ECE 312
Electronic Circuits (A)

Lec. 12: General Frequency Considerations

Instructor

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Agenda

- Introduction
- Logarithms and Decibels
- General Frequency Considerations
- Normalization Process

Introduction

Introduction

- The analysis thus far has been limited to a particular frequency.
- We will now investigate the frequency effects introduced by the larger capacitive elements of the network at low frequencies and the smaller capacitive elements of the active device at high frequencies.
- Because the analysis will extend through a wide frequency range, the logarithmic scale will be defined and used throughout the analysis.
- In addition, because industry typically uses a decibel scale on its frequency plots, the concept of the decibel is introduced.

Logarithms and Decibels

Logarithms

- We use it to cover a wide range.

$$a = b^x, \qquad x = \log_b a$$

the logarithm of a number taken to a power is simply the power of the number if the number matches the base of the logarithm

$\log_{10} 10^0$	$= 0$
$\log_{10} 10$	$= 1$
$\log_{10} 100$	$= 2$
$\log_{10} 1{,}000$	$= 3$
$\log_{10} 10{,}000$	$= 4$
$\log_{10} 100{,}000$	$= 5$
$\log_{10} 1{,}000{,}000$	$= 6$
$\log_{10} 10{,}000{,}000$	$= 7$
$\log_{10} 100{,}000{,}000$	$= 8$
etc.	

$$\text{Common logarithm:} \quad x = \log_{10} a$$

$$\text{Natural logarithm:} \quad y = \log_e a$$

$$\log_e a = 2.3 \log_{10} a$$

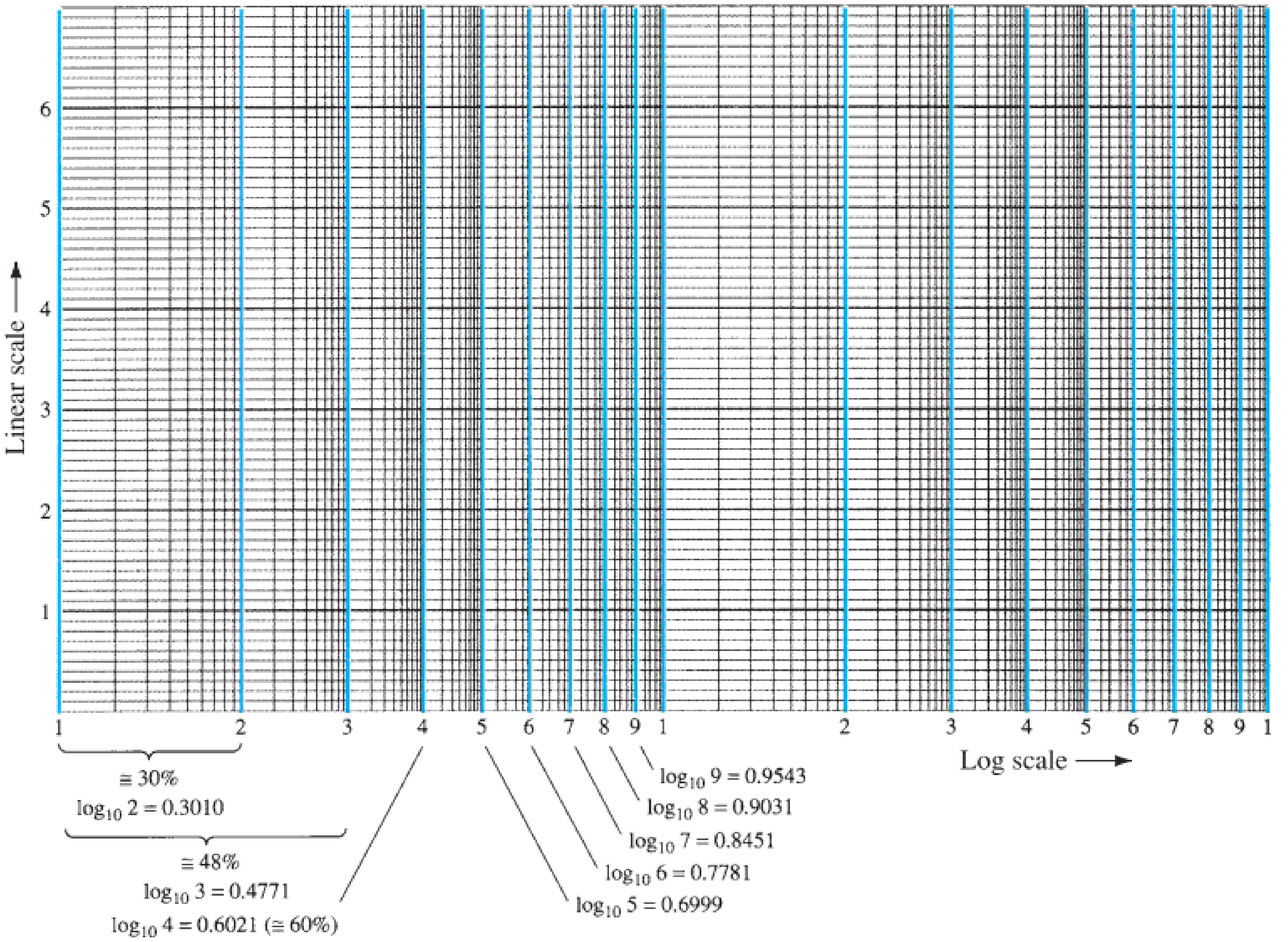
$$\log_{10} 1 = 0$$

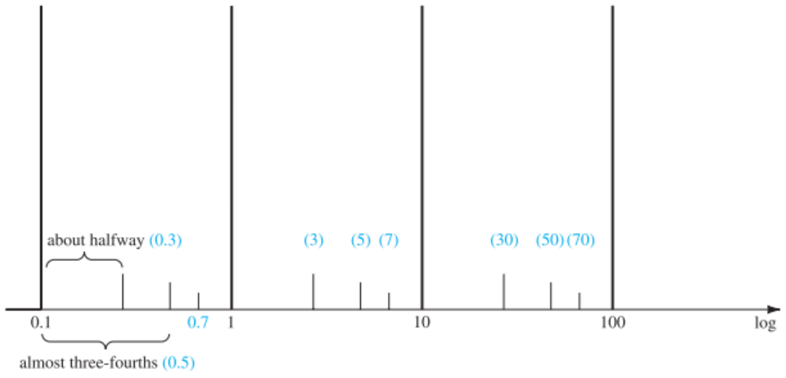
$$\log_{10} \frac{a}{b} = \log_{10} a - \log_{10} b$$

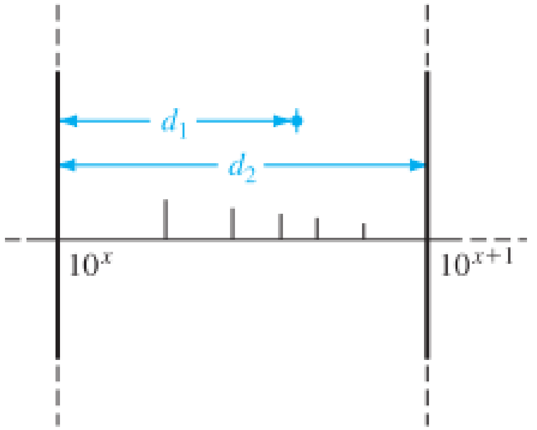
$$\log_{10} \frac{1}{b} = -\log_{10} b$$

$$\log_{10} ab = \log_{10} a + \log_{10} b$$

Semi-log graph paper







$$\text{Value} = 10^x \times 10^{d_1/d_2}$$

Decibels

- **Power Levels**

$$G = \log_{10} \frac{P_2}{P_1} \quad \text{bel}$$

$$G_{dB} = 10 \log_{10} \frac{P_2}{P_1} \quad \text{dB}$$

$$G_{dBm} = 10 \log_{10} \frac{P_2}{1 \text{ mW}}\bigg|_{600\ \Omega} \quad \text{dBm}$$

$$G_{dB} = 10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \frac{V_2^2/R_i}{V_1^2/R_i} = 10 \log_{10}\left(\frac{V_2}{V_1}\right)^2$$

$$G_{dB} = 20 \log_{10} \frac{V_2}{V_1} \quad \text{dB}$$

- Human Auditory Response !

- **Cascaded Stages**

$$|A_{v_T}| = |A_{v_1}| \cdot |A_{v_2}| \cdot |A_{v_3}| \cdots |A_{v_n}|$$

$$G_{dB_T} = G_{dB_1} + G_{dB_2} + G_{dB_3} + \cdots + G_{dB_n} \quad \text{dB}$$

- **Voltage Gains versus dB Levels**

Comparing $A_v = \frac{V_o}{V_i}$ *to dB*

Voltage Gain, V_o/V_i	dB Level
0.5	–6
0.707	–3
1	0
2	6
10	20
40	32
100	40
1000	60
10,000	80
etc.	

Example

EXAMPLE 9.8 An amplifier rated at 40-W output is connected to a 10-Ω speaker.

a. Calculate the input power required for full power output if the power gain is 25 dB.
b. Calculate the input voltage for rated output if the amplifier voltage gain is 40 dB.

Solution:

a. Eq. (9.11): $25 = 10 \log_{10} \frac{40\text{ W}}{P_i} \Rightarrow P_i = \frac{40\text{ W}}{\text{antilog}\,(2.5)} = \frac{40\text{ W}}{3.16 \times 10^2}$

$$= \frac{40\text{ W}}{316} \cong \mathbf{126.5\ mW}$$

b. $G_v = 20 \log_{10} \frac{V_o}{V_i} \Rightarrow 40 = 20 \log_{10} \frac{V_o}{V_i}$

$$\frac{V_o}{V_i} = \text{antilog}\,2 = 100$$

$$V_o = \sqrt{PR} = \sqrt{(40\text{ W})(10\text{ V})} = 20\text{ V}$$

$$V_i = \frac{V_o}{100} = \frac{20\text{ V}}{100} = 0.2\text{ V} = \mathbf{200\ mV}$$

General Frequency Considerations

Low, High & Mid Frequency Range

Variation in $X_C = \frac{1}{2\pi f_C}$ with frequency for a 1-μF capacitor

f	X_C	
10 Hz	15.91 kΩ	Range of possible effect
100 Hz	1.59 kΩ	
1 kHz	159 Ω	
10 kHz	15.9 Ω	
100 kHz	1.59 Ω	Range of lesser concern (≅ short-circuit equivalence)
1 MHz	0.159 Ω	
10 MHz	15.9 mΩ	
100 MHz	1.59 mΩ	

Variation in $X_C = \frac{1}{2\pi fC}$ with frequency for a 5 pF capacitor

f	X_C	
10 Hz	3,183 MΩ	Range of lesser concern (≅ open-circuit equivalent)
100 Hz	318.3 MΩ	
1 kHz	31.83 MΩ	
10 kHz	3.183 MΩ	
100 kHz	318.3 kΩ	Range of possible effect
1 MHz	31.83 kΩ	
10 MHz	3.183 kΩ	
100 MHz	318.3 Ω	

- The larger capacitors of a system will have an important impact on the response of a system in the low-frequency range and can be ignored for the high-frequency region.
- The smaller capacitors of a system will have an important impact on the response of a system in the high-frequency range and can be ignored for the low-frequency region.
- The effect of the capacitive elements in an amplifier are ignored for the mid-frequency range when important quantities such as the gain and impedance levels are determined.

Typical Frequency Response

$$P_{o_{mid}} = \frac{|V_o^2|}{R_o} = \frac{|A_{v_{mid}} V_i|^2}{R_o}$$

$$P_{o_{HPF}} = \frac{|0.707\, A_{v_{mid}} V_i|^2}{R_o} = 0.5 \frac{|A_{v_{mid}} V_i|^2}{R_o}$$

$$\boxed{P_{o_{HPF}} = 0.5\, P_{o_{mid}}}$$

$$\boxed{\text{bandwidth (BW)} = f_H - f_L}$$

The band frequencies define a level where the gain or quantity of interest will be 70.7% of its maximum value.

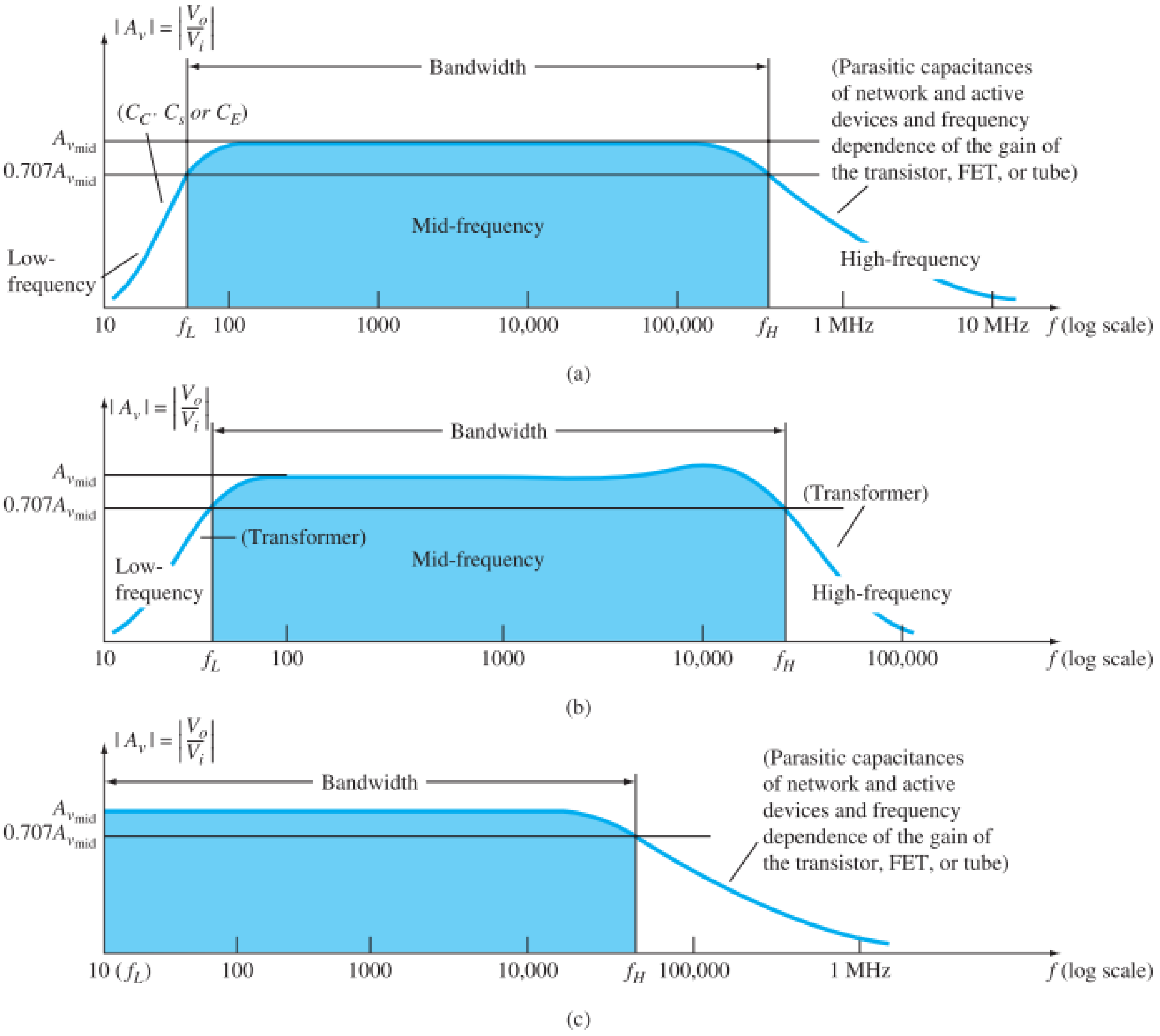


FIG. 9.8

Gain versus frequency: (a) RC-coupled amplifiers; (b) transformer-coupled amplifiers; (c) direct-coupled amplifiers.

Normalization Process

- Normalized plot

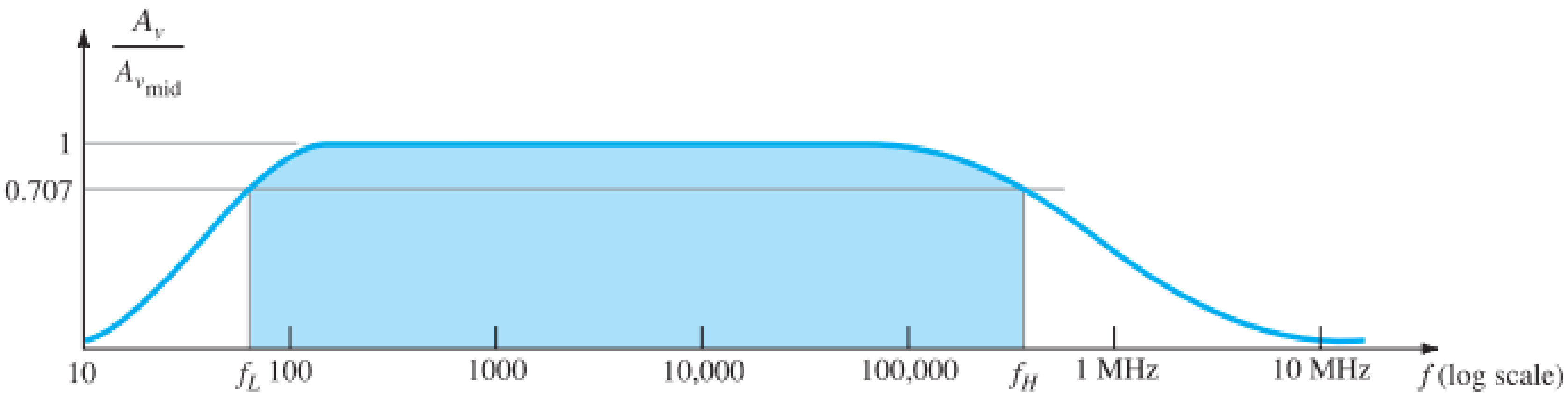


FIG. 9.9

Normalized gain versus frequency plot.

- Decibel plot

$$\left.\frac{A_v}{A_{v_{mid}}}\right|_{dB} = 20 \log_{10} \frac{A_v}{A_{v_{mid}}}$$

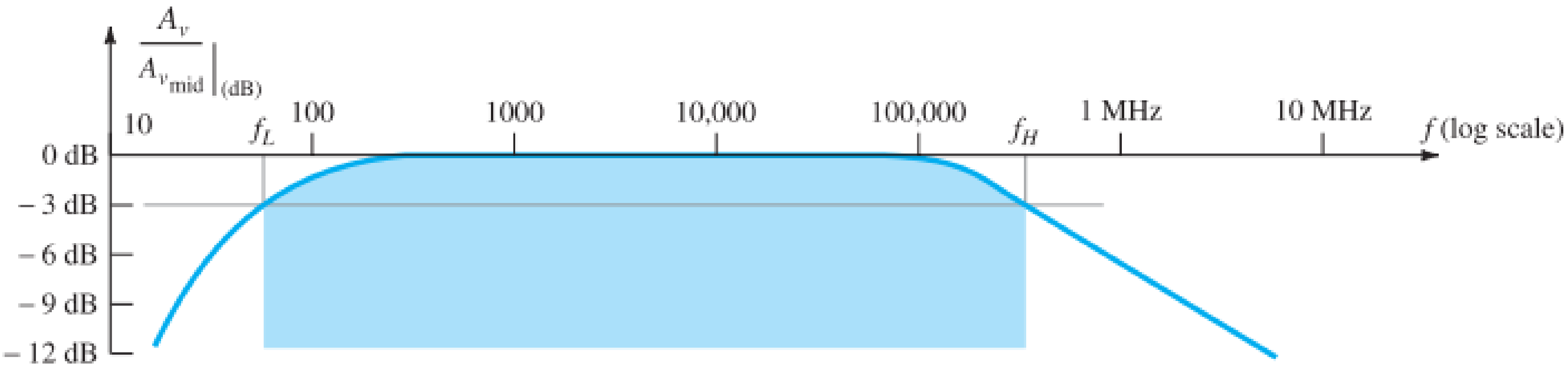


FIG. 9.12

Decibel plot of the normalized gain versus frequency plot of Fig. 9.9.