Chapter 14

Frequency Response

By Eng. Emad Mahdy

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Chapter 14 Laws:

Frequency Response

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Content محتوي الشابتر

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14.1 Introduction

The frequency response of a circuit is the variation in its behavior with change in signal frequency.

استجابة التردد هو تغير سلوك الدائرة مع تغير الاشارة الداخلة لها

- frequency responses of circuits are used in many applications, especially in communications and control systems.

  تستخدم دوائر استجابة التردد في العديد من التطبيقات خاصة في الاتصالات وانظمة التحكم

- A specific application is in electric filters that block out or eliminate signals with unwanted frequencies and pass signals of the desired frequencies.

  أحد التطبيقات هو دائرة المرشح electric filter ويتم استخدامه للحصول على ترددات معينة من الدائرة

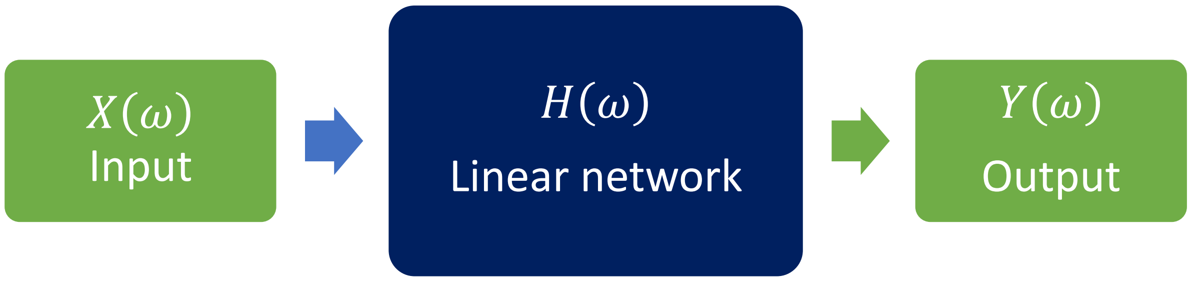
  وازالة ترددات اخري

- Filters are used in radio, TV, and telephone systems to separate one broadcast frequency from another.

  تستخدم دوائر المرشح في الراديو والتليفزيون

14.2 Transfer Function

Transfer function



where is: $\mathbf{H}(\omega) = \frac{Y(\omega)}{X(\omega)}$

	Time-domain	Frequency domain
Input	$x(t)$	$X(\omega)$
Output	$y(t)$ *[response]*	$Y(\omega)$
Transfer function	$h(t)$ *[impulse response]*	$H(\omega)$ *[transfer function]*

poles and zeros:

$$\mathbf{H}(\omega) = \frac{N(\omega)}{D(\omega)}$$

- **لو عاوز اجيب ال zeros:** نساوي البسط ب صفر $(N(\omega) = 0)$ ونحل المعادلة
- **لو عاوز اجيب ال poles:** نساوي المقام ب صفر $(D(\omega) = 0)$ ونحل المعادلة

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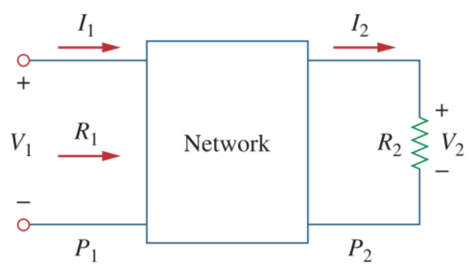
14.3 The Decibel Scale

Gain

- power gain: $G_{dB} = 10\log_{10}\frac{P_2}{P_1}$
- voltage gain: $G_{dB} = 20\log_{10}\frac{V_2}{V_1}$
- current gain: $G_{dB} = 20\log_{10}\frac{I_2}{I_1}$
- tansfer function: $H_{dB} = 20\log_{10}|H(\omega)|$



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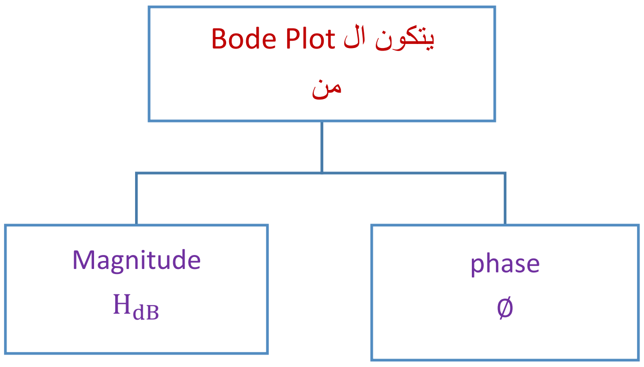
14.4 Bode Plots



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عندما يطلب في المسألة رسم ال bode plot فانه يطلب رسم شيئين:

- Magnitude
- Phase

اولا نجعل ال transfer function $H(s)$ على الشكل القياسي

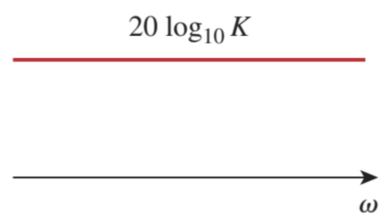
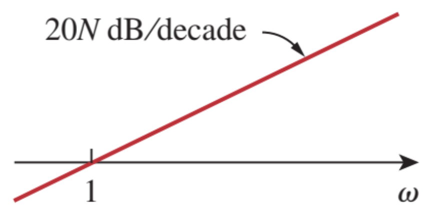
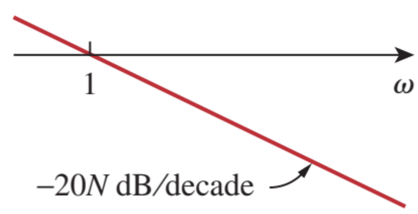
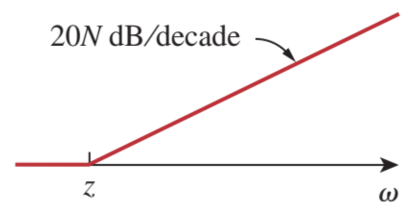
- أي مقدار في البسط هو عبارة عن zero

$$H(s) = \frac{K(j\omega)\left(1+\frac{j\omega}{z}\right)}{\left(1+\frac{j\omega}{p_1}\right)\left(1+\frac{j\omega}{p_2}\right)}$$

- أي مقدار في المقام هو عبارة عن pole

- أي poles له ميل سالب
- اي zero له ميل موجب

نقوم برسم ال magnitude H_{dB} بالقواعد الاتية:

K	
$(j\omega)^N$	
$\frac{1}{(j\omega)^N}$	
$\left(1+\frac{j\omega}{z}\right)^N$	

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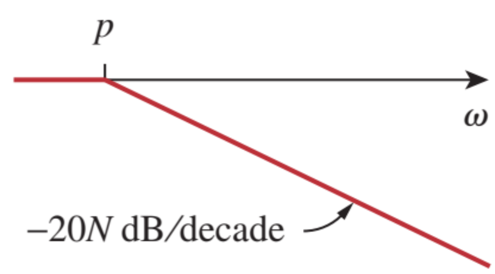
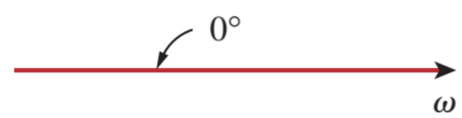
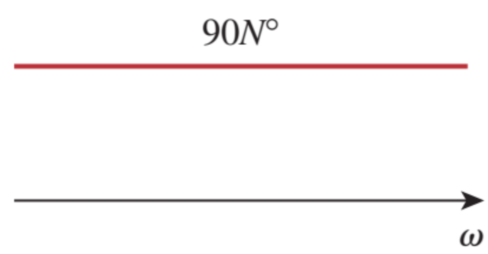
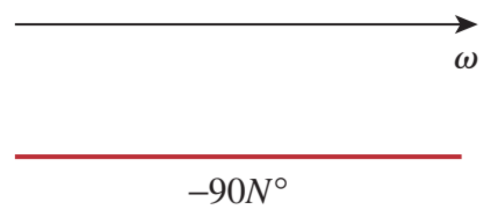
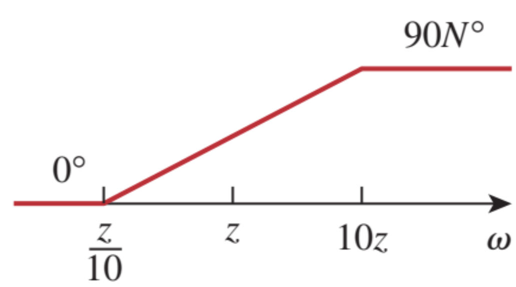
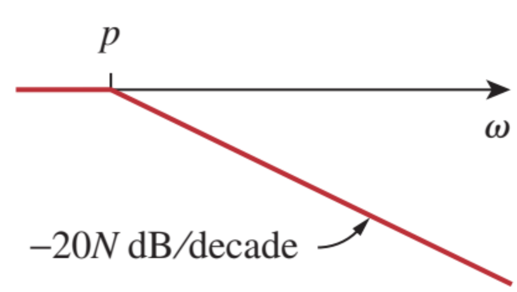
$\frac{1}{\left(1+\frac{j\omega}{p}\right)^N}$	

ارسم ال phase Ø بالقواعد الاتية:

K	
$(j\omega)^N$	
$\frac{1}{(j\omega)^N}$	
$\left(1+\frac{j\omega}{z}\right)^N$	
$\frac{1}{\left(1+\frac{j\omega}{p}\right)^N}$	

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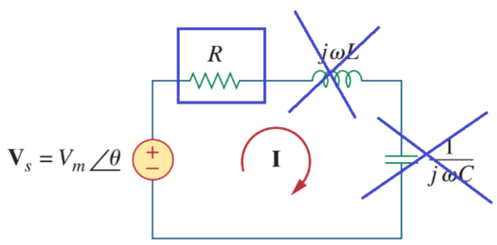
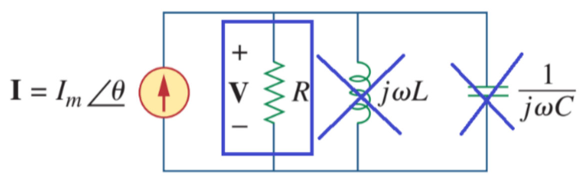
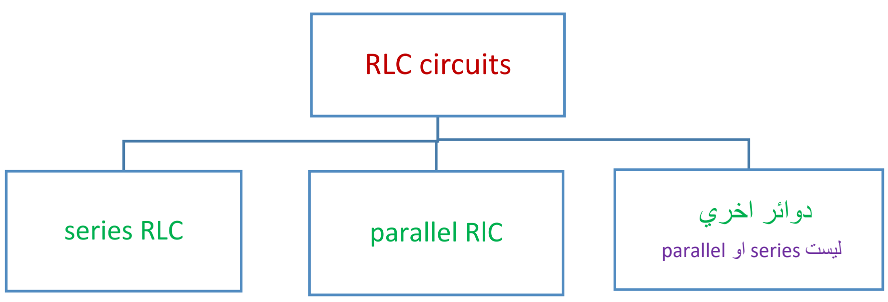
14.5 Series Resonance and 14.6 Parallel Resonance

دائرة الرنين resonance circuit

هي دائرة RLC تلاشي فيها المقاومة الناتجة عن ال L المقاومة الناتجة عن ال C وبالتالي تصبح المقاومة الوحيدة المؤثرة هي ال R وتصبح الدائرة عبارة عن purely resistive impedance

Series RLC circuits	Parallel RLC circuits
	



ملخص قوانين series and parallel RLC circuits

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series and parallel RLC circuits ملخص قوانين	
Resonant frequency ω_o	$\omega_o = \frac{1}{\sqrt{LC}}$ rad/s
Half-power frequencies ω_1, ω_2	$\omega_1 = -\frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}$ $\omega_2 = \frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}$ حالة خاصة: عند $Q \geq 10$ $\omega_1 \approx \omega_o - \frac{B}{2}$ $\omega_2 \approx \omega_o + \frac{B}{2}$
Bandwidth, B	RLC circuit B= $\frac{\omega_o}{Q} = \omega_2 - \omega_1$ series RLC circuits B= $\frac{R}{L}$ parallel RLC circuits B= $\frac{1}{RC}$
Quality factor, Q	RLC circuit $Q = \frac{\omega_o}{B}$ series RLC circuits $Q = \frac{1}{\omega_o CR}$ parallel RLC circuits $Q = \omega_o CR$
dissipated power at resonant frequency, $P(\omega_o)$	$P(\omega_o) = \frac{1}{2}\frac{{V_m}^2}{R}$
dissipated power at cut-off frequency, $P(\omega_1), P(\omega_2)$	$P(\omega_1) = P(\omega_2) = \frac{1}{4}\frac{{V_m}^2}{R}$

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بالنسبة لأي دائرة RLC أخري (ليست series ولا parallel):

طريقة ايجاد ω_0:

الطريقة الاولي:

- احسب ال Z_{eq} الكلية للدائرة
- ضع ال $\mathrm{Im}(Z) = 0$ لأيجاد قيمة ω_o

الطريقة الثانية:

- احسب ال Y_{eq} الكلية للدائرة
- ضع ال $\mathrm{Im}(Y) = 0$ لأيجاد قيمة ω_o

ملاحظات على دوائر الرنين

1. The impedance is purely resistive (the LC series combination acts like a short circuit)
2. The voltage and the current are in phase ($\mathrm{pf} = 1$).

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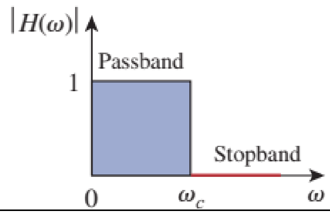
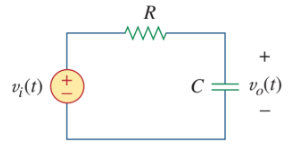
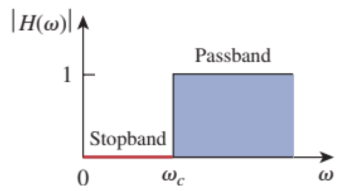
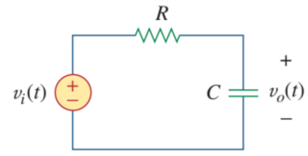
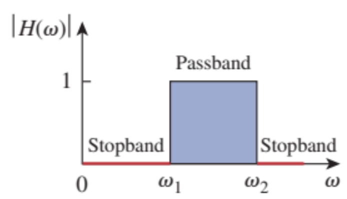
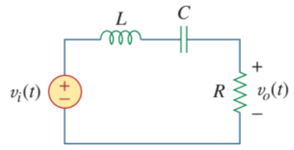
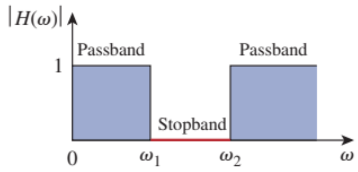
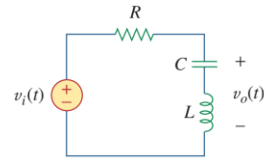
14.7

أي passive filter يتكون من:

Passive filters = resistors + capacitors + Inductors.

passive Filters				
نوع ال Filter	شكل ال Filter	ال transfer function للفلتر	ω_c	دائرة ال filter
low-pass filter		$\mathbf{H}(\omega) = \frac{1}{1 + j\omega RC}$	$\omega_c = \frac{1}{RC}$	
high-pass filter		$\mathbf{H}(\omega) = \frac{j\omega RC}{1 + j\omega RC}$	$\omega_c = \frac{1}{RC}$	
band-pass filter		$\mathbf{H}(\omega) = \frac{R}{R + j(\omega L - \frac{1}{\omega C})}$	$\omega_o = \frac{1}{\sqrt{LC}}$	
band-stop filter		$\mathbf{H}(\omega) = \frac{j(\omega L - \frac{1}{\omega C})}{R + j(\omega L - \frac{1}{\omega C})}$	$\omega_o = \frac{1}{\sqrt{LC}}$	

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Type of filter	$H(0)$	$H(\infty)$	$H(\omega_o)$ or $H(\omega_c)$
Low-pass	1	0	$\frac{1}{\sqrt{2}}$
High-pass	0	1	$\frac{1}{\sqrt{2}}$
Band-pass	0	0	1
Band-stop	1	1	0

ملاحظة هامة:

ال Band-pass filter و band-stop filters هم عبارة عن series RLC circuit وبالتالي يمكن التعامل معهم بنفس القوانين دوائر resonance RLC

14.8 Active Filters

اي active filter يتكون من:

Passive filters = resistors + capacitors + OpAmps.

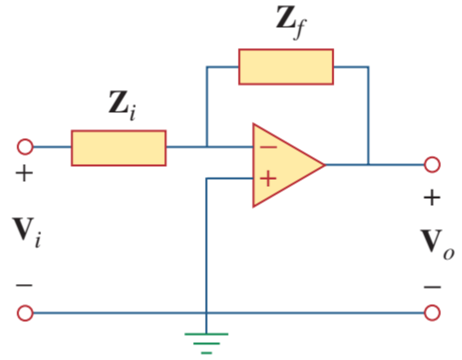
There are three major limitations to the passive filters

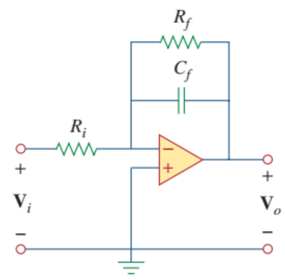
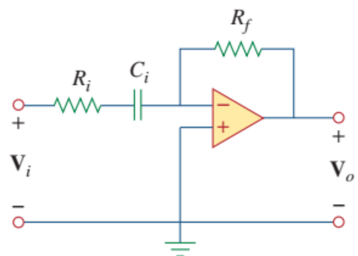
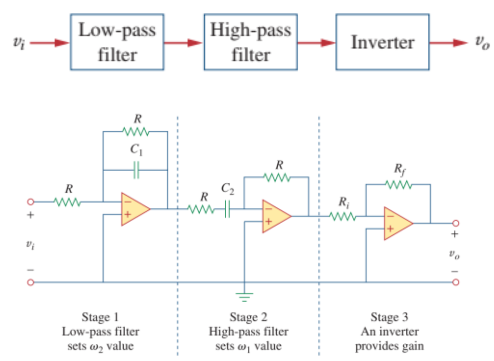
1. they cannot generate gain greater than 1; passive elements cannot add energy to the network.
2. they may require bulky and expensive inductors.
3. they perform poorly at frequencies below the audio frequency range but, passive filters are useful at high frequencies.
4. Active circuits are often smaller and less expensive (because they do not require inductors).
5. active filters can be combined with buffer amplifiers to isolate each stage of the filter from source and load impedance effects.

Filters	Passive Filters	Active Filters
Gain	cannot generate Gain greater than 1. (passive elements cannot add energy to the network.)	Can generate gain greater than one (using buffer amplifiers)
Inductors	Require Inductors	they do not require inductors (so, they are smaller and less expensive)
High frequencies	passive filters are can operate at high frequencies	The practical limit of most active filters can operate below Frequency ≤ 100 kHz
Components	Passive filters = resistors + capacitors + Inductors.	Active filters = resistors + capacitors + opamps.

First Order Filters

ال الشكل العام لدائرة أي فلتر من الدرجة الأولي first order filter



نوع ال First order Filter	ال transfer function للفلتر	Corner frequency ω_c	Gain	دائرة ال filter
low-pass filter	$H(\omega) = -\frac{R_f}{R_i}\frac{1}{1 + j\omega C_f R_f}$	$\omega_c = \frac{1}{C_f R_f}$	dc gain $(at\ \omega \to 0\ )$ $K = -\frac{R_f}{R_i}$	
high-pass filter	$H(\omega) = -\frac{j\omega C_i R_f}{1 + j\omega C_i R_i}$	$\omega_c = \frac{1}{C_i R_i}$	dc gain $(at\ \omega \to \infty)$ $K = -\frac{R_f}{R_i}$	
band-pass filter	$H(\omega) = -\frac{R_f}{R_i}\frac{j\omega\omega_2}{(\omega_1 + j\omega)(\omega_2 + j\omega)}$	$\omega_o = \sqrt{\omega_1\omega_2}$	passband gain $K = \frac{R_f}{R_i}\frac{\omega_2}{\omega_1 + \omega_2}$	
band-stop filter	غير مهم	غير مهم	غير مهم	غير مهم

14.9 Scaling

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