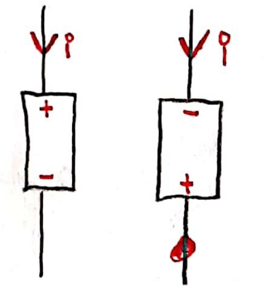
CIRCUIT THEORY

şafak bilici

Power

$p = v \cdot i$

$p = i^2 \cdot R$



$p = +vi$ $\quad$ $p = -vi$

Tellegen's Theorem

$$\sum p = 0$$

$$w = \int_{t_0}^{t} p\,dt = \int_{t_0}^{t} vi\,dt$$

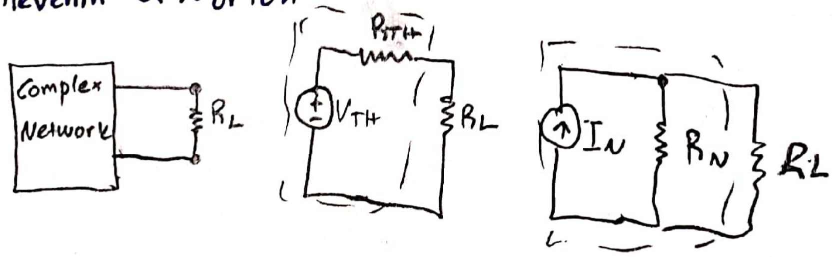
Kirchhoff's Current Law (KCL)

$$\sum_{n=1}^{N} i_n = 0$$

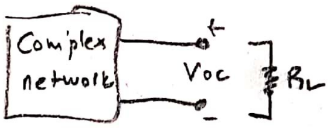
Kirchhoff's Voltage Law (KVL)

$$\sum_{n=1}^{N} V_n = 0$$

Thevenin & Norton



$P = V i$ $\quad$ V, $i(t) = \frac{1}{L} \cdot \int_{t_0}^{t_1} i_L\, d_L + i(t_0)$

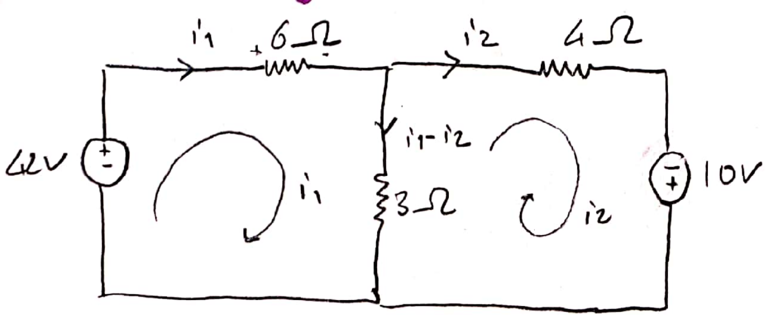


$V_{oc} = V_{TH} = 8V$

$L \cdot i_L \cdot \int_{t_0}^{t_1} i_L\, dt_L$ $\quad$ $W = L \cdot \frac{i^2}{2}$

Circuit Practice

[redacted]

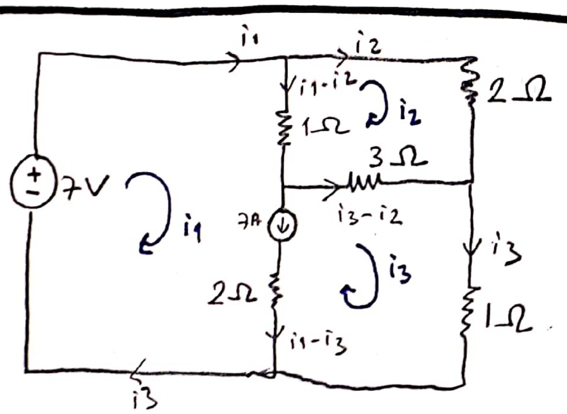


$6i_1 + 3i_1 - 3i_2 - 42 = 0$

$4i_2 - 3i_1 + 3i_2 - 10 = 0$

$9i_1 - 3i_2 = 42$

$7i_2 - 3i_1 = 10$



$2\cancel{i_2} + 3\cancel{i_2} - 3i_3 + i_2 - i_1 = 0$

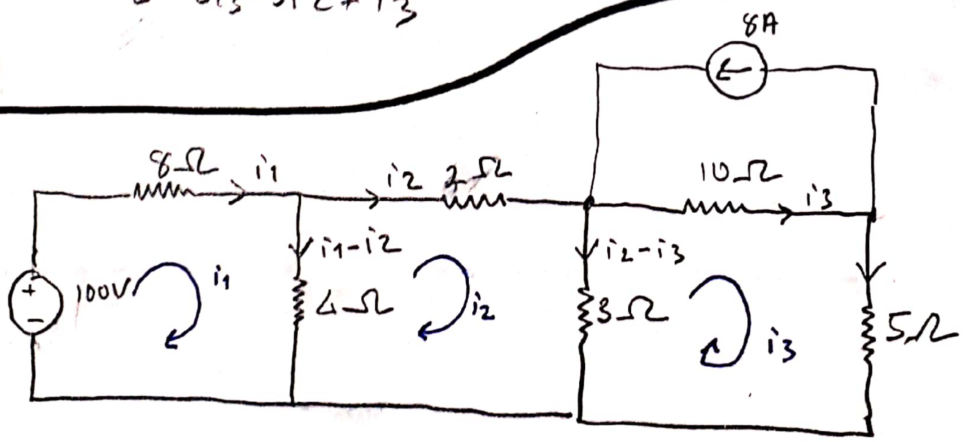
$-i_1 + 6i_2 - 3i_3 = 0$

$i_1 - i_3 = 7$

$i_1 - 4i_2 + i_3 = 7$

$i_1 + 3i_3 - 3i_2 + i_3 = 7$

$i_1 - i_2 + 3i_3 - 3i_2 + i_3$



$8i_1 + 4i_1 - 4i_2 = 100$

$2i_2 + 3i_2 - 3i_3 - 4i_1 + 4i_2 = 0$

$10\cancel{i_3} + 5\cancel{i_3} - 3i_2 + 3i_3 = -80$

$12i_1 - 4i_2 = 100$

$-4i_1 + 9i_2 - 3i_3 = 0$

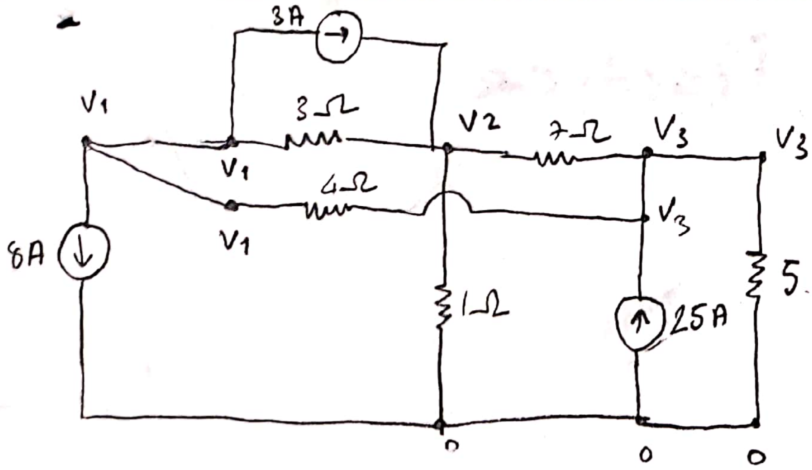
$-3i_2 + 18i_3 = -80$

$|\Delta i| = 1548$

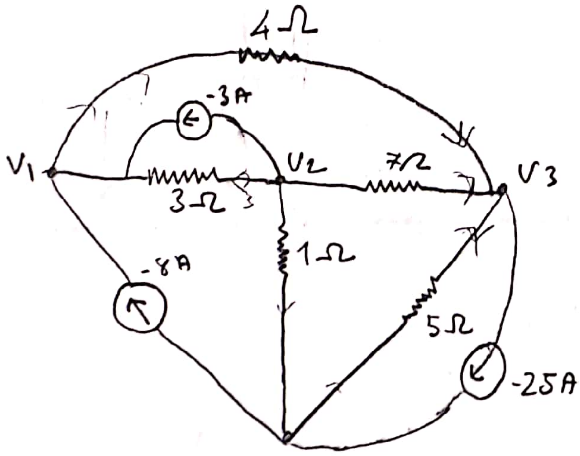
$|\Delta i_2| = 4320$

$$\Delta i = \begin{bmatrix} 12 & -4 & 0 \\ -4 & 9 & -3 \\ 0 & -3 & 18 \end{bmatrix} \qquad \Delta i_2 = \begin{bmatrix} 12 & 100 & 0 \\ -4 & 0 & -3 \\ 0 & -80 & 18 \end{bmatrix}$$

$$\frac{|\Delta i_2|}{|\Delta i|} = 2.79 = i_2$$



Determine the nodal voltages



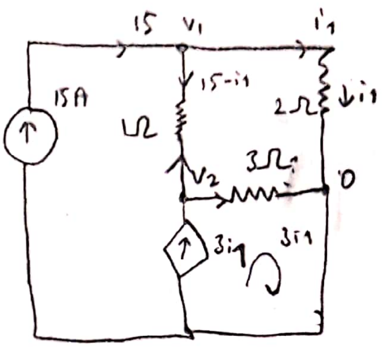
$$-8-3 = \frac{V_1-V_3}{4} + \frac{V_1-V_2}{3}$$

$$-3 = \frac{V_1-V_2}{3} - \frac{V_2}{1} + \frac{V_3-V_2}{7}$$

$$-25 = -\frac{V_3}{5} + \frac{V_2-V_3}{7} + \frac{V_1-V_3}{4}$$

$$3 = \frac{V_2-V_1}{3} + \frac{V_2}{1} + \frac{V_2-V_3}{7}$$

$$25 = \frac{V_3}{5} + \frac{V_3-V_2}{7} + \frac{V_3-V_1}{4}$$



Determine the nodal voltages

$$i_1 = \frac{V_1}{2}$$

$$3V_1 - 2V_2 = 30$$

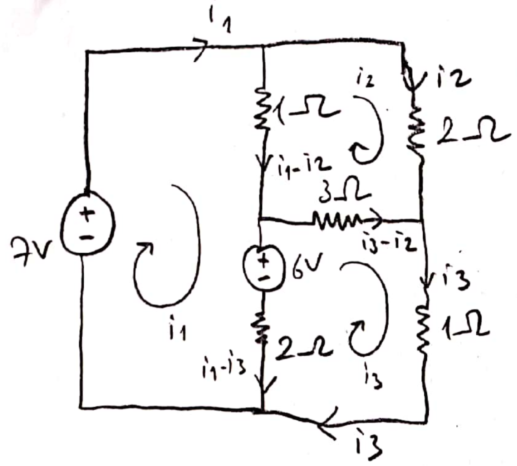
$$15V_1 - 8V_2 = 0$$

$$15 = \frac{V_1-V_2}{1} + \frac{V_1}{2}$$

$$3i_1 = -\frac{V_1+V_2}{1} + \frac{V_2}{3}$$

$$\frac{3V_1}{2} + \frac{V_1-V_2}{1} - \frac{V_2}{3} = 0$$

$$9V_1 + 6V_1 - 6V_2 - 2V_2$$



Determine the three mesh

$-2i_1 - 3i_2 + 6i_3 = 6$

$-i_1 + 6i_2 - 3i_3 = 0$

$3i_1 - i_2 - 2i_3 = 1$

$\cancel{3}i_3 - 3i_2 + \cancel{i_3} + 2\cancel{i_3} - 2i_1 - 6 = 0$

$2\cancel{i_2} + 3\cancel{i_2} - 3i_3 + \cancel{i_2} - i_1$

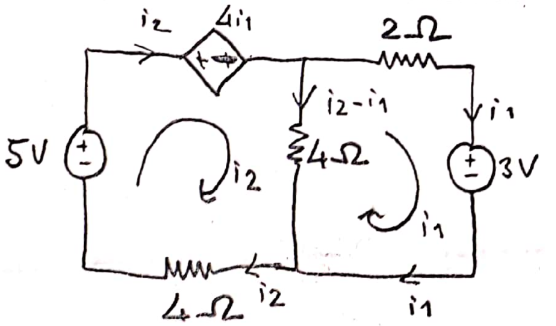
$\cancel{i_1} - \cancel{i_2} + 6 + 2\cancel{i_1} - 2i_3 - 7 = 0$

$$\Delta i = \begin{bmatrix} -2 & -3 & 6 \\ -1 & 6 & -3 \\ 3 & -1 & -2 \end{bmatrix} \qquad \Delta i_1 = \begin{bmatrix} 6 & -3 & 6 \\ 0 & 6 & -3 \\ 1 & -1 & -2 \end{bmatrix}$$

$|\Delta i| = -39$

$|\Delta i_1| = -117$

$\frac{|\Delta i_1|}{|\Delta i|} = 3$



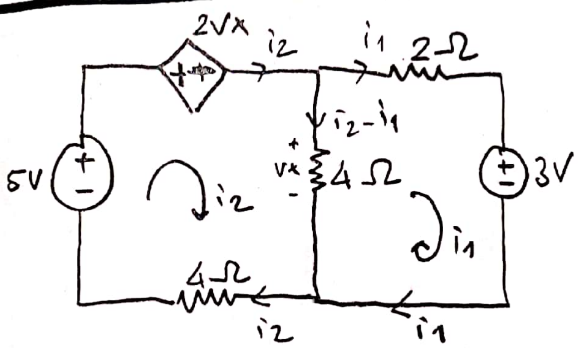
$8i_2 = 5$ $\qquad i_2 = \frac{5}{8}$ A

$6i_1 - 4i_2 = -3$ $\qquad i_1 = -\frac{1}{12}$ A

$\frac{5}{2} - 3 = \frac{-\frac{1}{2}}{6} = -\frac{1}{12}$

$4\cancel{i_1} + 4i_2 - 4\cancel{i_1} + 4i_2 = 5$

$2i_1 + 4i_1 - 4i_2 = -3$



$V_x = 4 \cdot i_2 - 4i_1$

$-8i_1 + 9i_2 = 5$

$6i_1 - 4i_2 = -3$

$$\Delta i = \begin{bmatrix} -8 & 9 \\ 6 & -4 \end{bmatrix}$$

$$\Delta i_1 = \begin{bmatrix} 5 & 9 \\ 3 & -4 \end{bmatrix}$$

$2V_x + 4i_2 - 4i_1 + i_2 = 5$

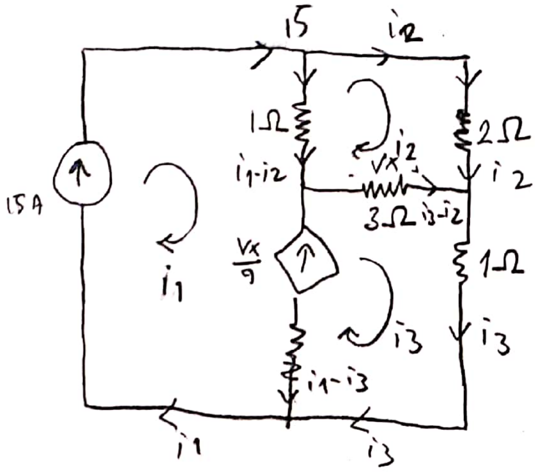
$|\Delta i| = -22$

$8i_2 - 8i_1 + i_2 = 5$

$|\Delta i_1| = -47$

$2\cancel{i_1} + 4\cancel{i_1} - 4i_2 = -3$

$i_1 = 2.1$



$i_1 = 15$

$$i_3 - i_1 = \frac{Vx}{9} = \frac{3(i_3 - i_2)}{9}$$

$$1 - \frac{1}{3}$$

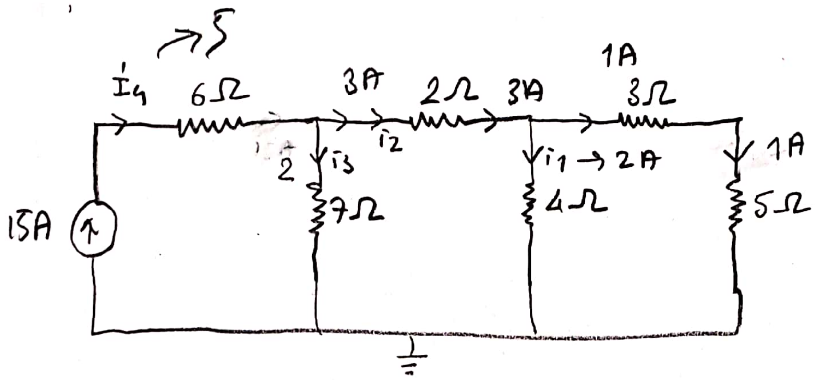
$$\frac{1}{3}(i_3 - i_2) = i_3 - i_1$$

$$\frac{i_3}{3} - \frac{i_2}{3} = i_3 - i_1$$

$$-i_1 + \frac{2i_3}{3} + \frac{1i_2}{3} = 0$$

$$\boxed{\frac{2.i_3}{3} + \frac{1}{3} i_2 = 15}$$

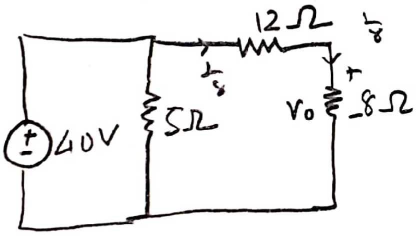
$$2i_2 + 3i_2 - 3i_3 + i_2 - i_1$$



$\frac{8 \cdot 4}{12}$ 3

$\frac{8}{3} + 2 = \frac{14}{3}$

$\frac{14}{3} \cdot 3$



$V_o = 1$ kabul et

Lineerlik kullanarak V_o bulun

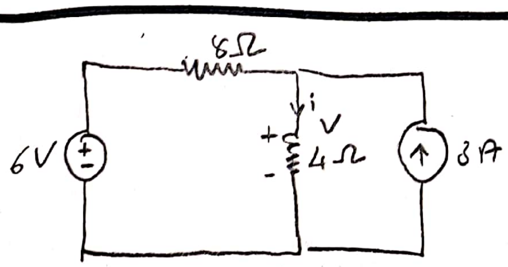
??

$\frac{12 \cdot 8}{20}$ 6 4 10 5

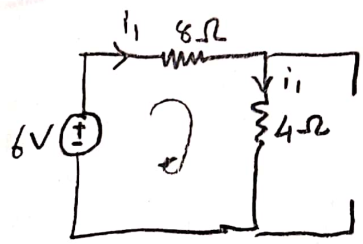
$\frac{24}{5} \cdot \frac{1}{8} = 5 \cdot i'$

$i' = \frac{3}{25}$

$\frac{3}{25} + \frac{1}{8}$

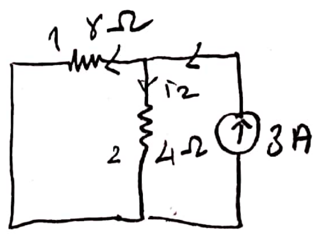


find V with superposition theorem



$i_1 = 0.5\,A$

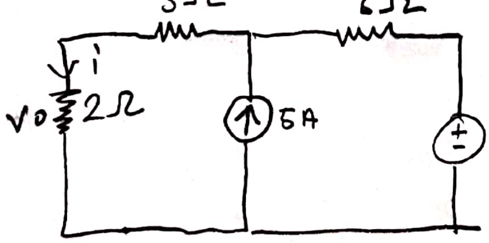
$\sim$



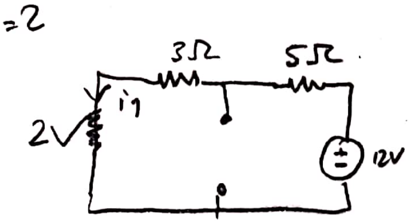
$i_2 = 2A$

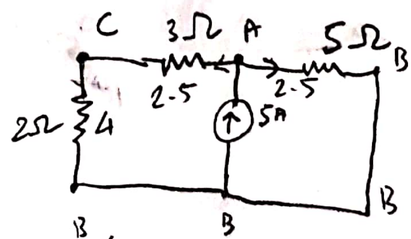
$i = i_1 + i_2 = 2.5A$

$V = 4 \cdot (2,5) = 10V$



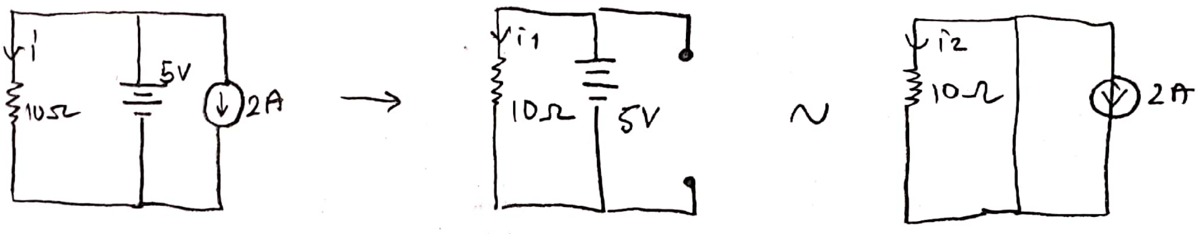
$V_o = 2$





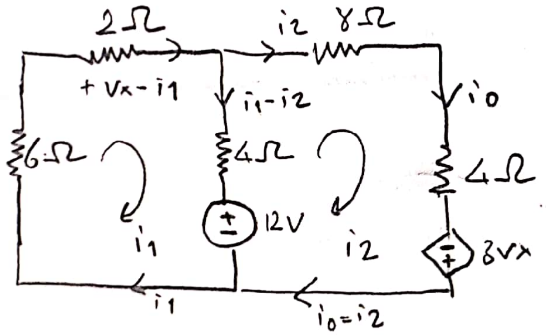
$i_1 = \frac{1,2}{2,5}$

$3.7 \times 2 = 7.4$



$i_1 = 0.5$ $\quad$ $i_2 = 0$

$i = i_1 + i_2 = 0.5$



$6i_1 + 2i_1 + 4i_1 - 4i_2 = -12\ 2$

$V_x = 2.i_1$

$8V_x = 6i_1$

$3i_1 - i_2 = -3$

$-5i_1 + 8i_2 = 6$

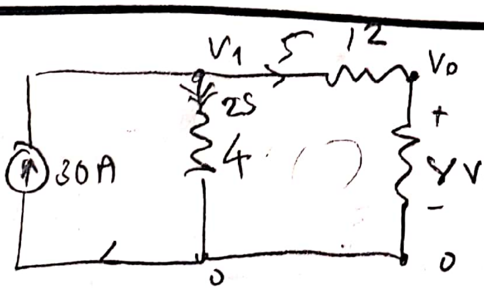
$8\cancel{i}2 + 4\cancel{i}2 - 6i_1 + \cancel{4i}_2 - 4i_1 = 12$

$\Delta i = \begin{bmatrix} 3 & -1 \\ -5 & 8 \end{bmatrix} \Delta_{i2} = \begin{bmatrix} 3 & -3 \\ -5 & 6 \end{bmatrix}$

$12i_2$ $\quad$ $16i_2 - 10i_1 = 12$

$\downarrow$ 19 $\quad$ $\downarrow$ 3

$\frac{|\Delta_{i2}|}{|\Delta i|} \rightarrow \frac{3}{19}$



$V_o = ?$

$V_o = 40$

$30 = \frac{V_1}{\underset{5}{4}} + \frac{V_1}{20}$

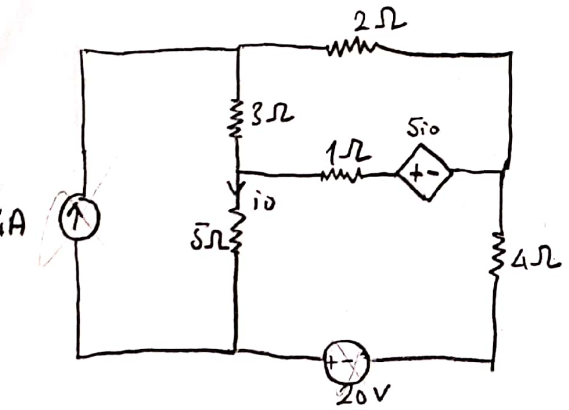
$5V_1$

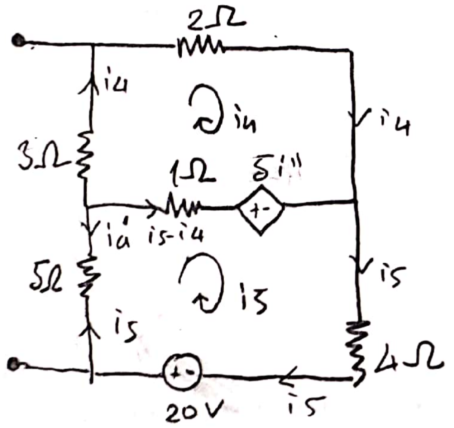
$\frac{\cancel{6}V_1}{20} = \cancel{30}\,5$

$V_1 = 100$

$i_o = ?$

Superposition





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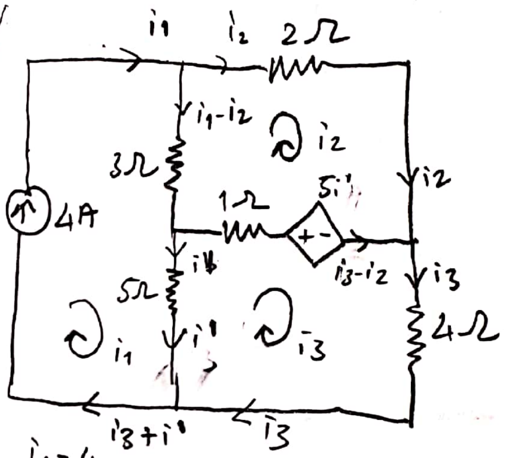


$i_1 = 4$

$i' = 4 - i_3$

$i_3 + i' = i_1 = 4$

$-20 + 5\cancel{i_5} + 5i'' + \cancel{i_5} - i_4 + \cancel{4i_5}$

$10i_5 - i_4 - 5i'' = 20$

$3i_4 + 2i_4 + i_4 + i_5 + 5i'' = 0 \qquad i_5 = -i''$

$6i_4 - i_5 - 5i'' = 0$

$6i_4 = 4i''$

6

$+5i'' - i_4 = 20$

$-4i'' + 6i_4 = 0$

$\Delta i = \begin{bmatrix} 5 & -1 \\ -4 & 6 \end{bmatrix} \qquad \Delta i'' = \begin{bmatrix} 20 & -1 \\ 0 & 6 \end{bmatrix}$

$|\Delta i| = -$

$|\Delta i''| =$

$i'' = \frac{-60}{17}$ A

$\cancel{3i_2} - \cancel{3i_1} + \cancel{2i_2} - 5i' + \cancel{i_2} - i_3 = 0$

$-3i_1 + 6i_2 - i_3 - 5i' = 0 \quad = 6i_2 - i_3 - 5i' = 12$

$6i_2 - i_3 - 20 + 5i_3 = 12$

$6i_2 + 4i_3 = 32$

$i_3 - i_2 + 4i_3 - \cancel{5i'} + \cancel{5i'} = 0$

$5i_3 - i_2 = 0$

$4i_3 + 6i_2 = 32$

$|\Delta x| = 34$

$\frac{32}{34} = i_3$

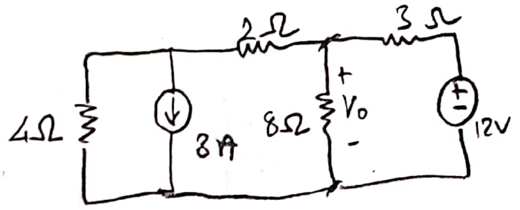
$4 - \frac{32}{34}$

34
×4
136
32
104
34

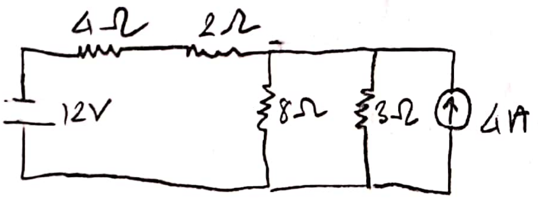
$\frac{52}{17}$

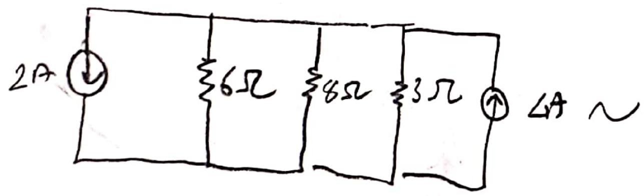
$\frac{52}{17} - \frac{60}{17} = i' + i'' = \frac{-8}{17}$

Thevenin



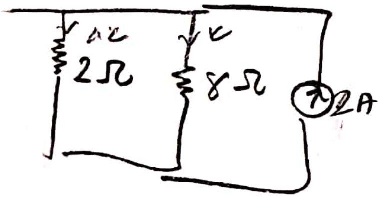
use source transformation to find V_o



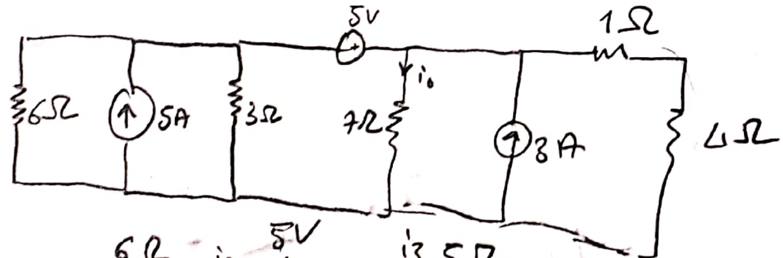


$5k = 2A$

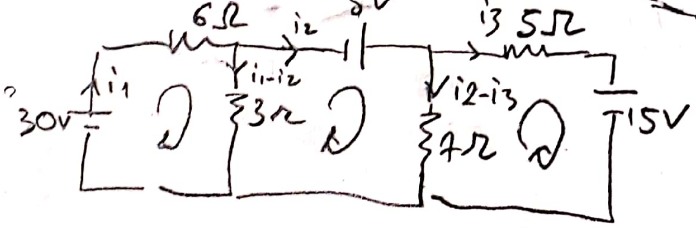
$k = \frac{2}{5} A$



$\frac{2}{5} \cdot 8 = 3.2V$



use source transformation to find i_o



??

$9i_1 - 3i_2 = 30$

$-3i_1 + 3i_2 = 5$

$-7i_2 + 12i_3 = -15$

$$\Delta i = \begin{bmatrix} 9 & -3 & 0 \\ -3 & 3 & 0 \\ 0 & -7 & 12 \end{bmatrix} \qquad \Delta i_3 = \begin{bmatrix} 9 & -3 & 30 \\ -3 & 3 & 5 \\ 0 & -7 & -15 \end{bmatrix}$$

$$\Delta i_2 = \begin{bmatrix} 9 & 30 & 0 \\ -3 & 5 & 0 \\ 0 & -15 & 12 \end{bmatrix}$$

$|\Delta i| = 216$

$|\Delta i_2| = 1620$

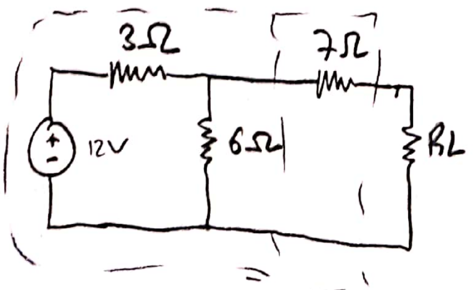
$|\Delta i_3| = 675$

$i_2 = 7.5$

$i_3 = 3.125$

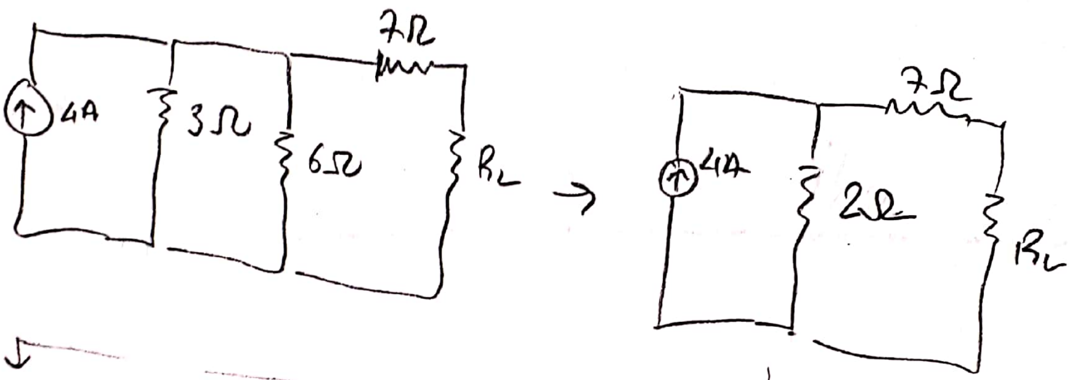
$$\begin{array}{r} 7.500 \\ -3.125 \\ \hline 4.465 \end{array}$$

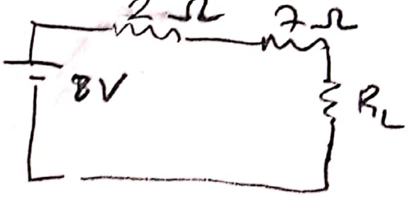
Thevenin & Norton



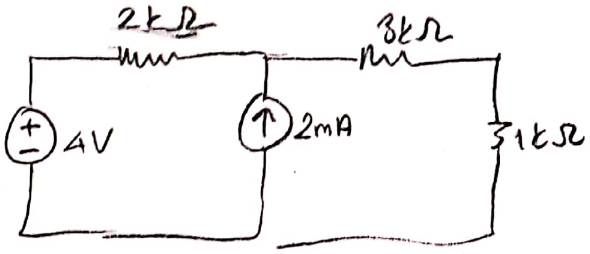
Network A

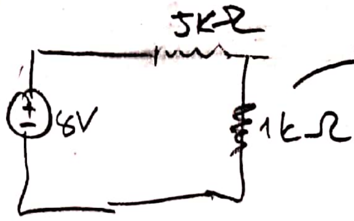
Compute the power delivered to the load resistor R_L and determine the Thevenin equivalent of Network A



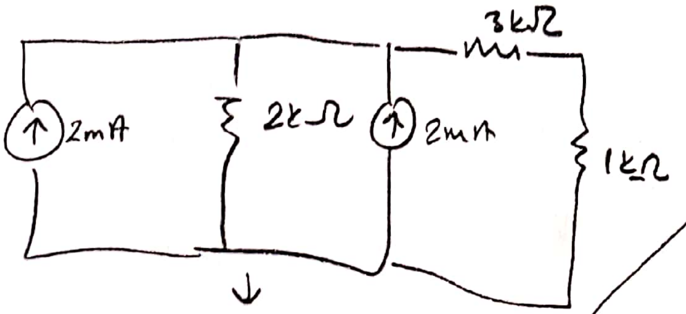


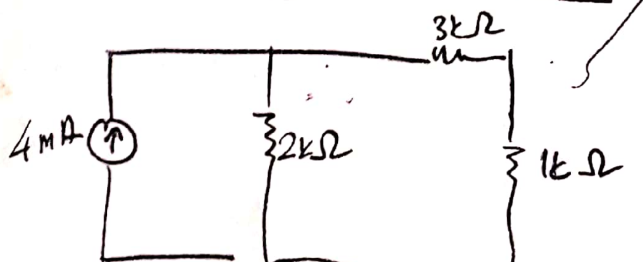
$$i = \frac{8}{9+R_L} \text{ A} \qquad P_L = \left(\frac{8}{9+R_L}\right)^2 \cdot R_L$$



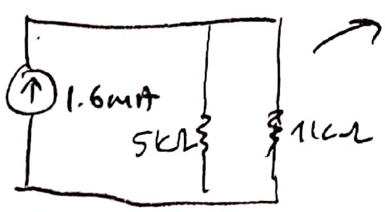


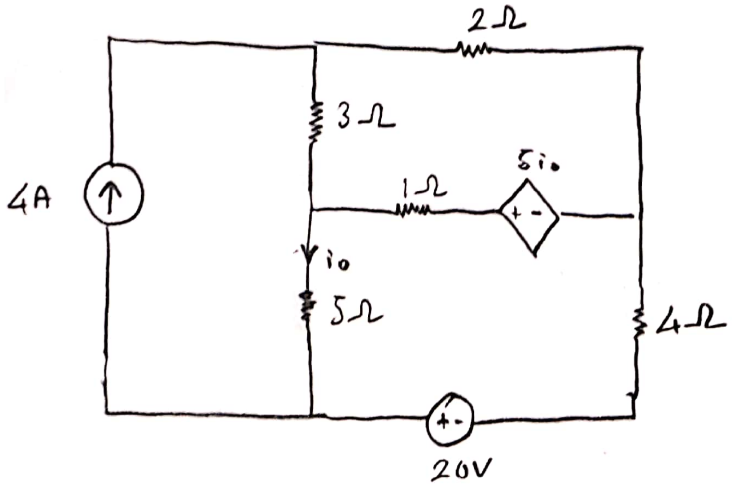
thevenin

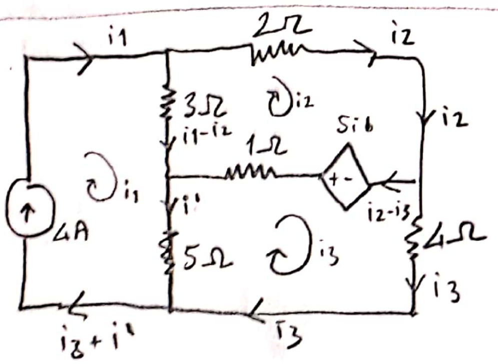




Norton



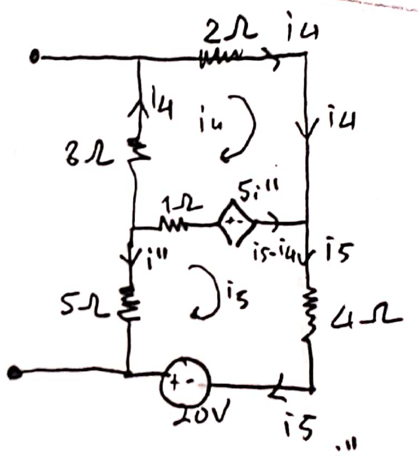




$i_1 = 4$

$i_3 + i' = 4 = i_1$

$i' = 4 - i_3$



$i_5 = -i''$

$\cancel{2i_2} + \cancel{i_2} - i_3 + \cancel{3i_2} - 3\underset{4}{i_1} = 20 - 4i_3$

$i_3 - i_2 + \cancel{5i'} + 4i_3 - \cancel{5i'} = 0$

$5i_2 + 3i_3 = 32$

$-i_2 + 5i_3 = 0$

$2i_4 - 5i'' + i_4 - \overset{i''}{i_5} + 3i_4 = 0$

$\overset{-5i''}{5i_5} + \overset{-i''}{i_5} - i_4 + \overset{-4i''}{4i_5} = 20$

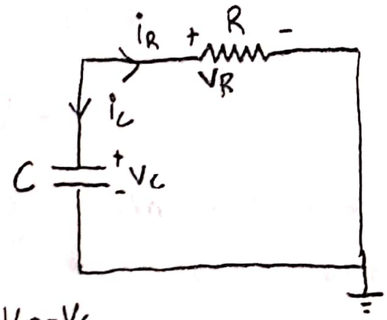
$6i_4 - 4i'' = 0$

$6 \times -i_4 - 10i'' = 20$

RC and RL

RC circuit

Suppose that there is some charge on a capacitor at time $t=0s$.
This charge could have been stored because a voltage current source had been in the circuit at $t<0s$, but was switched off at $t=0$.



$V_r = V_c$

$i_R = -i_c$

$i_c = C \cdot \frac{dV_c}{dt}$

$i_R = \frac{V_R}{R}$

$$C \cdot \frac{dV_c}{dt} + \frac{V_R}{R} = 0$$

$$V_R = V_c$$

$$\frac{dV_c}{dt} + \frac{V_c}{RC} = 0$$

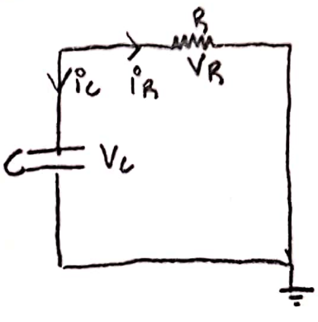
1

$$\frac{dV_c}{dt} \cdot \frac{1}{V_c} + \frac{1}{RC} = 0$$

$$\frac{dV_c}{V_c} = \frac{-dt}{RC} \longrightarrow \int \frac{dV_c}{V_c} = \int \frac{-dt}{RC}$$

$$\hookrightarrow \ln(V_c) = \frac{-t}{RC} + \ln\left(V_c\big|_{t=t_0}\right)$$

2



if $V_0 = V_c\big|_{t=0s}$ and $\tau = RC$

$V_c(t) = V_0 \cdot \exp(-t/\tau)$ when $t \geq 0s$

$I_R(t) = -I_c(t) = \frac{V_0}{R} \cdot \exp(-t/\tau)$

$P_r(t) = V_R I_R = \frac{V_0^2}{R} \cdot \exp(-2t/\tau)$

$$w(t) = \int_0^t P_r(t)\,dt = \frac{C \cdot V_0^2}{2}\left[1 - \exp(-2t/\tau)\right]$$

$I_c = C \cdot \frac{dV(t)}{dt}$

$\frac{230}{180 \cdot 90} = \frac{1}{60}$

$S_n = 2$

$n = \frac{2}{3} \cdot 2 \; \frac{4}{5}$

$\frac{4}{5k} + \frac{4}{5k}$

$\frac{4A_1}{5k}$

$\frac{4}{5}$

- The initial voltage $V(0) = V_0$ across the capacitor.

  - Can be obtained by inserting DC source to the circuit for a time much longer than τ (at least $t = -5\tau$) and then removing it at $t = 0$.

    - Capacitor

      - open circuit voltage

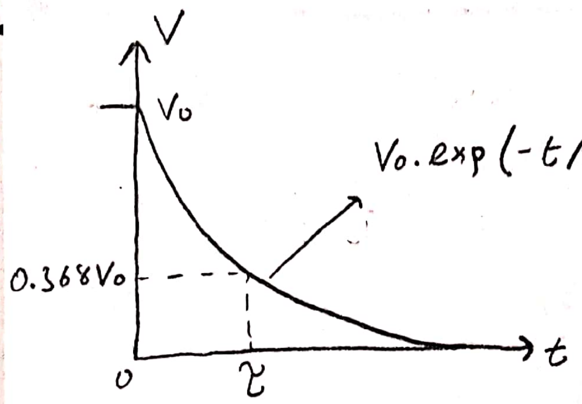
- The time constant τ.

  - In finding the time constant $\tau = RC$, R is often the Thevenin equivalent resistance at the terminals of the capacitor.

    - That is, we take out the capacitor C and find $R = R_{TH}$ at this terminals

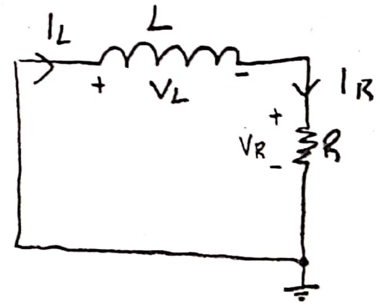
Time Constant

The natural response of a capacitive circuit refers to the behavior of the circuit itself, with no external sources of excitation.



$\tau = RC$

RL Circuit



14

$$I_L = I_R$$

$$V_L + V_R = 0$$

$$V_L = L \cdot \frac{dI_L}{dt}$$

$$I_R = V_R / R$$

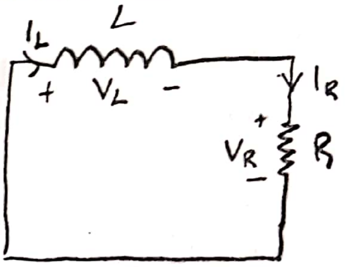
$$L \cdot \frac{dI_L}{dt} + R\, I_R = 0$$

$$\frac{dI_L}{dt} + \frac{R\, I_L}{L} = 0$$

$$\frac{dI_L}{dt} \cdot \frac{1}{I_L} = -\frac{R}{L}$$

$$\frac{dI_L}{I_L} = -\frac{R}{L}\, dt \longrightarrow \int \frac{dI_L}{I_L} = \int -\frac{R}{L}\, dt$$

$$\longrightarrow \ln(I_L) = -\frac{R}{L} t + \ln\left(I_L\big|_{t=0s}\right)$$



if $I_0 = I_L\big|_{t=0}$ and $\tau = \frac{L}{R}$

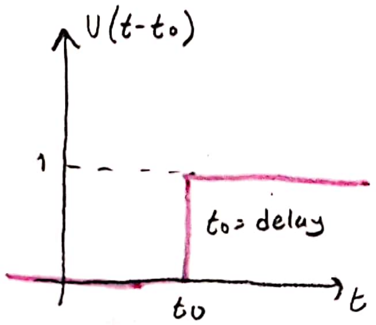
$$I_L(t) = I_0 \cdot \exp(-t/\tau) \quad \text{when } t \geq 0s$$

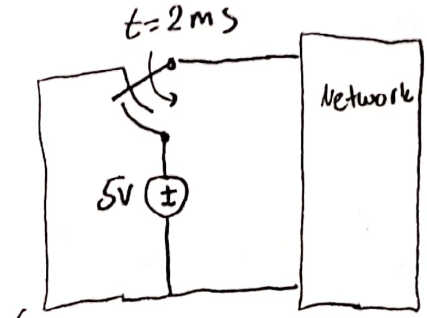
$$V_R(t) = -V_L(t) = R \cdot I_0 \cdot \exp(-t/\tau)$$

$$P_r(t) = V_R I_R = R \cdot I_0^2 \exp(-2t/\tau)$$

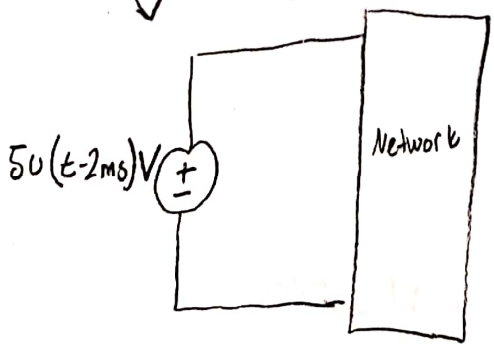
$$w(t) = \int P_r(t)\, dt = \frac{L I_0^2}{2} \cdot \left[1 - \exp(-2t/\tau)\right]$$

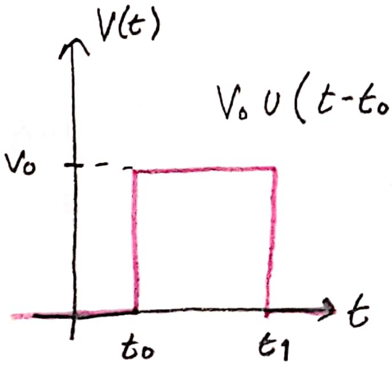
Unit-Step



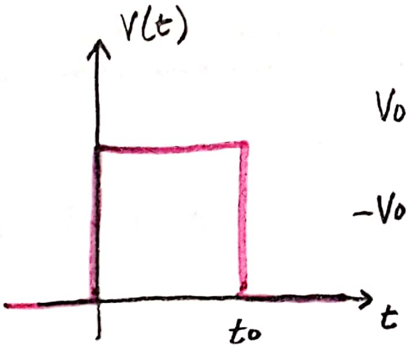


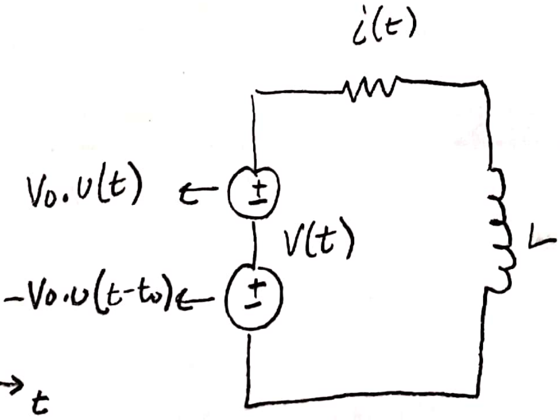
eşdeğer





$V_0 \, U(t-t_0) - V_0 \, u(t-t_1)$





[redacted]

General Equations

RC

$$V_c(t) = V_c(\infty) + [V_c(0) - V_c(\infty)] \cdot e^{-t/\tau}$$

$$I_c(t) = \frac{C}{\tau}[V_c(\infty) - V_c(0)] e^{-t/\tau}$$

$$\tau = RC$$

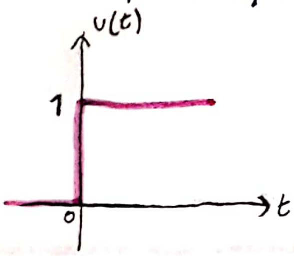
RL

$$I_L(t) = I_L(\infty) + [I_L(0) - I_L(\infty)] \cdot e^{-t/\tau}$$

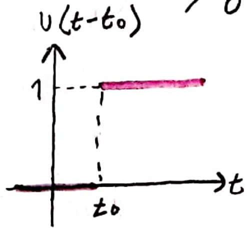
$$V_L(t) = \frac{L}{\tau}[I_L(\infty) - I_L(0)] \cdot e^{-t/\tau}$$

$$\tau = L/R$$

Unit Step Function / Birim Basamak Fonksiyonu

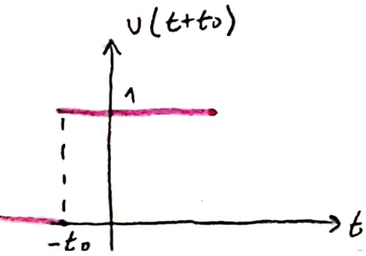


$$u(t) = \begin{cases} 1, & t>0 \\ nan & t=0 \\ 0, & t<0 \end{cases}$$

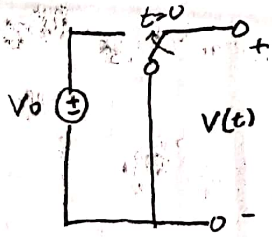


→ geciktirme

$$u(t-t_0) = \begin{cases} 1, & t>t_0 \\ nan & t=t_0 \\ 0 & , t<t_0 \end{cases}$$

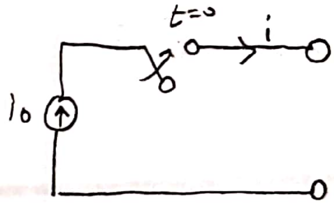


$$u(t+t_0) = \begin{cases} 1, & t>-t_0 \\ nan, & t=-t_0 \\ 0, & t<-t_0 \end{cases}$$



$$V(t) = \begin{cases} 0V, & t<0 \\ nan, & t=0 \\ V_oV & t>0 \end{cases}$$

$V(t) = V_o . u(t)\ V$

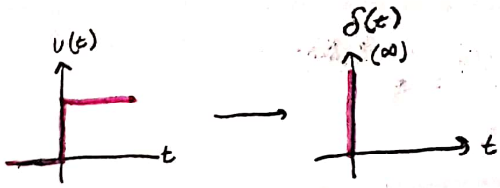


$$i(t) = \begin{cases} 0, & t<0 \\ nan, & t=0 \\ i_0 A & t>0 \end{cases}$$

$i(t) = i_0 . u(t)\ A$

Impulse Function / Dürtü Fonksiyonu

$$\delta(t) = \frac{d}{dt} u(t) = \begin{cases} 0, & t<0 \\ nan, & t=0 \\ 0, & t>0 \end{cases}$$



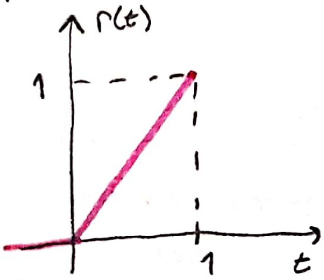
$$\left(\int_{0^-}^{0^+} \delta(t)dt = 1 \right)$$

→ sinyal gücü

$$\boxed{V(t) = V(\infty) + [V(0) - V(\infty)] . \exp(-t/\tau)}$$

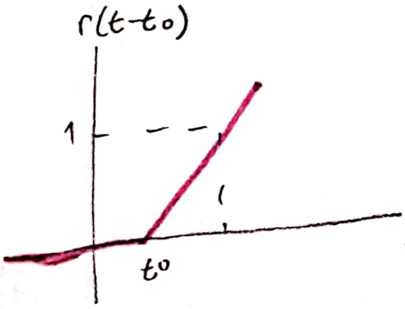
Genel Formül

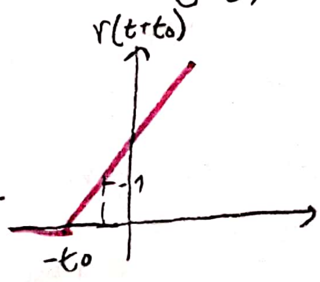
Rampa Fonksiyon



$$r(t) = \int_{-\infty}^{t} u(\lambda)\,d\lambda = t.u(t)$$

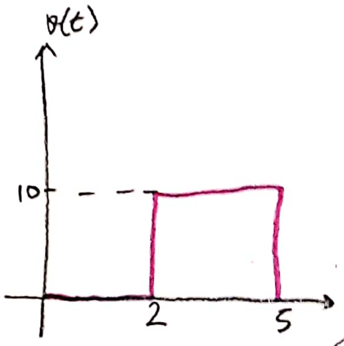
$$r(t) = \begin{cases} 0, & t \leq 0 \\ t, & t \geq 0 \end{cases}$$

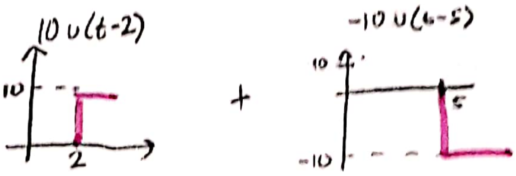




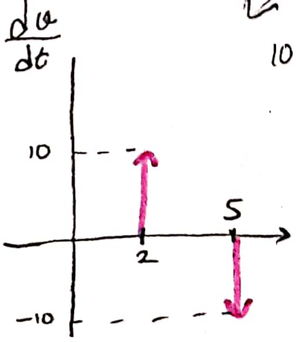
$$\delta = \frac{du(t)}{dt}$$

$$u(t) = \frac{dr(t)}{dt}$$

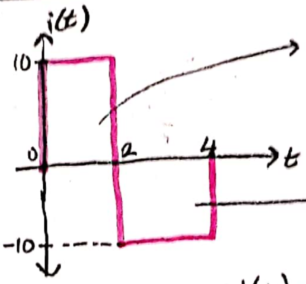




$$v(t) = 10\left(u(t-2) - u(t-5)\right)$$



$$10(\delta(t-2) - \delta(t-5))$$

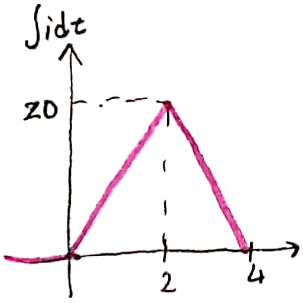


$\rightarrow 10u(t) - 10u(t-2)$

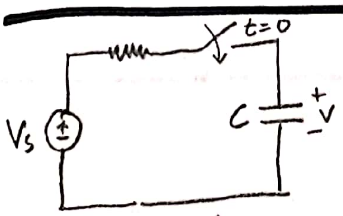
$+$

$\rightarrow -10[u(t-2) - u(t-4)]$

$$i(t) = 10u(t) - 20u(t-2) + 10u(t-4)$$



$$r(t) = 10r(t) - 10r(t-2) - 10r(t-2) + 10r(t-4) = 10r(t) - 20r(t-2) + 10r(t-4)$$

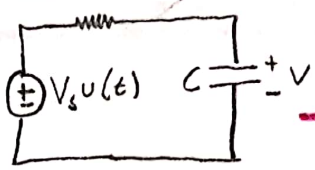


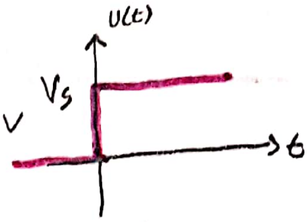
$$V_s u(t) = \begin{cases} 0, & t<0 \\ V_s, & t>0 \end{cases}$$

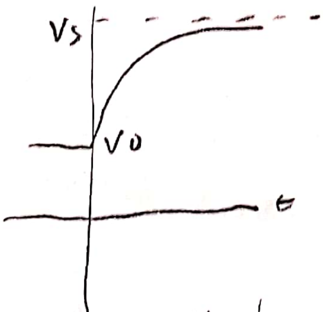
$$V(0^-) = V(0^+) = V_0$$

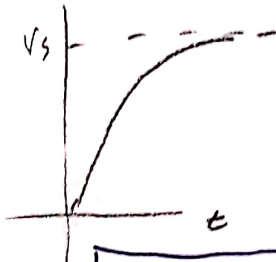
$$V(t) = V_s + (V_0 - V_s).\exp(-t/\tau), \; t>0$$

$\hookrightarrow$ birim basamak tepkisi









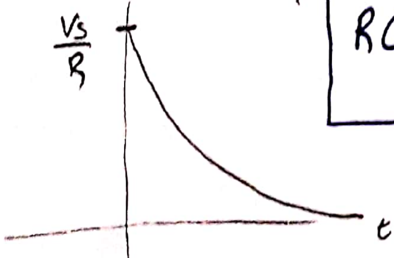
$$v(t) = \begin{cases} V_0, & t<0 \\ V_s + (V_0 - V_s)e^{-t/\tau} \end{cases}$$

$\downarrow$

$V_0 = 0$

$$v(t) = \begin{cases} 0, & t<0 \\ V_s(1-e^{-t/\tau}), & t>0 \end{cases}$$

$$v(t) = V_s.(1-\exp(-t/\tau)).u(t)$$



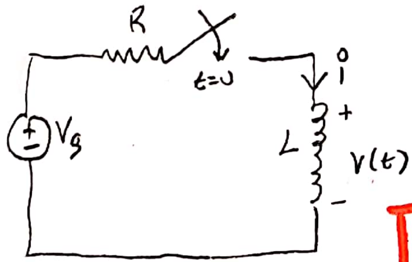
$\boxed{\text{RC devrenin basamak tepkisi}}$

Sistemin Tam tepkisi = Doğal Tepki + Zorlama tepki

$$V = V_n + V_f$$

$$V = V_0.\exp(-t/\tau) + V_s(1-\exp(-t/\tau))$$

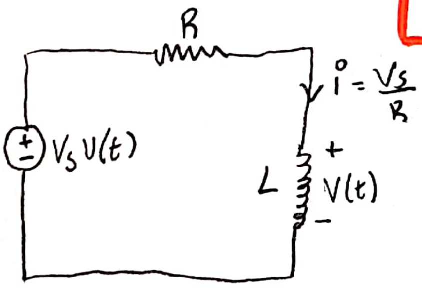
RL devrenin basamak tepkisi



$$i = i_t + i_{ss}$$

$$\boxed{i = A\exp(-t/\tau) + \frac{V_s}{R}}$$

$$i(0^-) = i(0^+) = i(0)$$



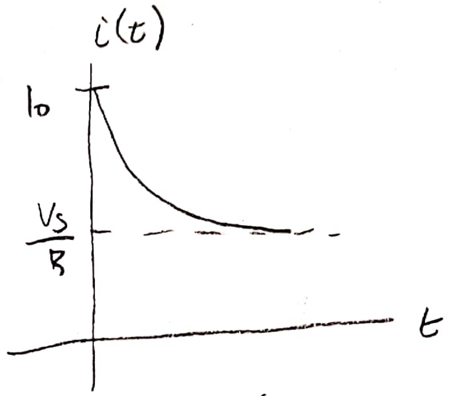
$$I_0 = A + \frac{V_s}{R} \rightarrow \boxed{A = I_0 - \frac{V_s}{R}}$$

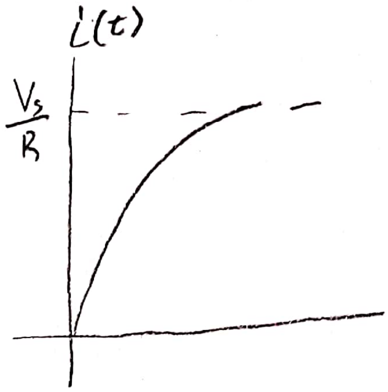
$$\tau = \frac{L}{R}$$

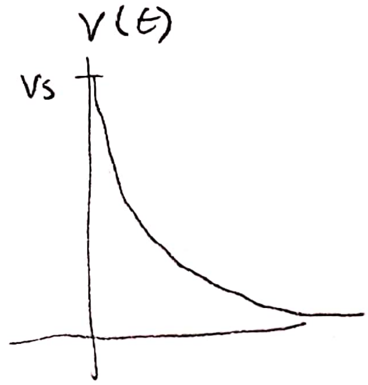
$$\boxed{i(t) = \frac{V_s}{R} + \left(I_0 - \frac{V_s}{R}\right)\exp(-t/\tau)}$$

$$\boxed{i(t) = i(\infty) + (i(0) - i(\infty))\exp(-t/\tau)}$$

$$\boxed{i(t) = i(\infty) + (i(t_0) - i(\infty))\exp(-(t-t_0)/\tau)}$$





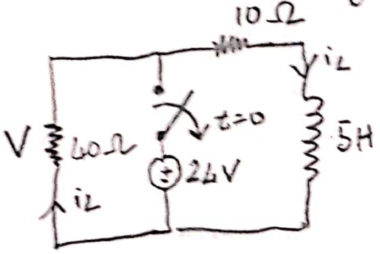


$i(0) = 0$ ise

$$i(t) = \frac{V_s}{R}\left(1 - \exp(-t/\tau)\right)$$

RL-RC

find the labeled voltage at t=200ms



$i_L(t) = I_0 \cdot \exp(-t/\tau)$ $\tau = \frac{L}{R}$

$V_R(t) = -V_L(t) = R_{eq} \cdot I_0 \cdot \exp(-t/\tau)$

$R_{eq} = 50\,\Omega$

$V_{R_{eq}} + V_L = 0$

$i_L = i_{R_{eq}}$

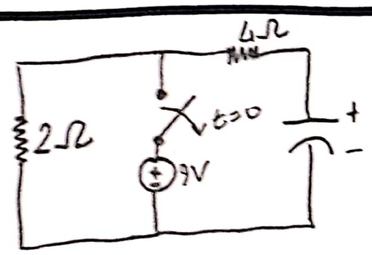
$\boxed{i_L(0.2) = \frac{12}{25} \cdot \exp(-2)}$

$\tau = \frac{5}{50} = 1/10$

$V_0 = 24V$

$24 = 50 \cdot I_0 \cdot 1$, $I_0 = \frac{24}{50}$

$\frac{12}{25} \cdot \exp(-2) \cdot 40 = V_{40\Omega}$



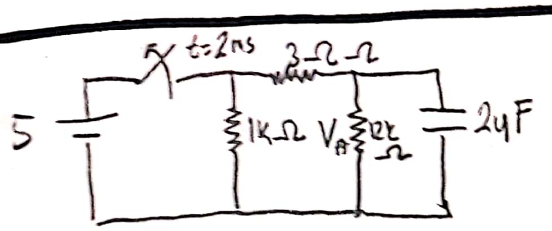
$V_0 = 9V$

$V_c = V_{R_{eq}} = V(t) = V_0 \cdot \exp(-t/\tau)$ $\rightarrow$ $\tau = R \cdot C$

t=200µs
=0.0002 saniye

$9 \cdot \exp\left(-2 \cdot 10^{-3} / 6 \cdot 10^{-4}\right)$
$= V(0.0002)$

$R = 6$
$RC = 10^{-4} \cdot 6$

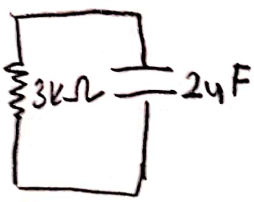


$V_c = V_a$ $V_a = \frac{12}{15} \cdot 5 = 4V = V_c$ $\frac{V_a}{9} \cdot 3 = 4$

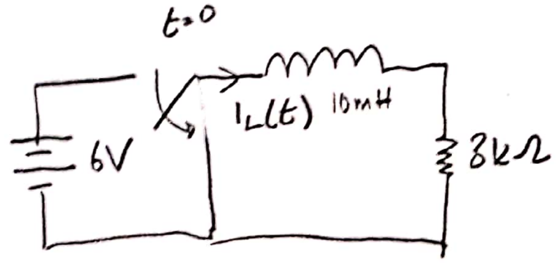
$R_{eq} = 3k\Omega$ $\tau = R_{eq} \cdot C = 3k\Omega \cdot 2\mu F = 6ms$

$V(t) = 5V[1 - u(t-2ms)]$ $\rightarrow$

$V_c = V(2ms) \cdot \exp\left(-(t-2ms)/\tau\right)$



$= 4V \cdot \exp\left(-(t-2ms)/6ms\right)$



$V_0 = 6V$

$\tau = \frac{L}{R} = \frac{10^{-3}H}{3\cdot10^{3}\Omega} = \frac{1}{3}\cdot10^{-6}s =$

$I_L(t) = I_0 \cdot exp(-t/\tau)$

$I_L = I_{Req}$

$V_L + V_{Req} = 0$

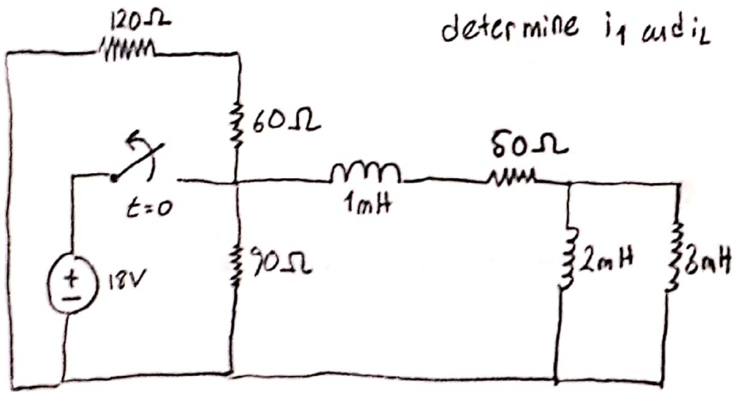
$I_0 = \frac{6}{3\cdot10^{+3}} = 2\cdot10^{-3}$

$I_L(t) = 2\cdot10^{-3}\cdot exp(-t/\frac{1}{3}\cdot10^{-6})$

$V_L(t) = -6 \cdot V \cdot exp(-t/\frac{1}{3}\cdot10^{-6})$

---

determine i_1 and i_L



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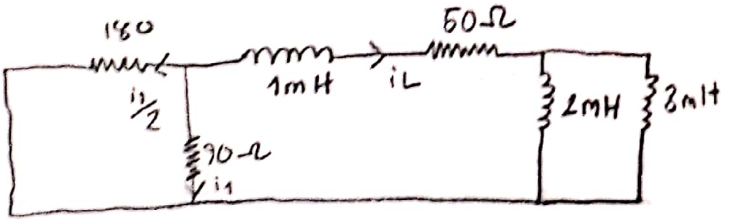

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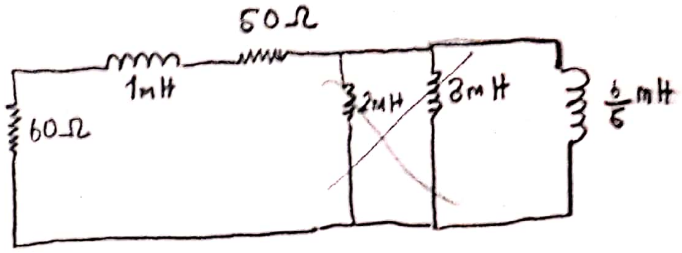
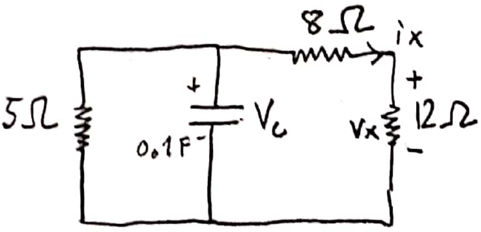
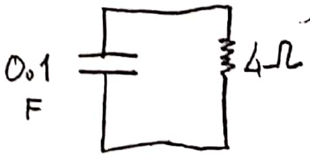


$V_c(0) = 15V$, $V_c, V_x, i_x = ?$

$\tau = RC$. saniye

$V(t) = V_0 . exp(-t/\tau)$

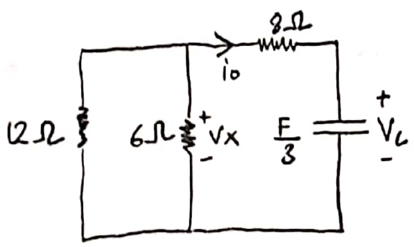


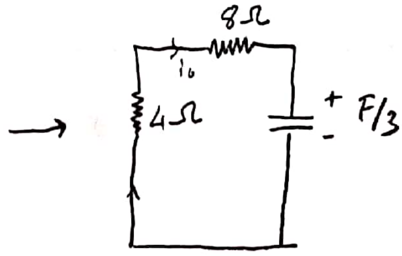


$\tau = 0,1 . 4 = 0,4 S$

- $V_c(t) = 15 . exp(-t/0,4t)$
- $V_x = V_c . \frac{12}{12+8} = V_c . \frac{3}{5} = 9 . exp(-t/0,4s)$
- $i_x = \frac{V_c}{20} = \frac{15}{20} . exp(-t/0,4s)$

$V_c(0) = 60V$, $V_c(t)$, V_x, i_o for $t \geq 0$





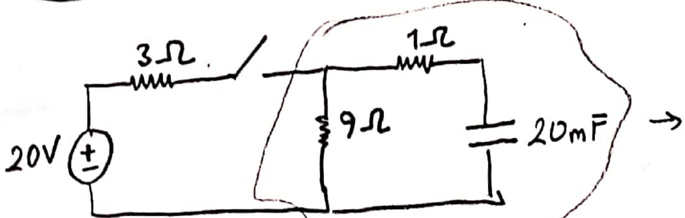
$\tau = R.C = 4sn$

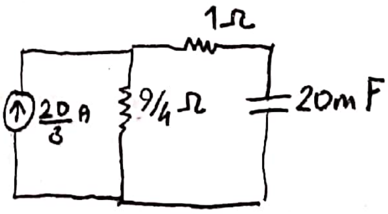
$V_c(t) = 60.exp(-t/4sn) V$

$V_x = V_c . \frac{4}{4+8} = 20 exp(-t/4sn) V$

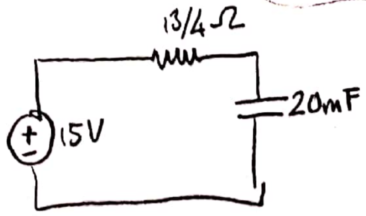
$i_o(t) = 5 . exp(-t/4sn) V$

$4 . i_o = V_x$

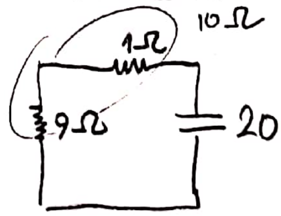




$\tau = 2.10^{-2} . 10 = 0,2$

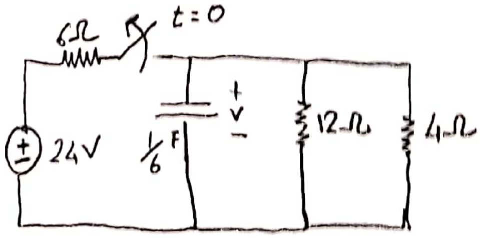


$V_0 \doteq 15V$



$V_c(t) = 15 exp(-t/0,2sn) V$

$E = 1/2 \, CV^2$



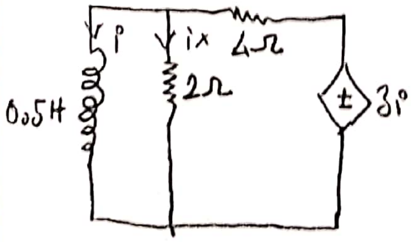
$V_c(t),\ E(0) = ?$

$\tau = RC = 3 \cdot 1/6 = 1/2\,sn$

$V_c(t) = 8V \cdot \exp(-t/0.5sn)$

$E(0) = \frac{1}{2} C V^2 = \frac{1}{2} \frac{1}{6} \cdot 64 = 16/3\,J$

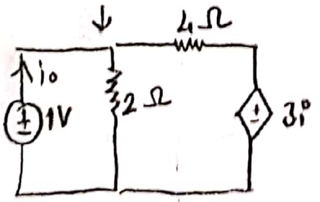
$V_0 = \frac{24}{9} \cdot 3 = 8V$



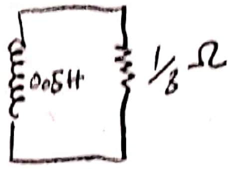
$I_0 = 10A$, $i(t) = ?$ $\to t>0$

$\tau = L/R$

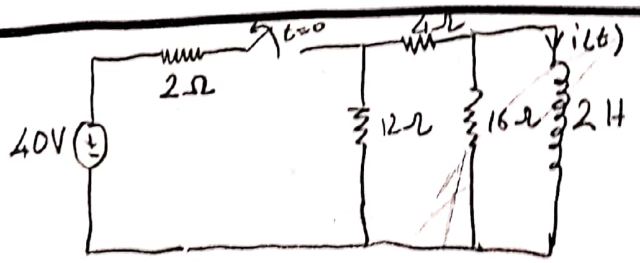
$i(t) = I_0 \cdot \exp(-t/\tau) = 10 \cdot \exp(-t/(3/2)sn)$

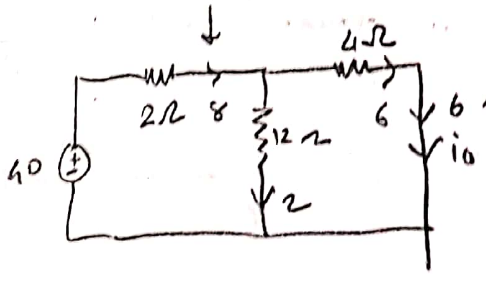


$R_{TH} = \frac{1V}{i_0} = \frac{1}{3}$ $\to$



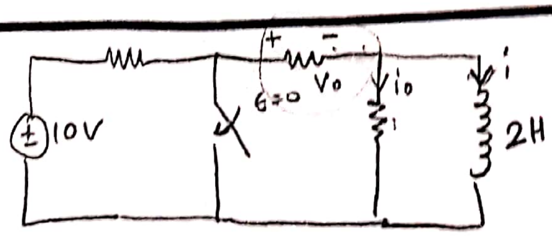
$\tau = 3/2\,sn$





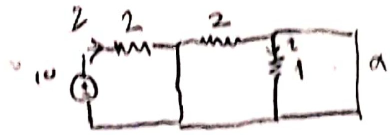
$\to I_0 = 6$

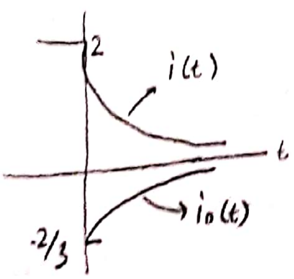
$I_L(t) = I_0 \cdot \exp(-t/\tau) = 6 \cdot \exp(-t/(1/4)sn)$

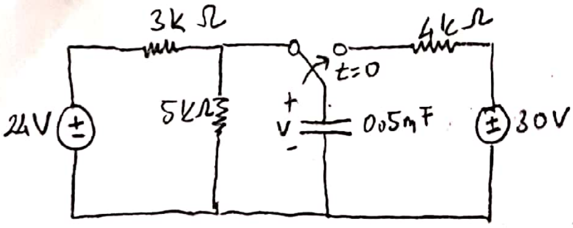


$V_0,\ i_0,\ i = ?$

Çöz







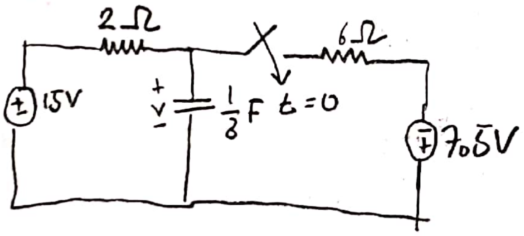
$\tau = RC = 4k\Omega \cdot 0.5mF = 2sn$

$V(0^-) = 15V$

$V(\infty) = 30V$

$V(t) = V(\infty) + [V(0) - V(\infty)] \cdot \exp(-t/\tau)$

$V(t) = 30 + (-15) \cdot \exp(-t/2sn) \longrightarrow t > 0$



$V(t)$, $t>0$?

$V(0) = 15V$

$V(\infty) = 9.375V$

$V_{TH} = 3/2$

$\tau = 3/2 \cdot \frac{1}{3} = 0.5sn$

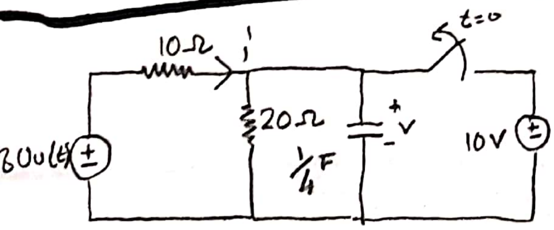
$\rightarrow V(t) = V(\infty) + (V(0) - V(\infty))\exp(-t/\tau)$

$= V(t) = 9.375 + (5.625) \cdot \exp(-t/0.5)$

$\frac{15}{2}\uparrow$ $\quad \frac{1}{2}$ $\quad \frac{1}{6}$ $\quad \frac{7.5}{6}\downarrow$

$\uparrow 6.25$ $\quad \frac{1}{\frac{12}{8}}$ $\quad 7.5 - \frac{7.5}{6} = 6.25$

$6.25 \times \frac{12}{8} = 9.375$



$u(t) = \begin{cases} 0 & t<0 \\ 1 & t>0 \end{cases}$

Kondansatör üstünden geçen akım $= C \cdot \frac{dV}{dt}$ / $\frac{V(t)}{R_{eq}}$

$V(0) = 10V$ $\quad$ $t<0$ iken $30u(t) = 0V$ ve $P = -1A$

$V(\infty) = 20V$ $\quad$ $t>0$ iken $30u(t) = 30V$

$\tau = RC = \frac{20}{3} \cdot \frac{1}{4} = \frac{5}{3} sn$

$V(t) = 20V - 10 \cdot \exp(-3t/5)\ V$

$\uparrow 3 \quad \frac{1}{10} \quad \frac{1}{20}$

$\uparrow 3 \quad \frac{200}{30}$

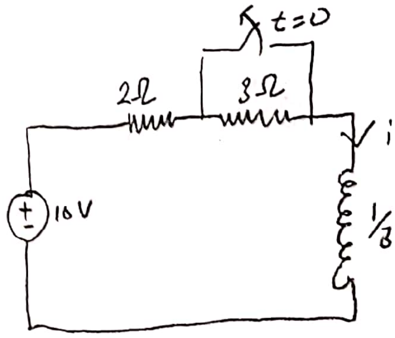
$20/3$

20

$i = \frac{V}{20} + C \cdot \frac{dV}{dt} = 1 - 0.5e^{-0.6t} + 3/2 \exp(-0.6t)$

$V(t) = \begin{cases} 10V, & t<0 \\ 20 - 10\exp(-0.6t), & t>0 \end{cases}$

$i(t) = \begin{cases} -1A, & t<0 \\ 1 + \exp(-0.6t), & t>0 \end{cases}$



$i = ?$

$i(0) = \frac{10}{2} = 5$

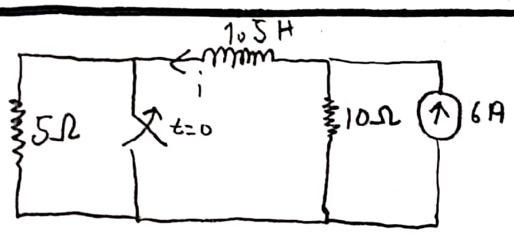
$i(\infty) = \frac{10}{5} = 2$

$R_{TH} = 5\Omega \quad \tau = 1/15$ sn

$i(t) = i(\infty) + [i(0) - i(\infty)]\, e^{-t/\tau}$

$i(t) = 2 + 3 \cdot \exp(-15t\,sn)$ A $\quad t > 0$

$i(t) = 5A \qquad t < 0$



$t < 0$ iken 10Ω ve 5Ω kısa devre

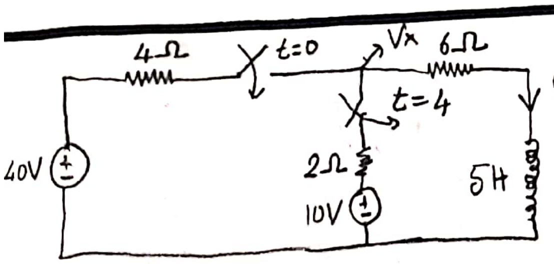
$i(0) = 6A$

$i(\infty) = 4A$

$R_{Eq} = 15\Omega$

$\tau = \frac{1}{10}$ sn

$i(t) = \begin{cases} 6A, & t < 0 \\ 4 + 2\exp(-10t)\,A, & t > 0 \end{cases}$

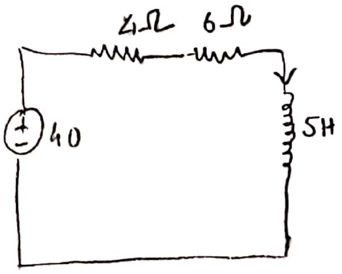


determine i for t=2s and t=5s

find i(t) for t>0

$t \leq 0,\ 0 \leq t \leq 4,\ t \geq 4$ (3)

$i(0) = 0A$



$\tau = \frac{L}{R} = \frac{5}{10} = 0.5$ sn

$5\tau = 2.5$ sn

$\frac{40}{10} = 4A$

$i(0) = 0A$

$i(\infty) = 4A$

$i(t) = 4(1 - \exp(-2t))\,A \rightarrow 0 \leq t \leq 4$

$i(4) = 4.(1 - e^{-8}) \approx 4A$

$i(\infty) = 30/11$ A

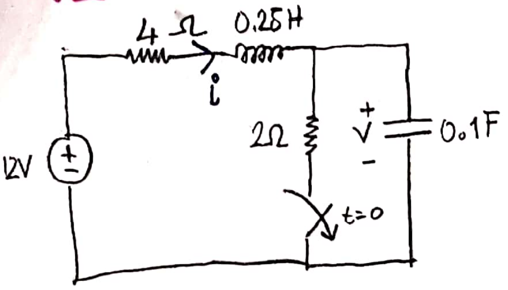
$i(t) = \frac{30}{11} + \frac{14}{11} \cdot \exp\left(-(t-4)/\tau\right)$ A

$\hookrightarrow t \geq 4$

$\frac{V_x - 40}{4} + \frac{V_x - 10}{2} + \frac{V_x}{6} = 0$

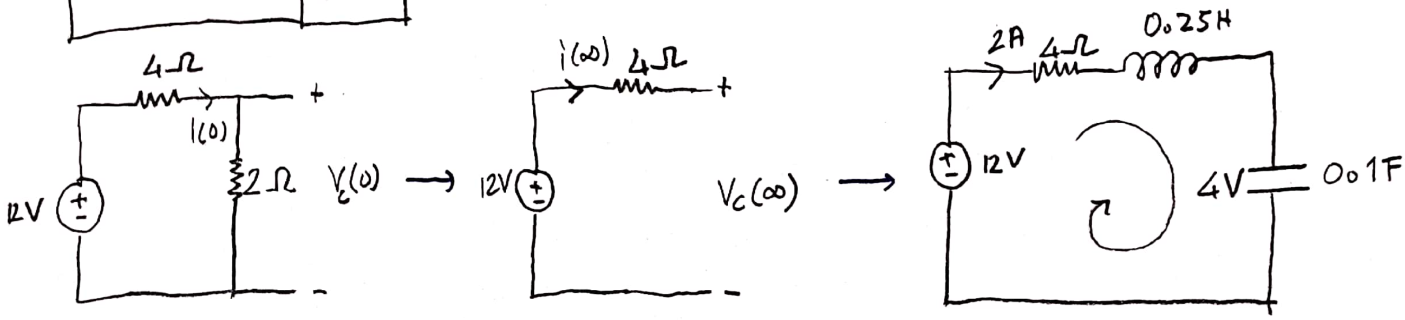
$V_x = \frac{180}{11}, \quad i(\infty) = \frac{180}{11} \cdot \frac{1}{6} = \frac{30}{11}$ A

RLC



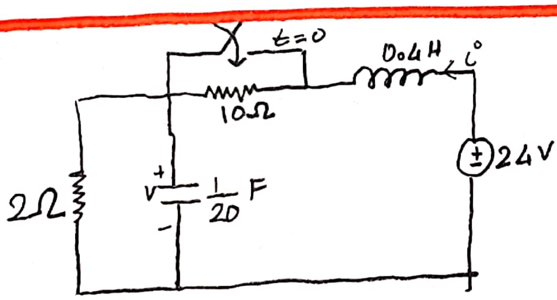
$i(0),\ i(\infty),\ \dfrac{di(0)}{dt}$

$V(0),\ V(\infty),\ \dfrac{dV(0)}{dt}$

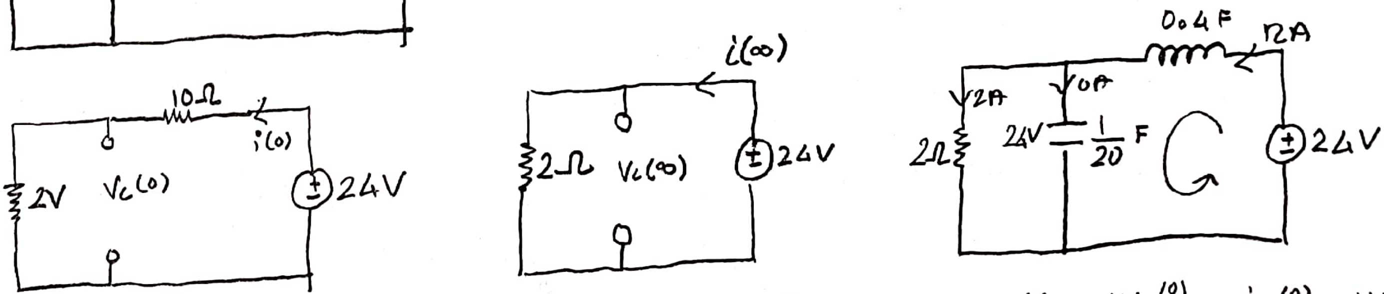


- $i(0) = 12/6 = 2A$
- $V_c(0) = 2*2 = 4V$
- $i(\infty) = 0A$
- $V_c(\infty) = 12V$
- $i_c = C \cdot \dfrac{dV_c}{dt} \rightarrow \dfrac{dV_c(0)}{dt} = \dfrac{i_c(0)}{C} = \dfrac{2A}{0.1F} = 20V/s$
- $-12V + 8V + V_L(0) + 4V = 0 \rightarrow V_L(0) = 0$

$V_L = L \cdot \dfrac{di_L}{dt} \rightarrow \dfrac{di_L(0)}{dt} = \dfrac{V_L(0)}{L} = \dfrac{0V}{0.25F} = 0\ A/s$



$i(0), i(\infty), V(0), V(\infty), \dfrac{di(0)}{dt}, \dfrac{dV(0)}{dt}$



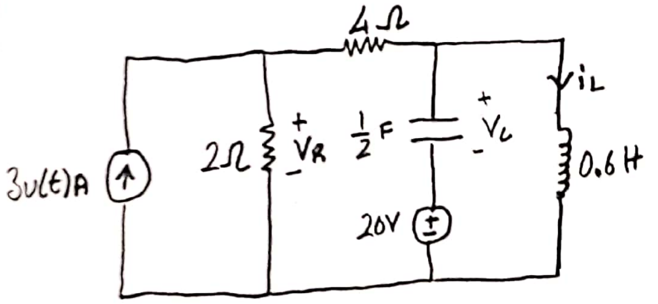
- $i(0) = 24/12 = 2A$
- $V_c(0) = 2*2 = 4V$
- $i(\infty) = 24/2 = 12A$
- $V(\infty) = 12*2 = 24V$
- $i_c^{(0)} = C \cdot \dfrac{dV_c^{(0)}}{dt} \rightarrow \dfrac{i_c^{(0)}}{C} = \dfrac{dV_c^{(0)}}{dt}$

$= \dfrac{0}{1/20} = 0\ V/s$

- $-24V + V_L + 4 = 0 \rightarrow V_L = 20V$

$V_L = L \cdot \dfrac{di_L}{dt} \rightarrow \dfrac{V_L^{(0)}}{L} = \dfrac{di_L^{(0)}}{dt}$

$= \dfrac{20}{0.4} = 50\ A/s$

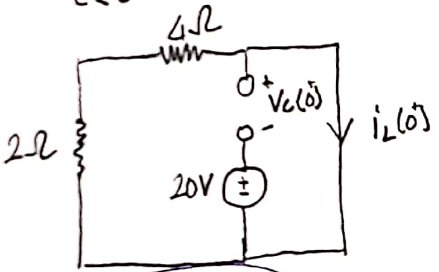


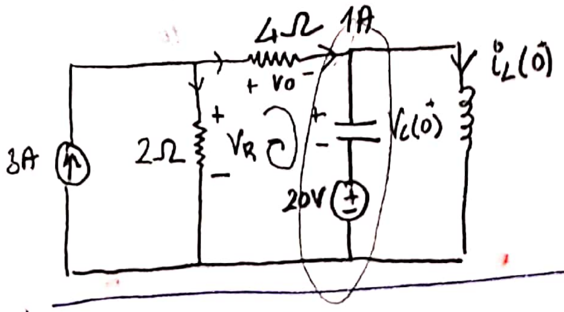
$i_L(0^+)$, $V_C(0^+)$, $V_R(0^+)$

$\frac{di_L(0^+)}{dt}$, $\frac{dV_C(0^+)}{dt}$, $\frac{dV_r(0^+)}{dt}$

$i_L(\infty)$, $V_C(\infty)$, $V_r(\infty)$

$t<0$





- $i_L(0^-)=0\,A$
- $V_C(0^-)=-20V$
- $V_R(0^-)=0V$

$$3=\frac{V_R}{2}+\frac{V_o}{4} \quad \Big| \quad -V_R+V_o+\cancel{V_C(0)}+20V=0$$

$$V_o=V_R$$

$$\hookrightarrow V_R(0^+)=V_o(0^+)=4V$$

$$V_L=L\cdot\frac{di_L}{dt} \rightarrow \frac{di_L}{dt}=\frac{V_L}{L}=\frac{V_C(0)+20V}{L}=\frac{0V}{L}=0\ A/s$$

$$i_C=C\frac{dV_C}{dt} \rightarrow \frac{dV_C}{dt}=\frac{i_C}{C}=\frac{1A}{\frac{1}{2}F}=2\,V/s$$

$$3=\frac{V_R}{2}+\frac{V_o}{4} \rightarrow 12=2V_r+V_o \longrightarrow 0=2\frac{dV_r}{dt}+\frac{dV_o}{dt}$$

$$-V_r+V_o+V_C+20=0 \longrightarrow -\frac{dV_r}{dt}+\frac{dV_o}{dt}+\underbrace{\frac{dV_C}{dt}}_{2}=0$$

$$-\frac{dV_r}{dt}+\frac{dV_o}{dt}=-2$$

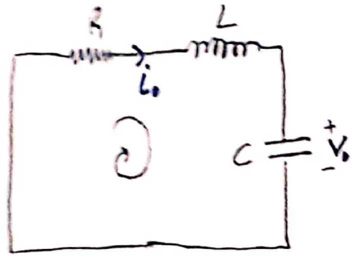
$$2\frac{dV_r}{dt}+\frac{dV_o}{dt}=0 \longrightarrow \boxed{\frac{dV_r}{dt}=2/3}$$

$V_C(\infty)=-20V$

$i_L(\infty)=3\cdot\frac{2}{6}=1A$

$V_R(\infty)=2*2=4V$

Seri RLC (Doğal Tepki)



- $V(0) = V_0 = \dfrac{1}{C} \cdot \displaystyle\int_{-\infty}^{0} i(t)\,dt$
- $i(0) = i_0$
- $Ri + L \cdot \dfrac{di}{dt} + \underbrace{\dfrac{1}{C} \cdot \displaystyle\int_{-\infty}^{0} i(t)\,dt}_{V_0} = 0$ *

$\hookrightarrow t = 0 \longrightarrow R \cdot i(0) + L \cdot \dfrac{di(0)}{dt} + \underbrace{\dfrac{1}{C} \cdot \displaystyle\int_{-\infty}^{0} i(t)\,dt}_{V_0} = 0$ *

$\hookrightarrow \dfrac{di(0)}{dt} = -\dfrac{1}{L} \cdot \left(R \cdot i_0 + V_0\right)$ *

- $R \cdot i + L \cdot \dfrac{di}{dt} + \dfrac{1}{C} \cdot \displaystyle\int_{-\infty}^{t} i(t)\,dt = 0 \longrightarrow R \cdot \dfrac{di}{dt} + L \cdot \dfrac{d^2 i}{dt^2} + \dfrac{i(t)}{C}$

$$\dfrac{d^2 i}{dt} + \dfrac{R}{L} \cdot \dfrac{di}{dt} + \dfrac{i}{LC} = 0 \qquad i(t) = A \cdot e^{st}, \quad A \neq 0$$

$$A \cdot s^2 \cdot \exp(st) + \dfrac{A \cdot R \cdot s}{L} \cdot \exp(st) + \dfrac{A \cdot \exp(st)}{LC} = 0 \longrightarrow A \cdot \exp(st)\left(s^2 + \dfrac{R}{L} \cdot s + \dfrac{L}{C}\right) = 0$$

$\longrightarrow s^2 + \dfrac{R}{L} \cdot s + \dfrac{L}{C} = 0, \quad s_{1,2} = \dfrac{-b \pm \sqrt{\Delta}}{2a}, \quad \Delta = b^2 - 4ac$

$\longrightarrow s_1 = -\dfrac{R}{2L} + \sqrt{\left(\dfrac{R}{2L}\right)^2 - \dfrac{1}{LC}}, \quad s_2 = -\dfrac{R}{2L} - \sqrt{\left(\dfrac{R}{2L}\right)^2 - \dfrac{1}{LC}}$ / $\overbrace{\dfrac{R}{2L} = \alpha}^{\text{sönümleme faktörü}}, \quad \overbrace{\dfrac{1}{\sqrt{LC}} = w_0}^{\text{rezonans frekans}}$

$\longrightarrow s_1 = -\alpha + \sqrt{\alpha^2 - w_0^2}, \quad s_2 = -\alpha - \sqrt{\alpha^2 - w_0^2} \longrightarrow$ doğal frekans

$\longrightarrow s^2 + 2as + w_0^2 = 0$ * $\longrightarrow$ $i(t) = A \cdot e^{st}$

$i(t) = A_1 \cdot e^{s_1 t} + A_1 \cdot e^{s_2 t}$

$\rightarrow i(t)=A.e^{st}$ $\longrightarrow i(0),\ \frac{di(0)}{dt}$

$i(t)=A_1.\exp(s_1.t)+A_2.\exp(s_2 t)$

$$\left.\begin{aligned} s_1&=-\alpha+\sqrt{\alpha^2-w_0^2}\\ s_2&=-\alpha-\sqrt{\alpha^2-w_0^2}\end{aligned}\right\} \begin{aligned} &\alpha>w_0 \longrightarrow \text{aşırı sönümlü devre}\\ &\alpha=w_0 \longrightarrow \text{Kritik sönümlü}\\ &\alpha<w_0 \longrightarrow \text{eksili sönümlü}\end{aligned}$$

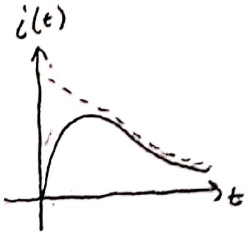
Aşırı Sönümlü / Overdamped

$\alpha > w_0$

$$\boxed{i(t)=A_1.\exp(s_1 t)+A_2\exp(s_2 t)}$$

$\rightarrow C > \frac{4L}{R^2}$ iken

$\lim_{t\to\infty} i(t)=0$ olur. $\longrightarrow$



Kritik Sönümlü / Critically Damped

$\alpha = w_0$

$$\left.\begin{aligned} s_1&=-\alpha+\sqrt{\alpha^2-w_0^2}\\ s_2&=-\alpha-\sqrt{\alpha^2-w_0^2}\end{aligned}\right\} s_1=s_2=-\alpha$$

$$i(t)=A_1\exp(-\alpha t)+A_2.\exp(-\alpha t)=A_3\exp(-\alpha t) \ \times$$

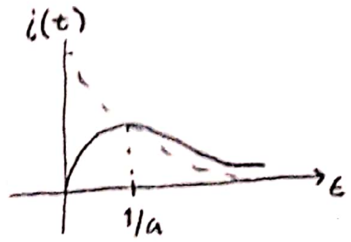
$$\frac{d^2i}{dt^2}+2\alpha\frac{di}{dt}+\alpha^2 i=0 \longrightarrow \frac{d}{dt}\underbrace{\left(\frac{di}{dt}+\alpha i\right)}_{f}+\alpha\underbrace{\left(\frac{di}{dt}+\alpha i\right)}_{f}=0$$

$$\frac{df}{dt}+\alpha.f=0 \longrightarrow f=A_1.\exp(-\alpha t)=\frac{di}{dt}+\alpha i$$

$$\frac{di}{dt}+\alpha i=A_1.\exp(-\alpha.t) \longrightarrow \underbrace{\exp(\alpha t)\frac{di}{dt}+\exp(\alpha t).\alpha.i}=A_1$$

$$\frac{d}{dt}\left(\exp(\alpha).i\right)=A_1 \longrightarrow \exp(\alpha t).i=A_1 t+A_2$$

$$\boxed{i=(A_1 t+A_2).\exp(-\alpha.t)}$$



Eksili Sönümlü

$\alpha < w_0$

$$s_1 = -\alpha + \sqrt{-(w_0^2 - \alpha^2)} = s_1 = -\alpha + jw_d$$
$$s_2 = -\alpha - \sqrt{-(w_0^2 - \alpha^2)} = s_2 = -\alpha - jw_d$$

$j = \sqrt{-1}$

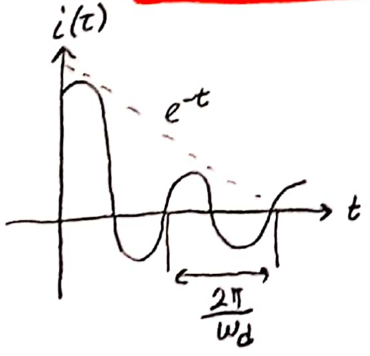
$w_d = \sqrt{w_0^2 - \alpha^2}$ → sönümleme frekansı

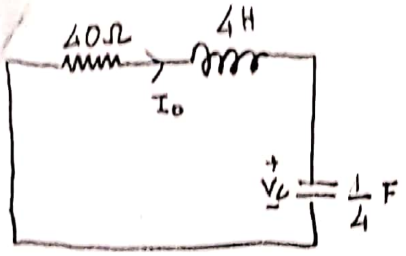
$$i(t) = A_1 \cdot \exp(-[\alpha - jw_d] \cdot t) + A_2 \cdot \exp(-[\alpha - jw_d] t)$$
$$= \exp(-\alpha t)\left(A_1 \cdot \exp(j w_d \cdot t) + A_2 \cdot \exp(-j \cdot w_d \cdot t)\right)$$

→ $e^{j\theta} = \cos\theta + j\sin\theta \;/\; e^{-j\theta} = \cos\theta - j\sin\theta$

→ $i(t) = \exp(-\alpha t)\left[A_1 \cdot (\cos w_d t + j\sin w_d t) + A_2 (\cos w_d t - j \sin w_d t)\right]$

$$= \exp(-\alpha t)\left[(A_1 + A_2) \cdot \cos w_d t + j(A_1 - A_2) \cdot \sin w_d t\right]$$
$$\boxed{= \exp(-\alpha t)\left[B_1 \cdot \cos w_d t + j B_2 \sin w_d t\right]}$$





$\alpha = \frac{R}{2L} = \frac{40}{8} = 5$

$w_0 = \frac{1}{\sqrt{LC}} = 1$

$\alpha > w_0$ Aşırı sönümlü

$s^2 + 2\alpha s + w_0^2$.

$i(t) = A_1 \cdot e^{s_1 t} + A_2 \cdot e^{s_2 t}$

$s_{1/2} = -5 \pm \sqrt{24}$ → $s_1 = -0.101$, $s_2 = -9.899$

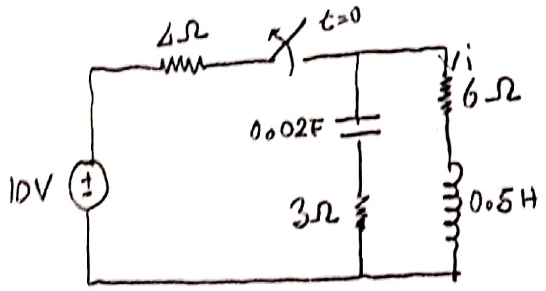
$R = 5$, $L = 5H$, $C = 2mF$, $\alpha = ?$, $w_0 = ?$, $s_1 = ?$, $s_2 = ?$

$\alpha = \frac{R}{2L} = 1$, $w_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{5.2/1000}} = 10$ $\alpha < w_0$ → Kritik sönümlü

$s_{1/2} = -1 \pm \sqrt{-99}$

$s_1 = -1 + j\sqrt{99}$

$s_2 = -1 - j\sqrt{99}$



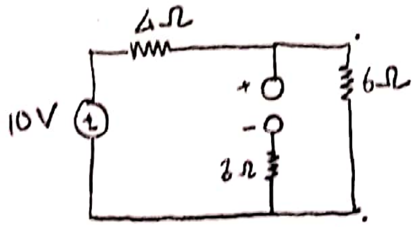
Find $i(t)$

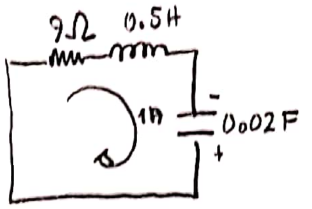
$t = 0^-$ 'de durgun durumda varsay.

$\alpha = \frac{R}{2L} = 9$, $w_0 = \frac{1}{\sqrt{LC}} = 10$

$\alpha - w_0 = -1 < 0$ → Eksik sönümlenme

$i(t) = e^{-\alpha t}(B_1 \cdot \cos w_d t + B_2 \sin w_d t)$





- $V_c(0) = 6 * 1 = 6V$
- $i(0) = 10/10 = 1A$

$9 + V_L - 6V = 0 \rightarrow V_L = -3V$

$\frac{di(0)}{dt} = \frac{V_L}{L} = \frac{-3}{0.5} = -6\,A/s$

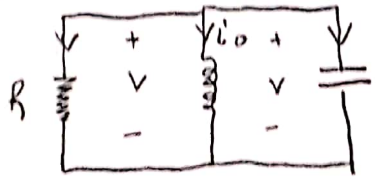
$w_d = \sqrt{w_0^2 - \alpha^2} = \sqrt{100-81} = \sqrt{19} \approx 4.359$ → $i(t) = e^{-9t}(B_1 \cos(4.359t) + B_2 \sin(4.359t))$

$i(0) = B_1 = 1$

$\frac{di(t)}{dt} = -9e^{-9t}[B_1 \cdot \cos(4.359t) + B_2 \sin(4.359t)] + e^{-9t}[-B_1(4.359) \cdot \sin(4.359t) + B_2(4.359) \cdot \cos(4.359t)]$

$\frac{di(0)}{dt} = -9B_1 + B_2 \cdot 4.359 = -6 \rightarrow B_2 = 0.6882$ ✓✓

Paralel RLC (Doğal Tepki)



$$i_L(0) = I_0 = \frac{1}{L} \cdot \int_{-\infty}^{0} V(t)\,dt$$

$$V_c(0) = V_0$$

$$\frac{V}{R} + \frac{1}{L} \cdot \int_{-\infty}^{t} V(t)\,dt + C \cdot \frac{dV}{dt} = 0$$

$$\frac{dV(0)}{dt} = -\frac{V_0}{RC} - \frac{I_0}{C} = -\frac{(J_0 + RJ_0)}{RC}$$

$$\frac{d^2V}{dt^2} + \frac{1}{RC} \cdot \frac{dV}{dt} + \frac{V}{L} = 0$$

$$\rightarrow s^2 + \frac{s}{RC} + \frac{1}{LC} = 0$$

$$S_1 = -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 - \frac{1}{\sqrt{LC}}}$$

$$S_2 = -\frac{1}{2RC} - \sqrt{\left(\frac{1}{2RC}\right)^2 - \frac{1}{\sqrt{LC}}}$$

$$\alpha = +\frac{1}{2RC}$$

$$W_0 = \frac{1}{\sqrt{LC}}$$

$$\rightarrow S_{1/2} = -\alpha \pm \sqrt{\alpha^2 - W_0^2}$$

$$\alpha < W_0 \longrightarrow V(t) = e^{-\alpha t} \cdot \left[B_1 \cdot \cos W_d t + B_2 \sin W_d t\right] \rightarrow W_d = \sqrt{W_0^2 - \alpha^2}$$

$$\rightarrow S_{1/2} = -\alpha \pm jW_d$$

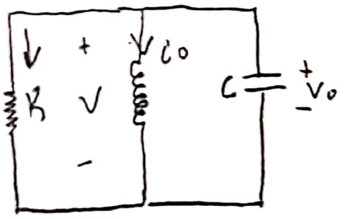
$$\alpha = W_0 \longrightarrow V(t) = (A_1 + A_2 t)\,e^{-\alpha t}$$

$$\alpha > W_0 \longrightarrow V(t) = A_1 e^{S_1 t} + A_2 e^{S_2 t}$$

find $v(t)$ for $t>0$ $\quad R=1.923 \quad$ / $R=5 \quad R=6.25$

sen 402

$V(0)=5V$, $i(0)=0$, $L=1H$, $C=10mF$



$$\alpha=\frac{1}{2RC}=\frac{1}{2.(1.923).10^{-2}}=26$$

$$W_0=\frac{1}{\sqrt{LC}}=\frac{1}{\sqrt{1.10^{-2}}}=10$$

$\alpha > W_0 \rightarrow$ overdamped

$s_{1/2}=-\alpha \pm \sqrt{\alpha^2-w_0^2} \longrightarrow s_1=-2,\ s_2=-50$

$$\frac{dV(0)}{dt}=-\frac{(V_0+RI_0)}{RC}=-260$$

$V(t)=A_1.e^{s_1t}+A_2e^{s_2t}=A_1.e^{-2t}+A^{-50t}$

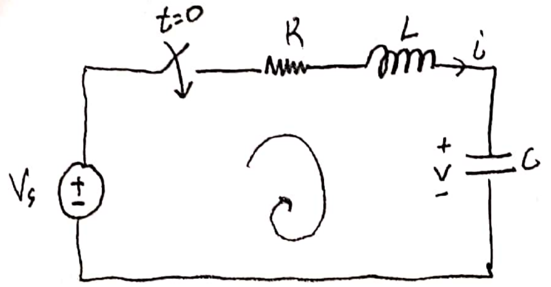
$V(0)=A_1+A_2=5$

$\frac{dV(t)}{dt}=-2A_1e^{-2t}-50A_2e^{-50t}$

$\frac{dV(0)}{dt}=-2A_1-50A_2=-260$

$A_1=0.2083$
$A_2=5.208$

Seri RLC (Basamak Tepkisi)



$$R \cdot i(t) + L \cdot \frac{di(t)}{dt} + \frac{1}{C} \cdot \int i(t)\,dt = V_s$$

$$i(t) = C \cdot \frac{dV(t)}{dt}$$

$$R \cdot C \cdot \frac{dV(t)}{dt} + L \cdot C \cdot \frac{d^2V(t)}{dt^2} + V(t) = V_s$$

$$\frac{d^2V(t)}{dt^2} + \frac{R}{L} \cdot \frac{dV(t)}{dt} + \frac{V(t)}{LC} = \frac{V_s}{LC}$$

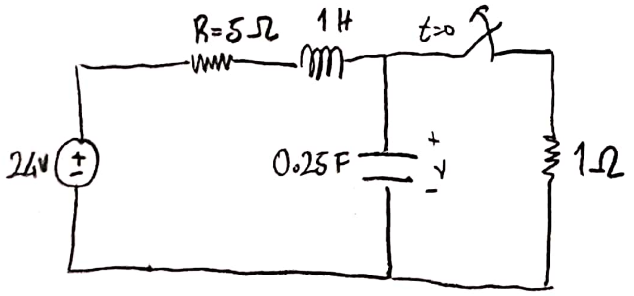
$$V(\infty) = V_s$$

$$\hookrightarrow s^2 + \frac{R}{L} \cdot s + \frac{1}{LC} = \frac{V_s}{LC}$$

$V(t) = V_s + A_1 e^{s_1 t} + A_2 e^{s_2 t} \longrightarrow$ Overdauped

$V(t) = V_s + (A_1 + A_2 t) . e^{-\alpha t} \longrightarrow$ Critically Dauped

$V(t) = V_s + (A_1 \cdot \cos w_d t + A_2 \sin w_d t)\, e^{-\alpha t} \longrightarrow$ Underdauped



$$\alpha = \frac{R}{2L} = \frac{5}{2} = 2.5$$

$i(0) = 24/6 = 4A$

$$W_0 = \frac{1}{\sqrt{LC}} = 2 \qquad S_{1/2} = -\alpha \pm \sqrt{\alpha^2 - w_0^2}$$

$V(0) = 1 \cdot 4 = 4V$

$V(\infty) = 24V$

$S_1 = -1$

$S_2 = -4$

$\alpha > w_0$

$\hookrightarrow$ overdumped

$V(t) = 24 + A_1 \cdot e^{-t} + A_2 e^{-4t}$

$V(0) = 24 + A_1 + A_2 = 4V$

$$i(0) = C \cdot \frac{dV(t)}{dt}$$

$$\frac{dV(t)}{dt} = -A_1 e^{-t} - 4A_2 e^{-4t}$$

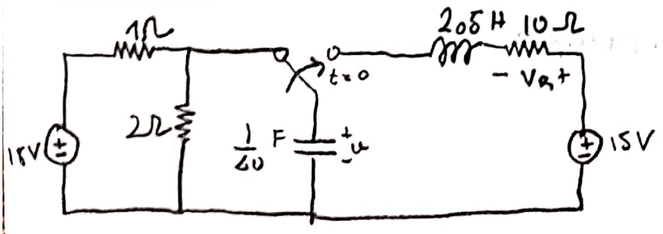
$$\frac{dV(0)}{dt} = \frac{i_0}{C} = \frac{4}{0.25} = 16$$

$$\frac{dV(0)}{dt} = -A_1 - 4A_2 = 16$$

$A_1 = -64/3$

$A_2 = 4/3$

$$V(t) = 24 + \frac{4}{3}\left(-16e^{-t} + e^{-4t}\right)V$$



$V(t) = ?$

$V_R(t) = ?$

$$\alpha = \frac{R}{2L} = 2 \qquad W_0 = \frac{1}{\sqrt{LC}} = 4 \qquad \alpha < W_0$$

$\hookrightarrow$ Eksili

$$V(0) = \frac{18}{3} \cdot 2 = 12V$$

$i(0) = 0A$

$$V(t) = e^{-\alpha t}(B_1 \cdot \cos w_d t + B_2 \sin w_d t) + V_s$$

$$C \cdot \frac{dV(0)}{dt} = i(0) \Rightarrow \frac{dV(0)}{dt} = 0 V/s$$

$V(0) = B_1 + V_s = B_1 + 15$

$W_d = \sqrt{W_0^2 - \alpha^2} = \sqrt{12} = 3.46$

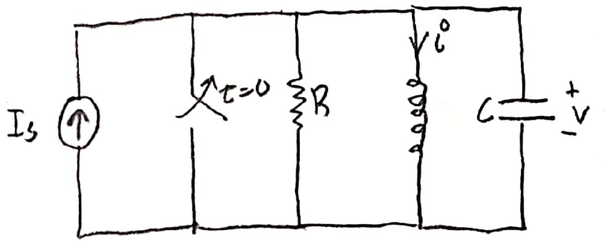
$B_1 = -3V$

$$\frac{dV(t)}{dt} = -2e^{-2t}\left[-3 \cdot \cos(3{,}46t) + B_2 \cdot \sin(3{,}46t)\right] + e^{-2t}\left[-3 \cdot 3{,}46 \sin(3{,}46t) + B_2 \cdot 3{,}46 \cdot \cos(3{,}46t)\right]$$

$$\frac{dV(0)}{dt} = -2 \cdot (-3) + B_2 \cdot 3{,}46 = 0 \rightarrow B_2 = -1.73$$

$$V_R(t) = R \cdot C \cdot \frac{dV(t)}{dt}$$

Paralel RLC (Basamak Tepkisi)



$$\frac{V}{R} + i + C \cdot \frac{dV}{dt} = I_s \quad , \quad V = L \cdot \frac{di}{dt}$$

$$\frac{di(0)}{dt} = \frac{V_C}{V_L} \rightarrow V_L$$

$i(0)$

$$\frac{d^2 i}{dt^2} + \frac{1}{RC} \cdot \frac{di}{dt} + \frac{1}{LC} = \frac{I_s}{LC}$$

$i(t) = I_s + A_1 e^{st} + A_2 e^{st} \rightarrow$ Overdamped

$\alpha = \frac{1}{2RC} \; , \quad w_0 = \frac{1}{\sqrt{LC}}$

$i(t) = I_s + (A_1 + A_2 t)\, e^{-\alpha t} \rightarrow$ Critically Damped

$i(t) = I_s + (A_1 \cos w_d t + A_2 \sin w_d t)\, e^{-\alpha t} \rightarrow$ Underdamped

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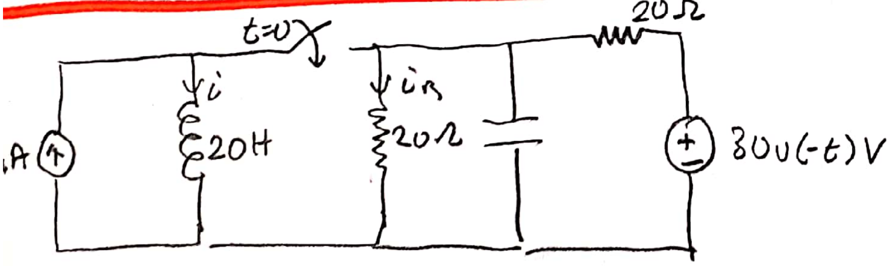


$i(t)$ ve $i_R(t) = ?$

$$u(-t) \Rightarrow \begin{cases} 1 & t<0 \\ 0 & t>0 \end{cases}$$

$i(0) = 4A$

$V(0) = \frac{30}{40} \cdot 20 = 15V$

$V_L(0) = \frac{di(0)}{dt} \cdot L \rightarrow \frac{di(0)}{dt} = \frac{15}{20} = 0{,}75\ A/s$

$\alpha = \frac{1}{2RC} = 6.25 \; , \quad W_0 = \frac{1}{\sqrt{LC}} = 2.5 \rightarrow 6.25 > 2.5 \rightarrow$ overdamped

$s_{1,2} = -\alpha \pm \sqrt{\alpha^2 - w_0^2} \rightarrow s_1 = -11.978$
$s_2 = -0.5218$

$i(t) = I_s + (A_1 \cdot e^{-11.978t} + A_2 \cdot e^{-0.5218t})\ A \qquad i(0) = 4 + A_1 + A_2 = 4 , \quad A_1 = -A_2$

$$\frac{di(t)}{dt} = -11.978 A_1 \cdot e^{-11.978t} - 0.5218 \cdot A_2 \cdot e^{-0.5218t}$$

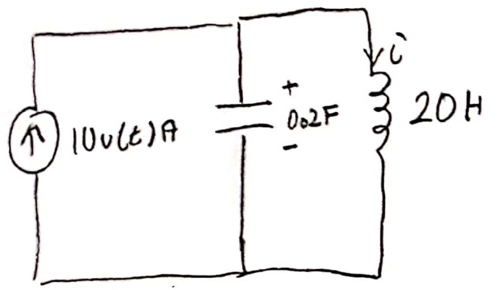
$-11.978 A_1 - 0.5218 A_2 = 0.75$

$\frac{di(0)}{dt} = 0{,}75$

$A_2 = 0.0655$

$A_1 = -0.0655$

$i_R(t) = \frac{V(t)}{R}$



$$C \cdot \frac{dv}{dt} + i = 10 \quad , \quad V = \frac{di}{dt} \cdot L$$

$$C \cdot L \cdot \frac{d^2 i}{dt^2} + i = 10$$

$$\frac{d^2 i}{dt^2} + \frac{i}{LC} = \frac{10}{LC}$$

$$s^2 + \omega_0^2 \longrightarrow \alpha = 0$$

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{20 \cdot 0{,}2}} = 0{,}5 \qquad \omega_d t = \sqrt{\omega_0^2 - \alpha^2} = \omega_0$$

$$i(t) = I_s + e^{-\alpha t}(B_1 \cdot \cos \omega_d t + B_2 \cdot \sin \omega_d t)$$

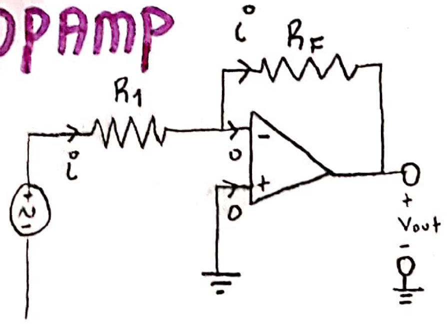
$$i(t) = 10 + B_1 \cdot \cos 0{,}5t + B_2 \sin 0{,}5t$$

$$i(0) = 10 + B_1 = 0 \rightarrow B_1 = -10$$

$$\frac{di(0)}{dt} = 0 \qquad B_2 = 0$$

OPAMP

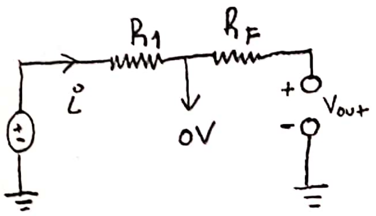
Ideal



Eviren Kuvvetlendirici

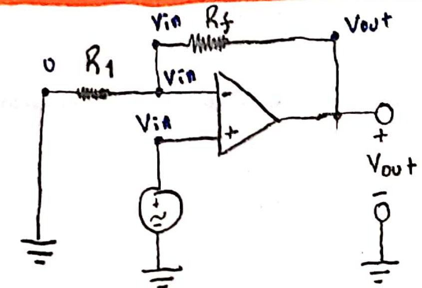
inverting amplifier

- $i = \dfrac{V_{in}}{R} = \dfrac{-V_{out}}{R_f}$



- $V_{out} = -V_{in} \cdot \dfrac{R_f}{R_1}$

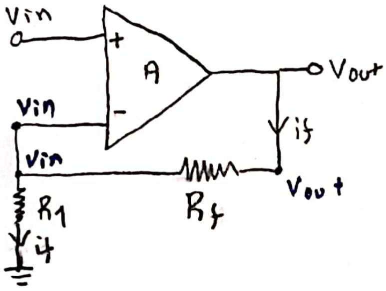
- $\text{Kazanç} = \dfrac{V_{out}}{V_{in}}$



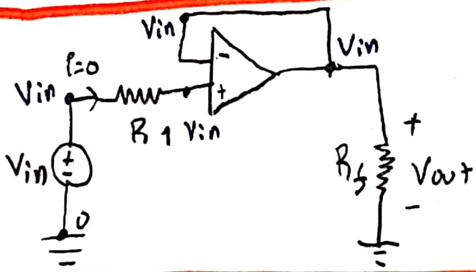
- $i_{R_1} + i_{R_f} = 0$
- $i_{R_1} = \dfrac{V_{in}}{R_1}$, $i_{R_f} = \dfrac{V_{in} - V_{out}}{R_f}$
- $V_{out} = V_{in} \cdot \left(1 + \dfrac{R_f}{R_1}\right)$

Evirmeyen Kuvvetlendirici

non-inverting amplifier



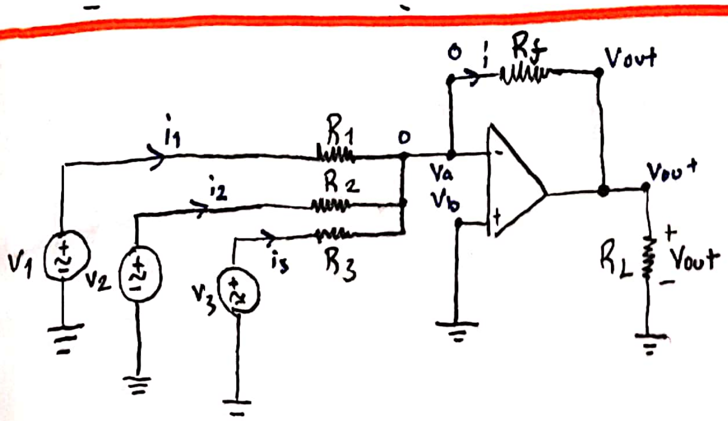
- $i_f = \dfrac{V_{in} - 0}{R_1} = \dfrac{V_{out} - V_{in}}{R_f}$
- $\text{Kazanç} = \left(1 + \dfrac{R_f}{R_1}\right)$
- $V_{out} = V_{in} \cdot \left(1 + \dfrac{R_f}{R_1}\right)$



- $V_{in} = V_{out}$

Buffer

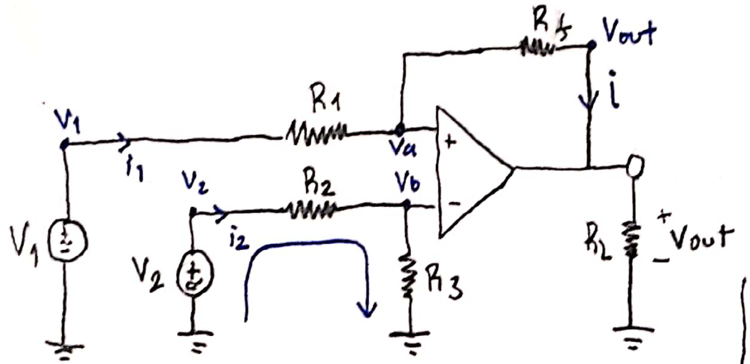
Voltage Follower



- $V_a = V_b = 0V$
- $i_1 + i_2 + i_3 = i \longrightarrow \dfrac{V_1}{R_1} + \dfrac{V_2}{R_2} + \dfrac{V_3}{R_3} = \dfrac{-V_{out}}{R_f}$
- $V_{out} = -R_f \cdot \left[\dfrac{V_1}{R_1} + \dfrac{V_2}{R_2} + \dfrac{V_3}{R_3}\right]$

Summing Amplifier

Toplayan Yükselteç



- $V_b = \left(\dfrac{V_2}{R_2+R_3}\right) \cdot R_3 = V_a$

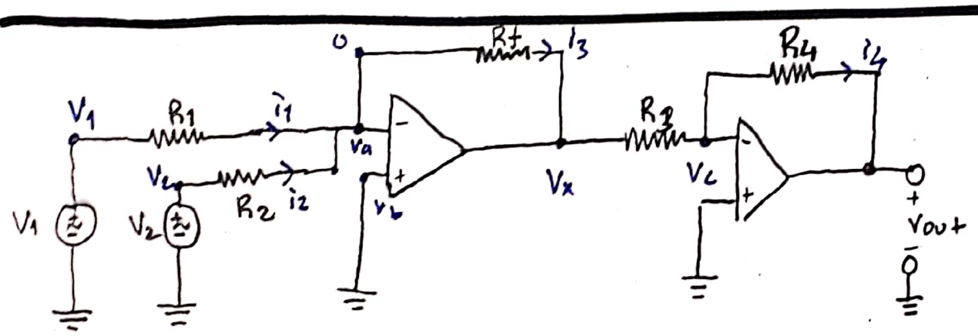
- $i_1 = i$

- $$\frac{\left(V_1 - \left[\frac{V_2}{R_2+R_3}\right] R_3\right)}{R_1} = \frac{\left(\left[\frac{V_2}{R_2+R_3}\right] R_3 - V_{out}\right)}{R_f}$$

- $V_{out} = -\dfrac{R_f}{R_1} \cdot (V_1 - V_a) + V_a$

- $$-\frac{R_f}{R_1} \cdot \left(V_1 - \left[\frac{V_2}{R_2+R_3}\right] R_3\right) + \left(\left[\frac{V_2}{R_2+R_3}\right] R_3\right) = V_{out}$$

Difference Amplifier



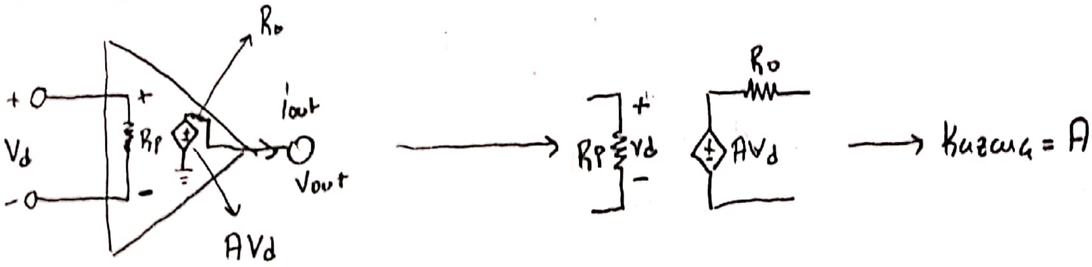
- $i_1 + i_2 = i_3 = i_4 \quad , \quad V_a = V_b = V_c = 0$

- $\dfrac{V_1}{R_1} + \dfrac{V_2}{R_2} = \dfrac{-V_x}{R_f} \longrightarrow V_x = -R_f \left(\dfrac{V_1}{R_1} + \dfrac{V_2}{R_2}\right)$

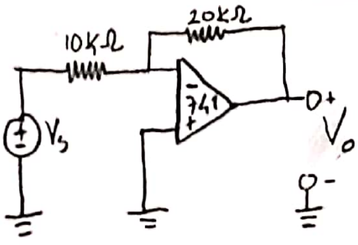
- $\dfrac{V_x}{R_3} = \dfrac{-V_{out}}{R_4} \longrightarrow V_{out} = \dfrac{R_4}{R_3} \cdot R_f \cdot \left(\dfrac{V_1}{R_1} + \dfrac{V_2}{R_2}\right)$

OpAmp

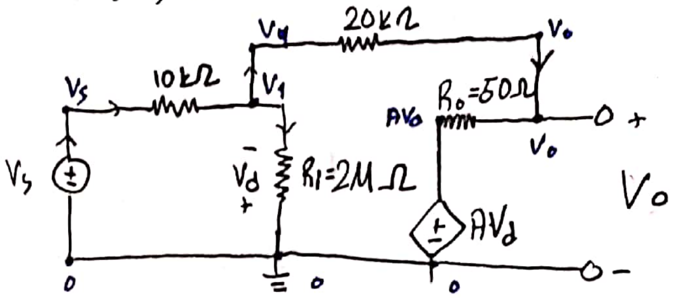
Ideal Olmayan



A 741 opamp has an open-loop voltage gain of 2×10^5, input resistance of $2M\Omega$ and input resistance of 50Ω. The opamp is used in the circuit of a. Find the closed-loop gain V_o/V_s, determine current i when $V_s = 2V$.



(a)



$A = 2 \times 10^5$

$$\frac{V_s - V_1}{10K} = \frac{V_1 - V_o}{20K} + \frac{V_1}{2M}$$

$$200V_s - 200V_1 = 100V_1 - 100V_o + V_1$$

$$301V_1 - 200V_s - 100V_o = 0$$

$$\approx 3V_1 - 2V_s - V_o = 0 \longrightarrow V_1 = \frac{2V_s + V_o}{3}$$

$$\frac{V_1 - V_o}{200K} = \frac{V_o - AV_1}{50}$$

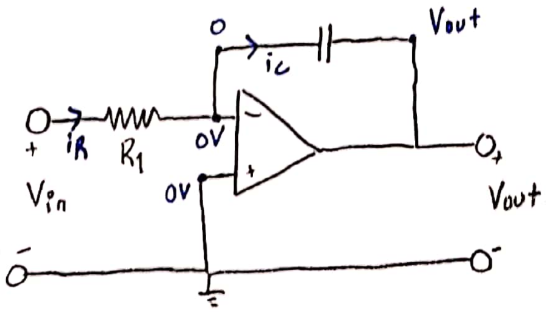
$$\downarrow$$

$$V_1 - V_o = 400(V_o + AV_1)$$

$$\frac{V_o}{V_s} \approx -2$$

1. Dereceden OPAMP

Integral Alıcı Devre



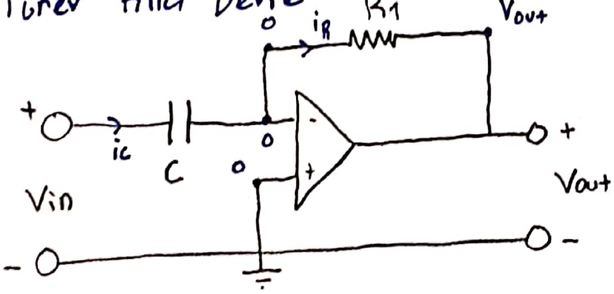
- $i_R = i_c$, $i_R = \dfrac{V_{in}}{R_1}$, $i_c = -C \cdot \dfrac{dV_{out}}{dt}$

- $\dfrac{V_{in}}{R} = -C \cdot \dfrac{dV_{out}}{dt} \rightarrow dV_{out} = -\dfrac{1}{RC} \cdot V_{in}\, dt$

  $\hookrightarrow \displaystyle\int dV_{out} = -\frac{1}{R_1C} \cdot \int_0^t V_{in} \cdot dt$

- $V_{out} = -\dfrac{1}{RC} \cdot \displaystyle\int_0^{t_1} V_{in} \cdot dt$

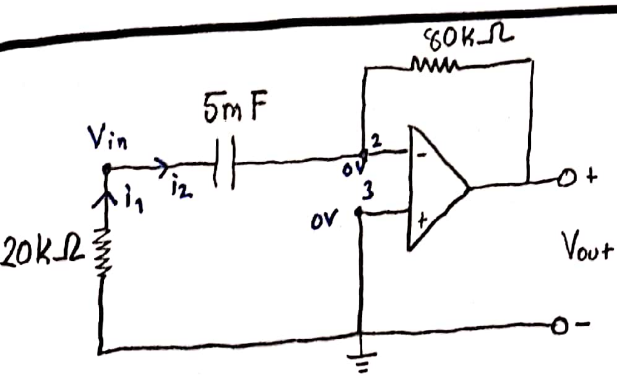
Türev Alıcı Devre



- $i_C = i_R \rightarrow i_R = \dfrac{-V_{out}}{R_1}$, $i_c = C \cdot \dfrac{dV_{in}}{dt}$

  $C \cdot \dfrac{dV_{in}}{dt} = \dfrac{-V_{out}}{R_1} \longrightarrow dV_{in} = -\dfrac{V_{out}\, dt}{R_1 C}$

- $V_{out} = -R_1 C \cdot \dfrac{dV_{in}}{dt}$



$V(0) = 3V$ $\quad V(t) = ?$, $t > 0$ $\quad \tau = RC = 20K \cdot 5mF$

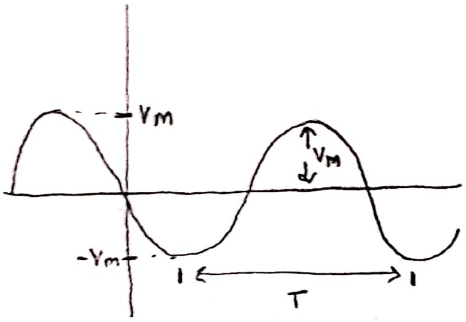
$i_1 = i_2 \longrightarrow V(t) = V_0 \cdot \exp(-t/\tau) = 3 \cdot \exp(-10t)$

$\dfrac{dV(t)}{dt} = -30 \cdot \exp(-10t)$

$i_1 = i_2 \longrightarrow \dfrac{V_{in}}{20K\Omega} = 5mF \cdot (-30) \cdot \exp(-10t)$

$V_{out} = -RC \cdot \dfrac{dV_{in}}{dt} = 12 \cdot \exp(-10t)$

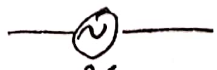
Sinüzodial Gerilim



$$\bullet\ V(t) = \underbrace{V_m}_{\text{Genlik}} \cdot \cos(\omega t + \phi)\ V$$

$$f = \frac{1}{T}\ (Hz)$$

$$\omega = 2\pi f = \frac{2\pi}{T}\ (rad/s)$$



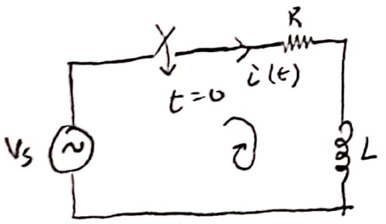
AC

$T \rightarrow$ periyot

$\phi \rightarrow$ faz

$$\bullet\ V_{rms} = \sqrt{\frac{1}{T} \cdot \int_{t_0}^{t_0+T} V_m^2 \cdot \cos^2(\omega t + \phi)\, dt}\ , \qquad \bullet\ V_{rms} = \frac{V_m}{\sqrt{2}}$$

$$V(t) = \underbrace{100}_{\text{galik}} \cdot \cos(\underbrace{2\pi \cdot 50}_{\text{frekans}} t + \underbrace{50}_{\text{faz}})\, V$$



$$\bullet\ L \cdot \frac{di}{dt} + R \cdot i = V_m \cos(\omega t + \phi)$$

$$V_s = V_m \cdot \cos(\omega t + \phi)$$

$$\bullet\ i = \underbrace{\frac{-V_m}{\sqrt{R^2 + \omega^2 L^2}} \cos(\phi - \theta)^{-(R/L)t}}_{\text{doğal (geçici)}} + \underbrace{\frac{V_m}{\sqrt{R^2 + \omega^2 L^2}} \cdot \cos(\omega t + \phi - \theta)}_{\text{kalıcı (zorlanmış)}}$$

$$i(t) = i_t(t) + i_{ss}(t)$$

Fazörler

Fazör, bir sinüzoidalin genlik ve faz bilgisini taşıyan karmaşık sayı.

- $e^{j\theta} = \cos\theta + j\sin\theta$ → $Re\{e^{j\theta}\} = \cos\theta$; $Im\{e^{j\theta}\} = \sin\theta$

- $V = V_m \cdot \cos(wt + \varnothing)$

$= V_m \cdot Re(e^{j(wt+\theta)}) = V_m \cdot Re(e^{jwt} \cdot e^{j\varnothing}) = Re(\underbrace{V_m}_{genlik} \cdot \overbrace{e^{j\varnothing}}^{faz} \cdot e^{j\overbrace{w}^{frekans}t})$

- $\overline{V} = V_m \cdot e^{j\varnothing} = P\{V_m \cdot \cos(wt + \varnothing)\}$

↳ fazör gösterim

- $\overline{V} = V_m \cdot e^{j\varnothing} = V_m \cdot \cos\varnothing + j \cdot V_m \cdot \sin\varnothing$

$V_m \cdot e^{j\varnothing} = V_m \cdot \angle\varnothing$

↳ polar gösterim

Ters Fazör Dönüşümü

$$V_m \cdot e^{j\phi} \xrightarrow{P^{-1}} V_m \cdot \cos(wt+\phi)$$

1) $V_m \cdot e^{j\phi} \times e^{jwt}$

2) $Re\{V_m \cdot e^{j\phi} \times e^{jwt}\}$

Kalıcı durum tepkisi $Re\{A \cdot e^{jB} \cdot e^{jwt}\}$

$$i_{ss}(t) = \underbrace{\frac{V_m}{\sqrt{R^2+w^2L^2}}}_{A} \cdot \cos(wt + \underbrace{\phi-\theta}_{B})$$

$L \cdot \frac{di}{dt} + R \cdot i = V_m \cdot \cos(wt+\phi)$, $i_{ss}(t) = Re\{I_m \cdot e^{jB} \cdot e^{jwt}\}$

$$\Rightarrow Re\{jwL e^{jB} \cdot e^{jwt}\} + Re\{R \cdot I_m \cdot e^{jB} \cdot e^{jwt}\} = Re\{V_m \cdot e^{j\phi} \cdot e^{jwt}\}$$

$$Re\{\underbrace{(jwL+R) \cdot I_m \cdot e^{jB}}_{\text{fazör}} \cdot e^{jwt}\} = Re\{\underbrace{V_m \cdot e^{j\phi}}_{\text{fazör}} \cdot e^{jwt}\}$$

$$(jwL+R) \cdot I_m \cdot e^{jB} = V_m \cdot e^{j\phi}$$

$$I_m \cdot e^{jB} = \frac{V_m \cdot e^{j\phi}}{R+jwL} \longrightarrow I_m \angle B$$

Kalıcı durum

$$\Rightarrow Re\{I_m \cdot e^{jB} \cdot e^{jwt}\} \xrightarrow{P^{-1}} i_{ss}(t) = I_m \cdot \cos(wt+B)$$

$$V = V_1 + V_2 + V_3 + \dots + V_n$$

$$\overline{V} = \overline{V_1} + \overline{V_2} + \dots + \overline{V_n}$$

$$y_1 = 200 \cdot \cos(wt - 30) \qquad y_2 = 40 \cdot \cos(wt + 60)$$

$$y_1 + y_2 = ? \longrightarrow \overline{y_1} + \overline{y_2} = 20\angle{-30^\circ} + 40\angle{60^\circ}$$

$$\downarrow$$

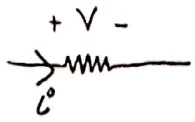
$$(17.32 - j10) + (20 + j34.64)$$

$$= 37{,}32 + j24.64 = 44.72\angle{33.43^\circ}$$

$$y_1 + y_2 = 44.72 \cdot \cos(wt + 33.43^\circ)$$

Fazör Bölgesinde Pasif Devre Elemanları

Direnç



$i = I_m \cdot \cos(\omega t + \phi_i)$

$V = R \cdot I_m \cdot \cos(\omega t + \phi_i)$

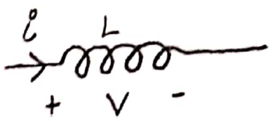
$\downarrow$

$\boxed{\bar{V} = R \cdot I_m \angle \phi_i} \longrightarrow I_m \cdot \angle \phi_i$: akımın fazör gösterimi

$\downarrow$

$\bar{V} = R \cdot \bar{I}$

İndüktör



$i = I_m \cdot \cos(\omega t + \phi_i) \longrightarrow I_m \angle \phi_i$

$V = L \cdot \dfrac{di}{dt} = -\omega L I_m \cdot \sin(\omega t + \phi_i)$

$\hookrightarrow -\omega L I_m \cdot \cos(\omega t + \phi_i - 90°)$

$\hookrightarrow -\omega L \cdot I_m e^{j(\phi_i - 90°)} = -\omega L \cdot I_m \angle \phi_i - 90$

$\hookrightarrow -\omega L \cdot I_m \cdot e^{j\phi_i} \cdot \underbrace{e^{-j90°}}_{-j}$

$\hookrightarrow j \omega L \underbrace{I_m \cdot e^{j\phi_i}}_{\bar{I}}$

$\boxed{\bar{V} = \omega \cdot L \cdot I_m \angle \phi_i + 90°}$

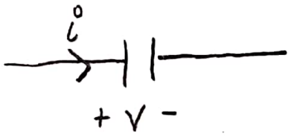
$\downarrow$

faz farkı ?

$\bar{V} = j \cdot \omega \cdot L \cdot \bar{I} = (\omega \cdot L \angle 90°)(I_m \angle \phi_i)$

$= \omega \cdot L \cdot I_m \cdot \angle \phi_i + 90°$

Kapasitör



$$V = V_m \cdot \cos(wt + \emptyset_v) \longrightarrow V_m \cdot \angle \emptyset_v$$

$$i = C \cdot \frac{dV}{dt} = -C\omega V_m \sin(wt + \emptyset_v)$$

$$= -C \cdot w \cdot V_m \cdot \cos(wt + \emptyset_v - 90°)$$

$$= -C \cdot w \cdot V_m \cdot e^{j(\emptyset_v - 90)} = -C \cdot w \cdot V_m \cdot e^{j\emptyset_v} \cdot \underbrace{e^{-j90}}_{-j}$$

$$= jC \cdot w \overbrace{V_m \cdot e^{j\emptyset_v}}^{\overline{V}}$$

$$= j \cdot C \cdot V_m \cdot \angle \emptyset_v$$

$$\overline{I} = jwC \cdot \underbrace{V_m \angle \emptyset_v}_{\overline{V}} \longrightarrow \overline{V} = \frac{\overline{I}}{jwC} = \frac{1}{jwC} \cdot I_m \angle \emptyset_i$$

$$= \frac{e^{-j90°}}{w \cdot C} \cdot I_m \angle \emptyset_i$$

$$\overline{V} = \frac{I_m}{wC} \cdot \angle \emptyset_i - 90°$$

Empedans Ve Reaktans

$$\overline{V} = R \cdot \overline{I} \qquad \overline{V} = j \cdot w \cdot L \, \overline{I} \qquad \overline{V} = \frac{1}{jwc} \cdot \overline{I}$$

direnç — indüktör — kapasitör

$$\overline{V} = Z \overline{I} \longrightarrow Z = \frac{\overline{V}}{\overline{I}}$$

Z → empedans

$Z_R = R$

$Z_I = j \cdot w \cdot L$

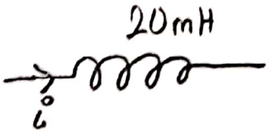
$Z_c = \dfrac{1}{jwc}$

$Z \longrightarrow$ ohm (Karmaşık sayı, fazör değil)

$Im\{Z\}$ = Reaktans

	Empedans	Reaktans
Direnç	R	X
indüktör	jwL	wL
Kapasitör	$j(-1/wc)$	$-1/wc$

$j = -\dfrac{1}{j}$



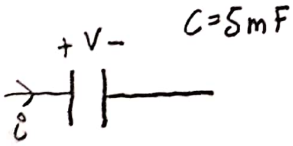
$i = 10\cos(10.000t + 30°)$ mA ise indüktans, empedans, fazör V? time V?

a) $wL = 200\Omega$

b) $JwL = J200\Omega$

c) $\overline{V} = JwL.\overline{I} = J \cdot 10.000 \cdot 20.10^{-3}.10^{-2}\angle 30° = J2\angle 30° = 2\angle 120°$

d) $V(t) = 2 \cdot \cos(10.000t + 120°)$ V



$V = 30.\cos(4000t + 25°)$ V

a) Reaktans $\longrightarrow -1/(wc) = -50\Omega$

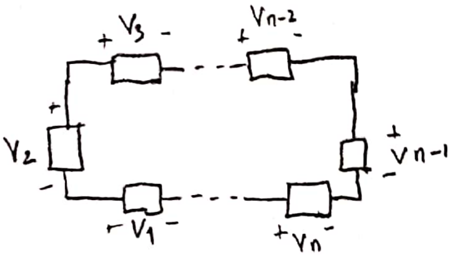
b) Empedans $\longrightarrow -J/wc = -J50\Omega$

c) Fazör Akım $\longrightarrow \overline{I} = Jwc.\overline{V} = J \cdot 4000 \cdot 5 \cdot 10^{-3}.30\angle 25° = J60\angle 25° = 0,6\angle 115°$

d) $I(t) = 0,6 \cdot \cos(4000t + 115°)$ A

Fazörlerde Devre Analizi

KVL-KCL



$$\overline{V_1}+\overline{V_2}+\overline{V_3}+\dots+\overline{V_n}=0$$

$$\overline{I_1}+\overline{I_2}+\overline{I_3}+\dots+\overline{I_n}=0$$

→ Devreyi fazör bölgesine götür.

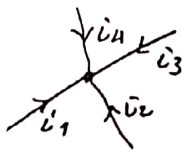
→ Karmaşık ifadelerle analiz yap.

→ Devreyi zaman bölgesine geri getir.

$i_1=100\cos(wt+25°)\,A$

$i_2=100\cos(wt+145°)\,A$

$i_3=100\cos(wt-95°)\,A$



$i_4=?$

$$100\angle 25° = 100\,e^{j25°} = 100(\cos 25° + j\sin 25°)$$

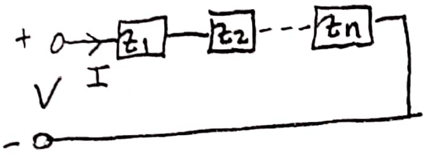
$$i_1+i_3+i_4+i_2=0 \longrightarrow \overline{I_1}+\overline{I_2}+\overline{I_3}+\overline{I_4}=0$$

$$\hookrightarrow 100\angle 25° + 100\angle 145° + 100\angle -95° + \overline{I_4}=0$$

$$90.63+j42.2-81.91+j57.3-8.71-j99.6+\overline{I_4}=0$$

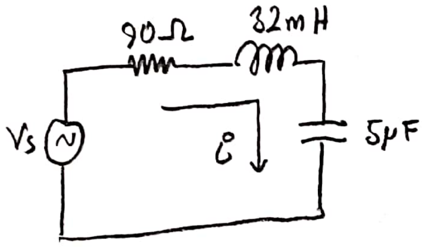
$$\overline{I_4}=0$$

Seri Empedans

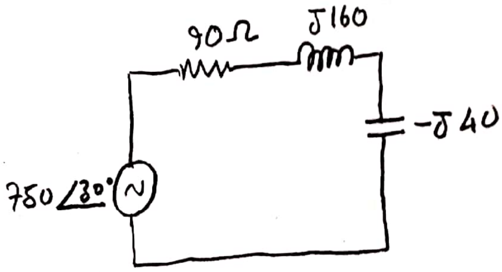


$$\bar{V} = Z_1 \cdot \bar{I} + Z_2 \cdot \bar{I} + Z_3 \bar{I} + Z_n \bar{I} = \bar{I}\,\underbrace{(Z_1 + Z_2 + Z_3 + \dots + Z_n)}_{Z_{eq}}$$

$$Z_{eq} = \frac{\bar{V}}{\bar{I}}$$



$$V_s = 750\cos(5000t + 30°)\ V = 750\angle 30° = 750 \cdot e^{j30°}$$



$Z_R = R = 90\Omega$

$Z_L = jwL = j \cdot 160\Omega$

$Z_C = -j/wC = -j40\Omega$

$\bar{V_s} = 750\angle 30°$

$$Z_{ab} = 90 + j160 - j40 = 90 + j120\ \Omega$$

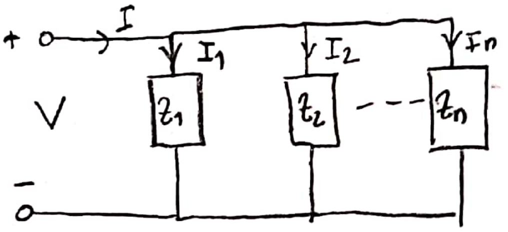
$$= 150\angle 53{,}13°$$

$$\bar{I} \cdot Z_{ab} = \bar{V}$$

$$\dot{I} = \frac{750\angle 30°}{150\angle 53{,}13} = 5\angle -23{,}13\ A$$

$\rightarrow i(t) = 5 \cdot \cos(5000t - 23{,}13°)\ A$

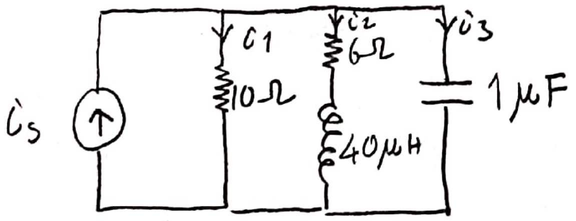
Paralel Empedans



$$\bar{I} = \bar{I}_1+\bar{I}_2+\bar{I}_3+\bar{I}_4+\dots+\bar{I}_n$$

Z_{eq}

$$\frac{\bar{V}}{Z_{eq}} = \bar{V}\left(\frac{1}{Z_1}+\frac{1}{Z_2}+\frac{1}{Z_3}+\dots+\frac{1}{Z_n}\right)$$



$i_s = 8\cos(200.000t)$ A

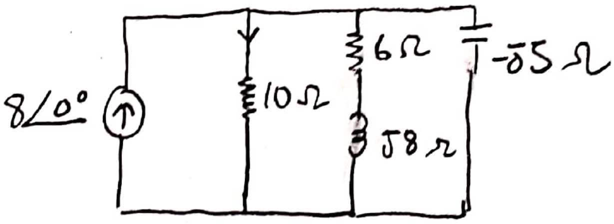
$\bar{i}_s = 8\angle 0°$

$Z_{10} = 10\Omega$

$Z_6 = 6\Omega$

$Z_{40} = j\omega L = j8\Omega$

$Z_1 = -j5\Omega$



$$\frac{1}{Z_{eq}} = \frac{1}{10}+\frac{1}{j8+6}-\frac{1}{j5} = 4-j3\,\Omega$$

$$|Z_{eq}| = \sqrt{4^2+3^2} = 5$$

$$\angle Z_{eq} = \tan\left(\frac{-3}{4}\right) = -36.87$$

$$\downarrow$$

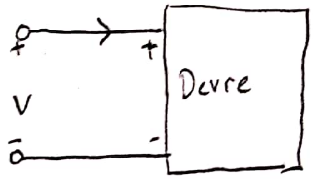
$$Z_{eq} = 5\angle -36.87$$

$$\bar{V} = Z_{eq}\cdot\bar{I} = 5\angle -36.87 \times 8\angle 0° = 40\angle -36.87$$

$$V(t) = 40\cos(200{,}000t - 36.87°)\,V$$

Anlık ve Ortalama Güç

$P = V \cdot I$



- $p(t) = v(t) \cdot i(t)$

$v(t) = V_m \cos(\omega t + \theta_v)$

$i(t) = I_m \cdot \cos(\omega t + \theta_i)$

$$p(t) = V_m \cdot I_m \cdot \cos(\omega t + \theta_v) \cdot \cos(\omega t + \theta_i)$$

$$= \frac{V_m I_m}{2} \left[\cos(\theta - \theta_i) + \cos(2\omega t + \theta_v + \theta_i) \right]$$

$$P(t) = \frac{V_m I_m}{2} \cdot \cos(\theta_v - \theta_i) + \frac{V_m I_m}{2} \cdot \cos(2\omega t + \theta_v + \theta_i)$$

Anlık güç

$$\hat{P} = \frac{1}{T} \cdot \int_0^T p(t)\,dt = \frac{V_m \cdot I_m}{2} \cdot \cos(\theta_v - \theta_i) = \frac{1}{2} \cdot \mathrm{Re}\left[\bar{V} \cdot I^*\right]$$

$v(t) = 120\cos(377t + 45°)\,V$, $i(t) = 10 \cdot \cos(377t - 10°)\,A$

anlık güç $= v(t) \cdot i(t) = 600(\cos(55) + \cos(754t + 35°))\,W$

ortalama güç