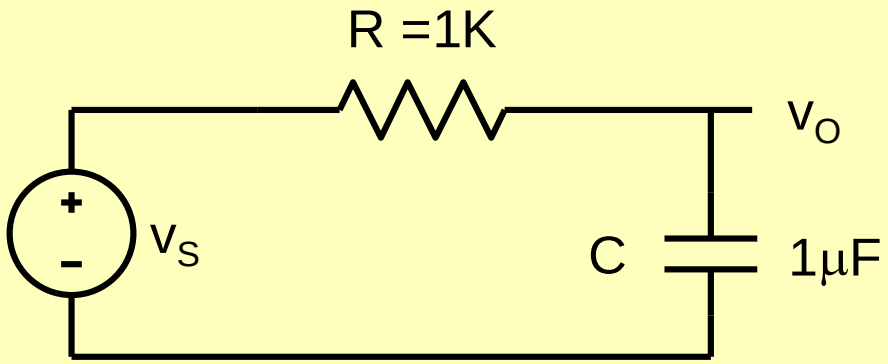

R =1K
v_O
v_S
C
1μF


RC_freq_response.CIR
20.000
0.000
-20.000
-40.000
-60.000
-80.000
1
10
100
1K
10K
100K
1M
db(V(VO))
F (Hz)

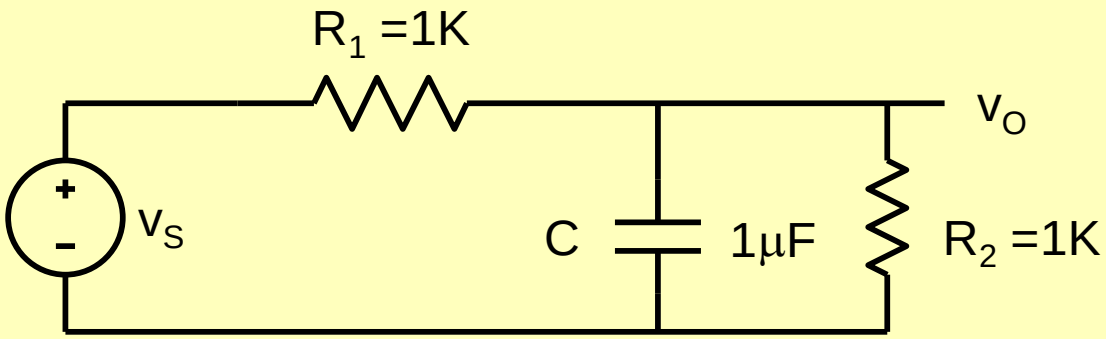

C
$v_O(t)$
v_S
R


12.000
0.000
-12.000
-24.000
-36.000
-48.000
10
100
1K
10K
100K
1M
10M
F (Hz)

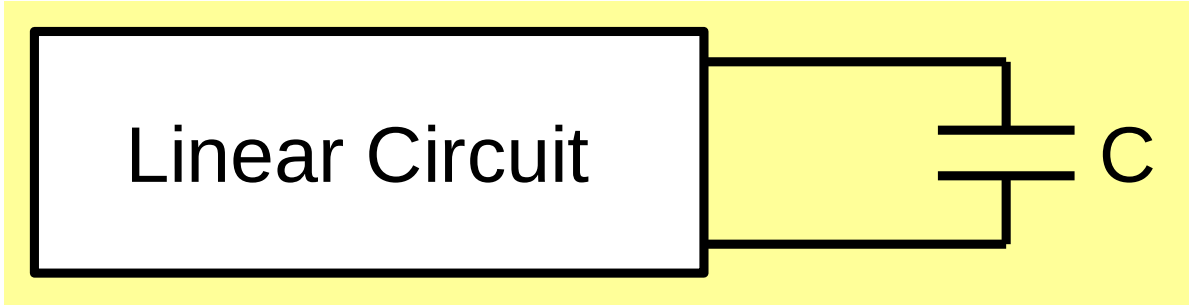
3dB Frequency of single capacitor filters



$$\omega_{3dB} = \frac{1}{RC} = 10^3 rad/s$$

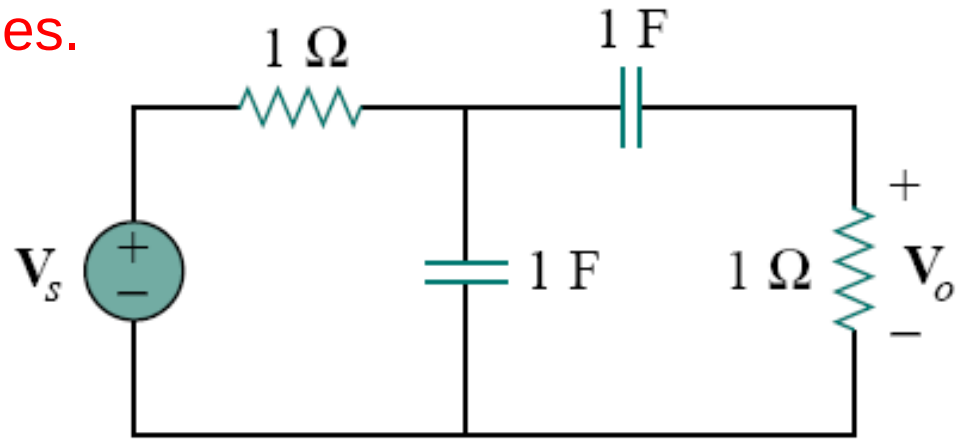


$$\omega_{3dB} = \frac{1}{R_1 \| R_2 C}$$



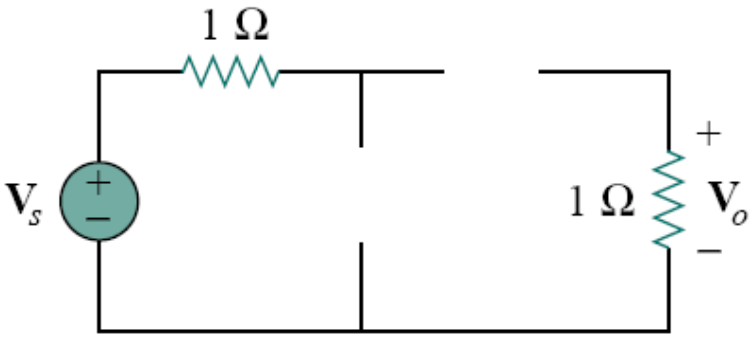
$$\omega_{3dB} = \frac{1}{\tau} = \frac{1}{R_{eq} C}$$

One can often tell the type of filter by looking at behavior at very low and very high frequencies and keeping in mind that capacitor offers very high impedance at low frequencies and very low impedance at high frequencies.

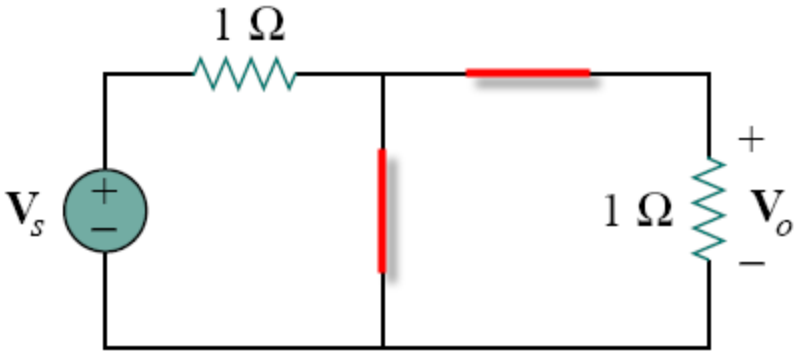


Low *f*

High *f*



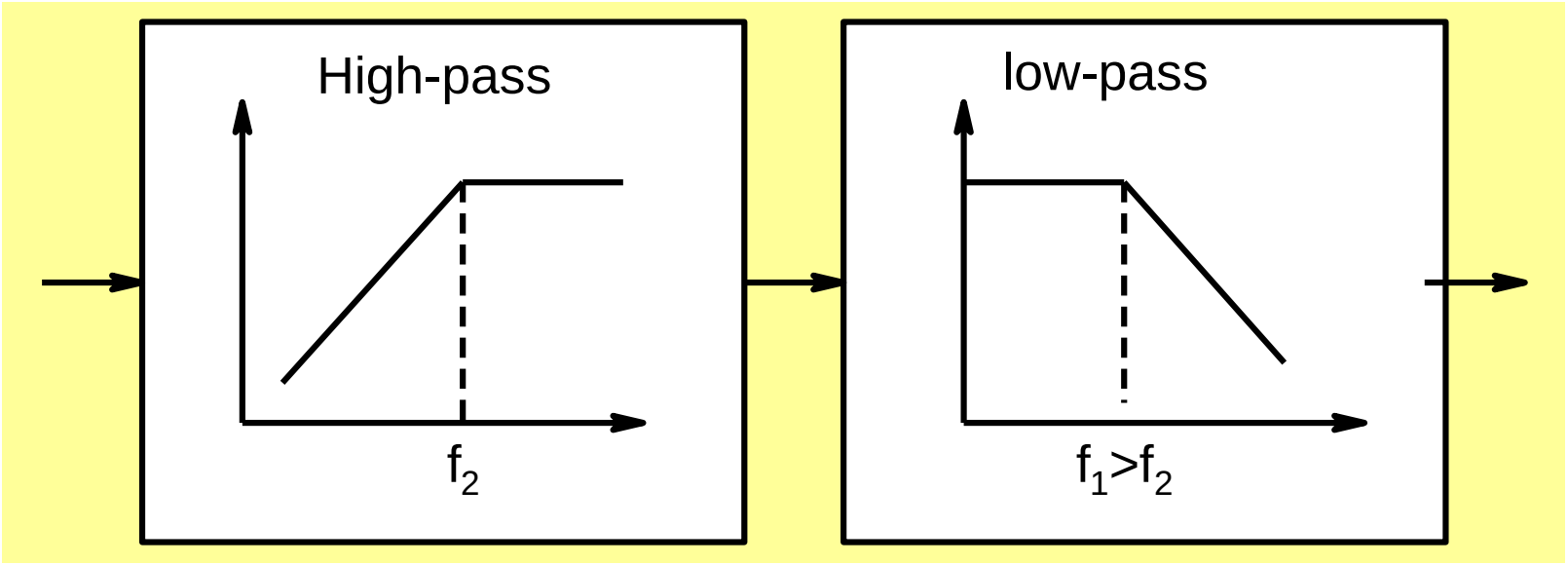
Vo ~0

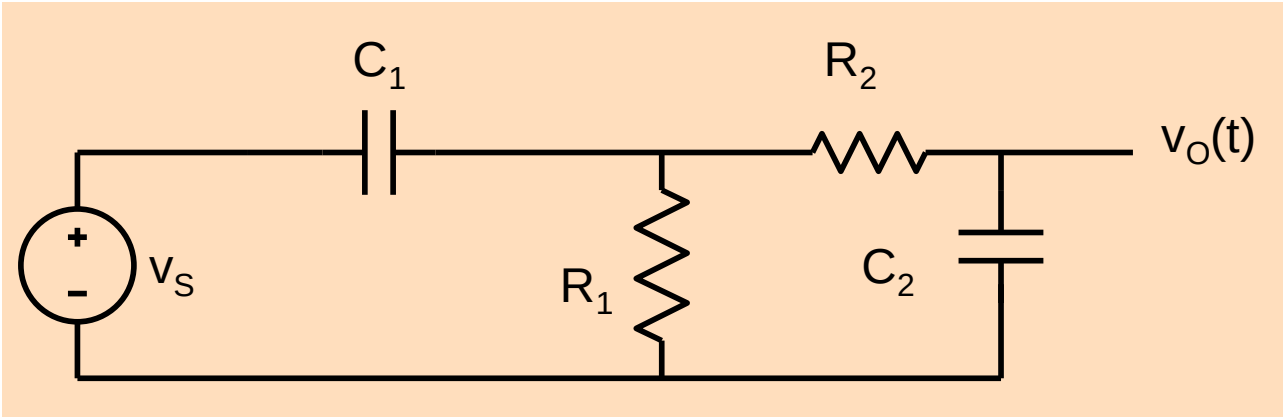


Vo ~0

Bandpass filter

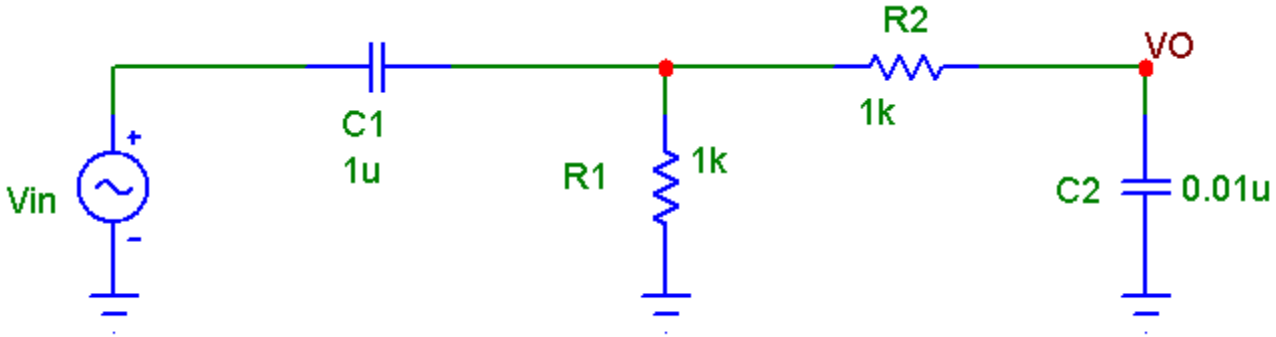
Bandpass Filter

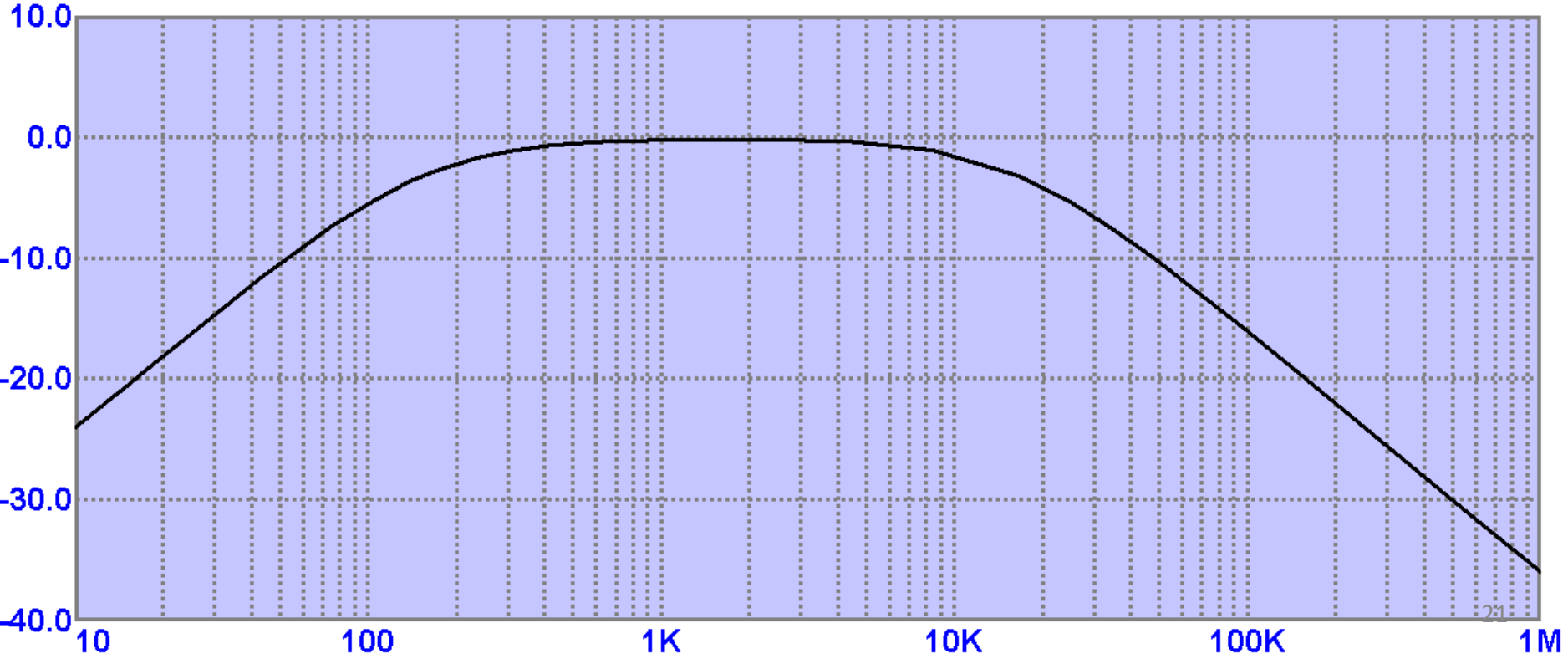




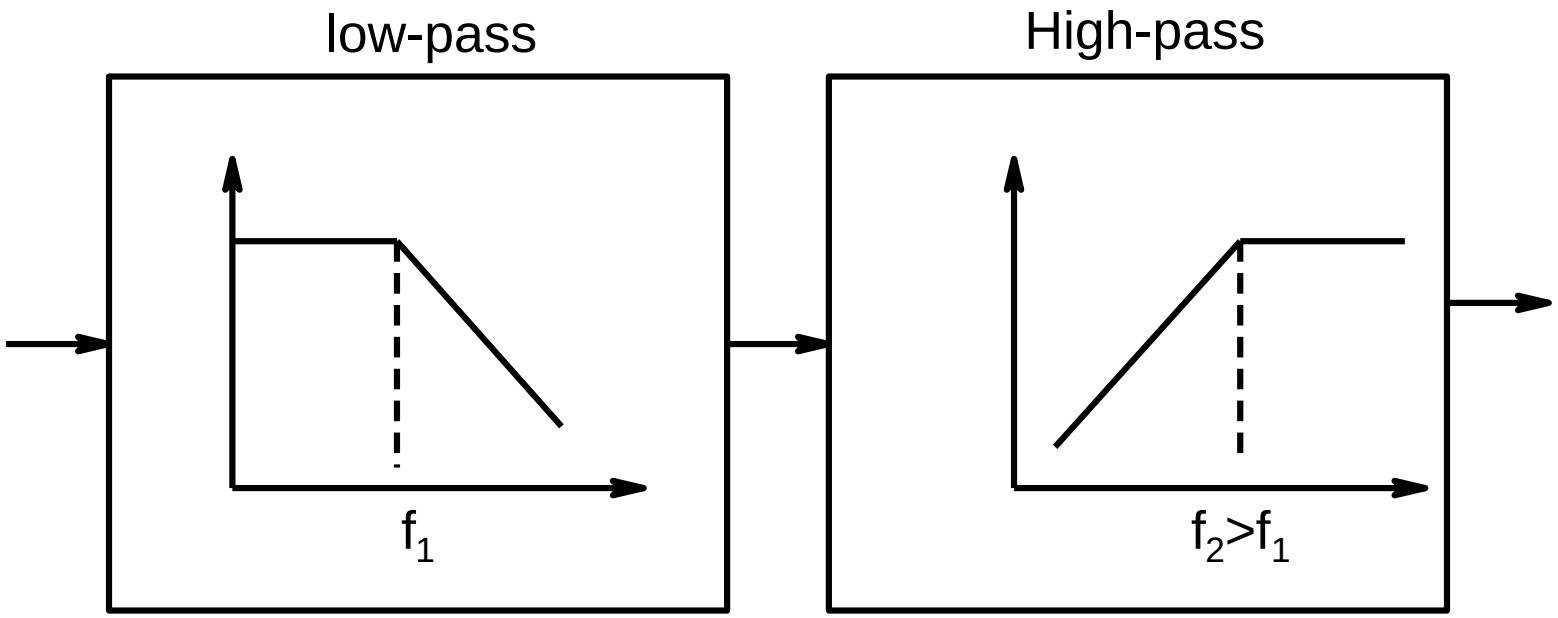
$$f_2 \cong \frac{1}{2\pi R_1 C_1} \; ; \; f_1 \cong \frac{1}{2\pi R_2 C_2}$$

Example: Band Pass filter



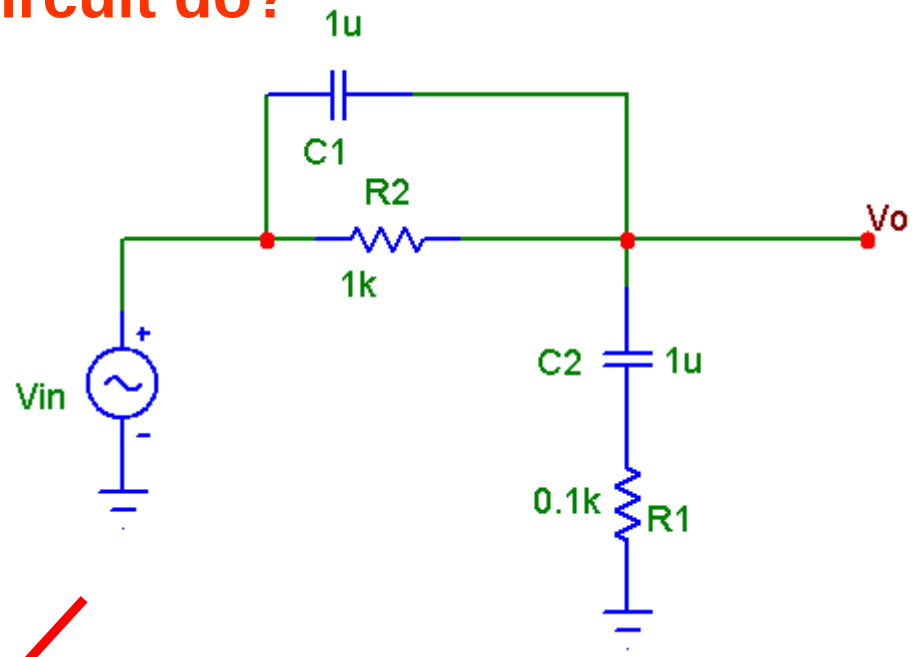


Bandstop Filter

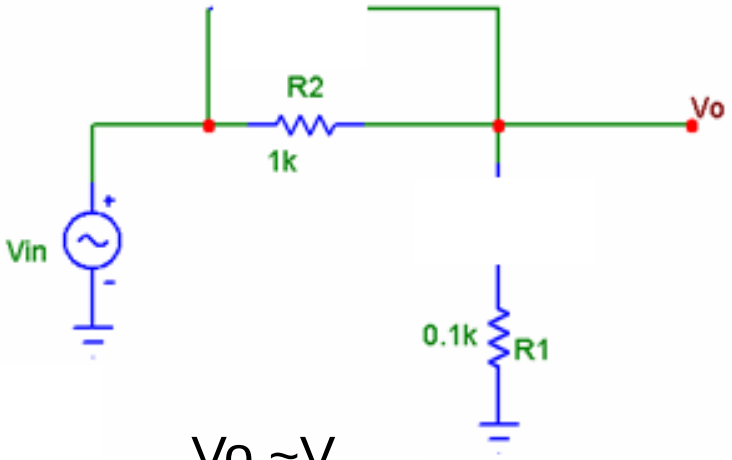


Will this work?

What does this circuit do?

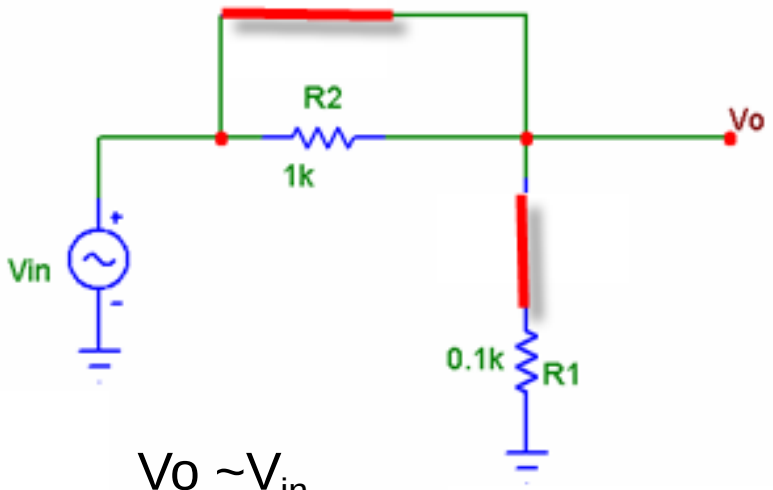


Low *f*



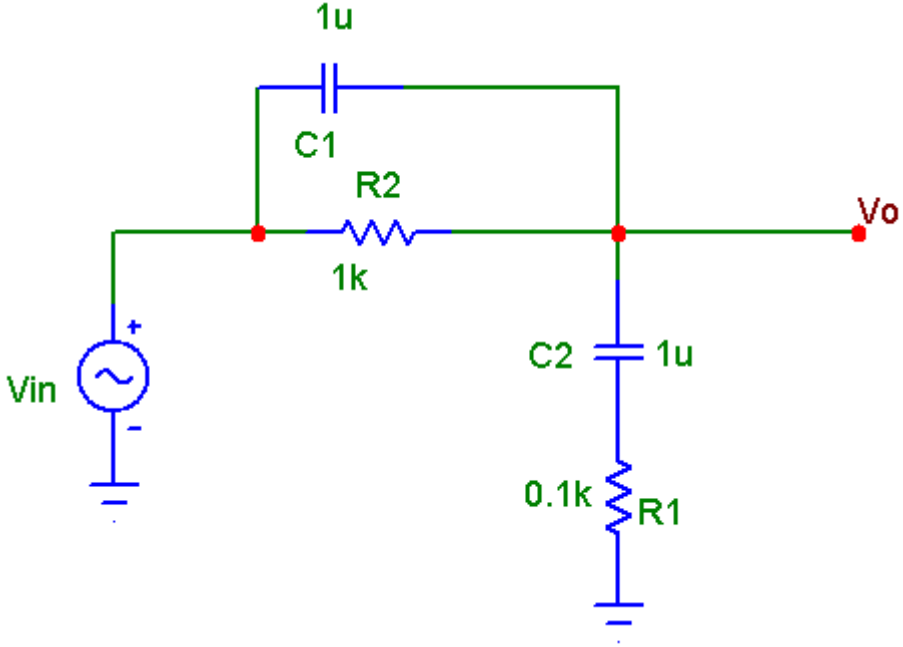
$Vo \sim V_{in}$

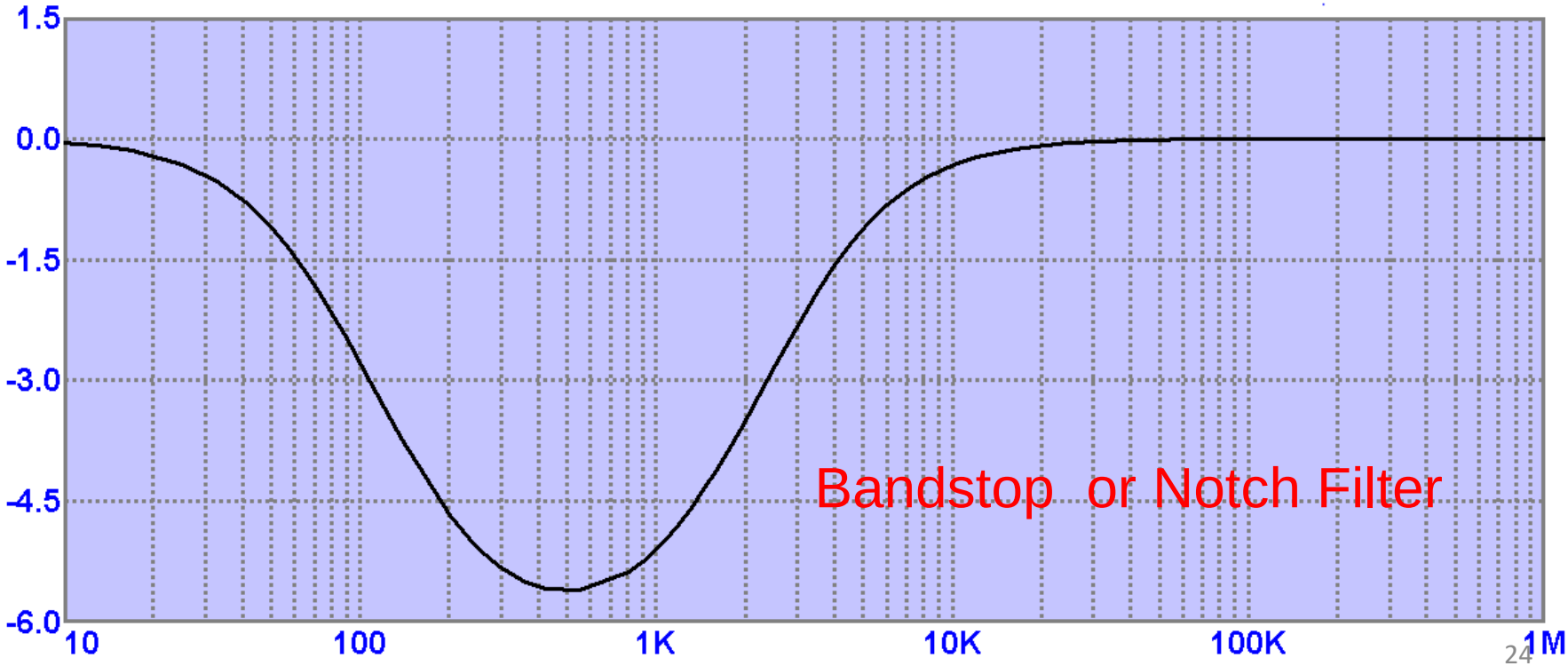
High *f*



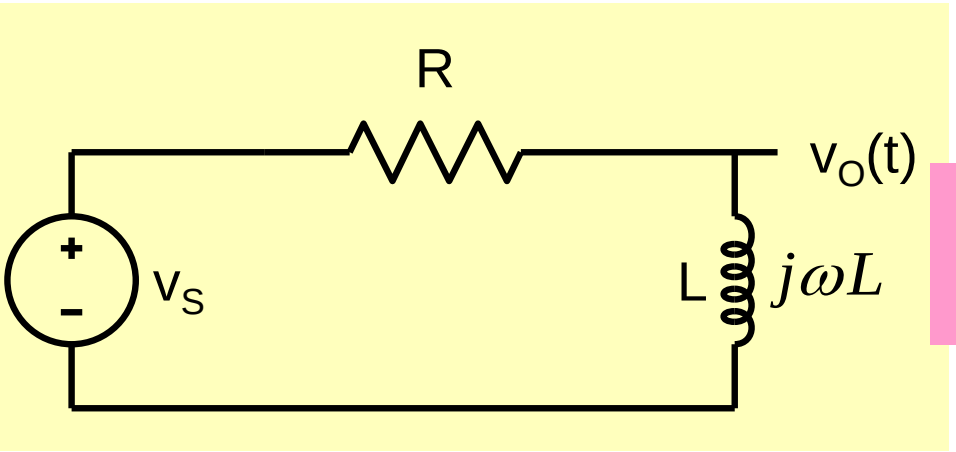
$Vo \sim V_{in}$

What does this circuit do?





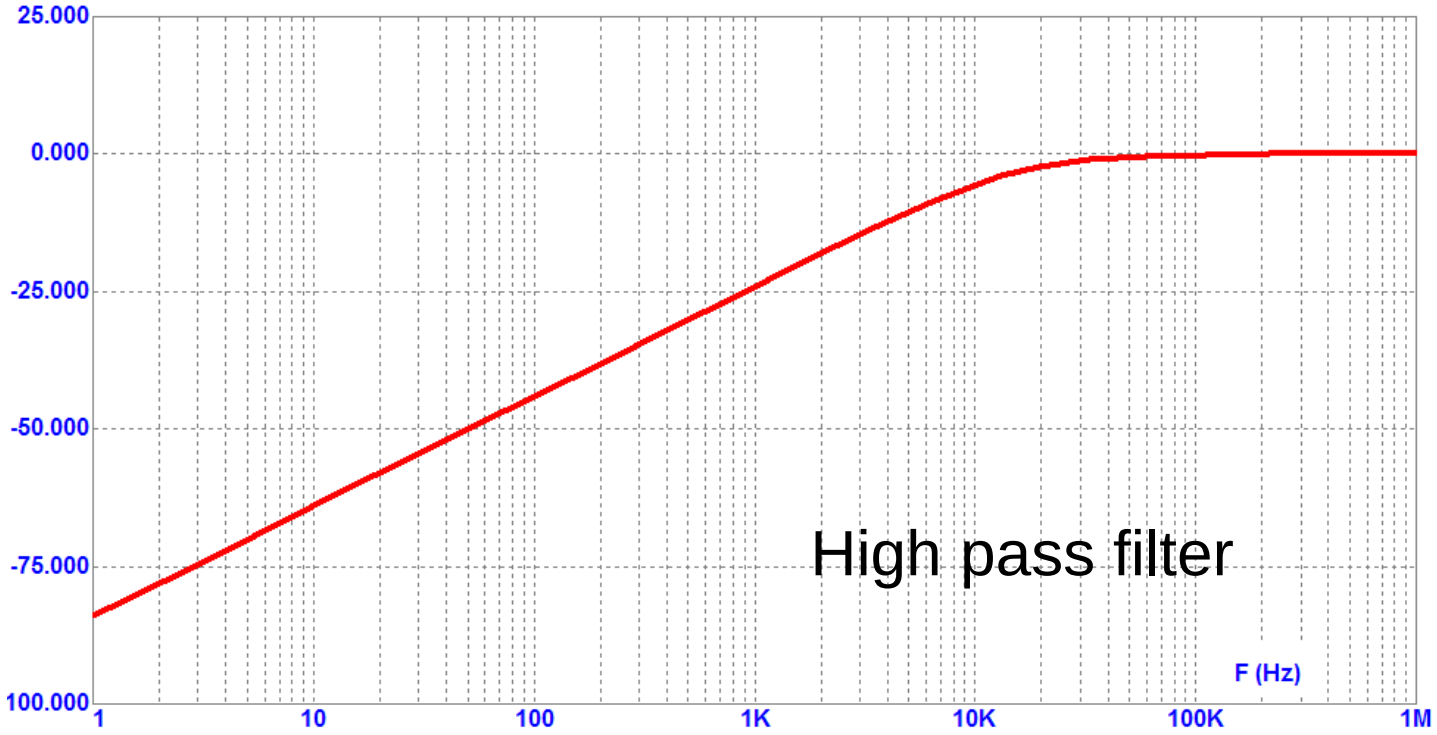
R-L Circuits (Filters)



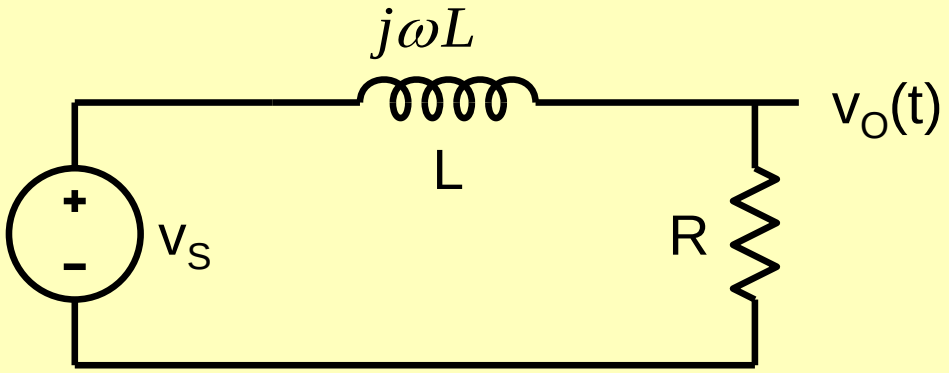
$$H(\omega) = \frac{V_O(\omega)}{V_S(\omega)}$$

$$H(\omega) = \frac{j\omega L}{R + j\omega L} = \frac{j(\omega/\omega_{3dB})}{1 + j(\omega/\omega_{3dB})}$$

$$\omega_{3dB} = \frac{R}{L}$$



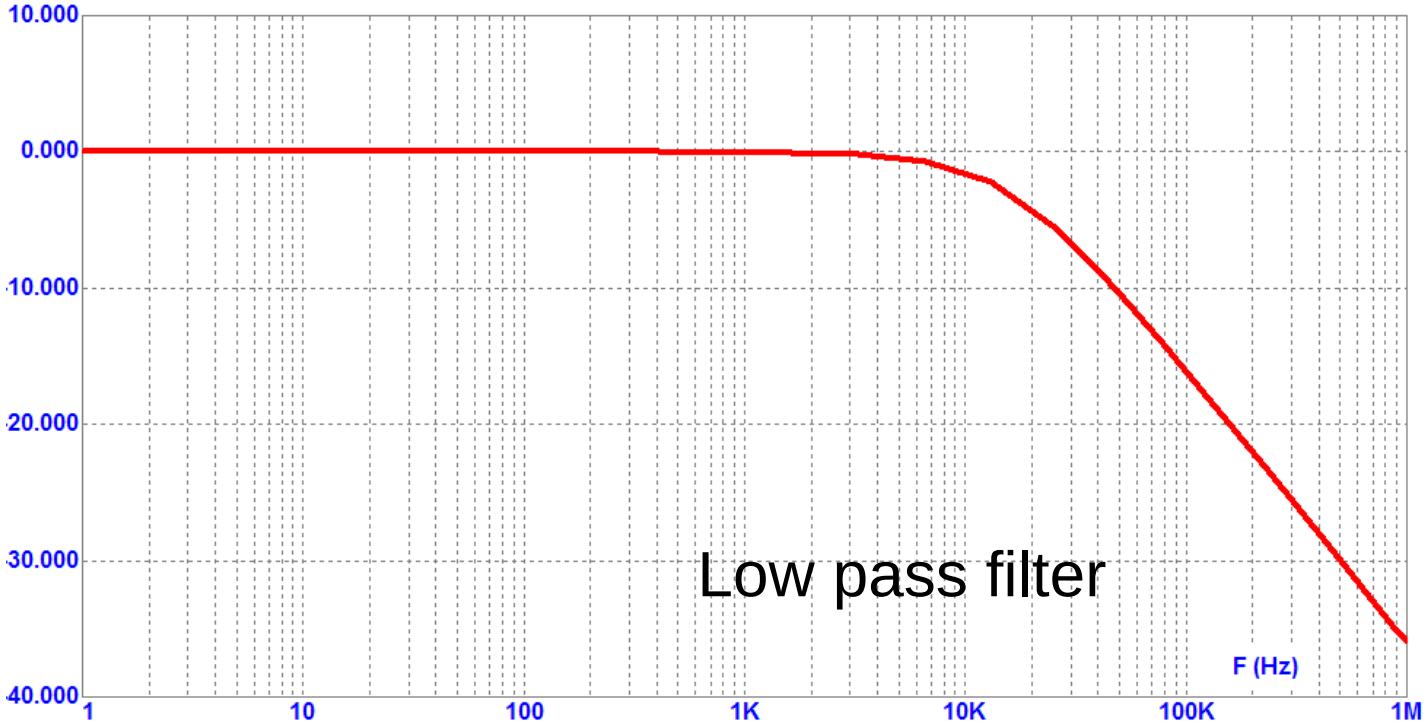
R-L Circuits



$$H(\omega) = \frac{V_O(\omega)}{V_S(\omega)}$$

$$H(\omega) = \frac{R}{R + j\omega L} = \frac{1}{1 + j(\omega/\omega_{3dB})}$$

$$\omega_{3dB} = \frac{R}{L}$$



Quiz 1 Instructions

1. Make sure you sit in the assigned Tutorial room only (as per your lab section). Your attendance will be marked only in the assigned room.

2. Fill your Name (in Capitals), Roll No., and Section No. in designated boxes only on the paper/answer sheet.

3. Answers for each question have to be written in the assigned space only. No extra sheets are to be used.

4. The exam is of 45 minutes duration.

5. It is a closed notes closed books exam. Calculators can be used but not phones.

6. Zero marks will be given for copied submissions and cases reported for disciplinary action.

Section	Tutorial Room
M1	T103
M2	T104
M3	T105
M4	T106
TU1	T107
TU2	T108
TU3	T109
TU4	T110
W1	T111
W2	T112
W3	T203
W4	T204
TH1	T205
TH2	T206
TH3	T207
TH4	T208
F1	T209
F2	T210
F3	T211
F4	T212