EECE301 NETWORK ANALYSIS II **Dr. Charles Kim**

Class Note 08: Passive Filters

A. Filter Introduction

Filter: A circuit that is designed to pass signals with desired frequencies and reject or attenuate others

Passive Filter: A filter consists of only passive elements such as R, L, and C

Characteristics:
1. Gain is less than 1
2. May require bulky and expensive inductors
3. Perform poorly at frequencies below the audio frequency
4. Works fine at high frequencies

Active Filter: A filter consists of active elements such as transistors and OP Amps in addition to passive elements.

Characteristics:
1. Amplifier Gain
2. No inductor is required
3. Smaller and less expensive
4 Less reliable and less stable
5. Works fine at low frequencies (below 100 KHz)

Order of filters: Number of poles in the transfer function G(s)

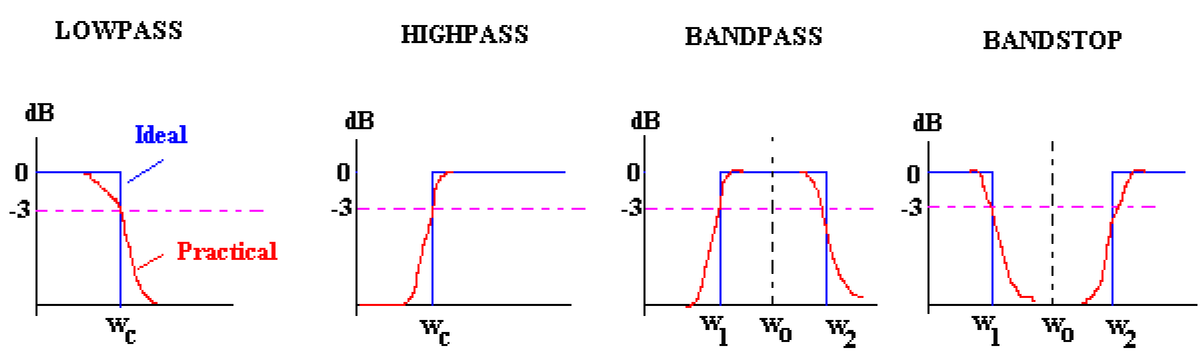
Four types of filters:

Low Pass Filter: $A_{dB}(0)=0dB$, $A_{dB}(\infty)=-\infty$ dB, $A_{dB}(w_c)=-3dB$

High Pass Filter: $A_{dB}(0)=-\infty dB$, $A_{dB}(\infty)= 0dB$, $A_{dB}(w_c)=-3dB$

Band Pass Filter: $A_{dB}(0)=-\infty dB$, $A_{dB}(\infty)=-\infty$ dB, $A_{dB}(w_c)=0dB$

Band Stop (or Band Reject or Notch) Filter: $A_{dB}(0)=0dB$, $A_{dB}(\infty)=0dB$, $A_{dB}(w_0)=0dB$



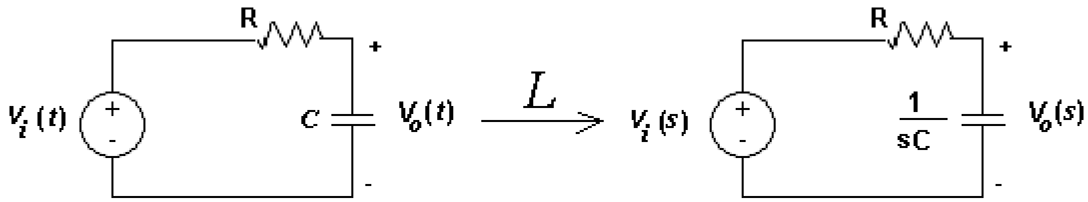
NOTE: Do you see that relative 3dB= $\frac{1}{\sqrt{2}}$ (absolute) ?

Is this an RMS value for a max value=1?

B. Passive Filters

1. Low Pass Filter with series RC

Circuit Configuration:



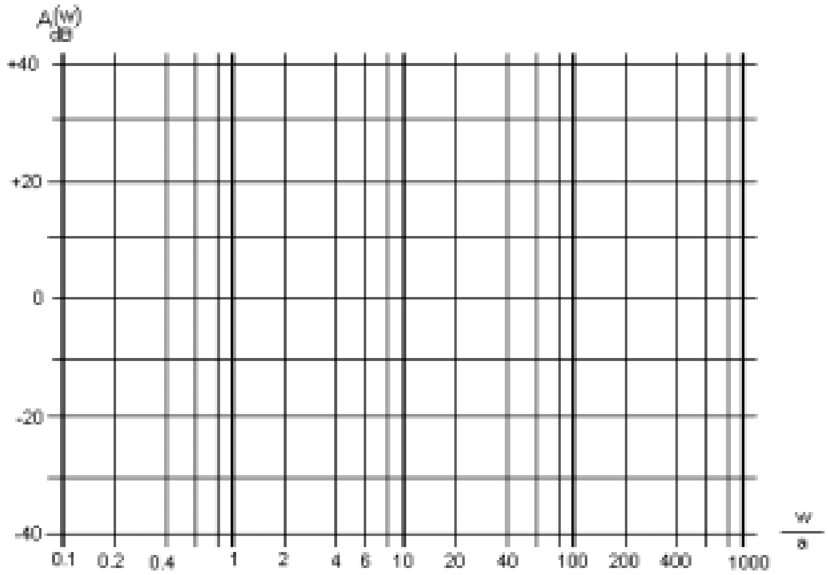
s-domain Transfer Function:

$$H(s) = \frac{V_o(s)}{V_i(s)} = \frac{V_i(s)\left(\frac{1/sC}{R+1/sC}\right)}{V_i(s)} = \frac{1/sC}{R+1/sC} = \frac{1}{1+RCs} = \frac{1}{1+\frac{s}{1/RC}}$$

Steady-State Transfer Function: $H(jw) = \frac{1}{1+j\frac{w}{1/RC}}$

Relative dB Amplitude: $A_{dB}(w) = 20\log\frac{1}{\sqrt{1+\left(\frac{w}{1/RC}\right)^2}} = -10\log[1+\left(\frac{w}{1/RC}\right)^2]$

Bode-Plot:



Do you see that the cut-off frequency (at –3dB) is $\frac{1}{RC}$? or $w_c RC = 1.0$

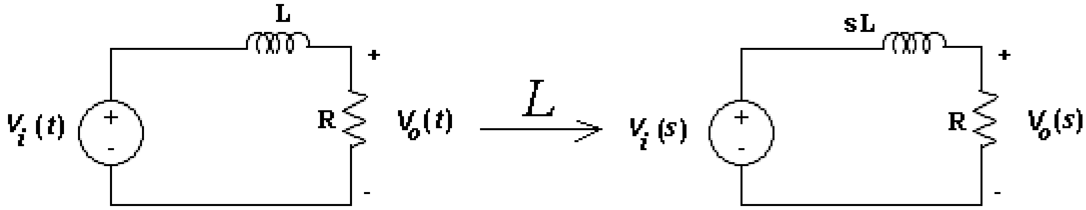
Can you choose the resistor R that will yield a low pass filter with a cutoff frequency of 3 KHz, if there is only 1uF capacitors?

<u>Response Example</u>: If the input is $v_i(t) = 480\cos wt$, write the steady-state expression for the response $v_o(t)$ at w=w_c, 0.2w_c, and 8w_c. (assume that R=20000 and C=4 nF)

(SOLUTION)

2. Low Pass Filter with series RL

Circuit Configuration:

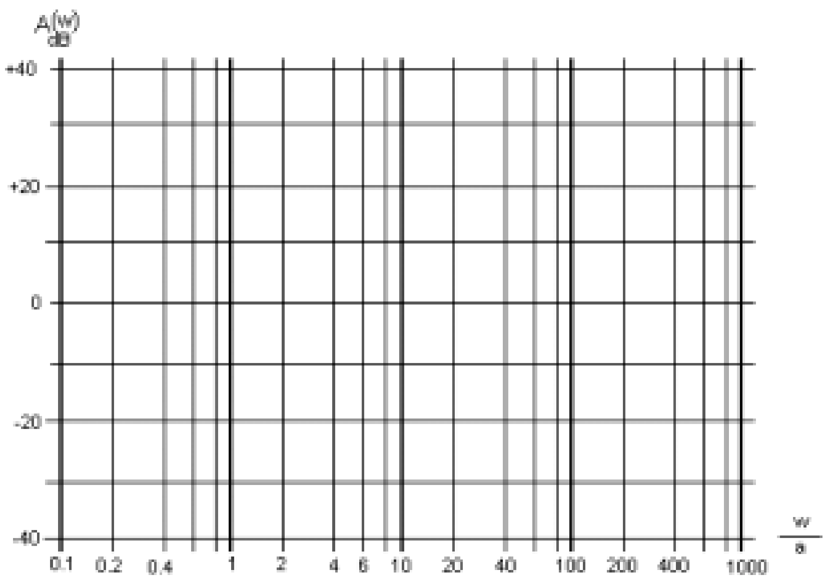


s-domain Transfer Function: $H(s) = \dfrac{V_o(s)}{V_i(s)} = \dfrac{V_i(s)\left(\dfrac{R}{R+sL}\right)}{V_i(s)} = \dfrac{R}{R+sL} = \dfrac{1}{1+sL/R} = \dfrac{1}{1+\dfrac{s}{R/L}}$

Steady-State Transfer Function: $H(jw) = \dfrac{1}{1+j\dfrac{w}{R/L}}$

Relative dB Amplitude: $A_{dB}(w) = 20\log\dfrac{1}{\sqrt{1+\left(\dfrac{w}{R/L}\right)^2}} = -10\log[1+\left(\dfrac{w}{R/L}\right)^2]$

Bode-Plot:



Do you see that the cut-off frequency (at –3dB) is $\dfrac{R}{L}$? or $\dfrac{w_c}{R/L} = 1.0$

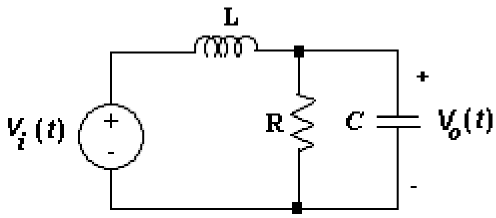
What is the cut-off frequency with R=6.3 Ωand L=100 mH?

Response Example: If the input is $v_i(t) = 480\cos 1000t$, find the **magnitude** of the output voltage at $w = w_c$, $0.2w_c$, and $8w_c$. (assume that R=1500 and L=0.25H)

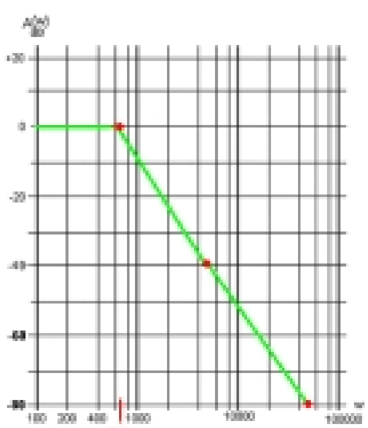
(SOLUTION)

<u>Example Problem:</u> Determine the filter type of the circuit below and draw a Bode plot, and find the cutoff frequency.

(R=2K, L=2 H, and C=2uF)

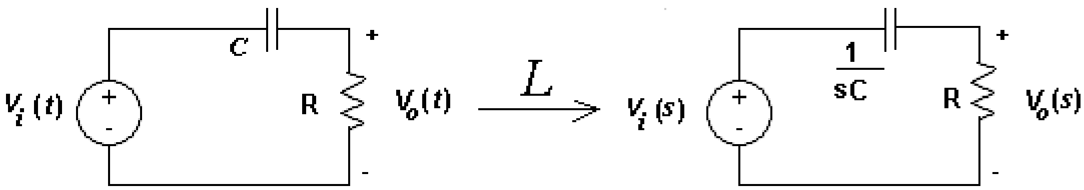


SOLUTION



3. High Pass Filter with series RC

Circuit Configuration:



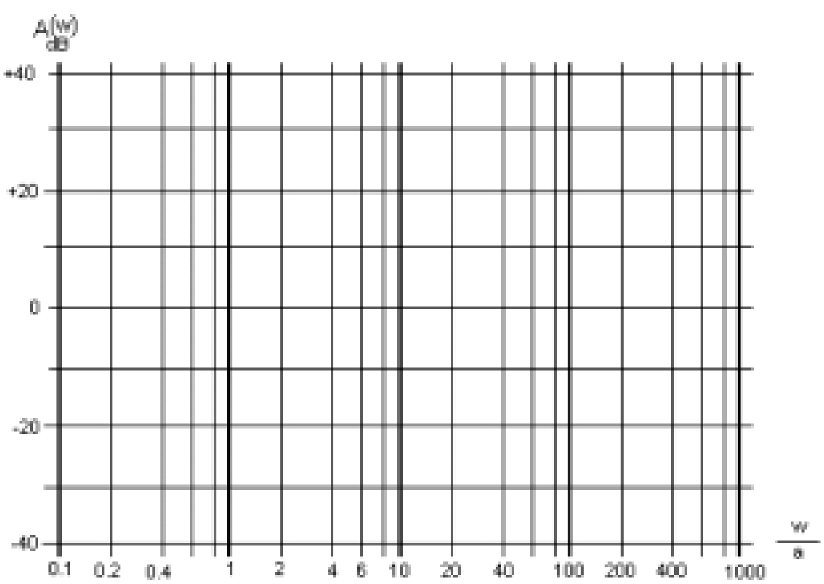
s-domain Transfer Function: $H(s) = \dfrac{V_o(s)}{V_i(s)} = \dfrac{V_i(s)\left(\dfrac{R}{R+1/sC}\right)}{V_i(s)} = \dfrac{R}{R+1/sC} = \dfrac{\dfrac{s}{1/RC}}{1+\dfrac{s}{1/RC}}$

Steady-State Transfer Function: $H(jw) = \dfrac{j\dfrac{w}{1/RC}}{1+j\dfrac{w}{1/RC}}$

Relative dB Amplitude:

$$A_{dB}(w) = 20\log\frac{\left(\dfrac{w}{1/RC}\right)}{\sqrt{1+\left(\dfrac{w}{1/RC}\right)^2}} = 20\log[\left(\frac{w}{1/RC}\right)] - 10\log[1+\left(\frac{w}{1/RC}\right)^2]$$

Bode-Plot:



Do you see that the cut-off frequency (at –3dB) is $\dfrac{1}{RC}$? or $w_c RC = 1.0$

Can you find the cutoff frequencies for the following resistor values:

100Ω, 5000Ω, and 30000Ω, if there is only 1uF capacitors?