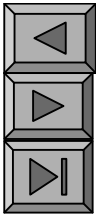
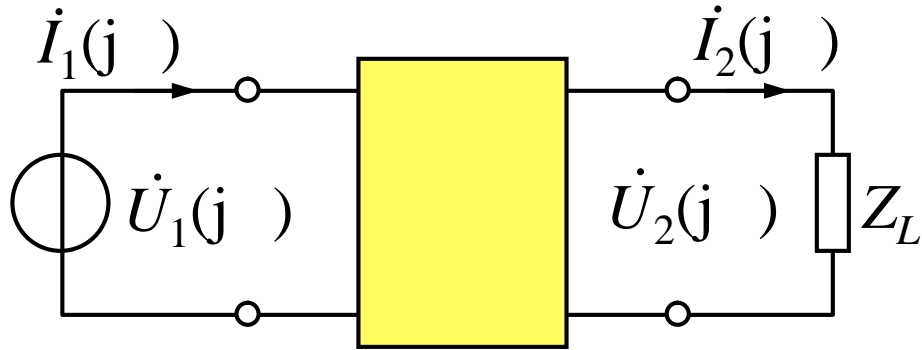


Bode

# 11-1



$$H(j) = \frac{\dot{R}_k(j)}{\dot{E}_{sj}(j)}$$

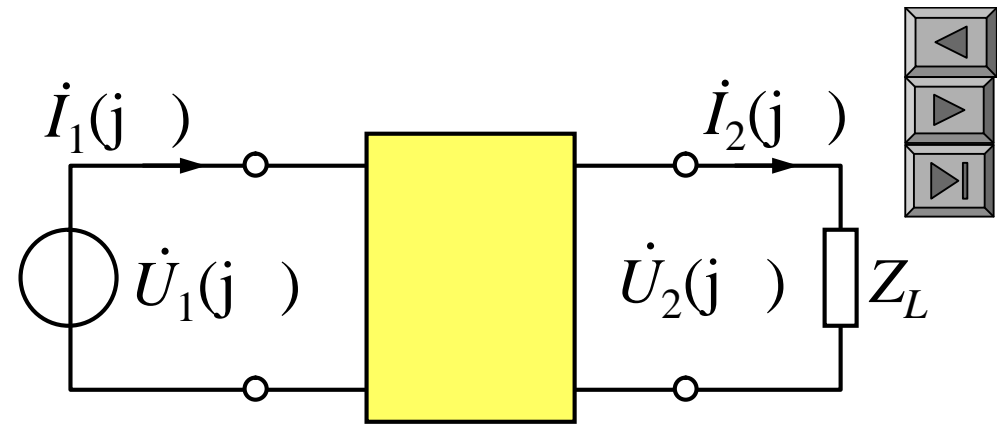


$$H(j) = \frac{\dot{U}_2(j)}{\dot{U}_1(j)}$$

$$H(j) = \frac{\dot{U}_2(j)}{\dot{I}_1(j)}$$

$$H(j) = \frac{\dot{I}_2(j)}{\dot{U}_1(j)}$$

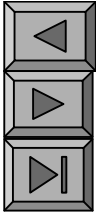
$$H(j) = \frac{\dot{I}_2(j)}{\dot{I}_1(j)}$$



$$H(j) = \frac{\dot{U}_1(j)}{\dot{I}_1(j)}$$

$$H(j) = \frac{\dot{I}_1(j)}{\dot{U}_1(j)}$$

# 11-1 *RLC*



1.

$$\begin{matrix} Z & R & j(X_L & X_C) \\ X_L & X_C & 0 \\ Z & R \end{matrix}$$

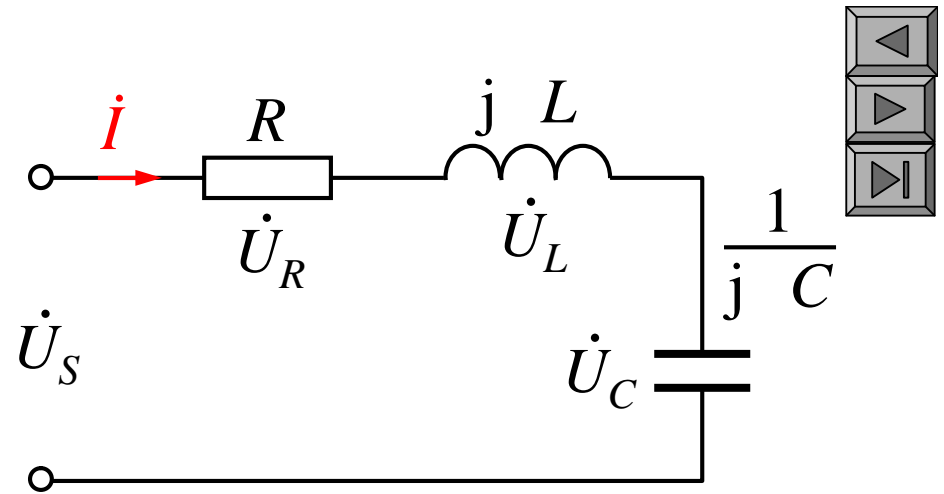


$$L \quad \frac{1}{C}$$



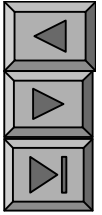
$$\frac{1}{\sqrt{LC}}$$

$$f \quad \frac{1}{2\sqrt{LC}}$$



*RLC*

*L C R*



(1)  $L \quad C$

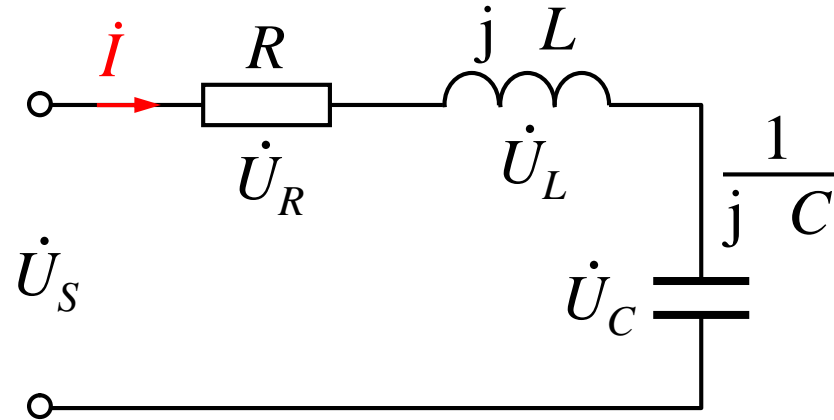
$f \quad L \quad C$

(2)  $f$

$L \quad C \quad C$

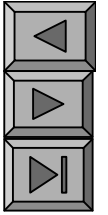
2.

(1)



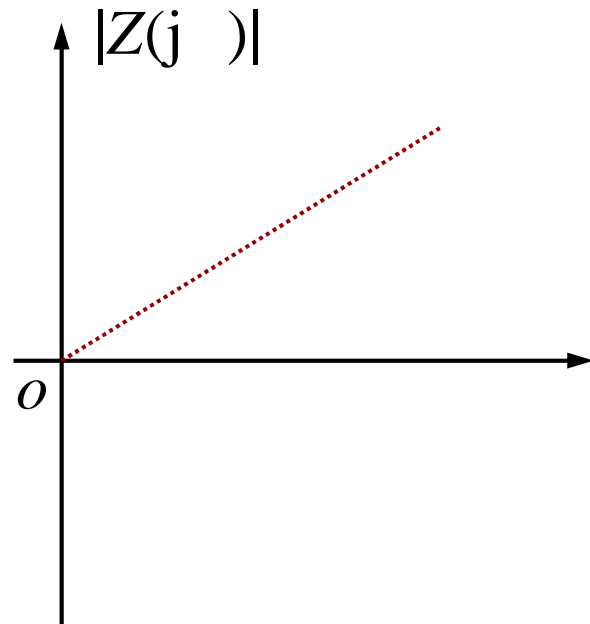
(2)  $Z(j \omega) = R$

$$|I(j \omega)| = \frac{|U_S(j \omega)|}{R}$$

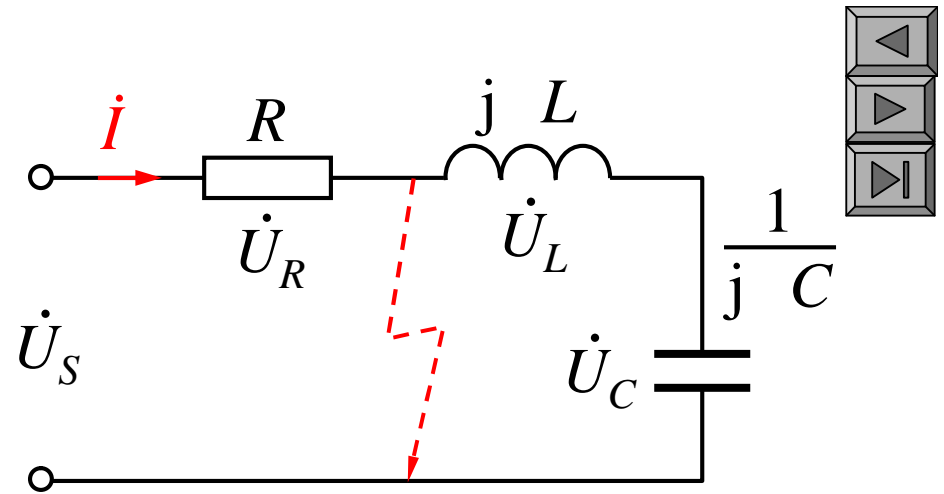


$$|Z(j\omega)|$$

$$Z(j\omega) = R + j\omega L$$



(3)



$$U_X(j\omega) = 0 \quad U_L(j\omega)$$

$$U_C(j\omega)$$

$$U_L(j\omega) = j\omega LI(j\omega) = j\omega L \frac{U_S}{R} = Q U_S$$

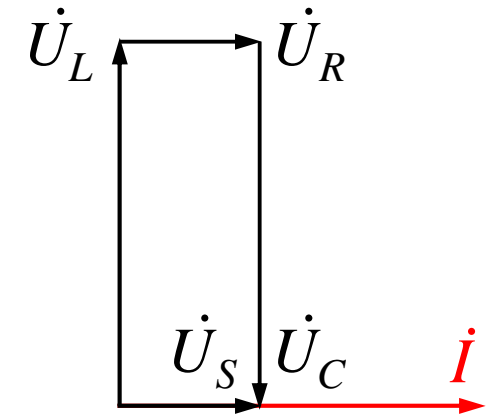
$$U_C(j\omega) = \frac{1}{j\omega C} I(j\omega) = \frac{1}{j\omega C} \frac{U_S}{R} = -Q U_S$$

$$Q = \frac{j\omega L}{R} = \frac{1}{\omega CR} = \frac{1}{R} \sqrt{\frac{L}{C}}$$

$$\frac{U_L(j\omega)}{U_S} = \frac{U_C(j\omega)}{U_S}$$

$$j\omega L \quad \frac{1}{j\omega C} \quad R \quad Q$$

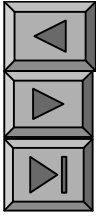
$$U_L(j\omega) \quad U_C(j\omega) \quad U_S$$







*L C*



*L C*

$$L \ 0.3\text{mH} \quad R \ 10$$

$$560\text{kHz}$$

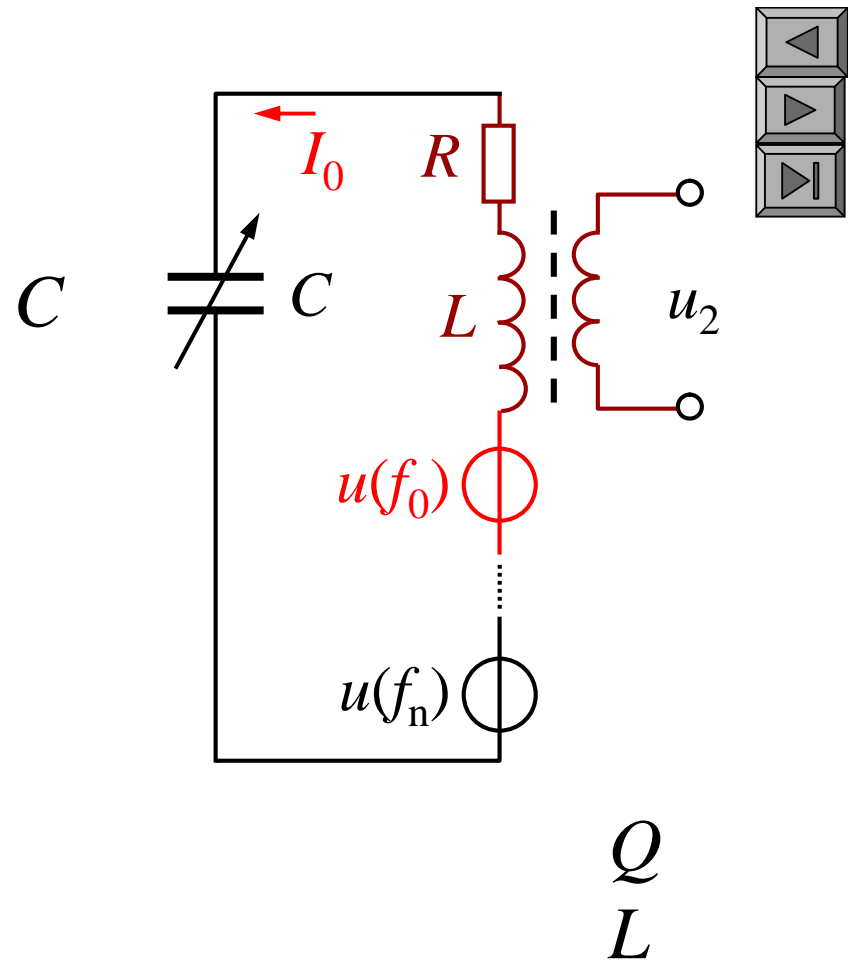
$$1.5 \text{ V}$$

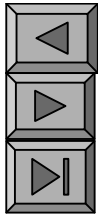
$$C = \frac{1}{(2 f_0)^2 L} = 269\text{pF}$$

$$I_0 = \frac{U}{R} = \frac{1.5}{10} \text{ A}$$

$$U_C = I_0 \frac{1}{C} = 1.5 \text{ V}$$

$$Q = 106$$



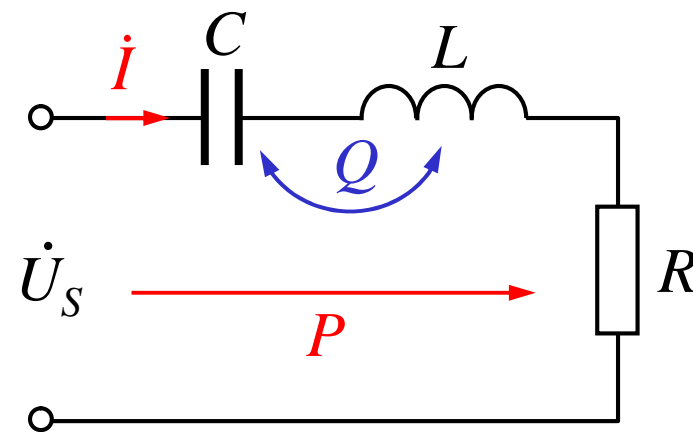


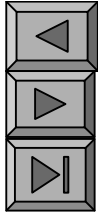
(4)

$$P(j\omega) = U_S I(j\omega) = I^2(j\omega)R$$

$$Q(j\omega) = Q_L(j\omega) - Q_C(j\omega)$$

$$\omega LI^2(j\omega) - \frac{1}{\omega C} I^2(j\omega)$$





(5)

$$i = I_m \cos \omega t$$

$$u_C = U_{Cm} \sin \omega t = I_m \omega L \sin \omega t$$

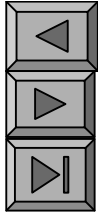
$$w_L = \frac{1}{2} L i^2 = \frac{1}{2} L I_m^2 \cos^2 \omega t$$

$$w_C = \frac{1}{2} C u_C^2 = \frac{1}{2} C I_m^2 \omega^2 \sin^2 \omega t$$



$$W = W_L + W_C = \frac{1}{2} L I_m^2 \cos^2 \omega t + \frac{1}{2} C I_m^2 \omega^2 \sin^2 \omega t = C Q^2 U_S^2$$





$$Q = \frac{\omega L}{R} \quad \frac{\omega L I^2(j\omega)}{R I^2(j\omega)} \quad \frac{|Q_L(j\omega)|}{P(j\omega)} \quad \frac{|Q_C(j\omega)|}{P(j\omega)}$$

$$\frac{\omega L I^2(j\omega)}{T_0 R I^2(j\omega)} \rightarrow$$



Q

“ ”

Q

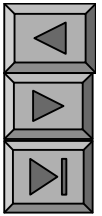
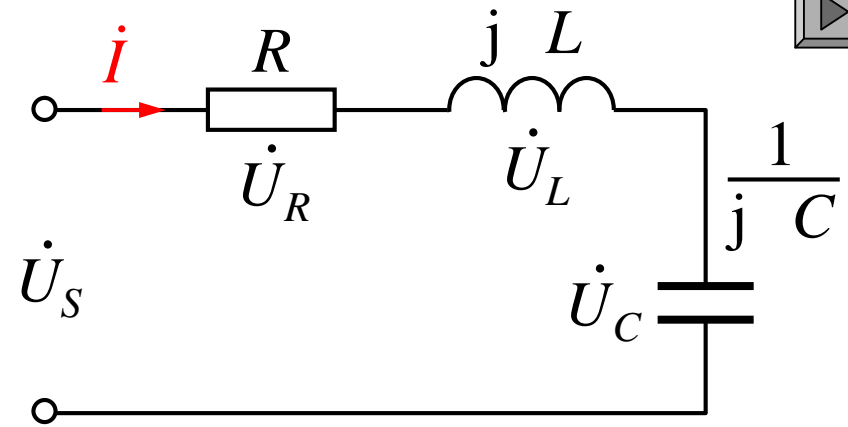
# 11-3 RLC



$u_S$

$R$

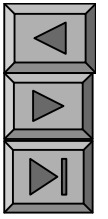
$L \quad C$

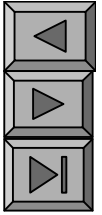


$\frac{R}{0}$

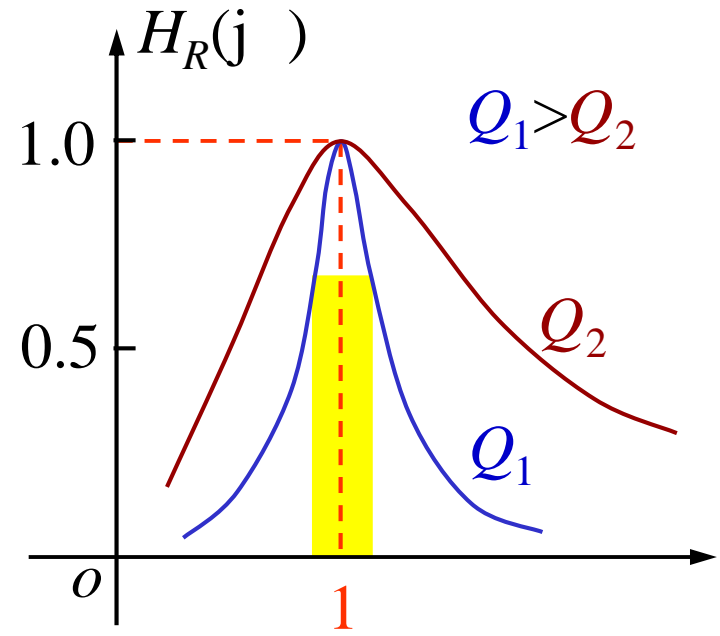
1.

$$H_R(j\omega) = \frac{\dot{U}_R(j\omega)}{\dot{U}_S(j\omega)} = \frac{R}{Z(j\omega)}$$





0  
0  
1 2



0



*Q*

0







( )

0.707

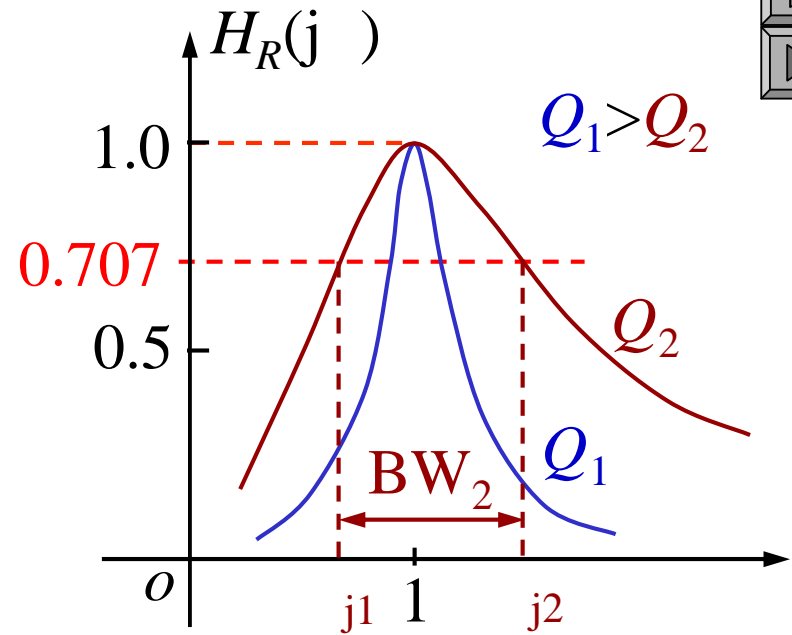
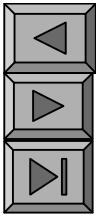
j1

j2

j2 j1)

$$\frac{1}{\sqrt{1 + Q^2 \left(\frac{\omega}{\omega_0} - \frac{1}{Q}\right)^2}} \quad \frac{1}{\sqrt{2}}$$

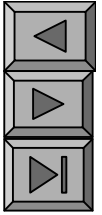
$$Q^2 \left(\frac{\omega}{\omega_0} - \frac{1}{Q}\right)^2 = 1$$



$$Q = \frac{1}{BW}$$

$$BW = \frac{1}{Q}$$

$$BW = \frac{0}{Q}$$

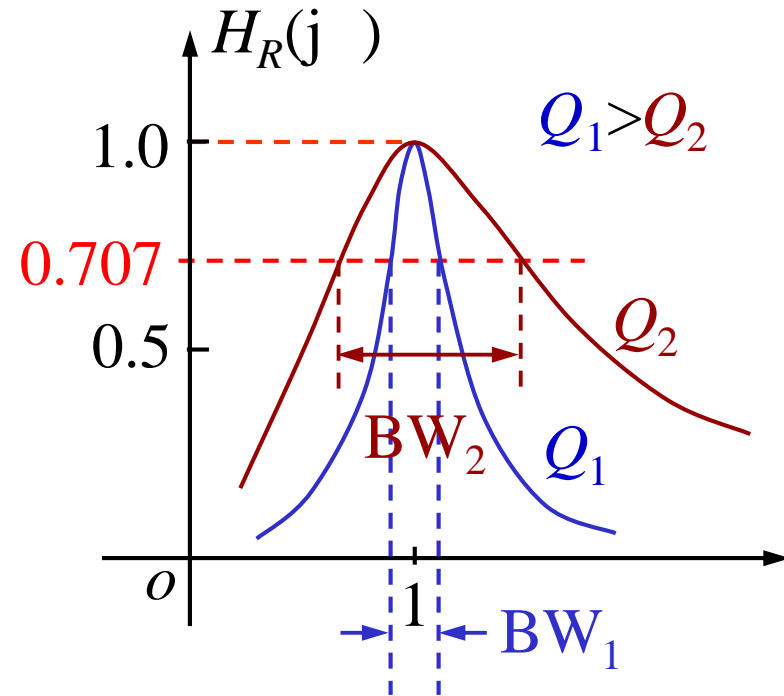


$$BW \quad j_2 \quad j_1 \quad \frac{0}{Q} \quad Q$$

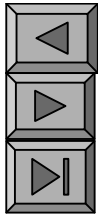
$BW$



$Q$



$Q$



2.

$$H_C(j\omega) = \frac{\dot{U}_C(j\omega)}{\dot{U}_S(j\omega)} = \frac{jQ}{jQ^2}$$

$$\dot{U}_C(j\omega) = \dot{U}_R(j\omega) \cdot 90^\circ$$

$$|H_C(j\omega)| = \frac{Q}{\sqrt{Q^2}}$$

$$c2 \sqrt{\frac{1}{4Q}}$$

$$\frac{d|H_C(j\omega)|}{d\omega}$$



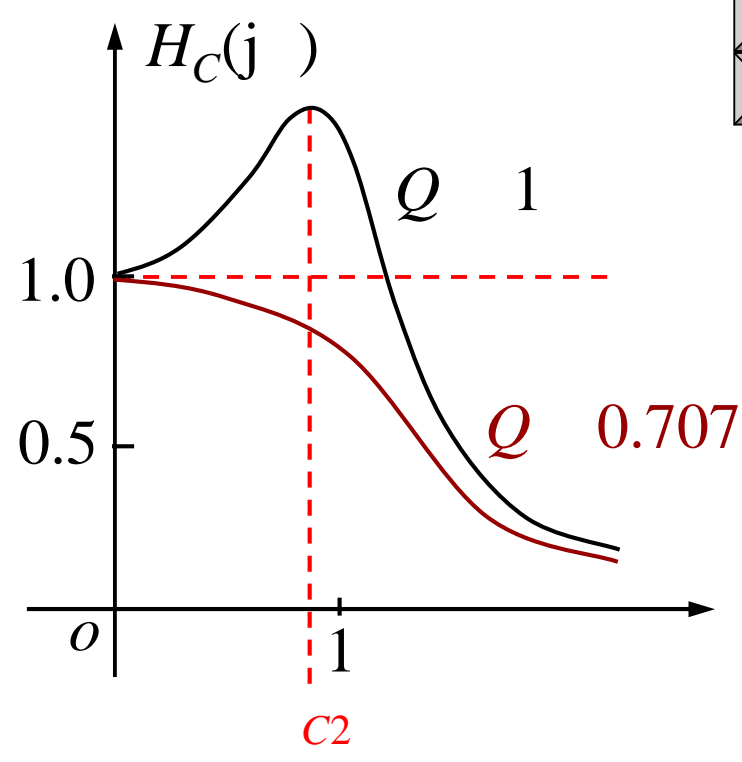
$$c_2 \sqrt{\frac{Q}{4Q}} = 1$$

$$|H_C(j \omega)| = \frac{Q}{\sqrt{\frac{Q}{4Q}}}$$

$$Q \frac{1}{\sqrt{2}}$$

$$Q \frac{1}{c_2} = 1$$

$$|H_C(j \omega)| = 1$$

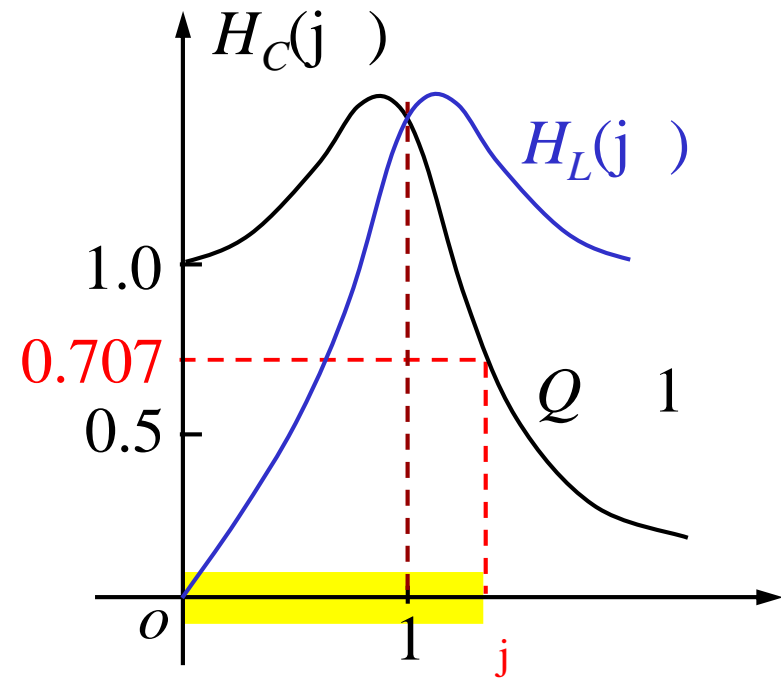
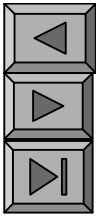
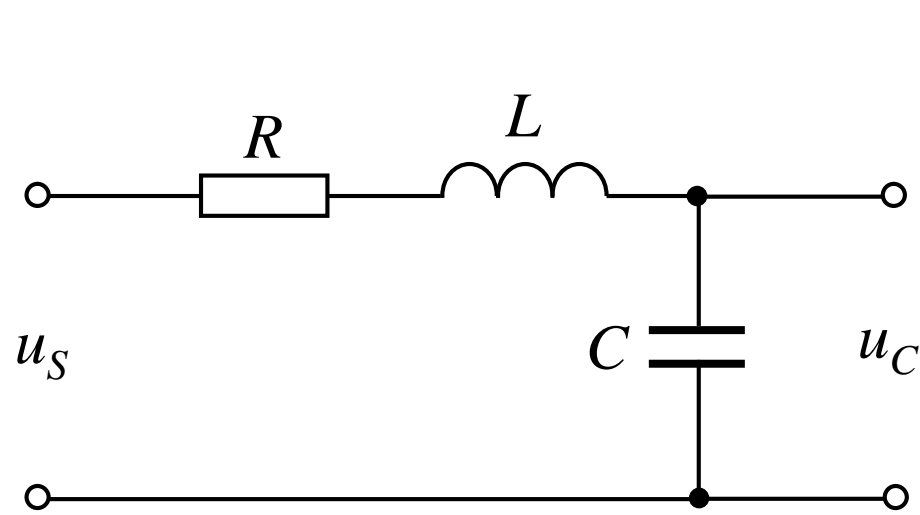


$$|H_C(j\omega)| = \frac{1}{\sqrt{2}}$$

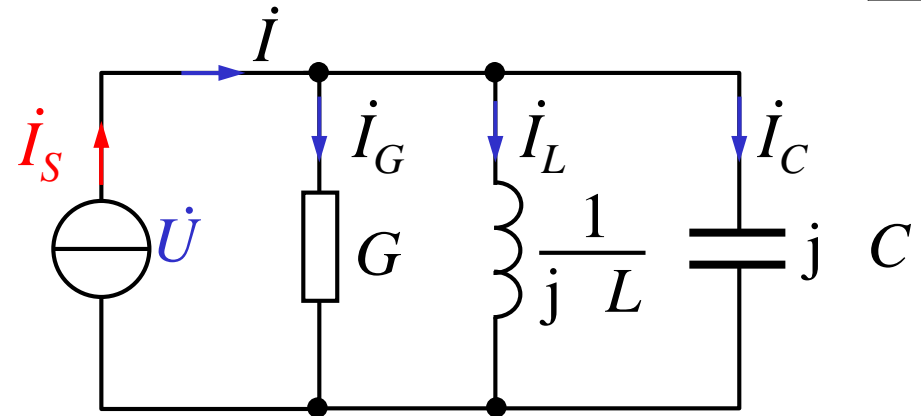
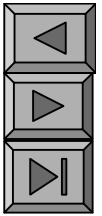
$$j\omega = 1.55$$

3.

$$|H_L(j\omega)| = |H_C(j\omega)|$$



# 11-4 RLC



$$Y(j\omega) = G + j\left(\omega C - \frac{1}{\omega L}\right)$$

1.

$$\omega_0 C = \frac{1}{\omega_0 L} \Rightarrow 0$$



$$\frac{1}{\sqrt{LC}}$$

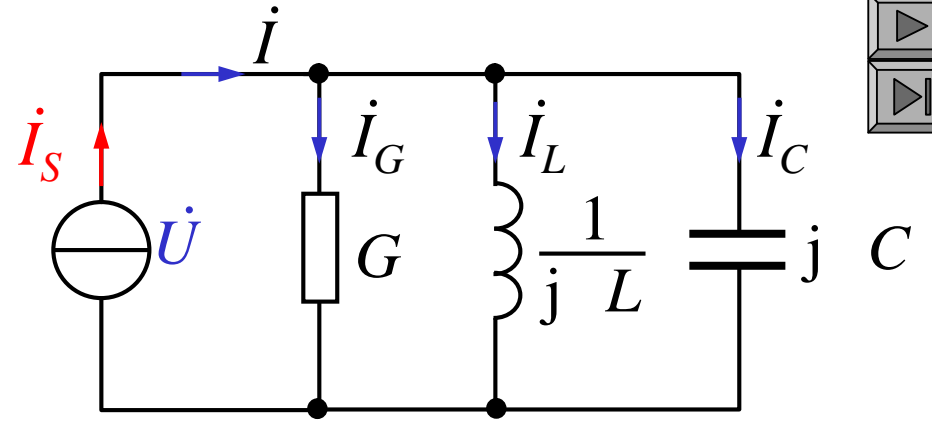
$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$G \quad L \quad C$

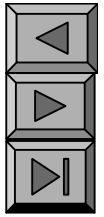
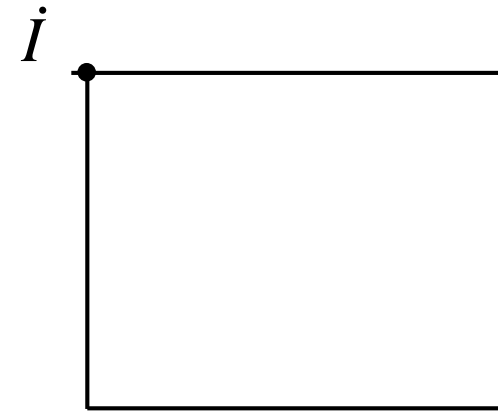
2.

(1)

(2)



$$I_L(0)$$



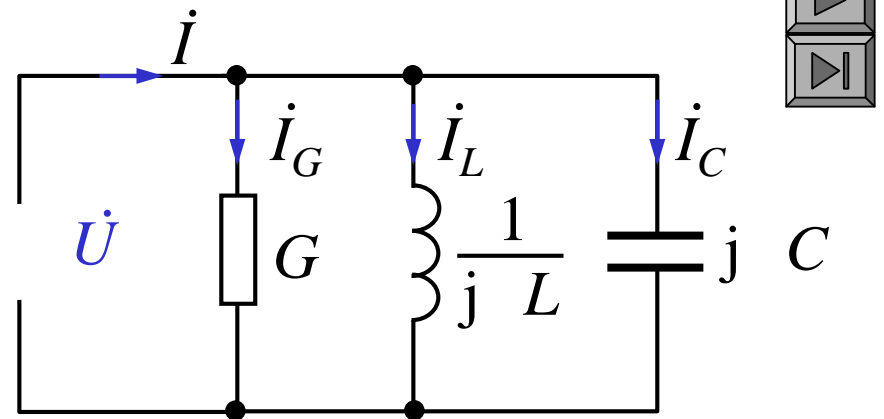


3.

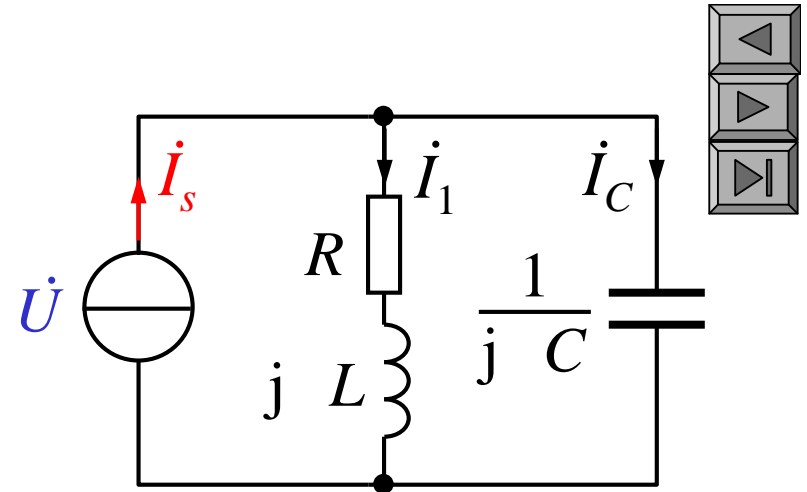
$$Q_C = \frac{1}{2} C U^2$$

$$Q_L = \frac{1}{2} L U^2$$

$Q$



4.



$$Y(j\omega) = \frac{1}{R + j\omega L} + j\omega C$$

$$\frac{R}{R^2 + (\omega L)^2} + j\omega C$$

$$\text{Im}[Y(j\omega)]$$

$$C - \frac{L}{R^2 + (\omega L)^2}$$

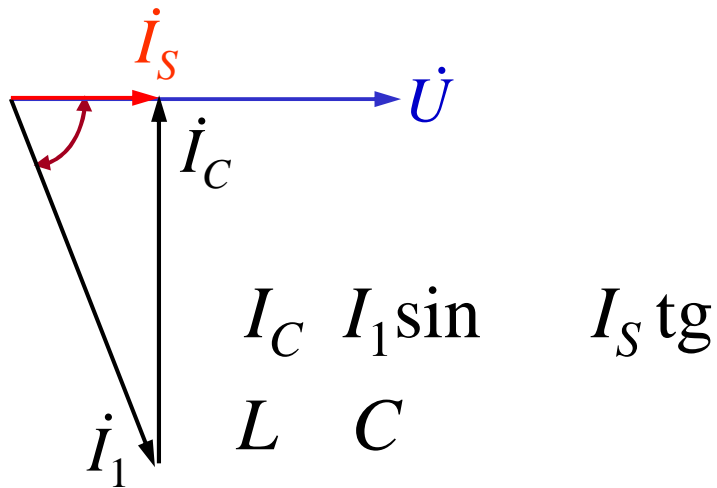
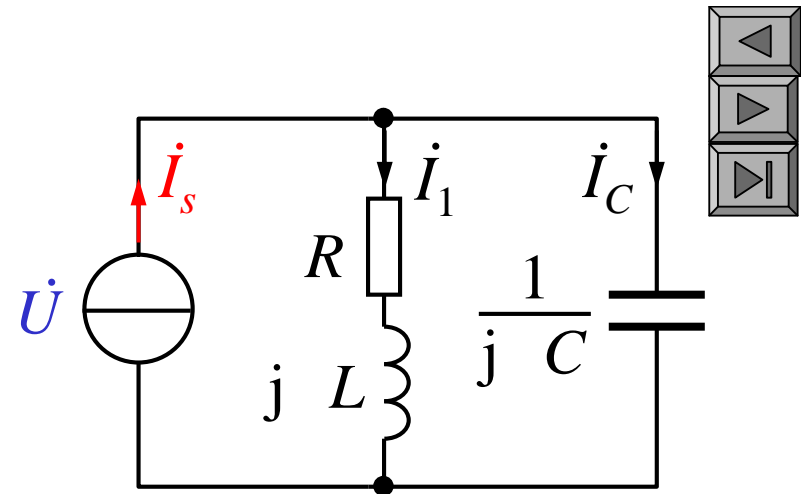
$$\omega = \frac{1}{\sqrt{LC}} \sqrt{1 - \frac{CR^2}{L}}$$

$$1 - \frac{CR^2}{L} > 0$$

$$R = \sqrt{\frac{L}{C}} \quad \omega = 0$$

$$R > \sqrt{\frac{L}{C}}$$

$$Y(j\omega) = \frac{C}{R^2 + (\omega L)^2} + \frac{RC}{L} \frac{1}{Z(j\omega)} = \frac{L}{RC}$$



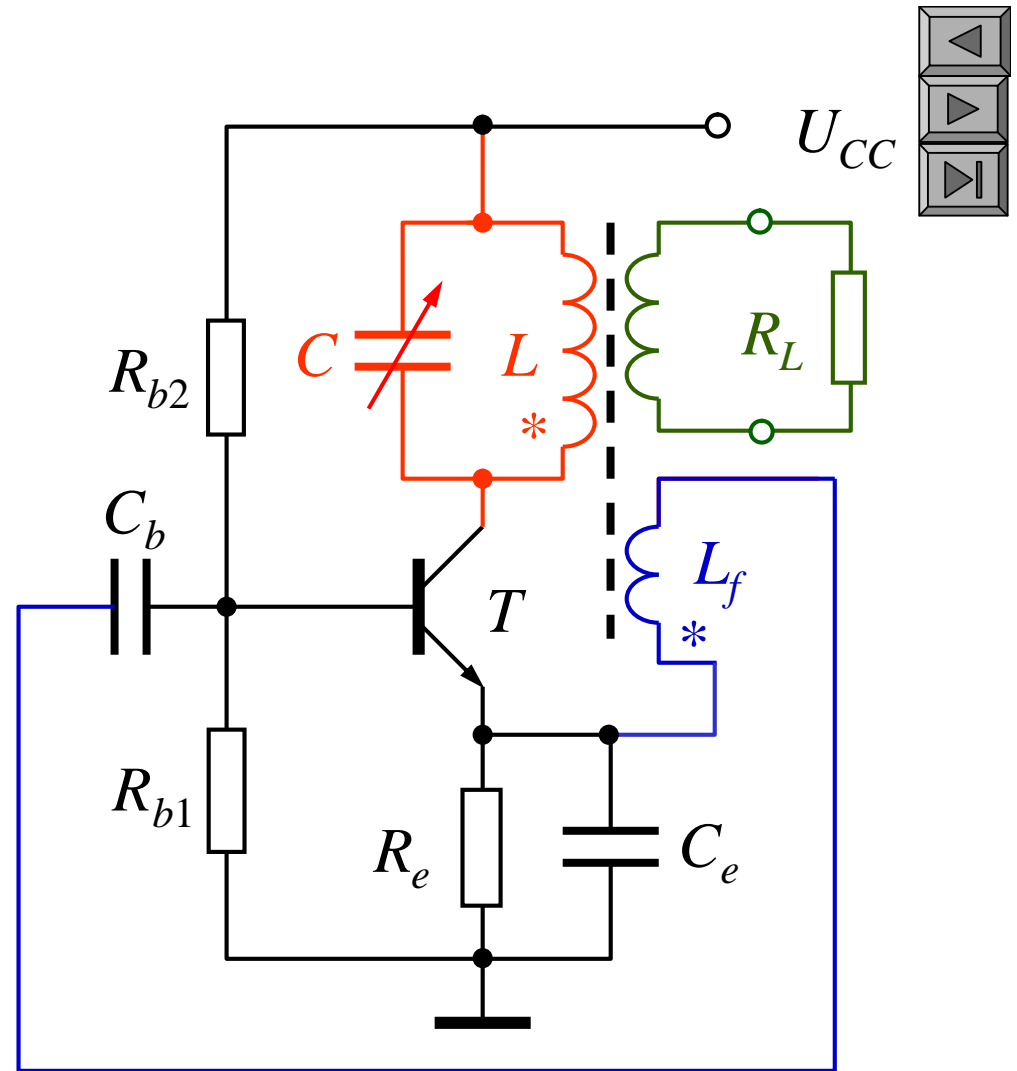
$$Q = \frac{1}{\sqrt{LC}} \left( \frac{\omega L}{R} - \frac{1}{\omega C} \right) = \frac{1}{R} \sqrt{\frac{L}{C}} \left( \frac{I_1}{I_s} - \frac{I_C}{I_s} \right)$$

$LC$

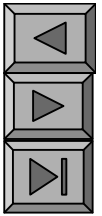
$L$

$$f = \frac{1}{2\sqrt{LC}}$$

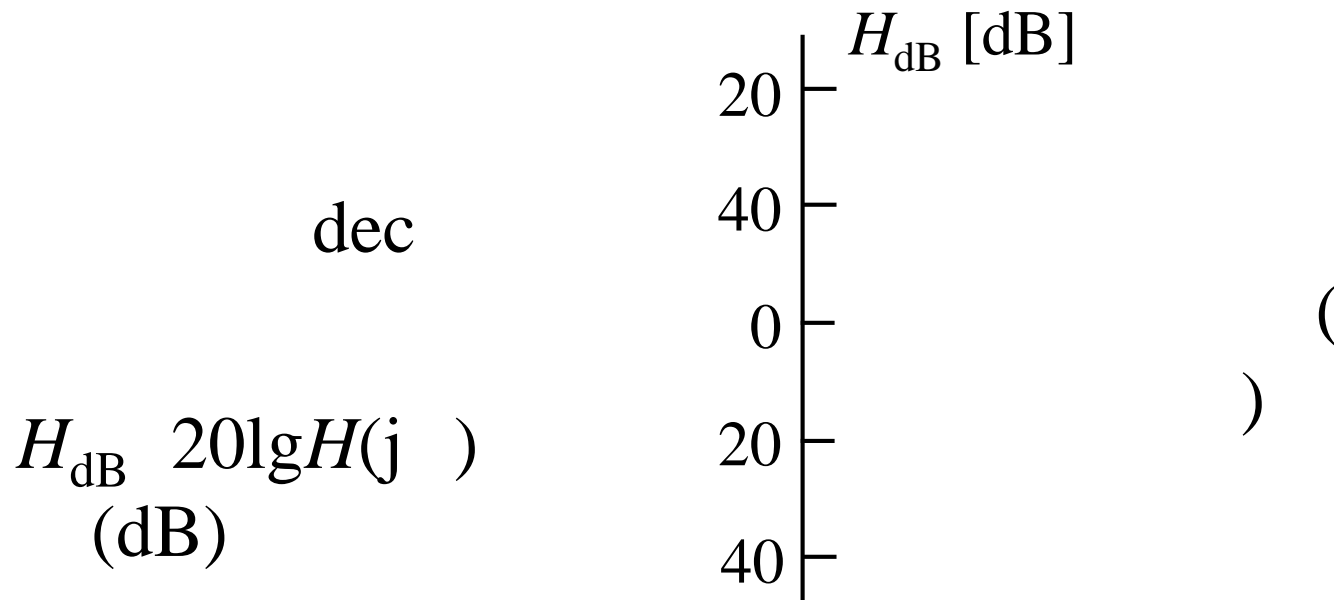
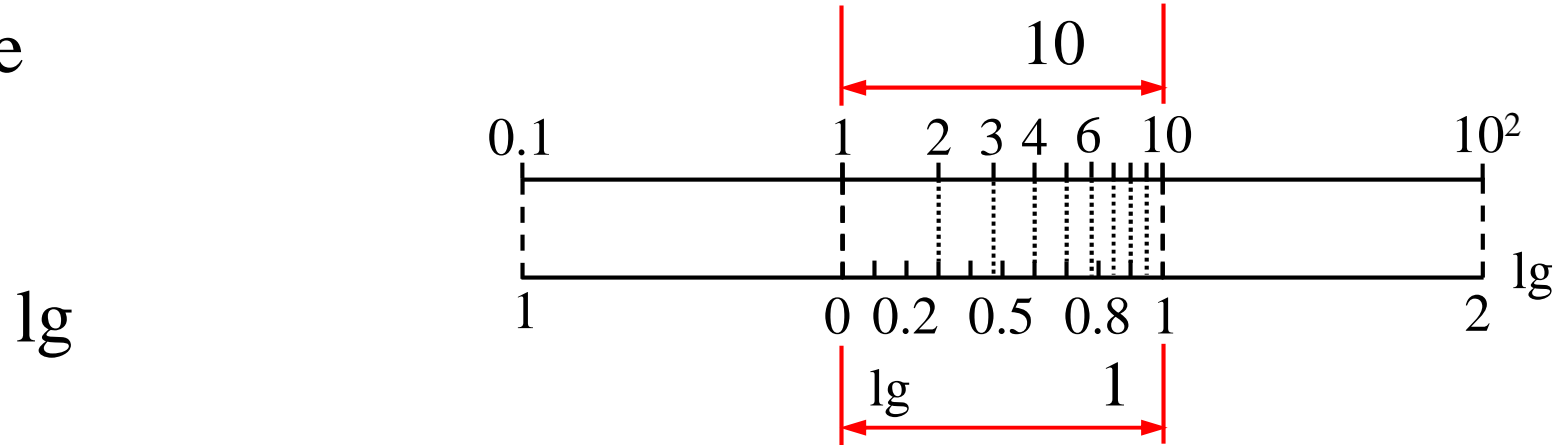
$C$

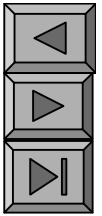
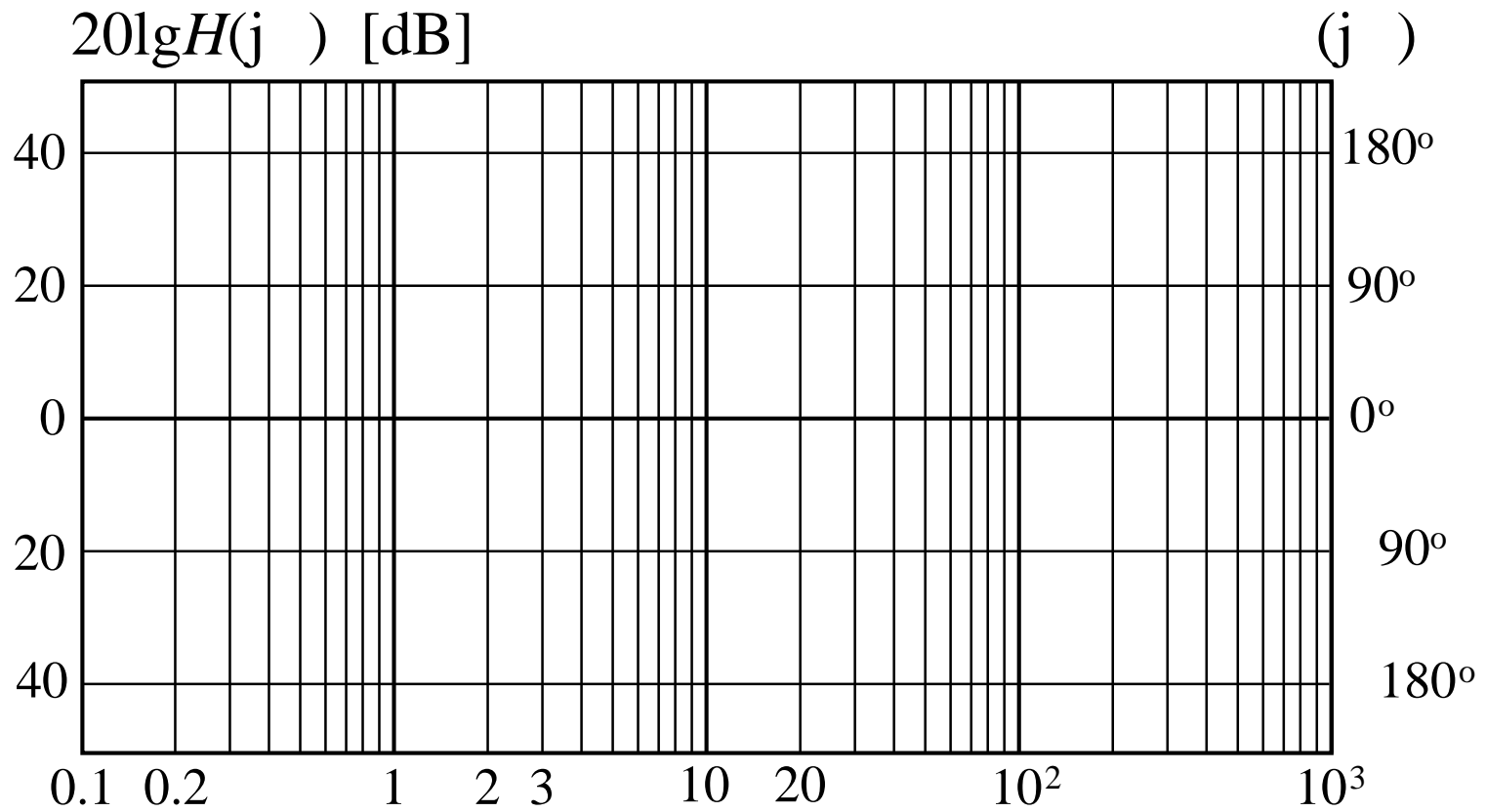


# 11 5 (Bode)

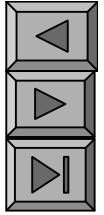


 Bode





( )



11 4

Bode

$$H(j\omega) = \frac{j200}{(j\omega/2)(j\omega/10)}$$

$$\frac{j10}{(1 - j\omega/2)(1 - j\omega/10)}$$

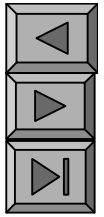
$$H_{dB} = 20\lg(10) + 20\lg|1 - j\omega/2| + 20\lg|1 - j\omega/10|$$

$$90^\circ = \arctg(\omega/2) + \arctg(\omega/10)$$

$$20\lg(10) = 20\lg(10) = 0\text{dB}$$

$$20\lg(10) = 0\text{dB}$$

$$(0) \quad 20\text{dB/dec}$$



$$H_{dB} = 20\lg(10) + 20\lg|1 - j/2| + 20\lg|1 - j/10|$$

$$20\lg|1 - j/2|$$

$$20\lg|1 - j/2| \approx 0\text{dB}$$

$$20\lg|1 - j/2| \approx 20\lg(1/2)$$

$$20\lg(1/2) \approx 0$$

$$(2 \quad 0)$$

$$20\lg(1/2) \approx 20\text{dB}$$

$$20\text{dB/dec}$$

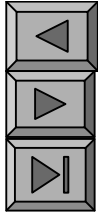
$$20\lg|1 - j/10|$$

$$20\lg|1 - j/10| \approx 0\text{dB}$$

$$(10 \quad 0)$$

$$20\text{dB/dec}$$





$90^\circ \arctg(1/2) \arctg(1/10)$

$90^\circ$

0.1

$0^\circ$

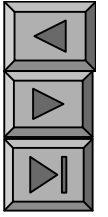
10

$90^\circ$

(0.1~10)

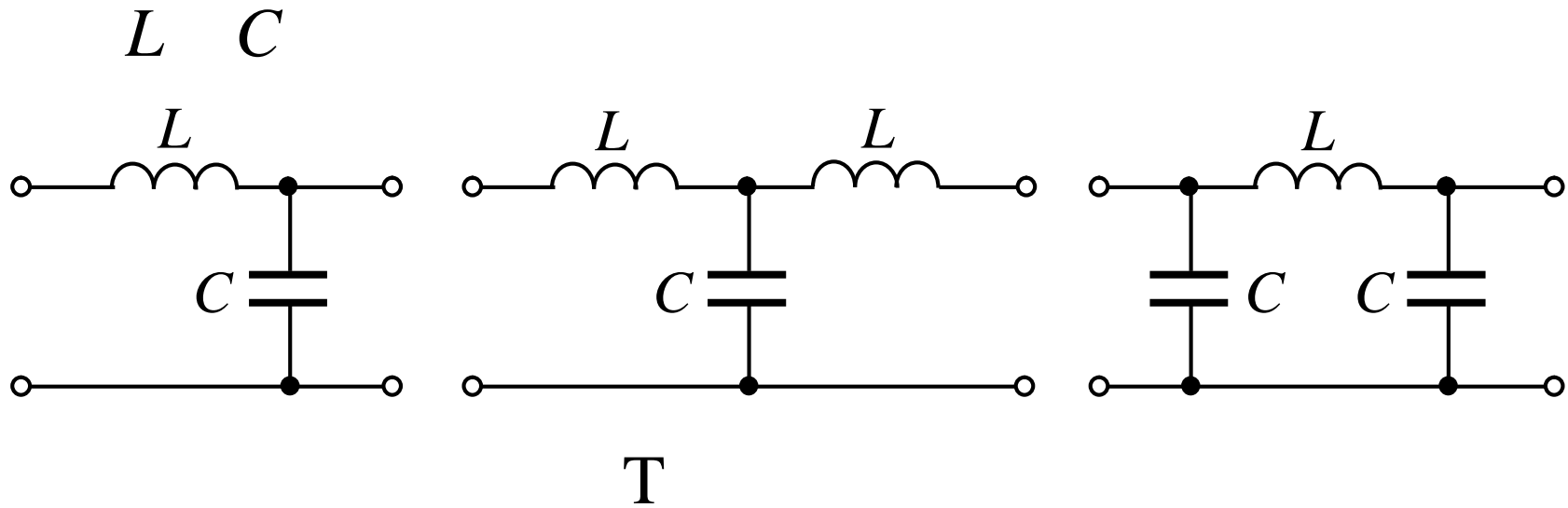
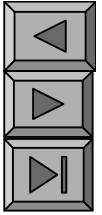
$45^\circ/\text{dec}$

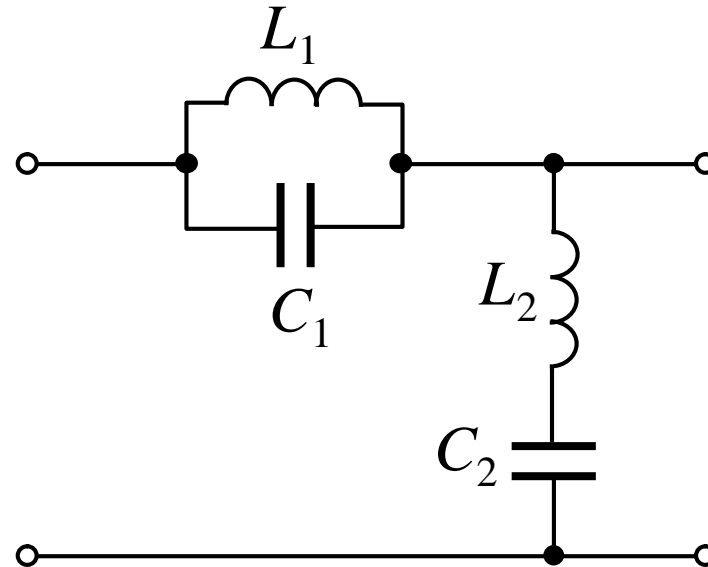
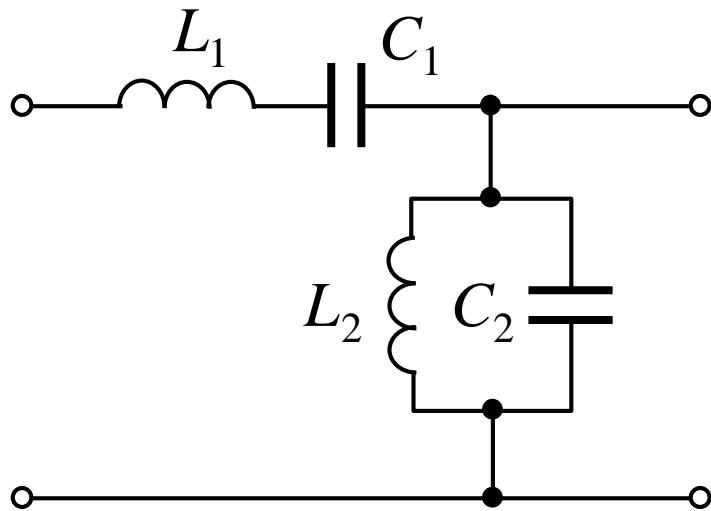
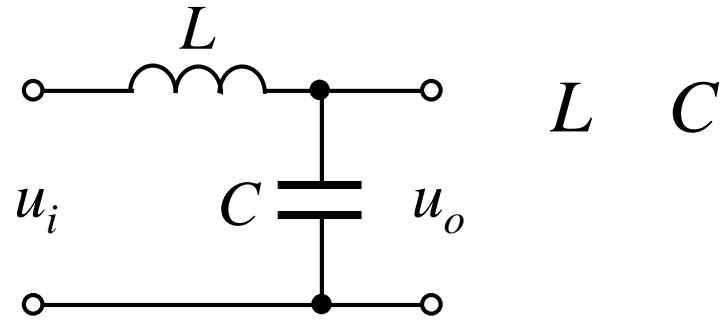
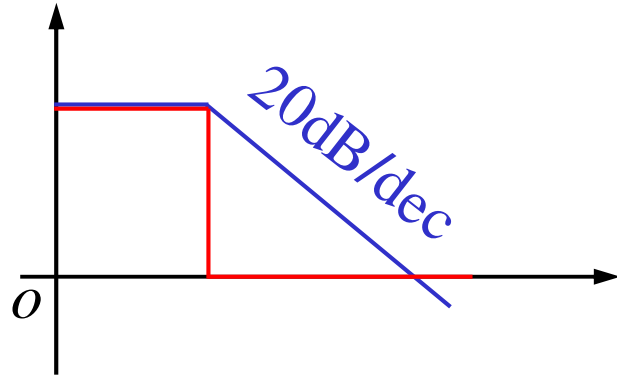
11 6

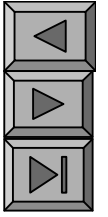


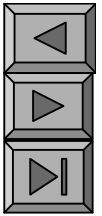
*LC*

*RC*



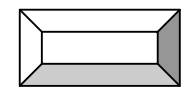
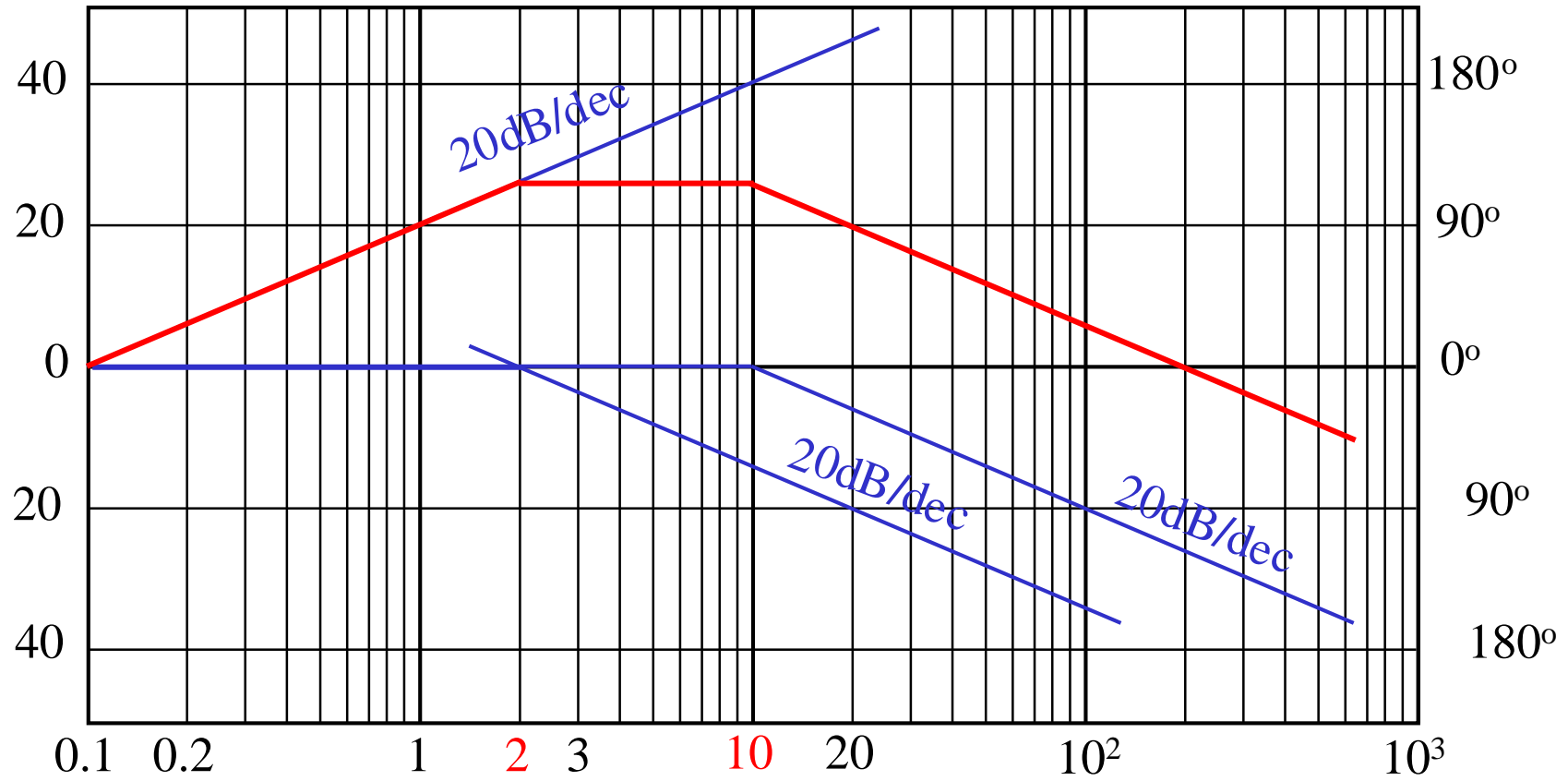


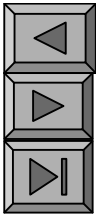




$20\lg H(j\omega)$  [dB]

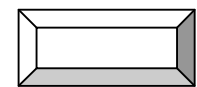
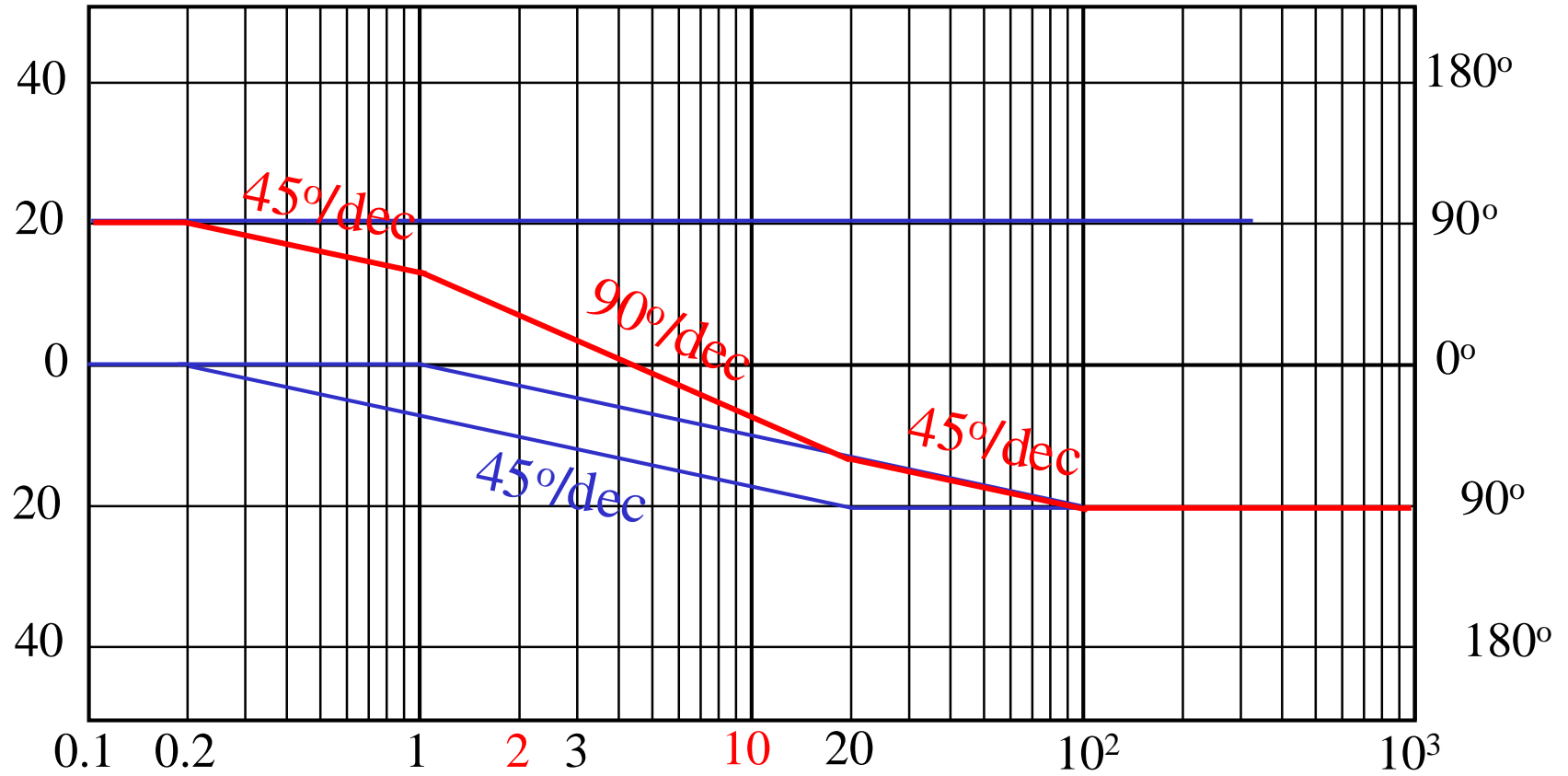
$\angle H(j\omega)$

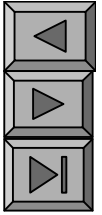




$20\lg H(j\omega)$  [dB]

$(j\omega)$





$$(1) H(j\omega) = \frac{1}{10j}$$

$$H(j\omega) = \frac{0.1}{1j}$$

10

$$H_{dB} = 20\lg 0.1 - 20\lg|1j| - 20$$

10

20dB

$$H_{dB} = 20\lg 0.1 - 20\lg(\omega/10)$$

(10 20)

20dB/dec

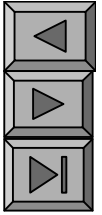
20dB

10

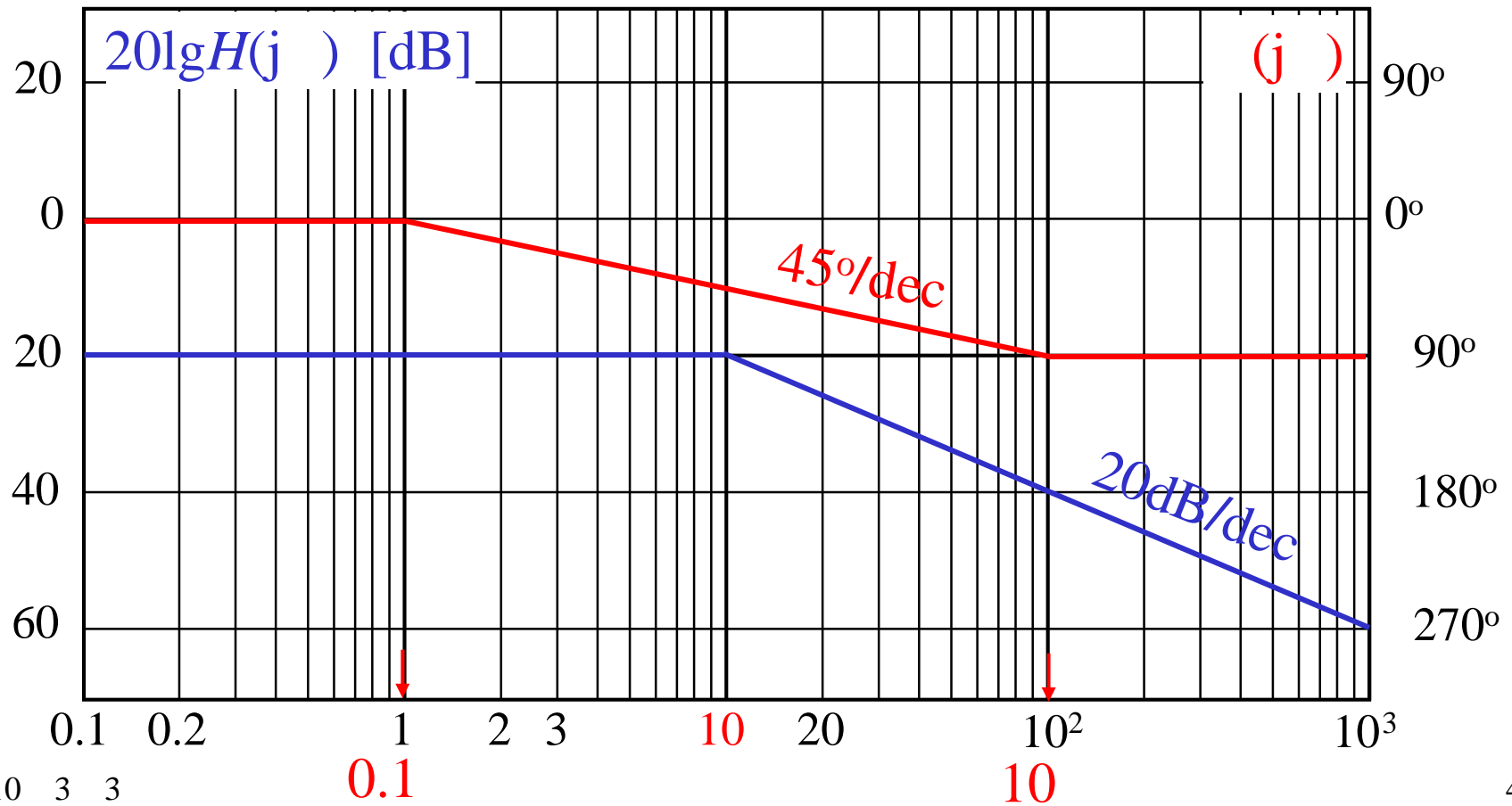
20dB/dec

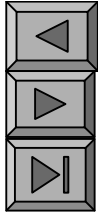
$$\arctg(\omega/10)$$





0.1 ( 10 ) 0°  
10 ( )  
(0.1~10) 45°/dec





$$11 \quad 19 \quad (2) \quad H(j\omega) = \frac{5j\omega^2}{j\omega(j\omega + 10)} \frac{1j\omega}{j\omega + 1}$$

$$H_{dB} = 20\lg |1j\omega|^2 - 20\lg |1j\omega + 10| - 20\lg |1j\omega + 1|$$

$$20\lg \omega^2 \quad (1 \quad 0)$$

20dB/dec

$$+20\text{dB/dec}$$
$$20\text{dB/dec}$$





$$H_{dB} = 20 \lg |1 - j\omega/\omega_0| + 20 \lg |1 - j\omega/\omega_1|$$

$$\phi = 90^\circ \arctg(\omega/\omega_0) + 90^\circ \arctg(\omega/\omega_1)$$

