$e(t)=u(t)$ → birim basamak alırsak söz $\frac{1}{s}$ olacak

matrissel geçiş = transfer fonksiyonu → birim vuruş

$$\text{Ör: } \begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \underbrace{\begin{bmatrix}1 & 0\\ 1 & -3\end{bmatrix}}_{A}\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \underbrace{\begin{bmatrix}1\\ 0\end{bmatrix}}_{B} e(t) \qquad e(t)=\delta(t), \quad \begin{bmatrix}x_1(0)\\ x_2(0)\end{bmatrix} = \begin{bmatrix}0\\ 0\end{bmatrix} \qquad y(t) = \underbrace{\begin{bmatrix}-\frac{1}{4} & 1\end{bmatrix}}_{C}\begin{bmatrix}x_1\\ x_2\end{bmatrix}$$

s bölgesinde durum denk. çözünüz. Matrissel geçiş (transfer) fonk. bulunuz.

Başlangıç değerine göre elde edilen çözüm

Kaynağa göre elde edilen çözüm

Çıkışın girişe oranı (Başlangıç değerlerinin 0 alındığı durumdaki)

$$\underline{X}(s) = \underbrace{[sI-A]^{-1}}_{\phi(s)}\underline{X}(0) + \underbrace{[sI-A]^{-1}B\,E(s)}_{\text{zorlanmış çözüm}}$$

öz çözüm

$$H(s) = \left.\frac{Y(s)}{U(s)}\right|_{X(0)=0} = C[sI-A]^{-1}B$$

$$\phi(s) = [sI-A]^{-1} = \left\{\begin{bmatrix}s & 0\\ 0 & s\end{bmatrix} - \begin{bmatrix}1 & 0\\ 1 & -3\end{bmatrix}\right\}^{-1} \qquad \phi(s) = \begin{bmatrix}s-1 & 0\\ -1 & s+3\end{bmatrix}^{-1} \qquad \Delta = s^2+2s-3 = (s-1)(s+3)$$

$$\boxed{\begin{matrix}s_1=1\\ s_2=-3\end{matrix}} \text{ kararsız}$$

$$\begin{bmatrix}\frac{s+3}{(s-1)(s+3)} & 0\\ \frac{1}{(s-1)(s+3)} & \frac{\cancel{s-1}}{(\cancel{s-1})(s+3)}\end{bmatrix} = \phi(s)$$

$$\mathcal{L}\{e(t)\} = E(s) = 1$$

$$\begin{bmatrix}X_1\\ X_2\end{bmatrix} = \begin{bmatrix}\frac{1}{s-1} & 0\\ \frac{1}{(s-1)(s+3)} & \frac{1}{s+3}\end{bmatrix}\underbrace{\begin{bmatrix}1\\ 0\end{bmatrix}}_{B}\underbrace{\begin{bmatrix}1\end{bmatrix}}_{E} \qquad \begin{bmatrix}X_1(s)\\ X_2(s)\end{bmatrix} = \begin{bmatrix}\frac{1}{s-1}\\ \frac{1}{(s-1)(s+3)}\end{bmatrix} = \begin{bmatrix}\frac{1}{s-1}\\ \frac{1/4}{s-1} + \frac{-1/4}{s+3}\end{bmatrix} =$$

$$= \begin{bmatrix}x_1(t)\\ x_2(t)\end{bmatrix} = \begin{bmatrix}e^{t}\\ \frac{1}{4}e^{t} - \frac{1}{4}e^{-3t}\end{bmatrix}$$

$t\to\infty$ $x_1\to\infty$, $x_2\to\infty$ olduğundan kararsızdır.

sürekli durum bileşeni

geçici durum bileşeni

$$H(s) = \left.\frac{Y(s)}{U(s)}\right|_{X(0)=0} = C.\phi(s).B = \begin{bmatrix}-\frac{1}{4} & 1\end{bmatrix}\begin{bmatrix}\frac{1}{s-1} & 0\\ \frac{1}{(s-1)(s+3)} & \frac{1}{(s+3)}\end{bmatrix}\begin{bmatrix}1\\ 0\end{bmatrix}$$

$$= \begin{bmatrix}-\frac{1}{4} & 1\end{bmatrix}\begin{bmatrix}\frac{1}{s-1}\\ \frac{1}{(s-1)(s+3)}\end{bmatrix} = \left[-\frac{1/4}{s-1} + \frac{1}{(s-1)(s+3)}\right]$$

Paydaları eşitle

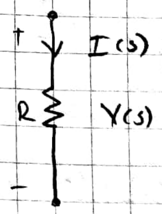
$$= \frac{-\cancel{s-1}}{4.(\cancel{s-1}).(s+3)} = -\frac{1}{4(s+3)} = H(s)$$

durumun çıkışının girişine oranı

transfer fonksiyonu

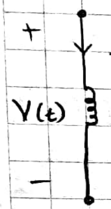
S Bölgesinde Devre Elemanlarının Tanımları

1) Direnç elemanı:



$V(s) = R.I(s) \qquad I(s) = \frac{1}{R}.V(s)$

2) Endüktans Elemanı:

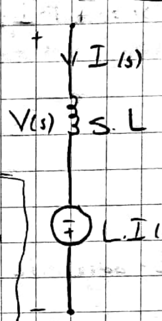


$V(t) = L.\frac{dI(t)}{dt}$

$I(t) = \frac{1}{L}\int_{t_0}^{t} V(t)\,dt + I(t_0)$

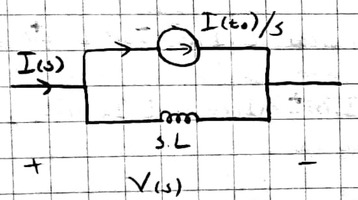
s bölgesinde

$V(s) = \underbrace{s.L.I(s)} - \underbrace{L.I(t_0)}$



s bölgesinde endüktans için gerilim eşdeğeri modeli

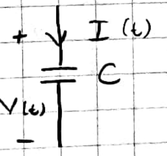
$I(s) = \frac{1}{sL}.V(s) + \frac{I(t_0)}{s}$ s bölgesinde akım tanımı



Akım eşdeğer devresi

3) Kapasite Elemanı

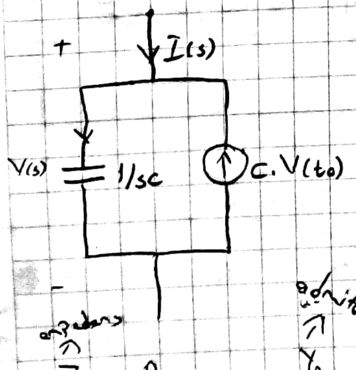
t bölgesinde $\xrightarrow{\mathcal{L}}$ s bölgesinde



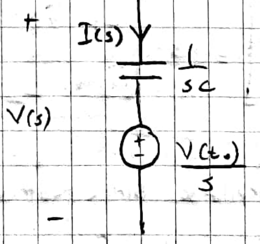
$I(t) = C.\frac{dV(t)}{dt} \qquad I(s) = s.C.V(s) - C.V(t_0)$

$V(t) = \frac{1}{C}\int_{t_0}^{t} I(t)\,dt + V_c(t_0) \qquad V(s) = \frac{1}{s.C}I(s) + \frac{V(t_0)}{s}$

Akım eşdeğeri: (s bölgesinde)



Gerilim eşdeğeri (s bölgesinde)



empedans

$Z_r = R$

$Z_L = sL$

$Z_C = \frac{1}{sC}$

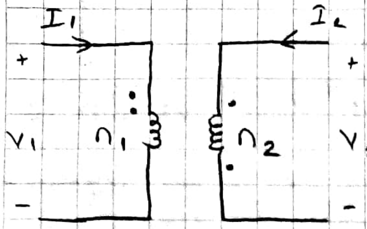
admitans

$Y_R = \frac{1}{R}$

$Y_L = \frac{1}{sL}$

$Y_C = sC$

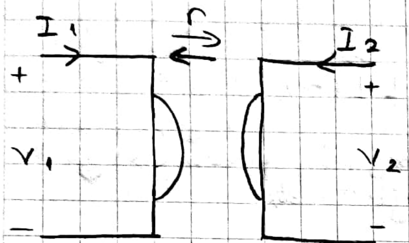
4) İdeal Transformatör



$$n = \frac{n_1}{n_2}$$

$$\frac{V_1(s)}{V_2(s)} = \mp n \qquad \frac{I_2(s)}{I_1(s)} = \pm n$$

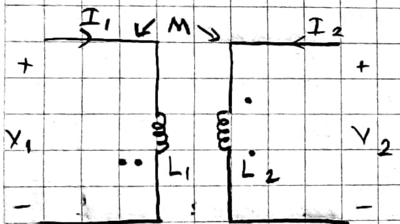
5) Jiratör Elemanı



$$V_1(s) = \pm r . I_2(s)$$

$$V_2(s) = \mp r I_1(s)$$

6) Fiziksel Transformatör



t-bölgesinde $\xrightarrow{\mathcal{L}}$ s bölgesinde

$$V_1 = L_1 \frac{dI_1}{dt} \mp M \frac{dI_2}{dt}$$

$$V_2 = \mp M \frac{dI_1}{dt} + L_2 \frac{dI_2}{dt}$$

$$V_1(s) = s.L_1.I_1(s) - L_1 I_1(t_0) \mp sM I_2(s) \pm M I_2(t_0)$$

$$V_2(s) = \mp sM I_1(s) \pm M I_1(t_0) + sL_2 I_2(s) - L_2 I_2(t_0)$$

$$\begin{bmatrix} V_1(s) \\ V_2(s) \end{bmatrix} = \begin{bmatrix} sL_1 & \mp sM \\ \mp sM & sL_2 \end{bmatrix} \begin{bmatrix} I_1(s) \\ I_2(s) \end{bmatrix} - \begin{bmatrix} L_1 & \mp M \\ \mp M & L_2 \end{bmatrix} \begin{bmatrix} I_1(t_0) \\ I_2(t_0) \end{bmatrix}$$

$$\begin{bmatrix} V_1(s) \\ V_2(s) \end{bmatrix} = s \begin{bmatrix} L_1 & \mp M \\ \mp M & L_2 \end{bmatrix} \begin{bmatrix} I_1(s) \\ I_2(s) \end{bmatrix} - \begin{bmatrix} L_1 & \mp M \\ \mp M & L_2 \end{bmatrix} \begin{bmatrix} I_1(t_0) \\ I_2(t_0) \end{bmatrix}$$

tersini alıp eşitliğin diğer tarafı ile çarparız.

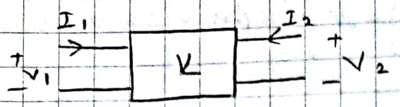
$$\begin{bmatrix} V_1(s) \\ V_2(s) \end{bmatrix} + \begin{bmatrix} L_1 & \mp M \\ \mp M & L_2 \end{bmatrix} \begin{bmatrix} I_1(t_0) \\ I_2(t_0) \end{bmatrix} = s \begin{bmatrix} L_1 & \mp M \\ \mp M & L_2 \end{bmatrix} \begin{bmatrix} I_1(s) \\ I_2(s) \end{bmatrix}$$

Tersi ile çarpılırsa birim matris olur.

$$\begin{bmatrix} I_1(s) \\ I_2(s) \end{bmatrix} = \begin{bmatrix} L_2/\Delta s & \pm M/\Delta s \\ \pm M/\Delta s & L_1/\Delta s \end{bmatrix} \begin{bmatrix} V_1(s) \\ V_2(s) \end{bmatrix} + \begin{bmatrix} I_1(t_0)/s \\ I_2(t_0)/s \end{bmatrix}$$

$$I_1(s) = \frac{L_2}{\Delta s} V_1(s) \pm \frac{M}{\Delta s} V_2(s) + \frac{I_1(t_0)}{s} \qquad I_2(s) = \pm \frac{M}{\Delta s} V_1(s) + \frac{L_1}{\Delta s} V_2(s) + \frac{I_2(t_0)}{s}$$

7) Negatif Çeviriciler



k: dönüştürme oranı

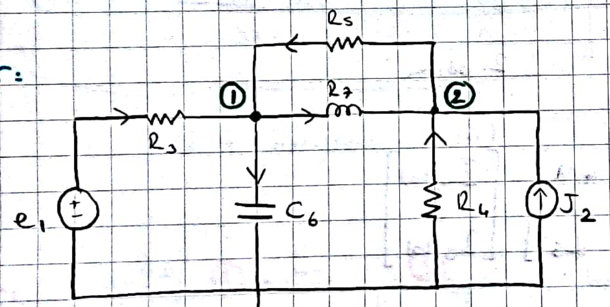
$$\left.\begin{aligned} V_1(s) &= k V_2(s) \\ I_2(s) &= k I_1(s) \end{aligned}\right\} INC \qquad \left.\begin{aligned} V_1(s) &= -k V_2(s) \\ I_2(s) &= -k I_1(s) \end{aligned}\right\} VNC$$

S – bölgesinde devrelerin çözümleri

1) Düğüm gerilimleri cinsinden düğüm denklemlerinin yazılması
2) Temel çevre denklemleri
3) Temel kesitleme denklemleri
4) Bağımsız çevre denklemleri

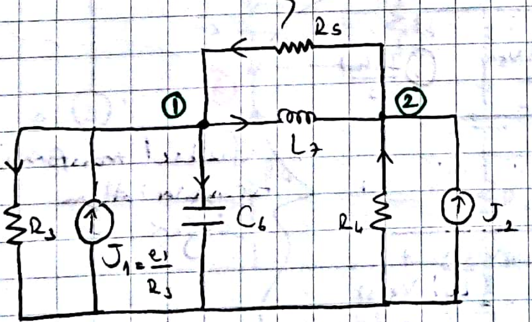
1) Düğüm denklemlerinin yazılması

Ör:



Verilen devrenin çözümünü sadece 1 ve 2 denklemlerini kullanarak düğüm denklemleri ile yazınız.

$$x = \begin{bmatrix} Vd_1(s) \\ Vd_2(s) \end{bmatrix}$$



1) $-J_1 + I_3 + I_6 - I_5 + I_7 = 0$

2) $-J_2 - I_4 + I_5 - I_7 = 0$

1) $-\dfrac{E_1(s)}{R_3} + G_3 V_3(s) + sC_6 V_6(s) - C_6 V_6(0) - G_5 V_5 + \dfrac{V_7(s)}{sL_7} + \dfrac{I_7(0)}{s} = 0$

2) $-J_2(s) - G_4 V_4(s) + G_5 V_5(s) - \dfrac{V_7(s)}{sL_7} - \dfrac{I_7(0)}{s} = 0$

$V_3(s) = Vd_1(s)$

$V_4(s) = -Vd_2(s)$

$V_5(s) = Vd_2(s) - Vd_1(s)$

$V_6(s) = Vd_1(s)$

$V_7(s) = Vd_1(s) - Vd_2(s)$

1) $-\dfrac{E_1(s)}{R_3} + G_3 Vd_1(s) + sC_6 Vd_1(s) - C_6 V_6(0) + C_5(Vd_2(s) - Vd_1(s)) + \dfrac{Vd_1(s) - Vd_2(s)}{sL_7} + \dfrac{I_7(t_0)}{s} = 0$

2) $-J_2(s) - G_4(-Vd_2(s)) + G_5(Vd_2(s) - Vd_1(s)) - \dfrac{Vd_1(s) - Vd_2(s)}{sL_7} - \dfrac{I_7(t_0)}{s} = 0$

1) $V_{d1}\left(G_3 + sC_6 + G_5 + \frac{1}{sL_7}\right) - V_{d2}\left(G_5 + \frac{1}{sL_7}\right) = \frac{E_1(s)}{R_3} + C_6 V_6(0) - \frac{I_7(0)}{s}$

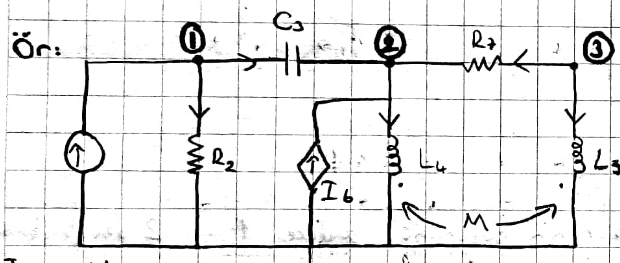
2) $-V_{d1}\left(G_5 + \frac{1}{sL_7}\right) + V_{d2}\left(G_4 + G_5 + \frac{1}{sL_7}\right) = + J_2(s) + \frac{I_7(t_0)}{s}$

$$\underbrace{\begin{bmatrix} G_3 + sC_6 + G_5 + \frac{1}{sL_7} & -G_5 - \frac{1}{sL_7} \\ -G_5 - \frac{1}{sL_7} & G_4 + G_5 + \frac{1}{sL_7} \end{bmatrix}} \underbrace{\begin{bmatrix} V_{d1}(s) \\ V_{d2}(s) \end{bmatrix}} = \underbrace{\begin{bmatrix} \frac{E_1(s)}{R_3} \\ J_2(s) \end{bmatrix}} + \begin{bmatrix} C_6 V_6(0) - \frac{I_7(0)}{s} \\ \frac{I_7(0)}{s} \end{bmatrix}$$

Yd : Düğümlere admitans matrisi $\quad \underline{Y_d} = \underline{J_s}$ + Başlangıç değerleri

$Y_d \cdot \underline{V_d}(s) = J(s)$ + Başlangıç değerleri

Ör:



$I_6 = g \cdot V_3$

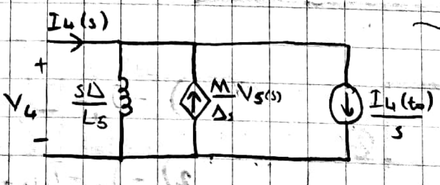
$$\begin{bmatrix} I_4(s) \\ I_5(s) \end{bmatrix} = \begin{bmatrix} L_5/\Delta_s & -M/\Delta_s \\ -M/\Delta_s & L_4/\Delta_s \end{bmatrix} + \begin{bmatrix} I_4(t_0)/s \\ I_5(t_0)/s \end{bmatrix}$$

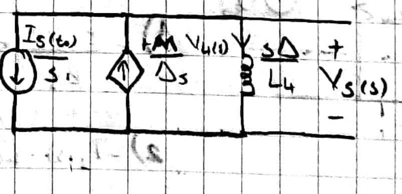
2. adım

1) $x = \begin{bmatrix} V_{d1} \\ V_{d2} \\ V_{d3} \end{bmatrix} \qquad \begin{bmatrix} V_4(s) \\ V_5(s) \end{bmatrix} = s \begin{bmatrix} L_4 & +M \\ +M & L_5 \end{bmatrix} \begin{bmatrix} I_4(s) \\ I_5(s) \end{bmatrix} - \begin{bmatrix} L_4 & +M \\ +M & L_5 \end{bmatrix} \begin{bmatrix} I_4(t_0) \\ I_5(t_0) \end{bmatrix}$

3) $I_4(s) = \frac{L_5}{\Delta_s} V_4(s) - \frac{M}{\Delta_s} V_5(s) + \frac{I_4(t_0)}{s}$

$I_5(s) = -\frac{M}{\Delta_s} V_4(s) + \frac{L_4}{\Delta_s} V_5(s) + \frac{I_5(t_0)}{s}$





fiziksel transformatör için Akım eşdeğeri

s bölgesinde

1) $-I_1 + I_2 + I_3 = 0$

$-I_3 + I_4 - I_6 - I_7 = 0$

$I_5 + I_7 = 0$

2) $-J_1(s) + G_2V_2 + sC_3V_3 - C_3V_3(t_0) = 0$

$-sC_3V_3 + C_3V_3(t_0) + \overbrace{\frac{L_5}{\Delta_s}V_4 - \frac{M}{\Delta_s}V_5 + \frac{I_4(t_0)}{s}}^{I_4} - gV_3 - G_7V_7 = 0$

$-\frac{M}{\Delta_s}V_4 + \frac{L_4}{\Delta_s}V_5 + \frac{I_5(t_0)}{s} + G_7V_7 = 0$

$V_2 = V_{d_1}$ $\quad V_5 = V_{d_3}$

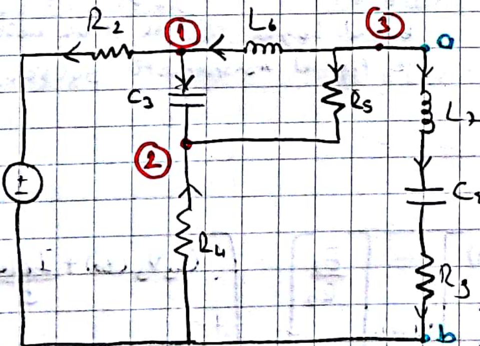
$V_3 = V_{d_1} - V_{d_2}$ $\quad V_7 = V_{d_3} - V_{d_2}$

$V_4 = V_{d_2}$

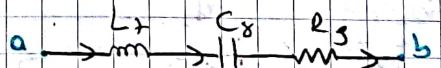
Bağımlı kaynağı kapatınca simetrik ise doğru yaptık, ve köşegen dışında elemanlar − olur.

$$\underbrace{\begin{array}{ccc} Y_{d_1} & V_{d_2} & V_{d_3} \\ \left[\begin{array}{ccc} G_2+sC_3 & -sC_3 & 0 \\ -sC_3-g & sC_3+\frac{L_5}{s\Delta}+g+G_7 & -\frac{M}{s\Delta}-G_7 \\ 0 & -\frac{M}{\Delta_s}-G_7 & \frac{L_4}{\Delta_s}+G_7 \end{array}\right] \end{array}}_{Y_d \text{ (Y admitans matrisi)}} \underbrace{\begin{bmatrix} V_{d_1}(s) \\ V_{d_2}(s) \\ V_{d_3}(s) \end{bmatrix}}_{V_d} = \underbrace{\begin{bmatrix} J_1(s) \\ 0 \\ 0 \end{bmatrix}}_{J(s)} + \underbrace{\begin{bmatrix} C_3V_3(t_0) \\ -C_3V_3(t_0)-\frac{I_4(t_0)}{s} \\ -\frac{I_5(t_0)}{s} \end{bmatrix}}_{\text{Başlangıç akımları}}$$

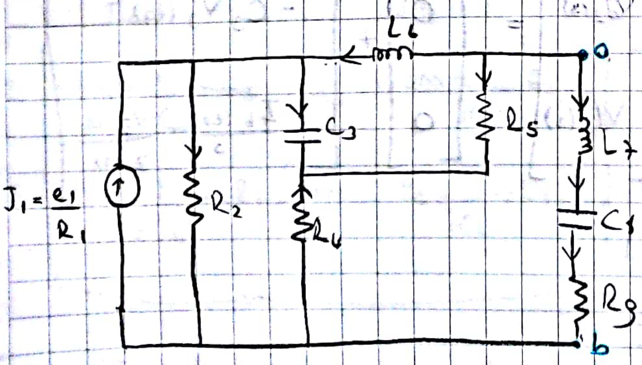
Ör:

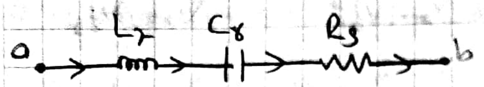


başlangıç değerleri ≠ 0. 1, 2, ve 3 düğüm denklemlerini doğrudan yazınız.



a, b düğümünü ortadan kaldırmak için bu elemanların akım eşdeğer empedansını bulup çizeriz. (akım kaynağı olduğu için akım eşdeğeri). Elemanlar seri olduğu için öncelikle gerilim eşdeğeri çizilir daha sonra akım eşdeğere geçilir.

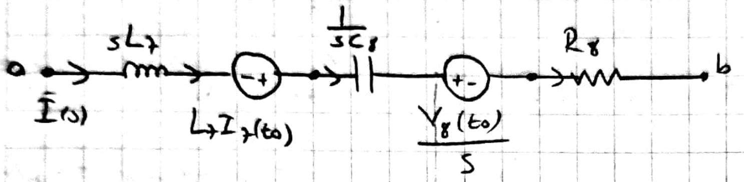




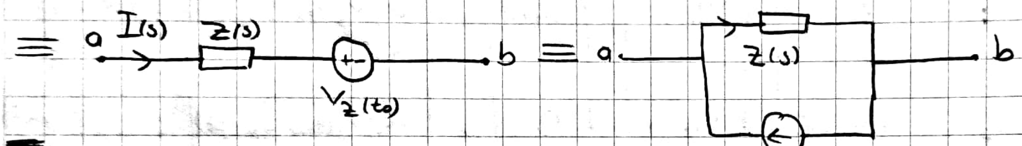
$$I_7(s) = \frac{1}{sL_7} V_7(s) + \frac{I_7(t_0)}{s} \qquad V_7(s) = sL_7 I_7(s) - L_7 I_7(t_0)$$

$$I_8(s) = sC_8 V_8(s) - C_8 V_8(t_0) \qquad V_8(s) = \frac{1}{sC_8} I_8(s) + \frac{V_8(t_0)}{s}$$

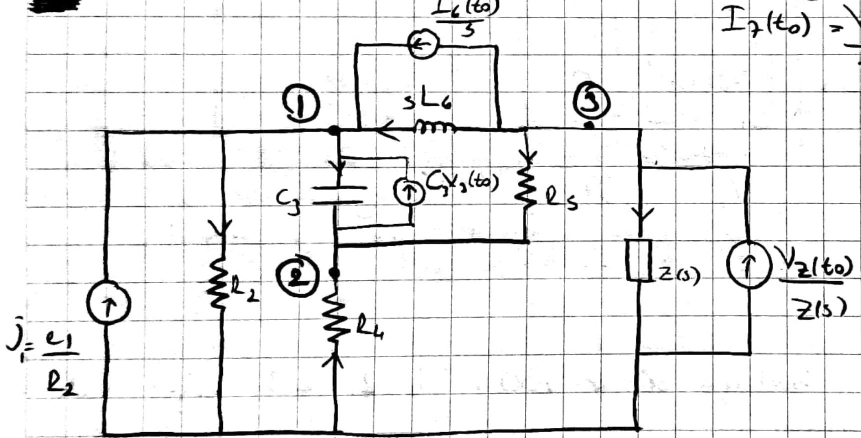
akım eşdeğeri



$$Z(s) = R_8 + sL_7 + \frac{1}{sC_8} \qquad V_Z(t_0) = \frac{V_8(t_0)}{s} - L_7 I_7(t_0)$$



$$I_7(t_0) = \frac{V_Z(t_0)}{Z(s)}$$



elemanlar

iki düğüm arasında olanlar - alınır.

bağımlı kaynak olmadığı için simetrik

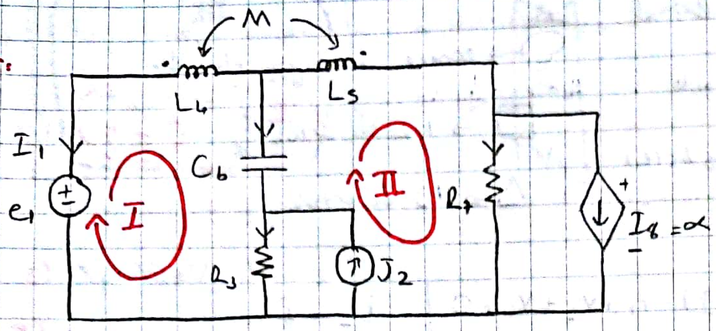
Köşegen üzeri +, değerleri hep −

bağımlı kaynak ve M ortak endüktansı ve fiziksel transformatör yoksa:

$$\underbrace{\begin{array}{ccc} V_{d1} & V_{d2} & V_{d3} \\ \left[\begin{array}{ccc} G_2 + sC_3 + \frac{1}{sL_6} & -sC_3 & -sL_6 \\ -sC_3 & sC_3 + G_4 + G_5 & -G_5 \\ -sL_6 & -G_5 & G_5 + \frac{1}{sL_6} + \frac{1}{Z(s)} \end{array}\right] \end{array}}_{Y \text{ düğümleme}} \begin{bmatrix} V_{d1}(s) \\ V_{d2}(s) \\ V_{d3}(s) \end{bmatrix} = \begin{bmatrix} \frac{E_1}{R_2} \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} C_3 V_3(t_0) + \frac{I_6(t_0)}{s} \\ -C_3 V_3(t_0) \\ -\frac{I_6(t_0)}{s} + \frac{V_Z(t_0)}{Z(s)} \end{bmatrix}$$

2) s Bölgesinde bağımsız çevre denklemlerinin yazılması

Ör:

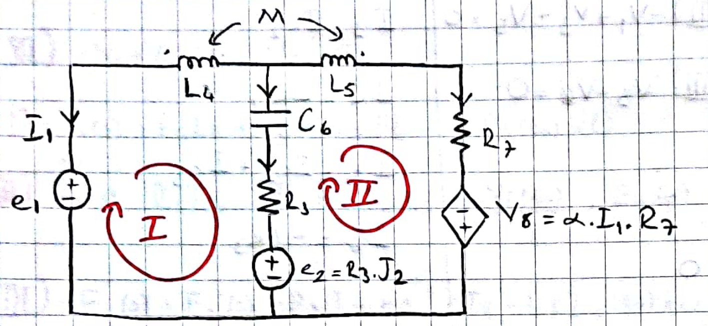


Başlangıç değerleri ≠ 0. gösterilen bağımsız çevreleri s bölgesinde yazınız.

$$x = \begin{bmatrix} I_{ç1} \\ I_{ç2} \end{bmatrix}$$

$I_{ç1}$ → I. çevre akımları

$I_{ç2}$ → II. çevre akımları



$$\begin{bmatrix} V_4(s) \\ V_5(s) \end{bmatrix} = s \begin{bmatrix} L_4 & -M \\ -M & L_5 \end{bmatrix} \begin{bmatrix} I_4(s) \\ I_5(s) \end{bmatrix} - \begin{bmatrix} L_4 & -M \\ -M & L_5 \end{bmatrix} \begin{bmatrix} I_4(t_0) \\ I_5(t_0) \end{bmatrix}$$

1)

I → $-V_1 + V_4 + V_6 + V_3 + V_2 = 0$

II → $-V_2 - V_3 - V_6 + V_5 + V_7 - V_8 = 0$

2) I → $-E_1(s) + sL_4 I_4 - sMI_5 - L_4 I_4(t_0) + MI_5(t_0) + \frac{1}{sC_6} I_6 + \frac{V_6(t_0)}{s} + R_3 I_3 + R_3 J_2(s) = 0$

II → $-R_3 J_2(s) - R_3 I_3 - \frac{1}{sC_6} I_6 - \frac{V_6(t_0)}{s} - sMI_4 + sL_5 I_5 + MI_4(t_0) - L_5 I_5(t_0) + R_7 I_7 - \alpha R_7 I_1 = 0$

3) $I_3 = I_{ç1} - I_{ç2}$ $\quad I_5 = I_{ç2}$ $\quad I_7 = I_{ç2}$

$I_4 = I_{ç1}$ $\quad I_6 = I_{ç1} - I_{ç2}$ $\quad I_1 = -I_{ç1}$

Köşegen üzeri öz çevre empedansı ve hep +

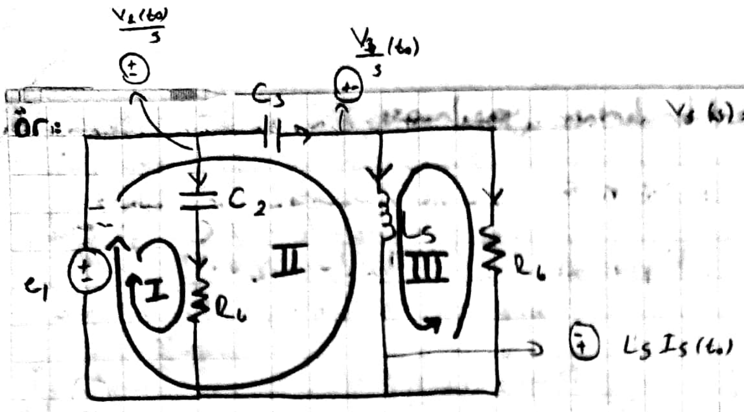
çevreler aynı yönlü ise köşegen dışı +, tersse − gelir.

$$\begin{array}{c|cc} & I_{ç1} & I_{ç2} \\ \hline \mathrm{I} & sL_4 + \frac{1}{sC_6} + R_3 & -sM - \frac{1}{sC_6} - R_3 \\ \mathrm{II} & -R_3 - \frac{1}{sC_6} + \alpha R_7 - sM & R_3 + \frac{1}{sC_6} + sL_5 + R_7 \end{array}$$

$$\underbrace{\begin{bmatrix} sL_4 + \frac{1}{sC_6} + R_3 & -sM - \frac{1}{sC_6} - R_3 \\ -R_3 - \frac{1}{sC_6} + \alpha R_7 - sM & R_3 + \frac{1}{sC_6} + sL_5 + R_7 \end{bmatrix}}_{Z_ç(s) = \text{bağımsız çevre empedans matrisi}} \underbrace{\begin{bmatrix} I_{ç1}(s) \\ I_{ç2}(s) \end{bmatrix}}_{I_ç} = \underbrace{\begin{bmatrix} E_1(s) - R_3 J_2(s) \\ R_3 J_2(s) \end{bmatrix}}_{\underline{E}(s)} + \underbrace{\begin{bmatrix} L_4 I_4(t_0) - MI_5(t_0) - \frac{V_6(t_0)}{s} \\ \frac{V_6(t_0)}{s} - MI_4(t_0) + L_5 I_5(t_0) \end{bmatrix}}_{\text{Başlangıç gerilimleri}}$$

$$Z_ç(s) \cdot \underline{I}_ç(s) = \underline{E}(s) + \text{Başlangıç değerleri}$$

Ör: $V_5(s) = sL_5 I_5 - L_5 I_5(t_0)$



○ → sadece çevredeki elemanlar

□ → 1,2 de ortak

△ → 1,3 de ortak

$$\begin{array}{c} \\ 1 \\ 2 \\ 3 \end{array}\begin{array}{c} \begin{array}{ccc} I_{c_1} & I_{c_2} & I_{c_3} \end{array} \\ \left[\begin{array}{ccc} \bigcirc & \square & \bigcirc \\ \square & \bigcirc & sL_5 \\ \triangle & sL_5 & \bigcirc \end{array}\right] \end{array}$$

I) $-V_1 + V_2 + V_4 = 0$

II) $-V_1 + V_3 + V_5 = 0$

III) $V_5 - V_6 = 0$

$I_2 = I_{c_1}$

$I_3 = I_{c_2}$

$I_4 = I_{c_1}$

$I_5 = I_{c_2} + I_{c_3}$

$I_6 = -I_{c_3}$

I) $-E_1(s) + \dfrac{1}{sC_2} I_2(s) + \dfrac{V_2(t_0)}{s} + I_4(s).R_4 = 0$

II) $-E_1(s) + \dfrac{1}{sC_3} I_3(s) + \dfrac{V_3(t_0)}{s} + sL_5 I_5(s) - L_5 I_5(t_0) = 0$

III) $sL_5 I_5(s) - L_5 I_5(t_0) - I_6(s).R_6 = 0$

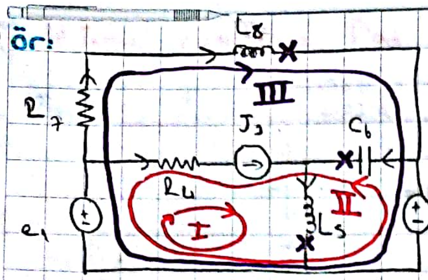
I) $-E_1(s) + \dfrac{1}{sC_2} I_{c_1} + \dfrac{V_2(t_0)}{s} + I_{c_1}.R_4 = 0$

II) $-E_1(s) + \dfrac{1}{sC_3} I_{c_2} + \dfrac{V_3(t_0)}{s} + sL_5(I_{c_2} + I_{c_3}) - L_5 I_5(t_0) = 0$

III) $sL_5(I_{c_2} + I_{c_3}) - L_5 I_5(t_0) + I_{c_3}.R_6 = 0$

$$\begin{array}{c} \begin{array}{ccc} I_{c_1} & I_{c_2} & I_{c_3} \end{array} \\ \begin{bmatrix} \dfrac{1}{sC_2} + R_4 & 0 & 0 \\ 0 & \dfrac{1}{sC_3} + sL_5 & sL_5 \\ 0 & sL_5 & sL_5 + R_6 \end{bmatrix} \end{array} \begin{bmatrix} I_{c_1} \\ I_{c_2} \\ I_{c_3} \end{bmatrix} = \begin{bmatrix} E_1(s) \\ E_1(s) \\ 0 \end{bmatrix} + \begin{bmatrix} -\dfrac{V_2(t_0)}{s} \\ -\dfrac{V_3(t_0)}{s} + L_5 I_5(t_0) \\ L_5 I_5(t_0) \end{bmatrix}$$

ör:



$$X = \begin{bmatrix} I_{c_1} \\ \cancel{I_{c_2}} \\ I_{c_3} \\ V_3 \end{bmatrix}$$

3 çevre var 4 bilinmeyen var. Bilinmeyenlerden birini diğeri cinsinden yazarak yok ederiz.

$J_3 = I_{c_1} - I_{c_2}$ $\qquad$ $I_{c_2} = I_{c_1} - J_3(s)$

2) I) $-V_1 + V_4 + V_3 + V_3 + V_5 = 0$

II) $V_1 - V_4 - V_3 + V_6 - V_2 = 0$

III) $-V_1 + V_2 + V_7 + V_8 = 0$

3) I) $-E_1(s) + R_4 I_4 + V_3 + sL_5 I_5 - L_5 I_5(t_0) = 0$

II) $E_1(s) - R_4 I_4 - V_3 + \dfrac{1}{sC_6} I_6 + \dfrac{V_6(t_0)}{s} - E_2(s) = 0$

III) $-E_1(s) + E_2(s) + R_7 I_7 + sL_8 I_8 - L_8 I_8(t_0) = 0$

4) $I_4 = I_{c_1} - I_{c_2} = J_3(s)$, $I_5 = I_{c_1}$, $I_6 = I_{c_2} = I_{c_1} - J_3(s)$, $I_7 = I_{c_3}$, $I_8 = I_{c_3}$

5) I)

II)

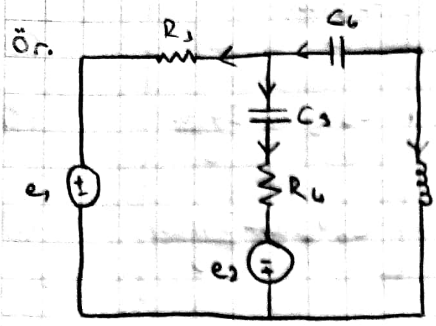
III)

6)

$$\begin{array}{c} \\ \mathrm{I} \\ \mathrm{II} \\ \mathrm{III} \end{array}
\begin{array}{c} \begin{array}{ccc} I_{c_1} & I_{c_2} & I_{c_3} \end{array} \\ \begin{bmatrix} sL_5 & 0 & 1 \\ \dfrac{1}{sC_6} & 0 & -1 \\ 0 & R_7 + sL_8 & 0 \end{bmatrix} \end{array}
\begin{bmatrix} I_{c_1} \\ I_{c_2} \\ I_{c_3} \end{bmatrix} =
\begin{bmatrix} E_1(s) - R_4 J_3(s) \\ -E_1(s) + E_2(s) + \left(R_4 + \dfrac{1}{sC_6}\right) J_3(s) \\ E_1(s) - E_2(s) \end{bmatrix} +
\begin{bmatrix} L_5 I_5(t_0) \\ -\dfrac{V_6(t_0)}{s} \\ L_8 I_8(t_0) \end{bmatrix}$$

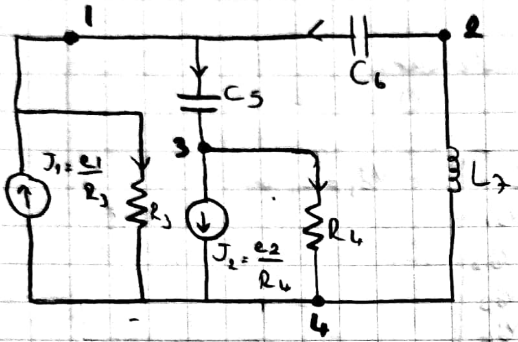
4) Temel Kesitleme Denk.

Ör.

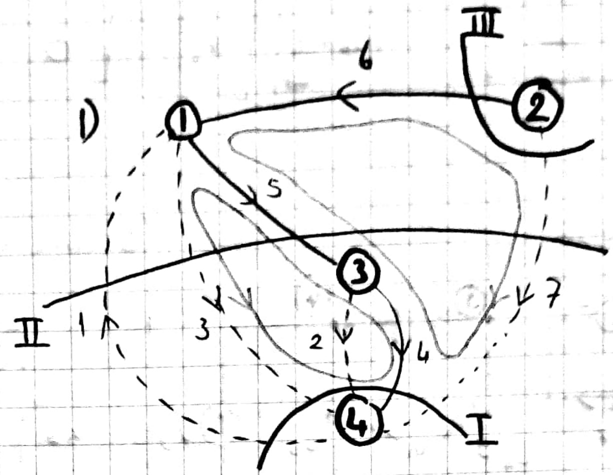


$n = 6 \quad n-1 = dal = 5$

$n_e = 7 \quad n_e - n + 1 = kiriş = 2$



1)



$x = [V_{dal}] \quad x = \begin{bmatrix} V_4 \\ V_5 \\ V_6 \end{bmatrix}$

2) I) $-I_1 + I_3 + I_2 + I_4 + I_7 = 0$

II) $-I_1 + I_3 + I_5 + I_7 = 0$

III) $I_6 + I_7 = 0$

3) I) $-\frac{E_1(s)}{R_3} + G_3 \underline{V_3} + \frac{E_2(s)}{R_4} + G_4 V_4 + \frac{1}{sL_7} \underline{V_7} + \frac{I_7(t_0)}{s} = 0$ $\quad V_3, V_7$ 'ye çevre atarız

II) $-\frac{E_1(s)}{R_3} + G_3 V_3 + s C_5 V_5 - C_5 V_5(t_0) + \frac{1}{sL_7} V_7 + \frac{I_7(t_0)}{s} = 0$

III) $s C_6 V_6 - C_6 V_6(t_0) - \frac{1}{sL_7} V_7 + \frac{I_7(t_0)}{s} = 0$

$V_3 = V_4 + V_5 \qquad V_7 = V_4 + V_5 + V_6$

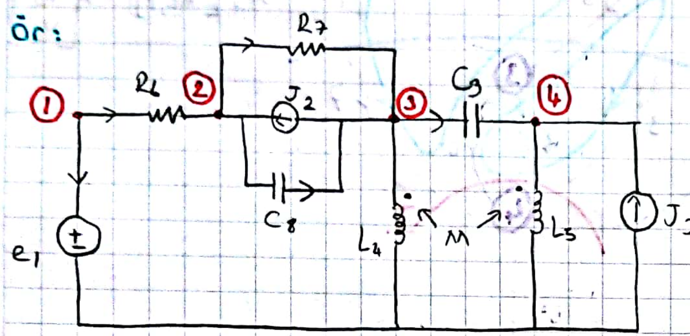
I)

II)

III)

$$\begin{array}{c|c}
 & \begin{array}{ccc} V_4 & V_5 & V_6 \end{array} \\
\begin{array}{c} I \\ \\ II \\ \\ III \end{array} &
\begin{bmatrix} G_3+G_4+\frac{1}{sL_7} & G_3+\frac{1}{sL_7} & \frac{1}{sL_7} \\ G_3+\frac{1}{sL_7} & G_3+\frac{1}{sL_7}+sC_5 & \frac{1}{sL_7} \\ \frac{1}{sL_7} & \frac{1}{sL_7} & sC_6+\frac{1}{sL_7} \end{bmatrix}
\begin{bmatrix} V_4 \\ V_5 \\ V_6 \end{bmatrix} = \begin{bmatrix} \frac{E_1(s)}{R_3}-\frac{E_2(s)}{R_4} \\ \frac{E_1(s)}{R_3} \\ 0 \end{bmatrix} + \begin{bmatrix} \frac{-I_7(t_0)}{s} \\ C_5V_5(t_0)-\frac{I_7(t_0)}{s} \\ C_6V_6(t_0)-\frac{I_7(t_0)}{s} \end{bmatrix}
\end{array}$$

Ör:



(Düğüm denklemleri

$$X = \begin{bmatrix} I_1 \\ \cancel{V_{d1}} \\ V_{d2} \\ V_{d3} \\ V_{d4} \end{bmatrix} \qquad V_{d1} = e_1$$

1)

$$\begin{bmatrix} V_4 \\ V_5 \end{bmatrix} = s\begin{bmatrix} L_4 & -M \\ -M & L_5 \end{bmatrix}\begin{bmatrix} I_4 \\ I_5 \end{bmatrix} - \begin{bmatrix} L_4 & -M \\ -M & L_5 \end{bmatrix}\begin{bmatrix} I_4(t_0) \\ I_5(t_0) \end{bmatrix}$$

$$\begin{bmatrix} I_4 \\ I_5 \end{bmatrix} = \begin{bmatrix} L_5/\Delta_s & M/\Delta_s \\ M/\Delta_s & L_4/\Delta_s \end{bmatrix}\begin{bmatrix} V_4 \\ V_5 \end{bmatrix} + \begin{bmatrix} I_4(t_0)/s \\ I_5(t_0)/s \end{bmatrix}$$

2) ① $I_1 + I_6 = 0$

② $-I_2 - I_6 + I_7 + I_8 = 0$

③ $I_2 - I_8 - I_4 - I_7 + I_9 = 0$

④ $-I_9 + I_5 - I_3 = 0$

3) ① $I_1 + G_6V_6 = 0$

② $J_2 - G_6V_6 + G_7V_7 + sC_8V_8 - C_8V_8(t_0) = 0$

③ $J_2 - sC_8V_8 + C_8V_8(t_0) - \frac{L_5}{\Delta_s}V_4 - \frac{M}{\Delta_s}V_5 - \frac{I_4(t_0)}{s} - G_7V_7 + sC_9V_9 - C_9V_9(t_0) = 0$

④ $-sC_9V_9 + C_9V_9(t_0) + \frac{M}{\Delta_s}V_4 + \frac{L_4}{\Delta_s}V_5 + \frac{I_4(t_0)}{s} - J_3 = 0$

$V_4 = -V_{d3}$, $V_5 = V_{d4}$, $V_6 = V_{d1} - V_{d2} = e_1 - V_{d2}$, $V_7 = V_{d2} - V_{d3}$, $V_8 = V_{d2} - V_{d3}$

$V_9 = V_{d3} - V_{d4}$

①

②

③

④

4)

$$
\begin{array}{c}
\begin{array}{cccccc}
 & I_1 & V_{d2} & V_{d3} & V_{d4} & \\
\end{array} \\
\begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \end{array}
\begin{bmatrix}
1 & -G_6 & 0 & 0 \\
0 & G_6+G_7+sC_8 & -G_7-sC_8 & 0 \\
0 & -sC_8-G_7 & sC_8+G_7+sC_9+\frac{L_3}{\Delta_s} & -\frac{M}{\Delta_s}-sC_9 \\
0 & 0 & -sC_9-\frac{M}{\Delta_s} & sC_9+\frac{L_4}{\Delta_s}
\end{bmatrix}
\begin{bmatrix} I_1 \\ V_{d2} \\ V_{d3} \\ V_{d4} \end{bmatrix}
=
\begin{bmatrix} -G_6 E_1(s) \\ G_6 E_1(s)+J_2(s) \\ -J_2(s) \\ J_3(s) \end{bmatrix}
\end{array}
$$

Sürekli durum (Sinüsoidal) bölgesinde devre çözümü:

Kullanılan kaynaklar sin veya cos dür. Başlangıç değerlerinin kullanılmadığı durumlardır. Başlangıç değerleri 0 dır. Kuvvetli akım alanında kullanılır. jw bölgesi çözümleri.

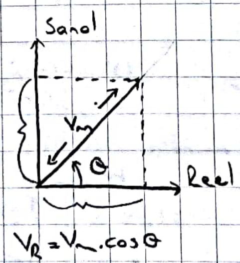
$V(t) = V_m \, \mathrm{Sin}(wt+\theta)$ Volt

V_m ↓ Max. değer; w ↓ açısal frekans (rad/sn); θ → faz farkı

Fazör Gösterimi:

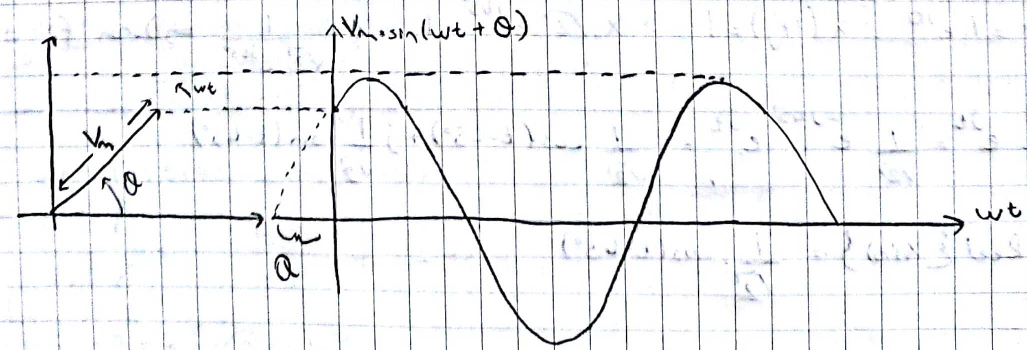
1) Duran fazör: $V(t)$ zaman bölgesinde

duran fazör ← $V = V_m \cdot e^{j\theta}$ $\quad V_s = V_m \cdot \sin\theta$



$V = V_m \cdot \cos\theta + j V_m \sin\theta$ $\quad V = V_R + jV_s$

2) Döner fazör:



Döner fazör → Duran fazör

$V(t) = V.e^{j\omega t} \Rightarrow V(t) = V_m . e^{j\theta} . e^{j\omega t} = V_m . e^{j(\omega t+\theta)} = \underbrace{V_m . \cos(\omega t+\theta)}_{reel} + \underbrace{j.V_m \sin(\omega t+\theta)}_{sanal}$

$V_c =$ sanal veya reel $\{V(t)\}$ ← Döner fazör

ör: $I(t) = 110 \cos(100t + 45°)$ A

$\omega = 100 \qquad \theta = 45°$

Duran fazör $I = 110.e^{j45°} = 110\cos 45 + j110\sin 45 = a + jb$

Döner fazör $I(t) = V.e^{j100t} = 110.e^{j45°}.e^{j100t} = 110\cos(100t+45°) + j110\sin(110t+45°)$

$I(t) = Reel\{I(t)\}$

Cevre yada düğüm denklemi yazdığınızda türev yada integral geliyor jw bölgesinde bunların karşılığı

$\int dt \longrightarrow \frac{1}{jw}$

$X(t) = X.e^{j\omega t}$

↓ Döner f. ↓ Duran f. $\quad x = x_m . e^{j\theta}$

$\frac{d}{dt} \longrightarrow jw$

1. türev: $\dot{X}(t) = jwX.e^{j\omega t} = jwX(t)$

$\ddot{X}(t) = (jw)^2 X.e^{j\omega t} = (jw)^2 . X(t)$

ör: $\dot{X}(t) + X(t) = \cos t$ jw bölgesinde $X(t)$'leri çöz. (jw bölgesinde elde edilen çözüm sinüsoidal, sürekli durum çözümüdür yani özel çözümdür)

$X(t) = ?$

$w = 1$ rad/sn

$\cos t = \underbrace{1.e^{j0}}_{Duran\ f.}$ → açı $\qquad \underbrace{1.e^{j0}.e^{jt}}_{Döner\ f.}$

Duran fazör ile çözüm yapalım

$\tan\varphi = \frac{1}{1}$

$jwX + X = 1.e^{j0} \qquad x(1+j) = 1 \qquad X.\sqrt{2}.e^{j45°} = 1 \qquad X = \frac{1}{\sqrt{2}.e^{j45°}} \Rightarrow$ Duran f.

Döner f

$X(t) = X.e^{jt} = \frac{1}{\sqrt{2}} e^{-j45}.e^{jt} = \frac{1}{\sqrt{2}}\cos(t-45°) + j\frac{1}{\sqrt{2}}\sin(t-45°)$

$X_a(t) = Reel\{X(t)\} = \frac{1}{\sqrt{2}}\cos(t-45°)$

ör: $\ddot{X}(t) + \dot{X}(t) + 110\,X(t) = 100\sqrt{2}\,\sin\left(\underset{\omega}{10}t + \frac{\pi}{4}\right)$ denklemini çözünüz.

sonal

$\omega = 10$ rad/sn

$(j10)^2 . X + (j10) . X + 110X = 100\sqrt{2}\,.\,e^{j\frac{\pi}{4}}$

$X\,[-100 + j10 + 110] = 100\sqrt{2}\,e^{j45°}$

$X\,[10 + j10] = 10\sqrt{2}\,e^{j45°}$

$X\sqrt{2}\,e^{j45°} = 10\sqrt{2}\,e^{j45°} \Rightarrow X = 10$ (duran f.)

Döner fazör $X(t) = 10 . e^{j10t} = 10\cos 10t + j10\sin 10t$

$X_c(t) = \text{san}\{X(t)\} = 10\sin 10t$

ör: $e(t) = 2\cos(2t + 60°) - 4\sin 2t + \frac{d}{dt}(2\sin 2t)$ ifadesini tek bir sinüs yada cosinüs şeklinde yazınız

$$\boxed{\begin{aligned}\cos(\omega t + \theta) &= \cos\omega t . \cos\theta - \sin\omega t . \sin\theta \\ \sin(\omega t + \theta) &= \sin\omega t . \cos\theta + \cos\omega t . \sin\theta\end{aligned}}$$

$e(t) = 2 . \cos 2t . \overset{1/2}{\cos 60} - 2\sin 2t . \overset{\sqrt{3}/2}{\sin 60} - 4\sin 2t + 4 . \cos 2t$

$= \underbrace{5}_{\cos\theta}\cos 2t - \sin 2t \underbrace{[\sqrt{3} + 4]}_{\sin\theta} = E_m . \cos(2t + \theta)$

kosinüs açılımıdır

$= 7,6 . \cos(2t + 48,8°)$

$\sqrt{5^2 + (\sqrt{3} + 4)^2}$

ispatı için açarsak

$\underbrace{5}_{E_m . \cos\theta}\cos 2t - \sin 2t \underbrace{[\sqrt{3} + 4]}_{E_m . \sin\theta} = E_m\cos(2t + \theta)$

$\tan\theta = \frac{E_m . \sin\theta}{E_m . \cos\theta} \Rightarrow \theta = 48,8°$

$E_m\cos(\omega t + \theta) = E_m . \cos\omega t . \cos\theta - \sin\omega t . \sin\theta$

$E_m^2\cos^2\theta + E_m^2\sin\theta^2 \qquad E_m\underbrace{\sqrt{\cos^2\theta + \sin^2\theta}}_{1}$

ör: $\dddot{X}(t) + 3\ddot{X}(t) + 5\dot{X}(t) + 7X(t) = \sqrt{3}\,\dot{y}(t) + y(t) \qquad X(t) = ?$

$y(t) = \frac{\sqrt{2}}{2}(\sin t + \cos t)$ katsayıların toplamının karekökü

sonda verilir

$1\sin t + 1\cos t = Y_m\sin(t + \theta) = \sqrt{2}\sin(t + 45°)$

$\underline{Y_m} . \sin t \underbrace{\cos\theta}_{1} + \underline{Y_m}\cos t . \underbrace{\sin\theta}_{1}$

$y(t) = \frac{\sqrt{2}}{2}\sqrt{2}\sin(t + 45) = \sin(t + 45°)$

$\omega = 1$ rad/sn $\quad Y = 1 . e^{j45}$

$X[j^3 + 3j^2 + 5j + 7] = [\sqrt{3} + 1]\,Y$

$$x\left[-j-3+5j+7\right]=x\left[4+4j\right]=\left[1+j\sqrt{3}\right]e^{j45^\circ}$$

$$x\,4\sqrt{2}\,e^{j45^\circ}=2e^{j60^\circ}e^{j45^\circ} \qquad x=\frac{e^{j60^\circ}}{2\sqrt{2}} \Rightarrow \text{Duran fazör}$$

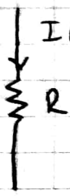
$$x(t)=\frac{e^{j(t+60^\circ)}}{2\sqrt{2}}=\frac{1}{2\sqrt{2}}\left(\cos(t+60)+j\sin(t+60^\circ)\right)$$

$$x(t)=\frac{1}{2\sqrt{2}}\sin(t+60^\circ) \rightarrow \text{Döner fazör}$$

jw bölgesinde devre elemanları (sürekli durum elemanları)

1) R direnç elemanı

Duran fazör olarak yaz, döner fazöre dönüştür döner fazörün sanal kısmını al.

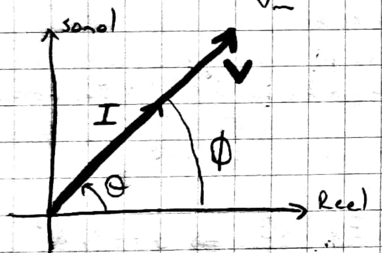


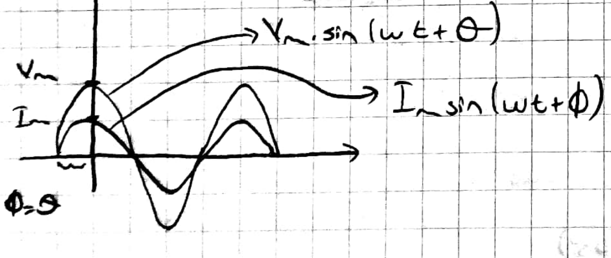
$I(t)=I_m\cdot\sin(\omega t+\phi)$ A

$I=I_m\cdot e^{j\theta}$ Duran f.

$I(t)=I\cdot e^{jt}$ Döner f.

$V=RI=\underbrace{R\cdot I_m}_{V_m}e^{j\theta} \qquad V=V_m\,e^{j\phi} \qquad V_m=R\cdot I_m \qquad \phi=\theta$ (faz farkı yok)





2) Endüktans Elemanı

$I(t)=I_m\sin(\omega t+\theta)$ A

$I=I_m\cdot e^{j\theta}$ A

$V(t)=L\cdot\frac{dI_L(t)}{dt}$

$V=j\omega LI=(j\omega LI_m)e^{j\theta}=\omega LI_m\cdot e^{j90^\circ}\cdot e^{j\theta}$

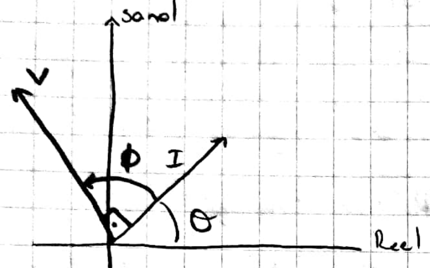
$\cancel{a}+jb$

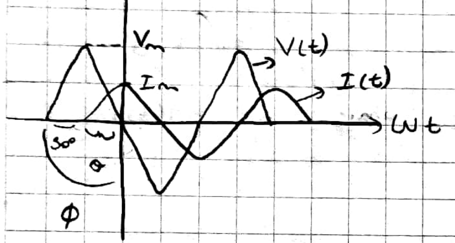
$=\underbrace{\omega LI_m}_{V_m}e^{j\overbrace{(\theta+90^\circ)}^{\phi}}=V_m\,e^{j\phi}$

$V_m=\omega LI_m \qquad \phi=\theta+90$

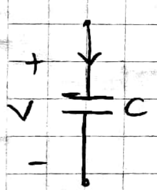
$$I(t) = \frac{1}{L}\int V(t)\,dt \qquad I = \frac{1}{j\omega L} V = \frac{1}{j\omega L} V_m e^{j\phi} = \underbrace{\frac{1}{\omega L} V_m}_{I_m} e^{j\overbrace{(\phi - 90^\circ)}^{\theta}}$$

$$Z(j\omega) = j\omega L \qquad Y(j\omega) = \frac{1}{j\omega L}$$





3) Kondansatör

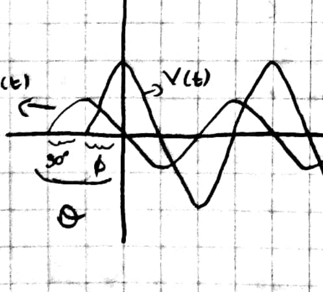


$$V(t) = V_m \sin(\omega t + \phi)\ V \qquad Z = \frac{1}{j\omega C} \qquad Y = j\omega C$$

admitans

$$V = V_m e^{j\phi}$$

$$I(t) = C\frac{dV(t)}{dt} \qquad I = j\omega C V = \omega C V_m e^{j(\phi + 90^\circ)} = I_m e^{j\theta}$$

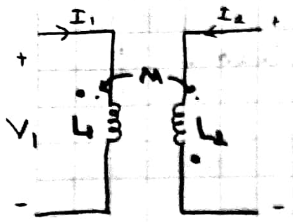


$$I = j\omega C V = \omega C V_m e^{j(\phi + 90^\circ)} = I_m e^{j\theta}$$

$$V = \frac{I}{j\omega C} = \frac{1}{j\omega C} I_m e^{j\theta} = \frac{1}{\omega C} I_m e^{j(\theta - 90^\circ)}$$

23.03.2017

4) Fiziksel Transformatör



t bölgesinde

$V_1 = L_1 D I_1 + M D I_2$

$V_2 = + M D I_1 + L_2 D I_2$ $D = j\omega$ Başlangıç değerler. 0

Duran fazör olarak

$$\left.\begin{aligned} V_1 &= j\omega L_1 I_1 \mp j\omega M I_2 \\ V_2 &= \mp j\omega M I_1 + j\omega L_2 I_2 \end{aligned}\right\} \quad \text{Burada} \quad \begin{aligned} I_1 &= I_{1m} e^{j\theta_1} \\ I_2 &= I_{2m} e^{j\theta_2} \end{aligned} \ \text{(Duran fazör)}$$

$V_1 = V_{1m} e^{j\phi_1}$

$V_2 = V_{2m} e^{j\phi_2}$

kaynak sin ise döner fazörün sanal kısmı } alınır
" cos " " " reel kısmı

Döner fazör olarak

$V_1(t) = V_{1m} e^{j\phi_1} \cdot e^{j\omega t}$

$V_2(t) = V_{2m} e^{j\phi_2} \cdot e^{j\omega t}$

Matrissel biçimde duran f.

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \underbrace{\begin{bmatrix} j\omega L_1 & \mp j\omega M \\ \mp j\omega M & +j\omega L_2 \end{bmatrix}}\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} V_{1m} e^{j\phi_1} \\ V_{2m} e^{j\phi_2} \end{bmatrix}$$

$$\Delta = -\omega^2 L_1 L_2 + \omega^2 M^2$$

Akım tanımı

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} \frac{j\omega L_2}{\Delta} & \frac{\pm j\omega M}{\Delta} \\ \frac{\pm j\omega M}{\Delta} & \frac{j\omega L_1}{\Delta} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} I_{1m} e^{j\theta_1} \\ I_{2m} e^{j\theta_2} \end{bmatrix}$$

$$I_1 = \frac{j\omega L_2}{\Delta} V_1 \pm \frac{j\omega M V_2}{\Delta}$$

$$I_2 = \pm \frac{j\omega M V_1}{\Delta} + \frac{j\omega L_1 V_2}{\Delta}$$