KCL KVL VCR

7 11

§14 1

1.

$f(t)$ $F(s)$

1.

$[0, +\infty]$ $f(t)$

$F(s)$

$$F(s)= [f(t)]=\int_{0_-}^{\infty} f(t)\mathrm{e}^{-st}\mathrm{d}t$$

$s=\sigma+\mathrm{j}\omega$

$F(s)$ $f(t)$ $f(t)$ $F(s)$

$F(s)$ $f(t)$

$$f(t)= {}^{-1}[F(s)]=\frac{1}{2\pi\mathrm{j}}\int_{c-\mathrm{j}\infty}^{c+\mathrm{j}\infty} F(s)\,\mathrm{e}^{st}\,\mathrm{d}t$$

c

(1) t=0$_-$

$$F(s)= \quad [f(t)]=\int_{0_-}^{\infty} f(t)\mathrm{e}^{-st}\mathrm{d}t=\int_{0_-}^{0_+} f(t)\mathrm{e}^{-st}\mathrm{d}t+\int_{0_+}^{\infty} f(t)\mathrm{e}^{-st}\mathrm{d}t$$

t=0$_-$ 0$_+$ $f(t)$

(2) F(s) I(s) U(s)

$f(t)$ $i(t)$ $u(t)$

F(s) $\mathrm{Re}[s]=s > c$

(

) $f(t)$

$F(s)$

2. P345 14-1

(1) $f(t) = \varepsilon(t)$

$$F(s) = \int_{0_-}^{\infty} \varepsilon(t)\, \mathrm{e}^{-st}\, \mathrm{d}t = \int_{0_-}^{\infty} \mathrm{e}^{-st}\, \mathrm{d}t = -\frac{1}{s}\, \mathrm{e}^{-st} \Big|_{0_-}^{\infty} \qquad [\varepsilon(t)] = \frac{1}{s}$$

(2) $\delta(t)$

$$F(s) = \int_{0_-}^{\infty} \delta(t)\, \mathrm{e}^{-st}\, \mathrm{d}t = \int_{0_-}^{0_+} \delta(t)\, \mathrm{e}^{-st}\, \mathrm{d}t = \mathrm{e}^{-s(0)} \qquad [\delta(t)] = 1$$

(3) $f(t) = \mathrm{e}^{\alpha t}$ (α)

$$F(s) = \int_{0_-}^{\infty} \mathrm{e}^{\alpha t}\, \mathrm{e}^{-st}\, \mathrm{d}t = \int_{0_-}^{\infty} \mathrm{e}^{-(s-\alpha)t}\, \mathrm{d}t = \frac{1}{-(s-\alpha)}\, \mathrm{e}^{-(s-\alpha)t} \Big|_{0_-}^{\infty}$$

$$[\mathrm{e}^{\alpha t}] = \frac{1}{s-\alpha}$$

P346 14 2 $f_1(t)=\sin(\omega t)$, $f_2(t)=K(1-e^{-\alpha t})$

[0, ∞],

$$[f_1(t)] = [\sin(\omega t)] \;=\!=\!=\; \left[\frac{1}{2j}(e^{j\omega t}-e^{-j\omega t})\right]$$

$$=\!=\!=\; \frac{1}{2j} \quad [e^{j\omega t}] \qquad [e^{-j\omega t}]$$

$$[e^{\alpha t}] = \frac{1}{s-\alpha}$$

$$=\frac{1}{2j}\left[\frac{1}{s-j\omega}-\frac{1}{s+j\omega}\right]=\frac{\omega}{s^2+\omega^2}$$

$$[\sin(\omega t)] = \frac{\omega}{s^2+\omega^2}$$

$$[f_2(t)] = [K(1-e^{-\alpha t})] \;=\!=\!=\; [K] - [Ke^{-\alpha t}]$$

$$=\frac{K}{s}-\frac{K}{s+\alpha}=\frac{K\alpha}{s(s+\alpha)}$$

$$[K(1-e^{-\alpha t})]=\frac{K\alpha}{s(s+\alpha)}$$

P347 14 3 $\cos(\omega t)$ $\delta(t)$

$$\frac{\mathrm{d}\sin(\omega t)}{\mathrm{d}t} = \omega\cos(\omega t) \qquad \frac{\mathrm{d}\varepsilon(t)}{\mathrm{d}t} = \delta(t)$$

$$[\sin(\omega t)] = \frac{\omega}{s^2+\omega^2} \qquad [\varepsilon(t)] = 1/s$$

$$[\cos(\omega t)] = \left[\frac{1}{\omega}\frac{\mathrm{d}\sin(\omega t)}{\mathrm{d}t}\right] = \frac{1}{\omega}\left[s\frac{\omega}{s^2+\omega^2} - \sin(0\_)\right]$$

$$[\cos(\omega t)] = \frac{s}{s^2+\omega^2}$$

$$[\delta(t)] = \left[\frac{\mathrm{d}\varepsilon(t)}{\mathrm{d}t}\right] = s\left(\frac{1}{s} \quad 0\right) = 1$$

3.

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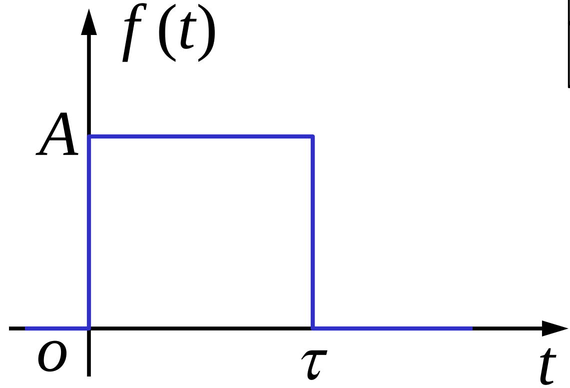
P349 14 5

$$f(t) = A\,[\varepsilon(t)-\varepsilon(t-\tau)]$$



$$[\varepsilon(t)] = \frac{1}{s}$$

$$[\varepsilon(t-\tau)] = \frac{1}{s}\,e^{-s\tau}$$

$$[f(t)] = \frac{A}{s} - \frac{A}{s}\,e^{-s\tau} = \frac{A}{s}(1- e^{-s\tau})$$

*5. $[e^{at} f(t)]=F(s-a)$

*6. $f(0)=[s\,F(s)]_{s\to\infty}$

*7. $f(\infty)=[s\,F(s)]_{s\to 0}$

P350 14–1

§ 14 3

$$f(t) = \frac{1}{2\pi \mathrm{j}} \int_{c-\mathrm{j}\infty}^{c+\mathrm{j}\infty} F(s)\, \mathrm{e}^{st}\, \mathrm{d}t$$

s

14–1

$F(s)$

$F(s)=F_1(s)+F_2(s)+\cdots$ $f(t)=f_1(t)+f_2(t)+\cdots$

$$F(s) = \frac{1}{s^2 + 3}$$

$$F(s) = \frac{1}{\sqrt{3}} \frac{\sqrt{3}}{s^2 + (\sqrt{3})^2}$$

$$[\sin(\omega t)] = \frac{\omega}{s^2+\omega^2}$$

$$f(t) = \frac{1}{\sqrt{3}} \sin\sqrt{3}\, t$$

1.

$$F(s) = \frac{N(s)}{D(s)} = \frac{a_0 s^m + a_1 s^{m-1} + \cdots + b_m}{b_0 s^n + b_1 s^{n-1} + \cdots + b_n}$$

m n $n \geq m$

14 1

$n > m$ $F(s)$

$n = m$ $F(s) = A + \dfrac{N_0(s)}{D(s)}$

$D(s)=0$

1 $D(s)=0$

$$F(s)=\frac{K_1}{s-p_1}+\frac{K_2}{s-p_2}+\cdots+\frac{K_n}{s-p_n}$$

p_1 p_2 $\cdots$ p_n $D(s)=0$ n

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K_1 K_2 $\cdots$ K_n

1 $K_i=\lim\limits_{s\to p_i}(s-p_i)F(s)$ $i=1,2,3,\cdots,n$

2 K_i

$$K_i=\lim_{s\to p_i}\frac{(s-p_i)N(s)}{D(s)}=\lim_{s\to p_i}\frac{(s-p_i)N'(s)+N(s)}{D'(s)}=\frac{N(p_i)}{D'(p_i)}$$

$i=1,2,3,\cdots,n$

P352 14 6 $F(s)=\dfrac{2s+1}{s^3+7s^2+10s}$

$s^3+7s^2+10s=0$ $p_1=0,\ p_2=-2,\ p_3=-5$

$$K_i=\lim_{s\to p_i}(s-p_i)F(s)$$

$$K_1=\lim_{s\to 0} sF(s)=\lim_{s\to 0} s\,\frac{2s+1}{s^3+7s^2+10s}=0.1$$

$$K_2=\lim_{s\to -2}(s+2)F(s)=\lim_{s\to -2}(s+2)\,\frac{2s+1}{s(s+2)(s+5)}=0.5$$

$$K_3=\lim_{s\to -5}(s+5)F(s)=\lim_{s\to -5}(s+5)\,\frac{2s+1}{s(s+2)(s+5)}=-0.6$$

$$F(s)=\frac{0.1}{s}+\frac{0.5}{s+2}+\frac{-0.6}{s+5}$$

$$f(t)=0.1+0.5e^{-2t}-0.6e^{-5t}$$

1 $D(s)=0$

$p_1=\alpha+\mathrm{j}\omega \quad p_2=\alpha-\mathrm{j}\omega$

$$K_1=\frac{N(\alpha+\mathrm{j}\omega)}{D'(\alpha+\mathrm{j}\omega)} \qquad K_2=\frac{N(\alpha-\mathrm{j}\omega)}{D'(\alpha-\mathrm{j}\omega)}$$

$F(s)$ K_1 K_2

( )

$K_1=|K_1|\,\mathrm{e}^{\mathrm{j}\theta_1} \qquad K_2=|K_1|\,\mathrm{e}^{-\mathrm{j}\theta_1}$

$$f(t)=K_1\mathrm{e}^{(\alpha+\mathrm{j}\omega)t}+K_2\mathrm{e}^{(\alpha-\mathrm{j}\omega)t}=|K_1|\mathrm{e}^{\mathrm{j}\theta_1}\,\mathrm{e}^{(\alpha+\mathrm{j}\omega)t}+|K_1|\mathrm{e}^{-\mathrm{j}\theta_1}\,\mathrm{e}^{(\alpha-\mathrm{j}\omega)t}$$

$$=|K_1|\mathrm{e}^{\alpha t}\left[\mathrm{e}^{\mathrm{j}(\theta_1+\omega t)}+\mathrm{e}^{-\mathrm{j}(\theta_1+\omega t)}\right]$$

$$f(t)=2|K_1|\,\mathrm{e}^{\alpha t}\cos(\omega t+\theta_1)$$

P353　14　7　$F(s) = \dfrac{s+3}{s^2+2s+5}$　$f(t)$

$$s^2+2s+5=0$$

$$p_1 = -1 + \mathrm{j}2 \qquad p_2 = -1 - \mathrm{j}2 \longrightarrow \alpha = -1 \qquad \omega = 2$$

$$K_1 = \frac{N(-1+\mathrm{j}2)}{D'(-1+\mathrm{j}2)} = 0.5 - \mathrm{j}0.5 = 0.5\sqrt{2}\,\mathrm{e}^{-\mathrm{j}\frac{\pi}{4}}$$

$$|K_1| = 0.5\sqrt{2} \qquad \theta_1 = -\frac{\pi}{4}$$

$$f(t) = 2|K_1|\,\mathrm{e}^{\alpha t}\cos(\omega t + \theta_1)$$

$$f(t) = \sqrt{2}\,\mathrm{e}^{-t}\cos(2t - \frac{\pi}{4})$$

2 $D(s)=0$ q (p_1 q)

$D(s)$ $(s-p_1)^q$ $F(s)$

$$F(s)=\frac{K_{11}}{(s-p_1)^q}+\frac{K_{12}}{(s-p_1)^{q-1}}+\cdots+\frac{K_{1q}}{s-p_1}+\sum_{i=1}^{n-q}\frac{K_{i+1}}{s-p_{i+1}}$$

K_{i+1} $K_{11}\sim K_{1q}$

$$K_{11}=\lim_{s\to p_1}(s-p_1)^q F(s) \qquad K_{12}=\lim_{s\to p_1}\frac{\mathrm{d}}{\mathrm{d}s}[(s-p_1)^q F(s)]$$

$$K_{1q}=\frac{1}{(q-1)!}\lim_{s\to p_1}\frac{\mathrm{d}^{q-1}}{\mathrm{d}s^{q-1}}[(s-p_1)^q F(s)]$$

$$f(t)=\left[\frac{K_{11}}{(q-1)!}t^{q-1}+\frac{K_{12}}{(q-2)!}t^{q-2}+\cdots+K_{1q}\right]\mathrm{e}^{p_1 t}+\sum_{i=1}^{n-q}K_{i+1}\mathrm{e}^{p_{i+1}t}$$

$$K_{1q}=\frac{1}{(q-1)!}\lim_{s\to p_1}\frac{\mathrm{d}^{q-1}}{\mathrm{d}s^{q-1}}\left[(s-p_1)^q F(s)\right]$$

P354 14 8 $F(s)=\dfrac{1}{s^2(s+1)^3}$

$$(s+1)^3 F(s)=\frac{1}{s^2}$$

K_{21} K_{22}

$$K_{11}=\lim_{s\to -1}\frac{1}{s^2}=1$$

$$s^2 F(s)=\frac{1}{(s+1)^3}$$

$$K_{12}=\lim_{s\to -1}\frac{\mathrm{d}}{\mathrm{d}s}\frac{1}{s^2}=2$$

$$K_{21}=\lim_{s\to 0}\frac{1}{(s+1)^3}=1$$

$$K_{13}=\lim_{s\to -1}\frac{1}{2!}\frac{\mathrm{d}^2}{\mathrm{d}s^2}\frac{1}{s^2}=3$$

$$K_{22}=\lim_{s\to 0}\frac{\mathrm{d}}{\mathrm{d}s}\frac{1}{(s+1)^3}=-3$$

$$f(t)=\frac{1}{2}t^2\mathrm{e}^{-t}+2t\mathrm{e}^{-t}+3\mathrm{e}^{-t}+t-3$$

§ 14 4

П .

1. KL

KL

KL

$$[\sum i(t)] = \sum [i(t)] = \sum I(s) = 0$$

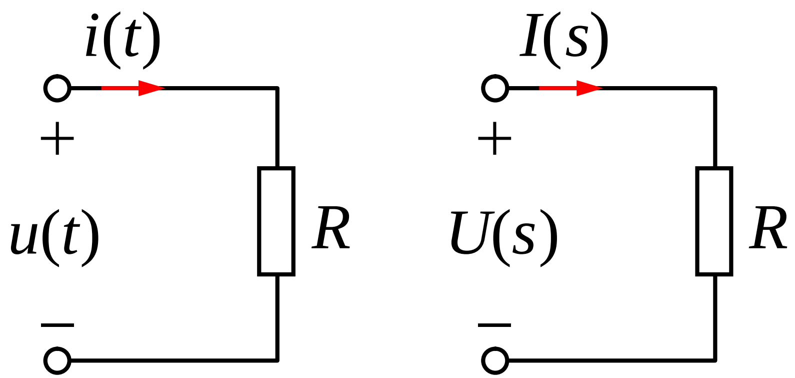
$$[\sum u(t)] = \sum [u(t)] = \sum U(s) = 0$$

2. VCR

(1) *R*

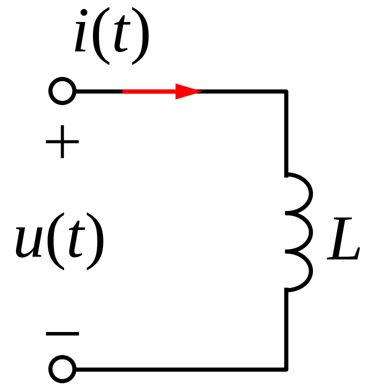
$$u(t) = Ri(t)$$

$$U(s) = RI(s)$$



(2) L

$$u(t) = L\frac{\mathrm{d}i(t)}{\mathrm{d}t}$$



$$U(s) = sLI(s) - Li(0_-)$$

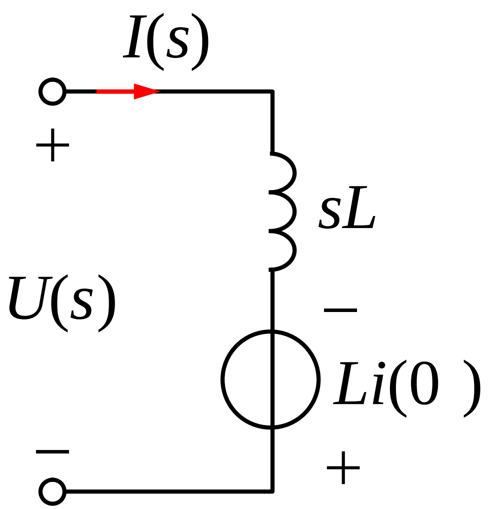
$$I(s) = \frac{1}{sL}U(s) + \frac{i(0_-)}{s}$$

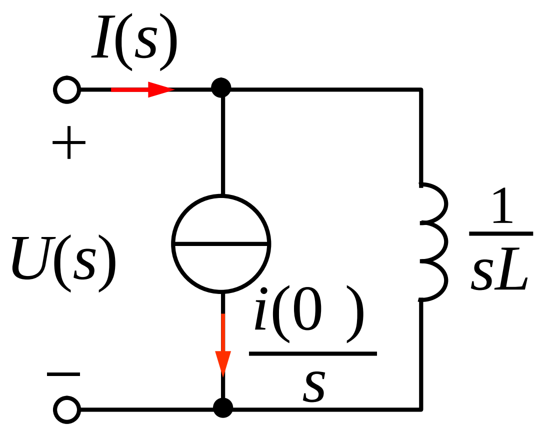
sL L

$1/sL$

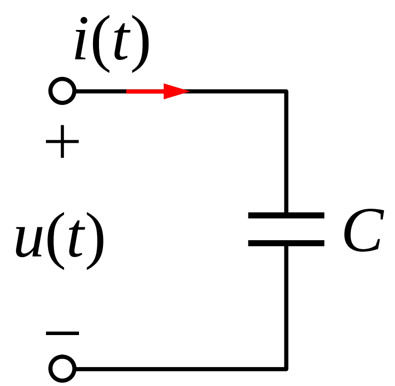
$i(0_-)$ L

L





(3) C



$$u(t) = \frac{1}{C}\int_{0_-}^{t} i(t)\,\mathrm{d}t + u(0_-)$$

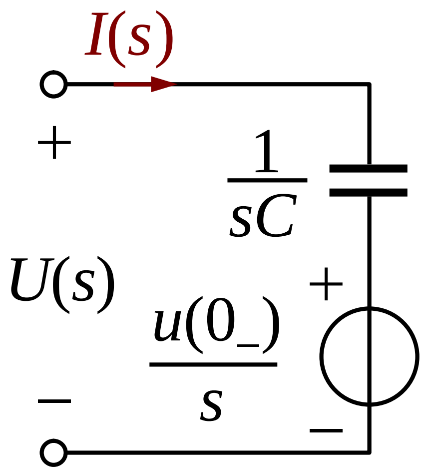
$$U(s) = \frac{1}{sC} I(s) + \frac{u(0_-)}{s}$$

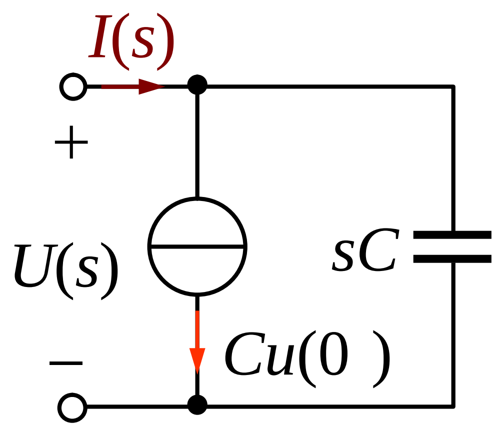
$$I(s) = sCU(s) - Cu(0_-)$$

$1/sC$ C

sC C

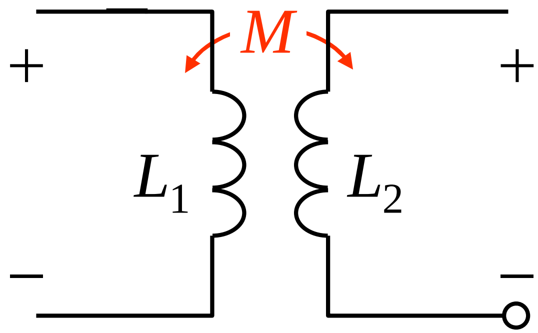
$u(0_-)$ C

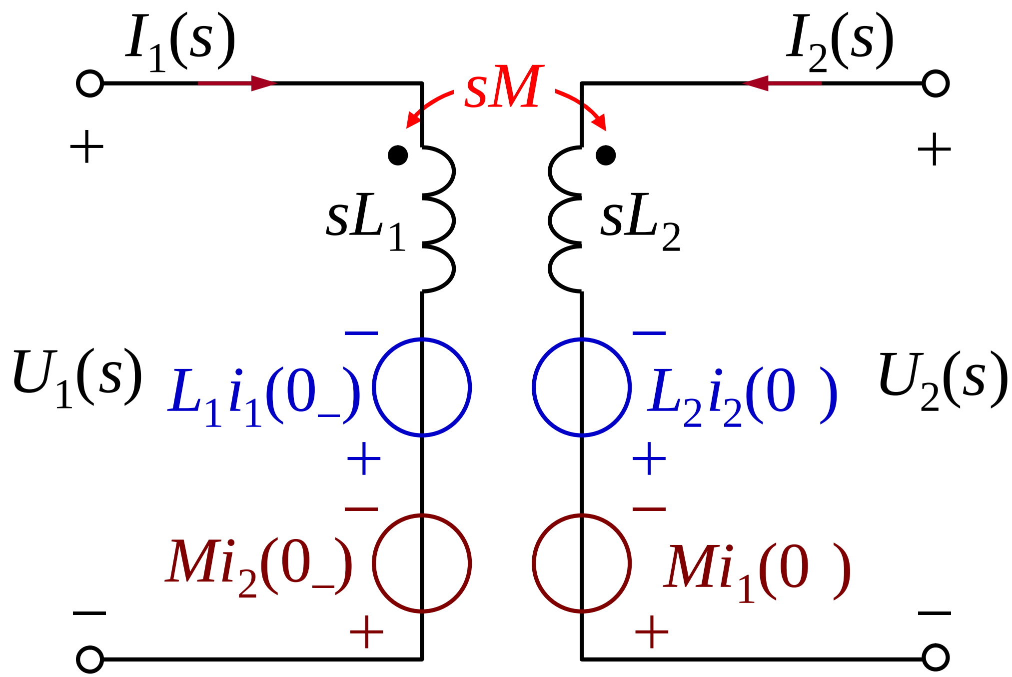




(4)

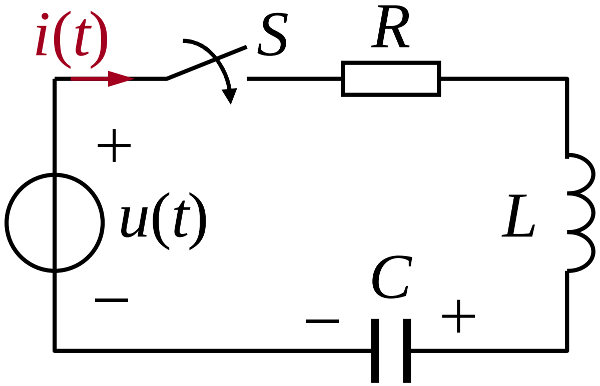
$$u_1 = L_1 \frac{\mathrm{d}i_1}{\mathrm{d}t} + M \frac{\mathrm{d}i_2}{\mathrm{d}t}$$

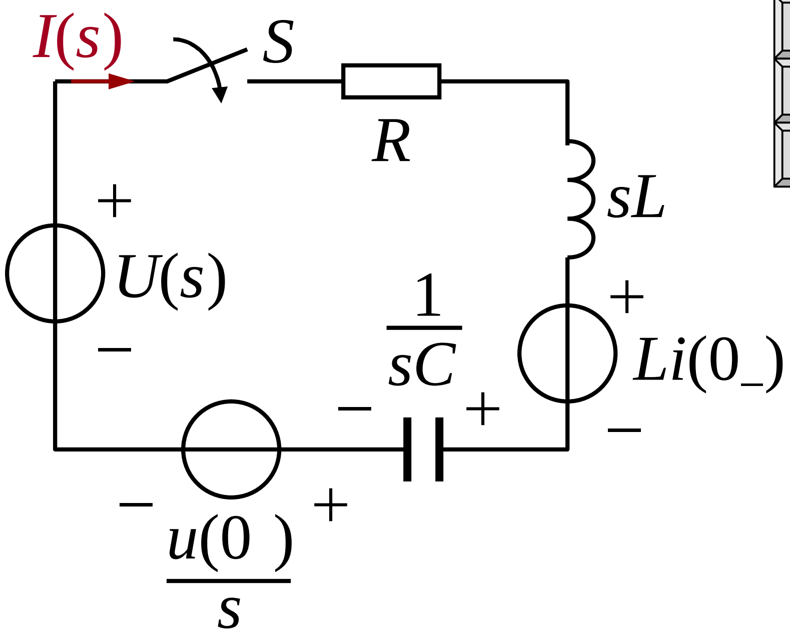




$$U_1(s) = sL_1I_1(s) - L_1i_1(0\_) + sMI_2(s) - Mi_2(0\_)$$
$$U_2(s) = sL_2I_2(s) - L_2i_2(0\_) + sMI_1(s) - Mi_1(0\_)$$

(5)





$u(0\ )$

$i(0\ )$

$$u=Ri+L\frac{\mathrm{d}i}{\mathrm{d}t}+\frac{1}{C}\int_{0_-}^{t} i\,\mathrm{d}t$$

$$U(s)=RI(s)+sLI(s)-Li(0_-)+\frac{1}{sC}I(s)-\frac{u(0\ )}{s}$$

$$\left(R+sL+\frac{1}{sC}\right)I(s)=\quad s$$

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§ 14 5

$i \rightarrow I(s) \quad u \rightarrow U(s) \quad R \rightarrow Z(s) \quad G \rightarrow Y(s)$

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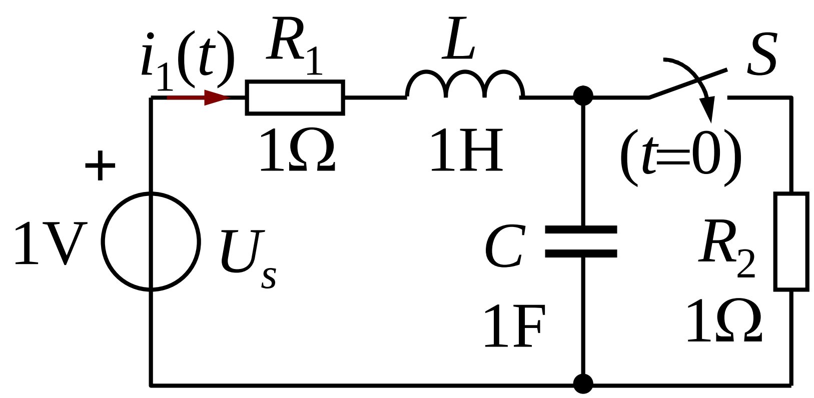
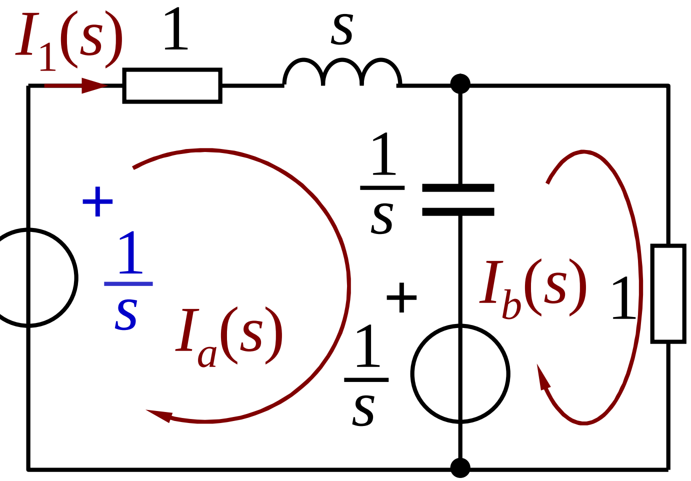
P359 14 9

t=0 S $i_1(t)$



$$i_L(0\_) = 0 \quad U_C(0\_) = U_S = 1\text{V}$$

$$[U_S] = \quad [1] = 1/s$$



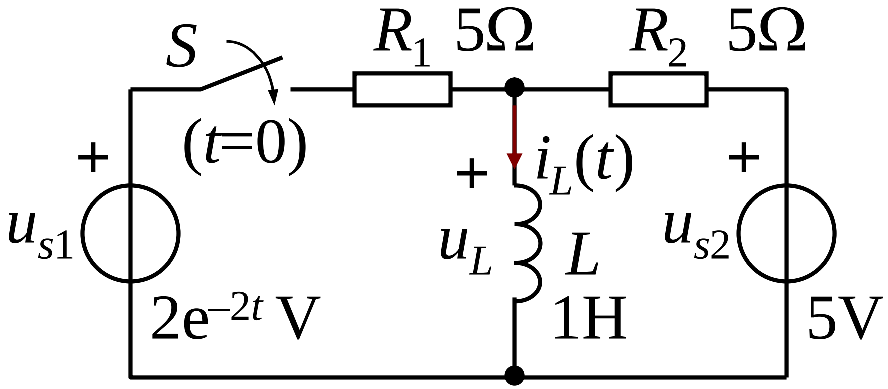
$$\left(1+s+\frac{1}{s}\right)I_a(s) - \frac{1}{s}I_b(s) = 0$$

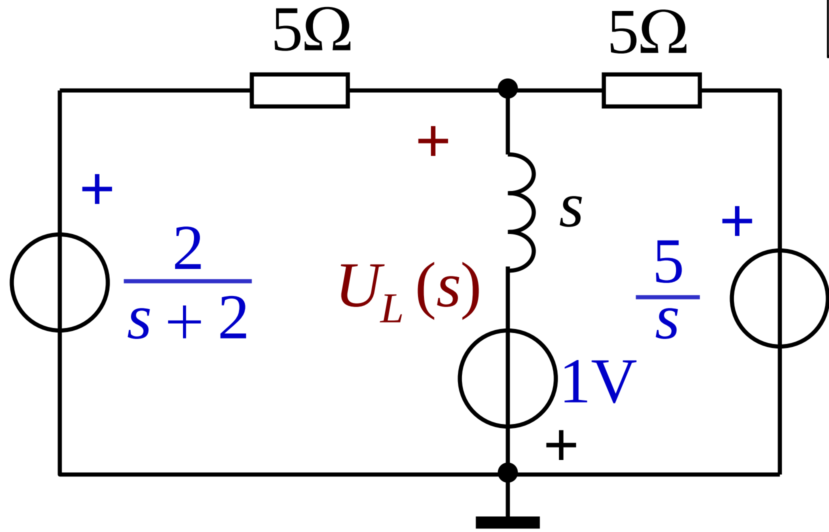
$$-\frac{1}{s}I_a(s) + \left(1+\frac{1}{s}\right)I_b(s) = \frac{1}{s}$$

$$I_1(s) = I_a(s) = \frac{1}{s\,(s^2+2s+2)}$$

$$[I_1(s)] = \frac{1}{2}\,(1+ e^{-t}\cos t - e^{-t}\sin t)\ \text{A}$$

P361 14 11 S $t \geq 0$ $u_L(t)$





$$i_L(0\ ) = \frac{u_{s2}}{R_2} = 1\text{A}$$

$$[2e^{-2t}] = \frac{2}{s+2} \qquad [5\ ] = \frac{5}{s}$$

$$U_L(s) = U_{n1}(s)$$

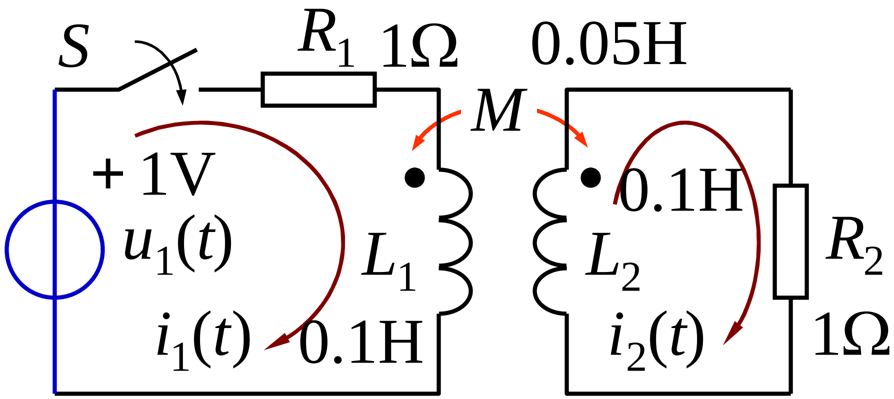
$$\left[\frac{1}{5} + \frac{1}{5} + \frac{1}{s}\right] U_{n1}(s) = \frac{\frac{2}{(s+2)}}{5} - \frac{1}{s} + \frac{\frac{5}{s}}{5}$$

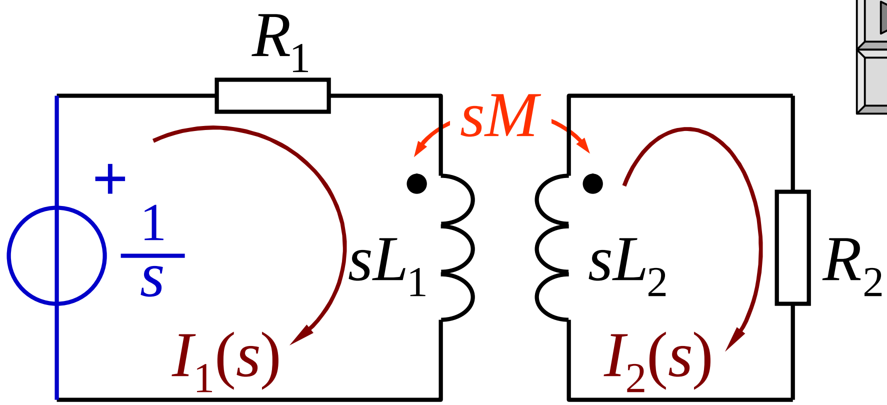
$$= \frac{2s}{(s+2)(2s+5)}$$

$$\frac{2s+5}{5s} U_{n1}(s) = \frac{2}{5(s+2)}$$

$$[U_L(s)] = (-4e^{-2t} + 5e^{-2.5t})\text{V}$$

P362 14 12 S $i_1(t)$ $i_2(t)$





$$(R_1+sL_1)I_1(s)-sMI_2(s)=(1/s)$$

$$-sMI_1(s)+(R_2+sL_2)I_2(s)=0$$

$$(1+0.1s)I_1(s)-0.05sI_2(s)=(1/s)$$

$$-0.05sI_1(s)+(1+0.1s)I_2(s)=0$$

$$I_1(s)=\frac{0.1s+1}{s(7.5\times 10^{3}s^{2}+0.2s+1)}$$

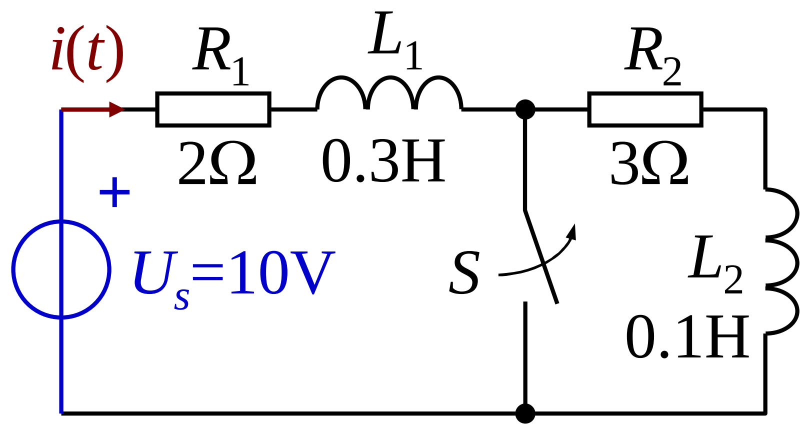
$$I_2(s)=\frac{0.05}{s(7.5\times 10^{3}s^{2}+0.2s+1)}$$

$$i_1(t)=(1\quad 0.5e^{\quad 6.67t}\quad 0.5e^{\quad 20t})\text{A}$$

$$i_2(t)=0.5(0.5e^{\quad 6.67t}\quad e^{\quad 20t})\text{A}$$

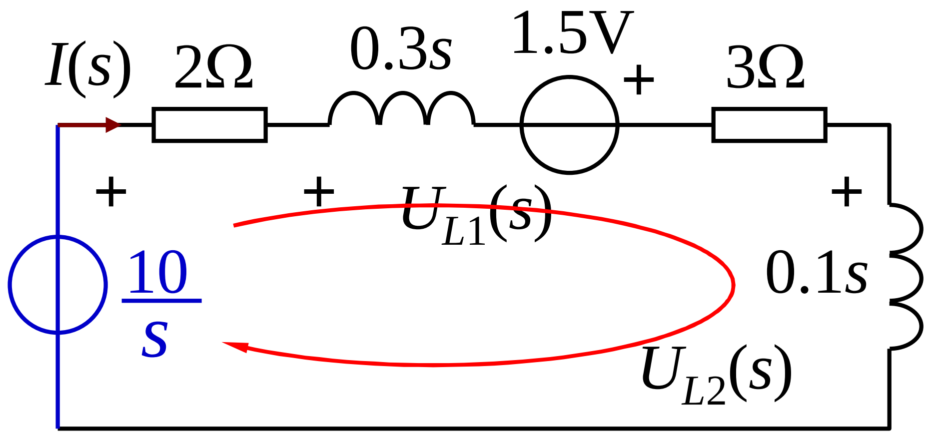
P363　14　13

S　$i(t)$



[10]=(10/s)

$i_{L1}(0\ )=5\text{A}$　$L_1 i_{L1}(0\ )=1.5\text{V}$



$$I(s)=\frac{\frac{10}{s}+1.5}{2+3+(0.3+0.1)s}=$$

$$\frac{(1.5s+10)}{s(0.4s+5)}=\frac{2}{s}+\frac{1.75}{s+12.5}$$

$$i(t)=(2+1.75e^{-12.5t})\text{A}$$

$$U_{L1}(s)=0.3sI(s)-1.5$$

$$=-\frac{6.56}{s+12.5}-0.375$$

$$U_{L2}(s)=0.1sI(s)=-\frac{2.19}{s+12.5}-0.375$$

$$u_{L1}(t)=[-6.56e^{-12.5t}-0.375\delta(t)]\ \text{V}$$

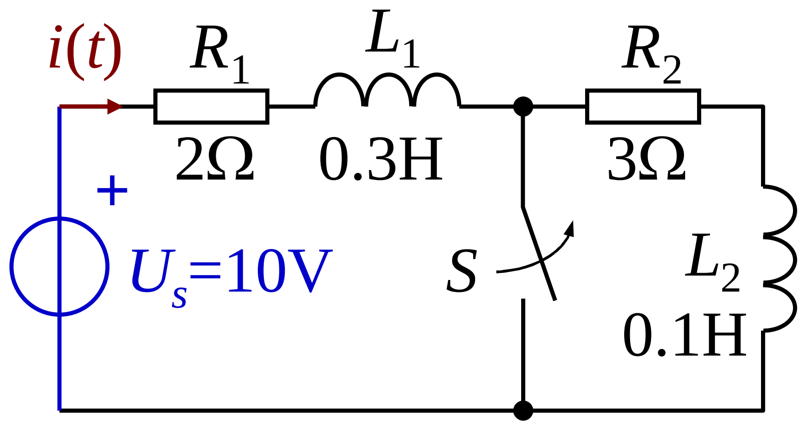
$$u_{L2}(t)=[-2.19e^{-12.5t}+0.375\delta(t)]\ \text{V}$$

$i_{L1}(0\ )=5\text{A}$

$i(t)=(2+1.75\text{e}^{\ 12.5t})\text{A}$

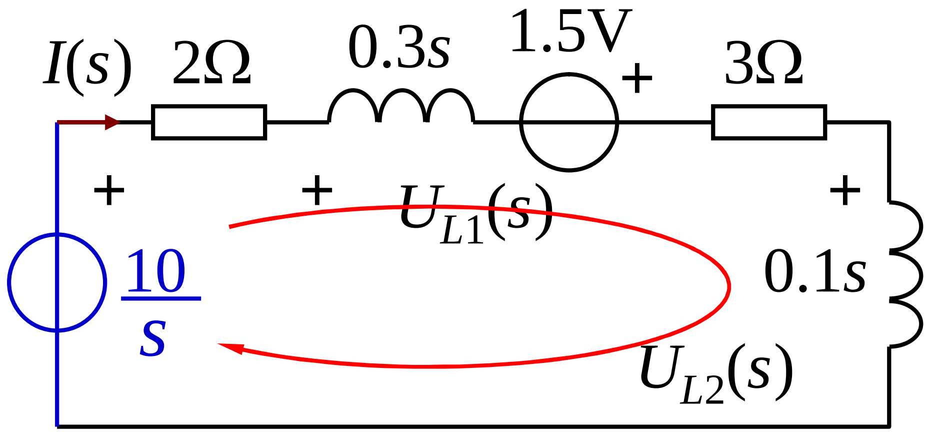
$u_{L1}(t)=[-6.56\text{e}^{\ 12.5t}-0.375\delta(t)]\text{V}$

$u_{L2}(t)=[-2.19\text{e}^{\ 12.5t}+0.375\delta(t)]\text{V}$



S $i_{L1}(0_+)=3.75\text{A}$

$u_{L1}(t)$



$u_{L2}(t)$

$u_{L1}(t)+u_{L2}(t)$

KVL

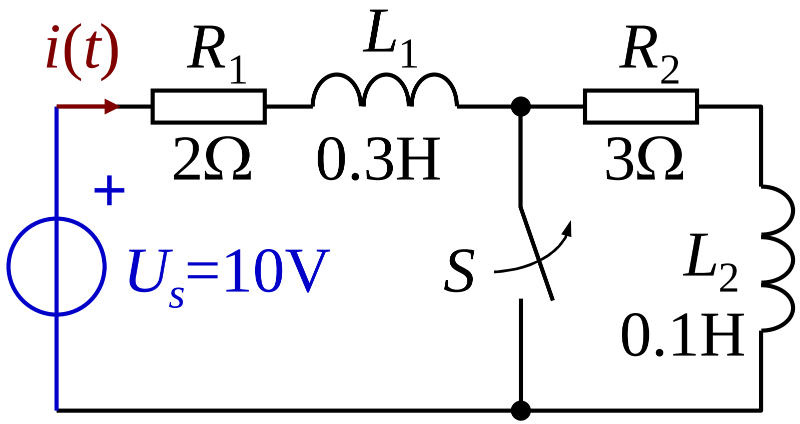
$i_L(t)$ $u_C(t)$

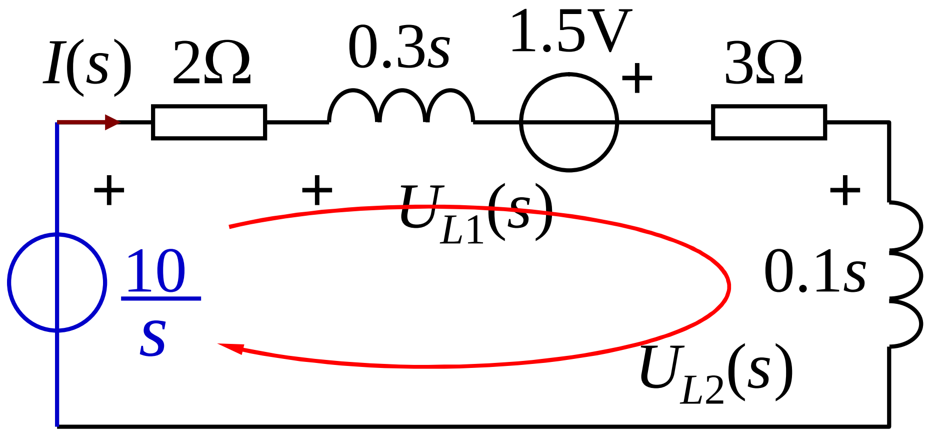
$i_{L1}(0\ )=5\text{A}$

$i(t)=(2+1.75\text{e}^{\ 12.5t})\text{A}$

$u_{L1}(t)=[-6.56\text{e}^{\ 12.5t}-0.375\delta(t)]\text{V}$

$u_{L2}(t)=[-2.19\text{e}^{\ 12.5t}+0.375\delta(t)]\text{V}$





$i(t)$

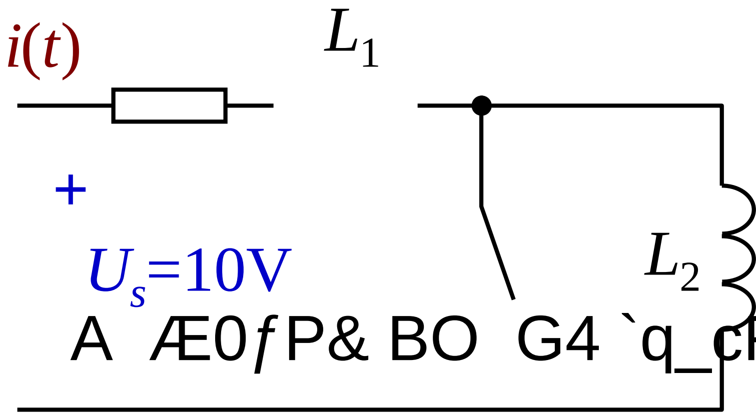
$i(t)$

$u_{L1}(t)$ $u_{L2}(t)$

$\varepsilon(t)$ $\varepsilon(t)$

$t<0$ 0

0 $\varepsilon(t)$



A ÆO f P& BO G4 `q_cF D C D O

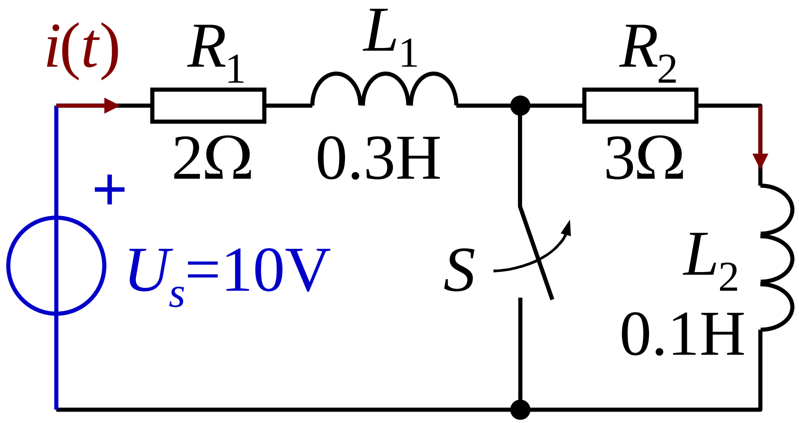
$$L_1 i_{L1}(0\ )+L_2 i_{L2}(0\ )=(L_1+L_2)i(0\ )$$

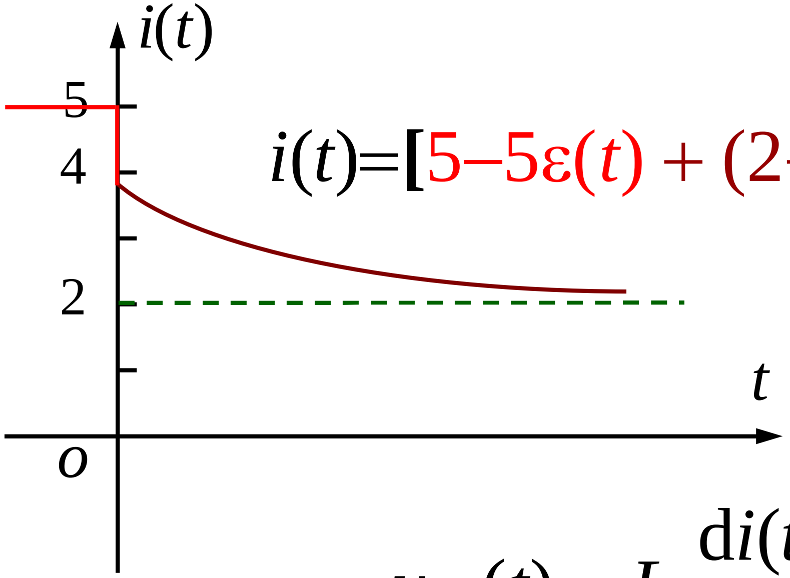
$$i(0\ )=\underline{\qquad\qquad\qquad}$$

$i(0_-) = i_{L1}(0_-) = 5\text{A}$

$i(t) = 2 + (3.75 - 2)\text{e}^{12.5t}\ \text{A}$

$t \geq 0$





$i(t) = [5 - 5\varepsilon(t) + (2 + 1.75\text{e}^{12.5t})\varepsilon(t)]\ \text{A} \quad (t \geq 0)$

$$u_{L1}(t) = L_1 \frac{\text{d}i(t)}{\text{d}t} = [-6.56\text{e}^{12.5t} - 0.375\delta(t)]\text{V}$$

§ 14 6

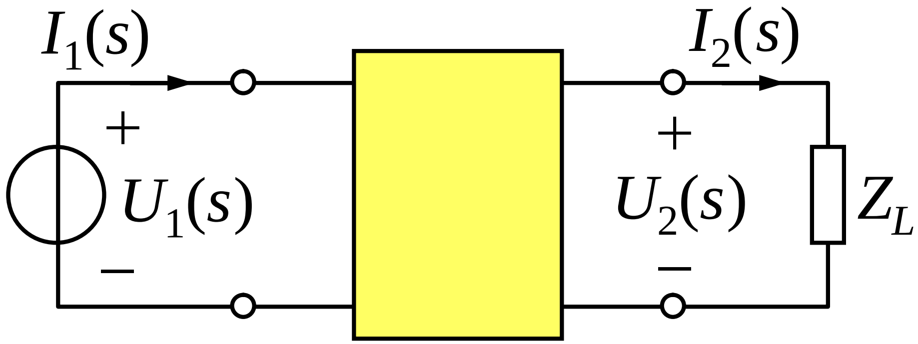
1.

$r(t)$

$R(s)$ $e(t)$ $E(s)$

$H(s)$ $R(s)$ $E(s)$

$$H(s) \stackrel{\text{del}}{=\!=} \frac{R(s)}{E(s)}$$



2.

$E(s)$

$R(s)$ $H(s)$

$$E(s) = 1, \qquad e(t) = \delta(t)$$

$$R(s) = H(s)E(s) = H(s)$$

$$h(t) = {}^{-1}[H(s)] = {}^{-1}[R(s)] = r(t)$$

$h(t)$

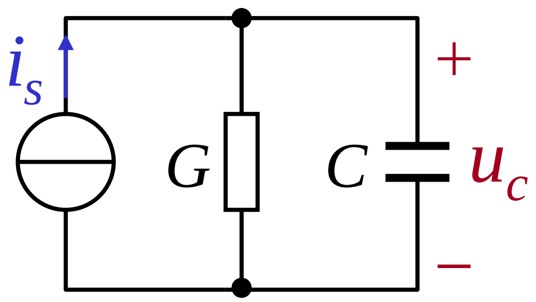
$H(s)$ $E(s)$ $R(s)$

$$R(s) = H(s)E(s)$$

P366 14-15

$i_s = \delta(t)$

$h(t) = u_c(t)$



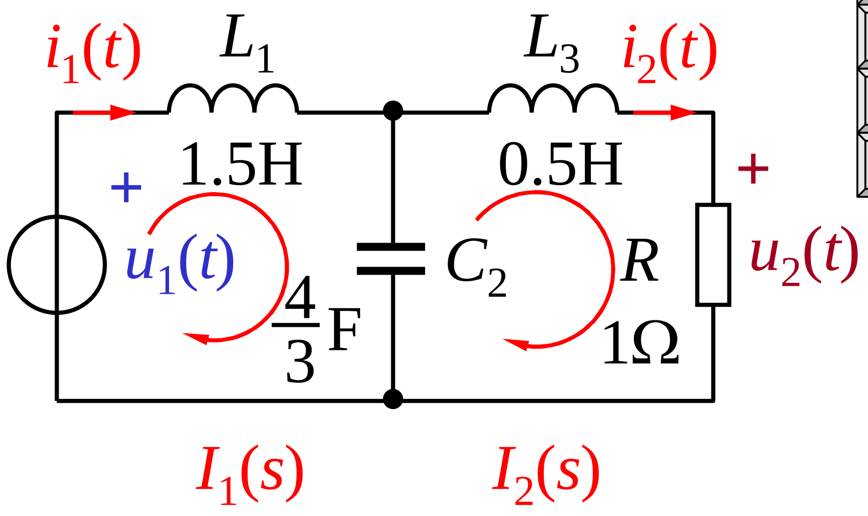
$$H(s) = \frac{R(s)}{E(s)} = \frac{U_c(s)}{I_s(s)} = Z(s)$$

$$Z(s) = \frac{1}{G + sC} = \frac{1}{C} \frac{1}{s + \frac{1}{RC}}$$

$$h(t) = u_c(t) = \quad {}^{1}[H(s)] = \frac{1}{C} \mathrm{e}^{-\frac{t}{RC}} \varepsilon(t)$$

P366 14 16

$u_1(t)$



$$(sL_1+\frac{1}{sC_2})I_1(s)-\frac{1}{sC_2}I_2(s)=U_1(s)$$

$$-\frac{1}{sC_2}I_1(s)+(sL_3+\frac{1}{sC_2}+R)\,I_2(s)=0$$

$$I_1(s)=\frac{L_3C_2s^2+RC_2s+1}{D(s)}U_1(s) \qquad I_2(s)=\frac{1}{D(s)}U_1(s)$$

$$I_1(s) = \frac{L_3C_2s^2 + RC_2s + 1}{D(s)} U_1(s)$$

$$I_2(s) = \frac{1}{D(s)} U_1(s)$$

$$D(s) = L_1L_3C_2\, s^3 + RL_1C_2\, s^2 + (L_1 + L_2)\, s + R$$

$$D(s) = s^3 + 2s^2 + 2s + 1$$

§14 7

$H(s)$ $H(s)$

( ) $H(s)$

R $L(M)$ C

$H(s)$ s

( )

1. $H(s)$

$$H(s)=\frac{N(s)}{D(s)}=\frac{b_m s^m + b_{m-1}s^{m-1} + \cdots + b_0}{a_n s^n + a_{n-1}s^{n-1} + \cdots + a_0}$$

$$H(s)=\frac{N(s)}{D(s)}=H_0\,\frac{(s-z_1)(s-z_2)\cdots(s-z_i)\cdots(s-z_m)}{(s-p_1)(s-p_2)\cdots(s-p_j)\cdots(s-p_n)}$$

$$=H_0\,\frac{\prod_{i=1}^{m}(s-z_i)}{\prod_{j=1}^{n}(s-p_j)} \qquad H_0$$

$z_1 \quad z_2 \quad \cdots\ z_m \quad N(s)=0$

$s=z_i \qquad H(s)=0$

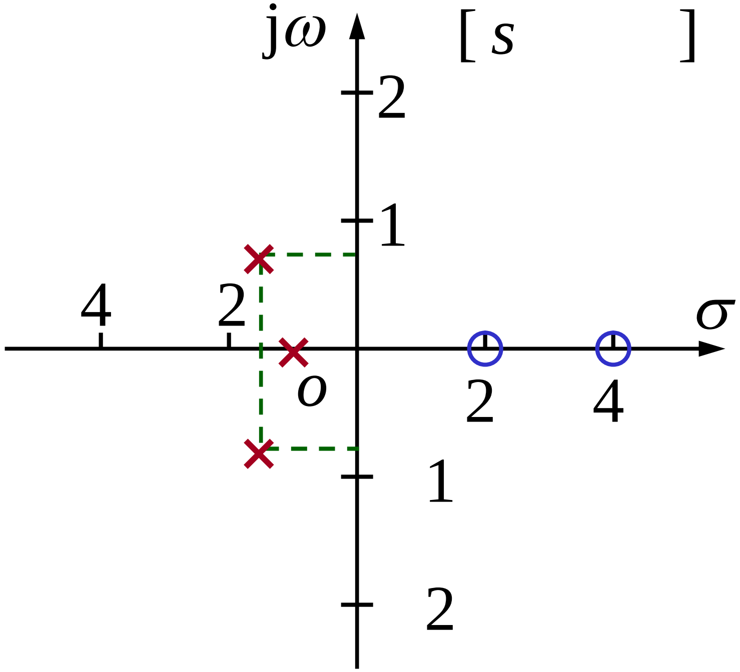
$p_1 \quad p_2 \quad \cdots\ p_m \quad D(s)=0$

$s=p_i \qquad H(s)\rightarrow\infty$

2.

s $H(s)$

"○" "×"



$$H(s)=\frac{2s^2-12s+16}{s^3+4s^2+6s+3}$$

$$2(s^2-6s+8)=2(s-2)(s-4)$$

$$(s+1)\ (s^2\ \ 3s+3)$$

$$=(s+1)\left(s+\frac{3}{2}+\mathrm{j}\frac{\sqrt{3}}{2}\right)\left(s+\frac{3}{2}-\mathrm{j}\frac{\sqrt{3}}{2}\right)$$

§ 14 8

$H(s)$

$$R(s) = H(s)\,E(s) = \frac{N(s)}{D(s)}\,\frac{P(s)}{Q(s)}$$

$H(s)$ $E(s)$ s $D(s)Q(s)=0$

$D(s)=0$ $Q(s)=0$

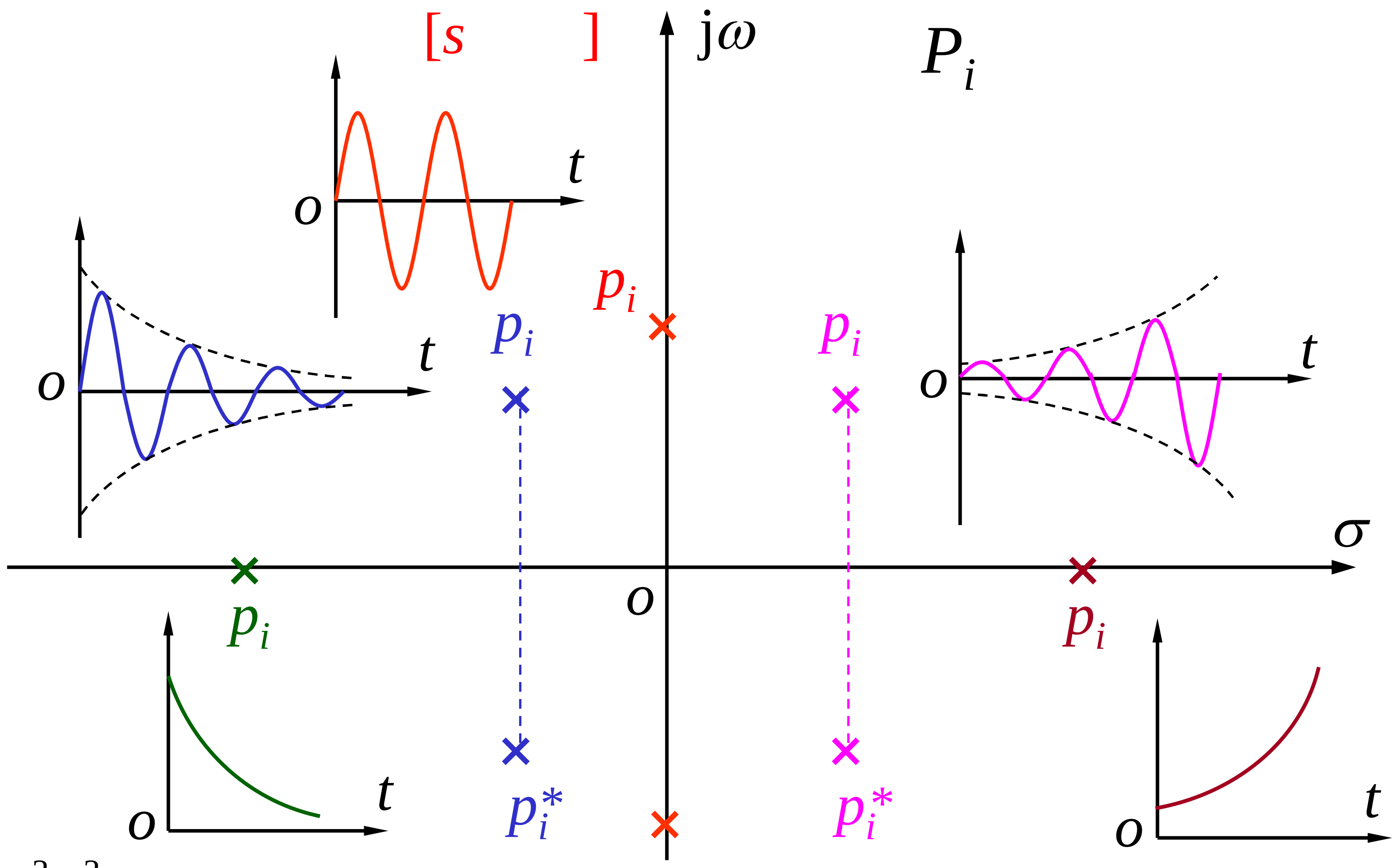
$Q(s)=0$

$D(s)=0$ ( )

$h(t)$ $(()))$ oÀö '–

$H(s)$ $D(s)=0$

$$h(t) = {}^{-1}[H(s)] = {}^{-1}\left[\sum_{i=1}^{n}\frac{K_i}{s-p_i}\right] = \sum_{i=1}^{n} K_i\, e^{p_i t}$$



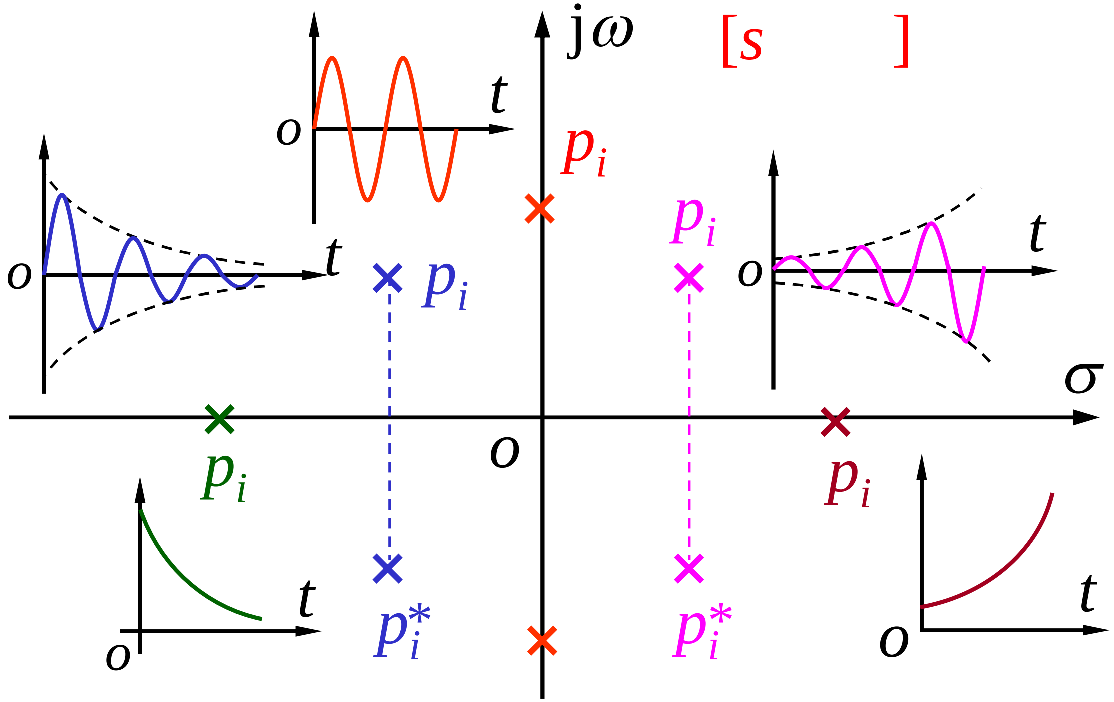
s

( )

p_i

s

( )



( )

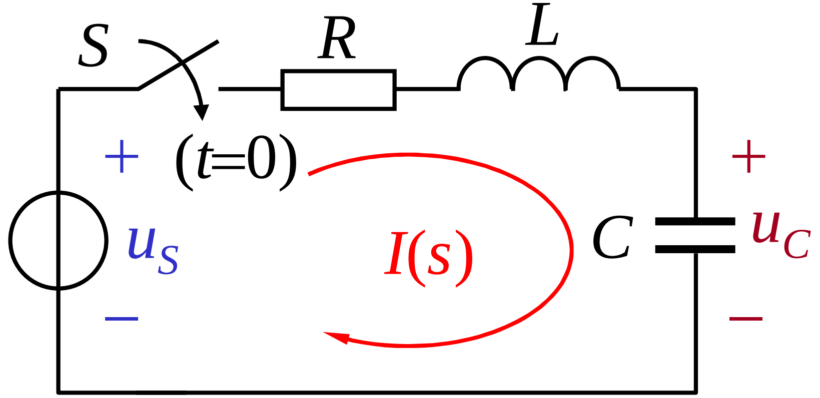
P371 14 18

$H(s)$

$u_C(t)$

$U_S(s)$

$U_C(s)$



$$H(s) = U_C(s)/U_S(s)$$

$$U_C(s) = I(s)\frac{1}{sC} = \frac{U_S(s)}{R + sL + \frac{1}{sC}}\frac{1}{sC} = \frac{U_S(s)}{s^2LC + sRC + 1}$$

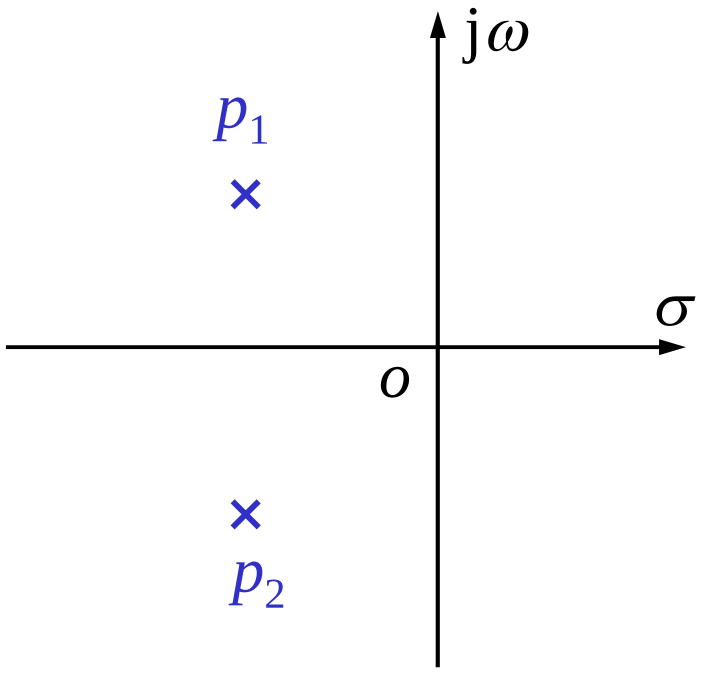
$$H(s) = \frac{1}{LC}\frac{1}{(s-p_1)(s-p_2)}$$

$$p_1 = -\frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}$$

p_1 p_2

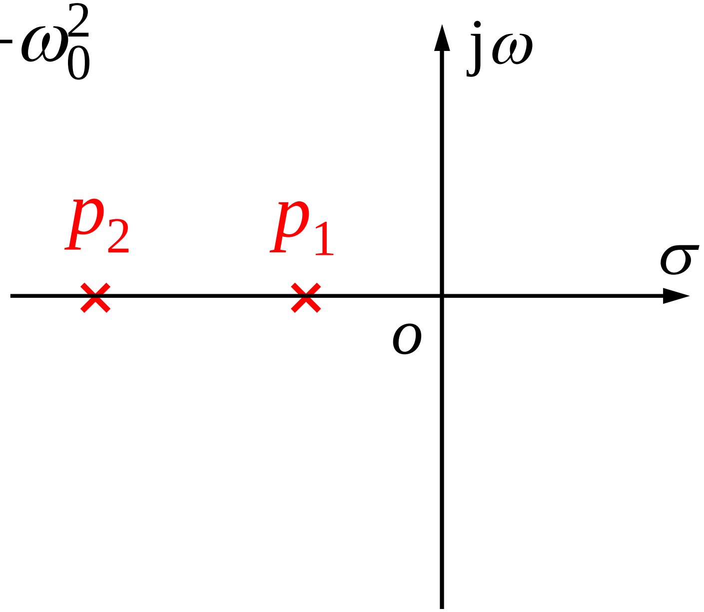
$$p_2 = -\frac{R}{2L} - \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}$$

(1) 0<



$$p_1 = -\frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}} \qquad p_2 = -\frac{R}{2L} - \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}$$

$$\delta = \frac{R}{2L} \qquad \omega_0 = \frac{1}{\sqrt{LC}} \qquad \omega_d = \sqrt{\delta^2 + \omega_0^2}$$



(3) $R > 2\sqrt{\frac{L}{C}}$

p_1 p_2

$u_C(t)$

$H(s)$

$u_C(t)$ $u_C(t)$

§ 14 9

$H(s)$ $s=\mathrm{j}\omega$ $H(\mathrm{j}\omega)$ ω

ω $H(\mathrm{j}\omega)$

$$H(\mathrm{j}\omega) = |H(\mathrm{j}\omega)| \underline{/\varphi(\mathrm{j}\omega)}$$

$|H(\mathrm{j}\omega)|$ ω $|H(\mathrm{j}\omega)|$ ω

$\varphi(\mathrm{j}\omega)$

$$H(\mathrm{j}\omega) = H_0 \frac{\prod_{i=1}^{m} (\mathrm{j}\omega - z_i)}{\prod_{j=1}^{n} (\mathrm{j}\omega - p_j)}$$

$$|H(\mathrm{j}\omega)| = H_0 \frac{\prod_{i=1}^{m} |(\mathrm{j}\omega - z_i)|}{\prod_{j=1}^{n} |(\mathrm{j}\omega - p_j)|}$$

(1)

$$\varphi(\mathrm{j}\omega) = \sum_{i=1}^{m} \arg(\mathrm{j}\omega - z_i) - \sum_{j=1}^{n} \arg(\mathrm{j}\omega - p_i) = \sum_{i=1}^{m} \varphi_i - \sum_{i=1}^{m} \theta_i$$

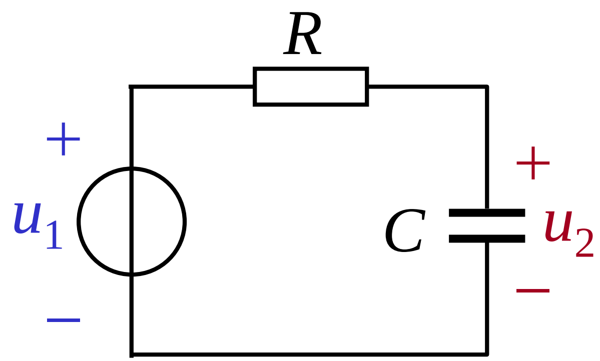
(2)

Bode

14 19 RC

u_2

(1)



$$H(\mathrm{j}\omega)=\frac{\dot U_2(\mathrm{j}\omega)}{\dot U_1(\mathrm{j}\omega)}=\frac{\frac{1}{RC}}{\mathrm{j}\omega+\frac{1}{RC}}$$

$$|H(\mathrm{j}\omega)|=\frac{H_0}{\left|\mathrm{j}\omega+\frac{1}{RC}\right|}$$

$$\varphi(\mathrm{j}\omega)=0-\theta(\mathrm{j}\omega)=-\mathrm{arctg}(\omega RC)$$

(2)

$\omega=0$ $|H(\mathrm{j}0)|=1$

$\varphi(\mathrm{j}0)=0$

$\omega=\omega_C=\frac{1}{RC}$

$|H(\mathrm{j}\omega_C)|=\frac{1}{\sqrt{2}}$

$\varphi(\mathrm{j}\omega_C)=45^{o}$

$\omega\to\infty$ $|H(\mathrm{j}\infty)|=0$

$\varphi(\mathrm{j}\infty)=90^{o}$

$$|H(\mathrm{j}\omega)| = \frac{H_0}{\left|\mathrm{j}\omega + \frac{1}{RC}\right|} = \frac{H_0}{M(\omega)}$$

$$\varphi(\mathrm{j}\omega) = -\theta(\omega) = -\mathrm{arctg}(\omega RC)$$

$\omega = \omega_1$ $\quad |H(\mathrm{j}\omega_1)| = H_0/M_1$

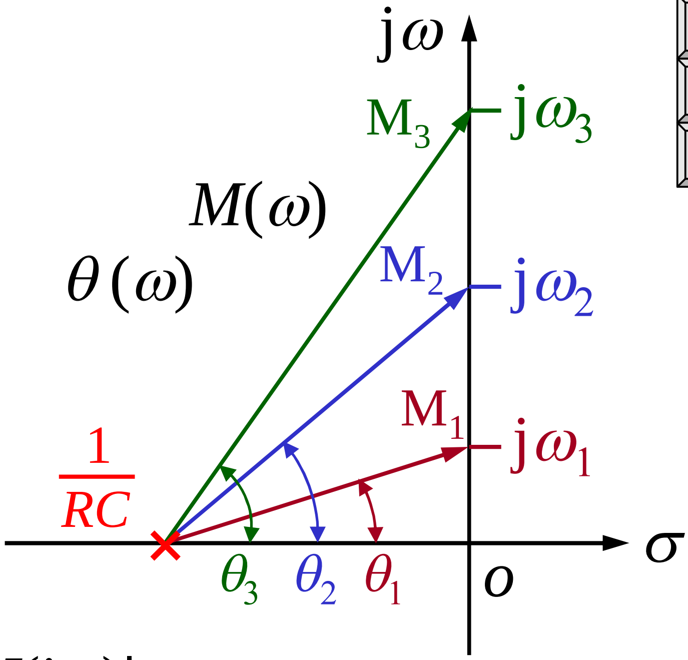
$$\varphi(\mathrm{j}\omega_1) = -\theta_1$$

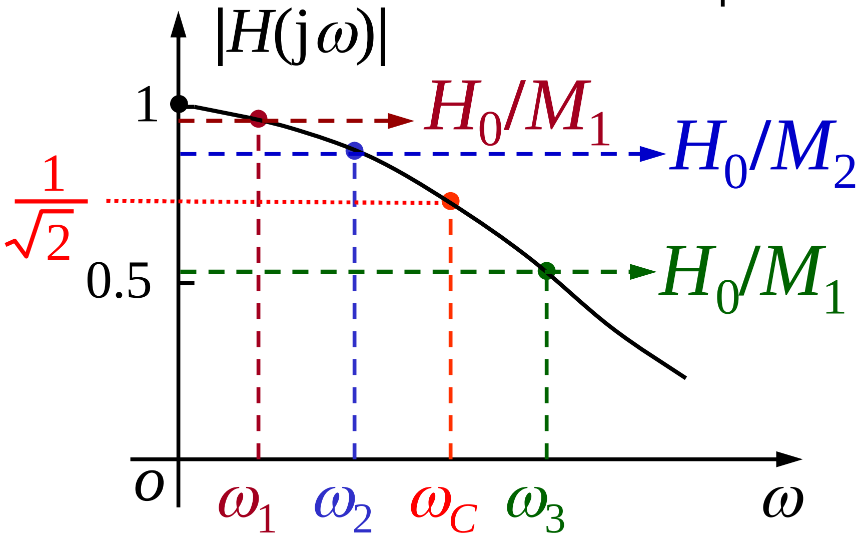
$\omega = \omega_2$ $\quad |H(\mathrm{j}\omega_2)| = H_0/M_2$

$$\varphi(\mathrm{j}\omega_2) = -\theta_2$$

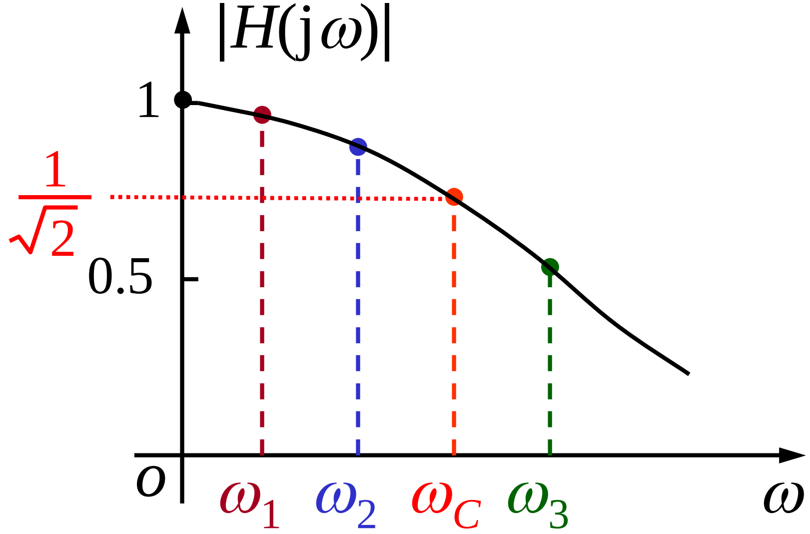
$\omega = \omega_3$ $\quad |H(\mathrm{j}\omega_3)| = H_0/M_3$

$$\varphi(\mathrm{j}\omega_3) = -\theta_3$$





ω_C

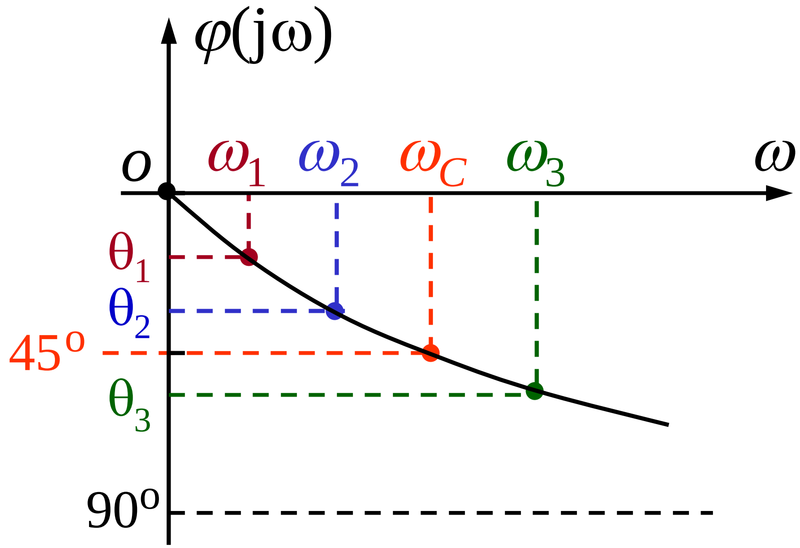


$$\omega_C - 0 = \omega_C$$

$$\omega_C = \frac{1}{RC}$$

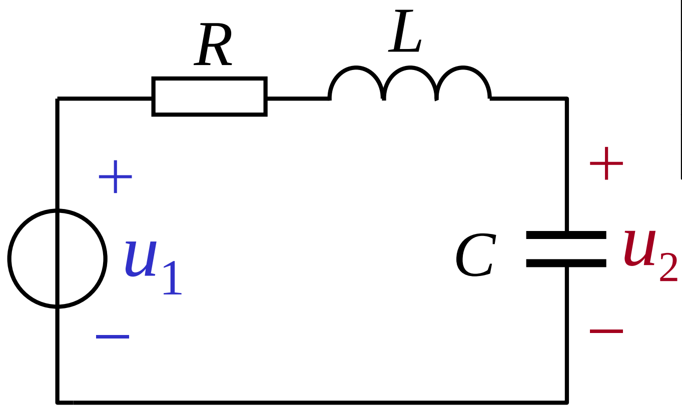
$M(\omega)$

$\theta(\omega)$



14 20 *RLC*

$$H(s)=\frac{U_2(s)}{U_1(s)}\ ,$$



$H(j\omega)$

P371 14 18

$$H(s)=\frac{1}{LC}\ \frac{1}{(s-p_1)(s-p_2)}=\frac{H_0}{(s-p_1)(s-p_2)}$$

$s=j\omega$ $$H(j\omega)=\frac{H_0}{(j\omega-p_1)(j\omega-p_2)}$$

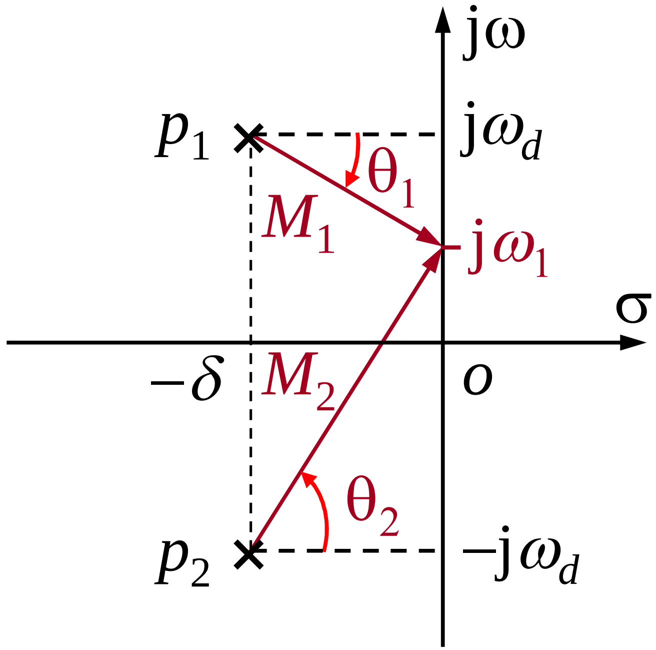
$$p_{1,\ 2}=-\frac{R}{2L}\pm\sqrt{\left(\frac{R}{2L}\right)^2-\frac{1}{LC}}$$

$$p_1 = -\delta + j\omega_d \qquad p_2 = -\delta - j\omega_d$$

$\delta \quad \omega_d \quad \omega_0$

$$|H(j\omega)| = \frac{H_0}{|j\omega - p_1|\,|j\omega - p_2|} = \frac{H_0}{M_1(\omega)\, M_2(\omega)}$$

$$\varphi(j\omega) = -(\theta_1 + \theta_2)$$



$\omega = \omega_1 \quad |H(j\omega_1)| = \dfrac{H_0}{M_1\, M_2}$

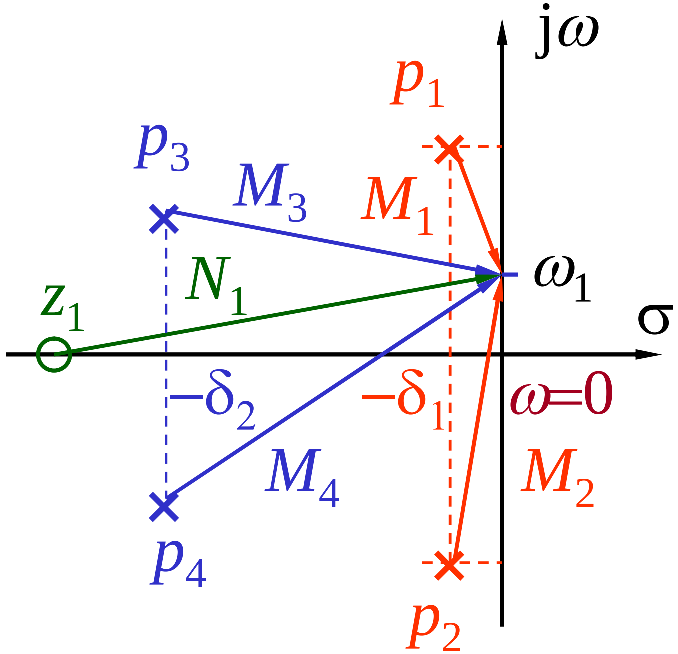
$\varphi(j\omega_1) = -(-\theta_1 \quad \theta_2)$

$\omega = \omega_2 \quad \ldots$

14-19

$$|H(\mathrm{j}\,\omega_1)| = \frac{N_1}{M_1\, M_2\, M_3 M_4}$$

$$|\varphi\,(\mathrm{j}\omega_1)| = \varphi_1 - (\theta_1 + \theta_2 + \theta_3 + \theta_4)$$



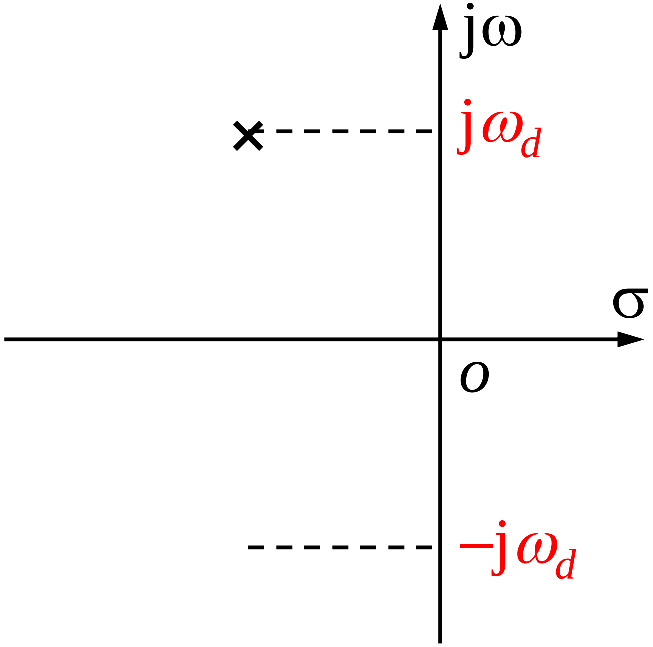
5

ω M_1 M_2 θ_1 θ_2

M_1 θ_1

Q_p

$$Q_p \overset{\text{def}}{=\!=} \frac{1}{2}\frac{\sqrt{\delta^2+\omega_d^2}}{\delta} = \frac{\omega_0}{2\delta}$$



§ 7 9

$f_1(t)$ $f_2(t)$

$$\int_{\infty}^{\infty} f_1(\xi)\, f_2(t-\xi)\, \mathrm{d}\xi$$

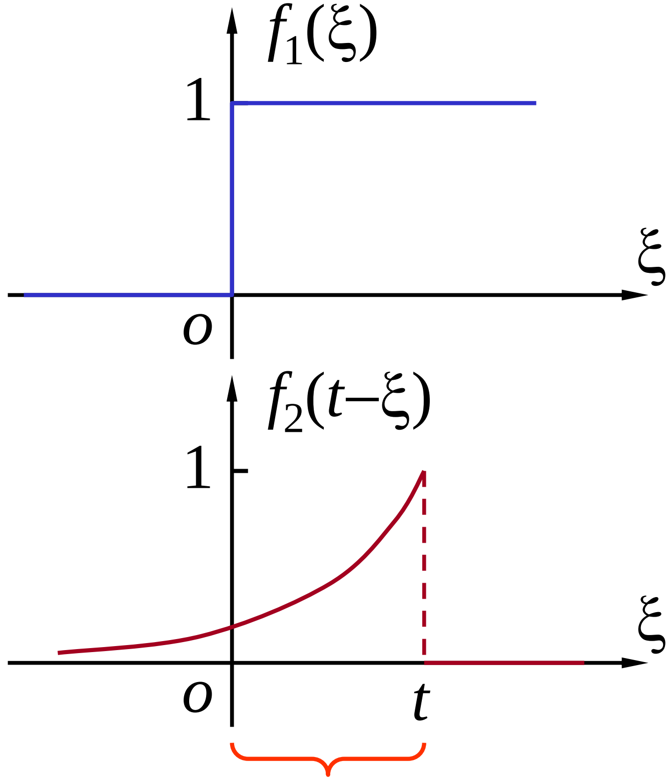
$f_1(t)$ $f_2(t)$ $f_1(t) * f_2(t)$

$$f_1(t) * f_2(t) = f_2(t) * f_1(t)$$

$$f_1(t) * [f_2(t) + f_3(t)] = f_1(t) * f_2(t) + f_1(t) * f_3(t)$$

$$f_1(t) = \varepsilon(t) \qquad f_2(t) = \begin{cases} 0 & t < 0 \\ e^{-t} & t \geq 0 \end{cases}$$

$$f_1(t) * f_2(t)$$



$$f_1(t)*f_2(t)=\int_{\infty}^{\infty} f_1(\xi)\, f_2(t-\xi)\,d\xi$$

$$f_1(\xi)$$

$$f_2(t-\xi)= e^{-(t-\xi)}$$

$$(t-\xi) \geq 0 \qquad \xi \leq t \qquad \neq 0$$

$$f_1(t)*f_2(t)=\int_0^t 1\cdot e^{-(t-\xi)}\,d\xi$$

$$= e^{-t}\int_0^t e^{\xi}\,d\xi = e^{-t}(e^{t}-1) = 1- e^{-t}$$

$$f_2(t) * f_1(t)$$

$$f_1(\xi)\, f_2(t-\xi) \neq 0$$

$$[0 \quad t]$$

$f_1(t)$ $f_2(t)$ $F_1(s)$ $F_2(s)$

$f_1(t) * f_2(t)$

$[f_1(t) * f_2(t)] = F_1(s) \cdot F_2(s)$

$^{-1}[F_1(s) \cdot F_2(s)] = f_1(t) * f_2(t)$

•

•

$e(t-\xi)\, h(\xi)$

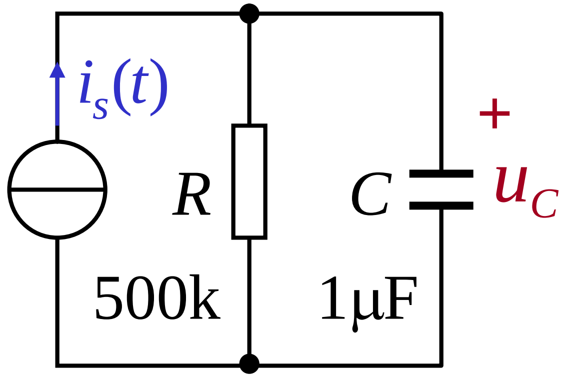
- $R(s) = E(s)\, H(s)$
- $r(t) = \ ^{-1}[E(s)\, H(s)] = \int^{t} \overbrace{e(\xi)\ h(t-\xi)}\, \mathrm{d}\xi$

$e(t)$ $h(t-\xi)$

14 7 $i_s(t)=2e^{-t}\,\mu A$

$u_C(t)$

P149 6 2



$$h(t) = \frac{1}{C} e^{-\frac{t}{RC}}$$

$$h(t) = 10^6 e^{-2t}$$

$$u_C(t) = \ ^{1}[I_S(s)H(s)]$$

$$u_C(t) = \int_0^t i_s(\xi)h(t-\xi)\,d\xi$$

$$= \int_0^t 2\times 10^{-6} e^{-\xi} \times 10^6 e^{-2(t-\xi)}\,d\xi$$

$$= 2\int_0^t e^{-\xi} e^{-2t} e^{2\xi}\,d\xi$$

$$= 2e^{-2t}\int_0^t e^{\xi}\,d\xi$$

$$= 2e^{-2t}(e^t - 1)$$

$$= 2(e^{-t} - e^{-2t})\,\varepsilon(t)\ V$$

$$F(s) = \frac{s^2}{(s^2+1)^2} \qquad f(t)$$

$$F(s) = \frac{s}{s^2+1}\ \frac{s}{s^2+1}$$

$$f(t) = \quad {}^{1}\left(\frac{s}{s^2+1}\ \frac{s}{s^2+1}\right)$$

$$= \cos t * \cos t = \int_0^t \cos\xi \cos(t-\xi)\,\mathrm{d}\xi$$

$$= \frac{1}{2}\int_0^t [\cos t + \cos(2\xi - t)]\,\mathrm{d}\xi$$

$$= \frac{1}{2}(t\cos t + \sin t)$$