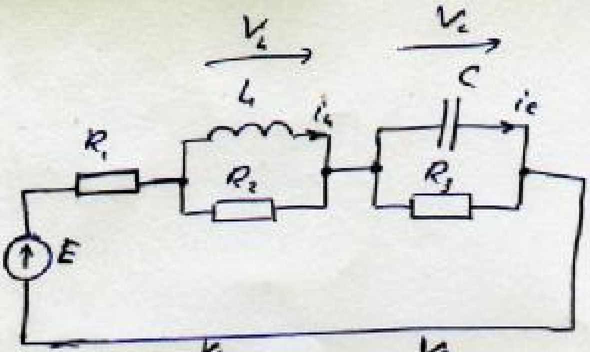
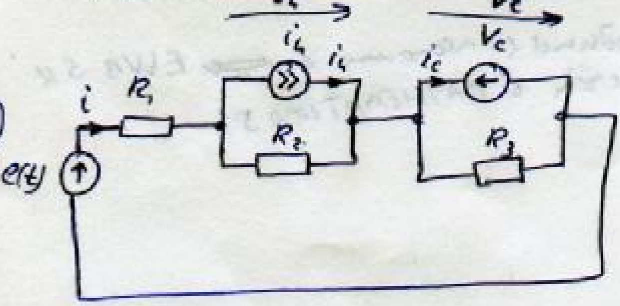


$R_1 = 34,7917$ Ом
$R_2 = 2,004 \cdot 10^4$ Ом
$R_3 = 2,004 \cdot 10^4$ Ом
$L = 2,829 \cdot 10^{-3}$ Гн
$C = 4,0575 \cdot 10^{-9}$ Ф

} начальная схема и её параметры

1)



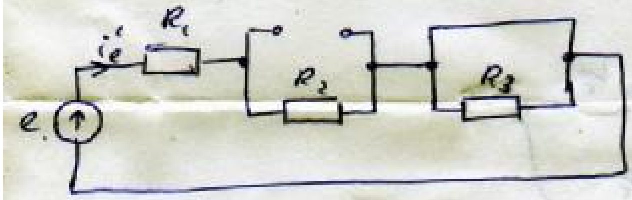
найти: „V_L" и „i_C"

2) $V_L = e - iR_1 - V_C$ i - неизвестно

$i_C = i - \frac{V_C}{R_3}$; i - неизвестно

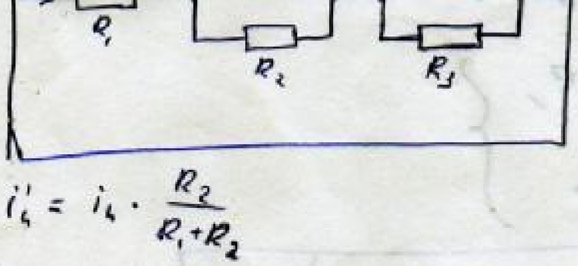
} найти общий ток цепи „i"

1) источник e:



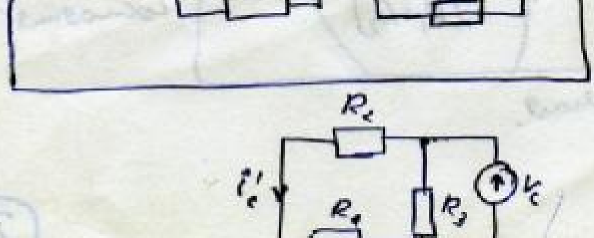
$$i'_e = \frac{e}{R_1 + R_2}$$

2) источник i_L



$$i'_L = i_L \cdot \frac{R_2}{R_1 + R_2}$$

3) источник V_C:



$$i'_C = -\frac{V_C}{R_1 + R_2}$$

$$i_{общ} = i'_e + i'_L + i'_C = \frac{e}{R_1+R_2} + i_L \frac{R_2}{R_1+R_2} - \frac{V_C}{R_1+R_2}$$

$$i = \frac{e}{R_1+R_2} + i_L\frac{R_2}{R_1+R_2} - \frac{V_c}{R_1+R_2} = \frac{e + i_L R_2 - V_c}{R_1+R_2}$$

$$\left.\begin{aligned} V_L &= e - iR_1 - V_c \\ i_c &= i - \frac{V_c}{R_3} \end{aligned}\right\}$$

$$\left.\begin{aligned} V_L &= e - R_1\frac{e + i_L R_2 - V_c}{R_1+R_2} - V_c \\ i_c &= \frac{e + i_L R_2 - V_c}{R_1+R_2} - \frac{V_c}{R_3} \end{aligned}\right\}$$

Сходится с лекциями в ~~...~~ EWB 5.12 расчёт в MATHEMATIKA 5

(3) Выразить V_L и i_c через производные ПС:

$$L\frac{di_L}{dt} = e - V_c - R_1\frac{e + i_L R_2 - V_c}{R_1+R_2};$$

$$C\frac{dV_c}{dt} = \frac{e + i_L R_2 - V_c}{R_1+R_2} - \frac{V_c}{R_3};$$

$$\left.\begin{aligned} L\frac{di_L}{dt} &= e - V_c - \frac{R_1}{R_1+R_2}e - \frac{R_1R_2}{R_1+R_2}i_L + \frac{R_1}{R_1+R_2}V_c \\ C\frac{dV_c}{dt} &= \frac{1}{R_1+R_2}e + \frac{R_2}{R_1+R_2}i_L - \frac{1}{R_1+R_2}V_c - \frac{1}{R_3}V_c \end{aligned}\right\}$$

$$\left.\begin{aligned} L\frac{di_L}{dt} &= -\frac{R_1R_2}{R_1+R_2}i_L - V_c\left(1 - \frac{R_1}{R_1+R_2}\right) + e\left(1 - \frac{R_1}{R_1+R_2}\right) \\ C\frac{dV_c}{dt} &= \frac{R_2}{R_1+R_2}i_L - V_c\left(\frac{1}{R_1+R_2} + \frac{1}{R_3}\right) + \frac{1}{R_1+R_2}e \end{aligned}\right\}$$

$$\left.\begin{aligned} \frac{di_L}{dt} &= -\frac{R_1R_2}{L(R_1+R_2)}i_L - \frac{R_2}{L(R_1+R_2)}V_c + \frac{R_2}{L(R_1+R_2)}e; \\ \frac{dV_c}{dt} &= \frac{R_2}{C(R_1+R_2)}i_L - \frac{R_1+R_2+R_3}{CR_3(R_1+R_2)}V_c + \frac{1}{C(R_1+R_2)}e \end{aligned}\right\}$$

$$\boxed{\frac{d}{dt}\begin{pmatrix} i_L \\ V_c \end{pmatrix} = \begin{pmatrix} -\frac{R_1R_2}{L(R_1+R_2)} & -\frac{R_2}{L(R_1+R_2)} \\ \frac{R_2}{C(R_1+R_2)} & -\frac{R_1+R_2+R_3}{CR_3(R_1+R_2)} \end{pmatrix}\begin{pmatrix} i_L \\ V_c \end{pmatrix} + \begin{pmatrix} \frac{R_2}{L(R_1+R_2)} \\ \frac{1}{C(R_1+R_2)} \end{pmatrix}(e)}$$

уравнение состояния

$$\frac{d}{dt}X = AX + BU$$ – краткий вид ур. состояния.

Решение системы ПС.

$$\left.\begin{aligned}
\frac{di_L}{dt} &= -\frac{R_1R_2}{L(R_1+R_2)}\,i_L - \frac{R_2}{L(R_1+R_2)}\,v_C + \frac{R_2}{L(R_1+R_2)}\,e \\
\frac{dv_C}{dt} &= \frac{R_2}{C(R_1+R_2)}\,i_L - \frac{R_1+R_2+R_3}{CR_3(R_1+R_3)}\,v_C + \frac{1}{C(R_1+R_2)}\,e
\end{aligned}\right\}$$

$$\frac{d}{dt}X = AX + Bu$$

$$X = X_0 + X_ч$$

Собственное решение X_0.

$$\frac{d}{dt}x = AX \qquad \det(A - pE) = 0.$$

$$\begin{vmatrix} -\frac{R_1R_2}{L(R_1+R_2)} - p & -\frac{R_2}{L(R_1+R_2)} \\ \frac{R_2}{C(R_1+R_2)} & -\frac{R_1+R_2+R_3}{CR_3(R_1+R_2)} - p \end{vmatrix} = 0$$

$$\left(-\frac{R_1R_2}{L(R_1+R_2)} - p\right)\left(-\frac{R_1+R_2+R_3}{CR_3(R_1+R_2)} - p\right) - \left(\frac{R_2}{C(R_1+R_2)}\cdot\left(-\frac{R_2}{L(R_1+R_2)}\right)\right) = 0$$

$$\left(\frac{R_1R_2}{L(R_1+R_2)} + p\right)\left(\frac{R_1+R_2+R_3}{CR_3(R_1+R_2)} + p\right) + \frac{R_2^2}{LC(R_1+R_2)^2} = 0$$

$$\cancel{\frac{R_1R_2(R_1+R_2+R_3)}{LCR_3(R_1+R_2)^2} + \frac{R_1R_2}{L(R_1+R_2)}p + \frac{R_1+R_2+R_3}{CR_3(R_1+R_2)}p + p^2 + \frac{R_2^2}{LC(R_1+R_2)^2}} = 0$$

$$p^2 + p\left(\frac{R_1R_2}{L(R_1+R_2)} + \frac{R_1+R_2+R_3}{CR_3(R_1+R_2)}\right) + \frac{R_2^2}{LC(R_1+R_2)^2} + \frac{R_1R_2(R_1+R_2+R_3)}{LCR_3(R_1+R_2)^2} = 0$$

$$p^2 + p\underbrace{\left(\frac{R_1R_2R_3C + L(R_1+R_2+R_3)}{LCR_3(R_1+R_2)}\right)}_{2\alpha} + \underbrace{\frac{R_2^2R_3 + R_1R_2(R_1+R_2+R_3)}{LCR_3(R_1+R_2)^2}}_{\omega_0^2} = 0$$

$$2\alpha = \frac{R_1R_2R_3C + L(R_1+R_2+R_3)}{LCR_3(R_1+R_2)} = 3\,6852{,}1$$

$$\omega_0^2 = \frac{R_2^2R_3 + R_1R_2(R_1+R_2+R_3)}{LCR_3(R_1+R_2)^2} = 8{,}04\cancel{84}\cdot 10^{12}$$

Н

$$\left(\frac{R_1R_2}{L(R_1+R_2)}+p\right)\left(\frac{R_1+R_2+R_3}{CR_3(R_1+R_2)}+p\right)+\frac{R_2}{C(R_1+R_2)}\cdot\frac{R_2}{L(R_1+R_2)}=0$$

$$p^2+p\left(\frac{R_1R_2}{L(R_1+R_2)}+\frac{R_1+R_2+R_3}{CR_3(R_1+R_2)}\right)+\frac{R_1R_2\cdot(R_1+R_2+R_3)}{LCR_3(R_1+R_2)^2}+\frac{R_2^2}{CL(R_1+R_2)^2}=0$$

$$2\alpha=\frac{R_1R_2}{L(R_1+R_2)}+\frac{R_1+R_2+R_3}{CR_3(R_1+R_2)}=\frac{CR_1R_2R_3+L(R_1+R_2+R_3)}{LCR_3(R_1+R_2)}=36852{,}1$$

$$\alpha=18426{,}1=1{,}84261\cdot10^4$$

$$\omega_0^2=\frac{R_1R_2\cdot(R_1+R_2+R_3)}{LCR_3(R_1+R_2)^2}+\frac{R_2^2}{CL(R_1+R_2)^2}=\frac{R_1R_2(R_1+R_2+R_3)+R_2^2\cdot R_3}{LCR_3(R_1+R_2)^2}=8{,}71181\cdot10^{10}\ (\text{рад}/\text{с})$$

$\omega_0=2{,}95158\cdot10^5$ рад/с

$$Q=\frac{\omega_0}{2\alpha}=\frac{2{,}95158\cdot10^5}{3{,}68521\cdot10^4}=8{,}009259$$ система составлена верно

$$p_{1,2}=-1{,}84261\cdot10^4\pm\sqrt{3{,}3952\cdot10^8-\cancel{2{,}95158\cdot10^5}\ 8{,}71181\cdot10^{10}}$$

$\alpha<\omega_0$ корни p_1 и p_2 комплексно сопряжённые

$$p_{1,2}=-1{,}84261\cdot10^4\pm j\sqrt{8{,}71181\cdot10^{10}-3{,}3952\cdot10^8}=-1{,}84261\cdot10^4\pm j\cdot2{,}94588\cdot10^5$$

$$p_1=-1{,}84261\cdot10^4+j\cdot2{,}94588\cdot10^5;$$
$$p_2=-1{,}84261\cdot10^4-j\cdot2{,}94588\cdot10^5.$$

$$p_{1,2}=-\alpha\pm j\beta.$$

$$Q\approx\frac{\beta}{2\alpha}=\frac{2{,}94588\cdot10^5}{3{,}68521\cdot10^4}=7{,}9936$$ тоже верно

$$X_0=\begin{pmatrix}i_L\\V_c\end{pmatrix}=\begin{pmatrix}a_1\\a_2\end{pmatrix}\cdot e^{p_1 t}+\begin{pmatrix}b_1\\b_2\end{pmatrix}\cdot e^{p_2 t}\qquad \overset{*}{a}=b$$

$$X_0=\begin{pmatrix}i_L\\V_c\end{pmatrix}=\begin{pmatrix}K_1\\K_2\end{pmatrix}\cdot e^{(-\alpha+j\beta)t}+\begin{pmatrix}K_1^*\\K_2^*\end{pmatrix}\cdot e^{(-\alpha-j\beta)t}$$ комплексная форма решения

$$i_L(t)=A_J\cdot e^{-\alpha t}\cdot\cos(\beta t+\varphi_J)$$
$$V_c(t)=A_V\cdot e^{-\alpha t}\cdot\cos(\beta t+\varphi_V)$$

$R_1 = 34{,}7917$

$R_3 = R_2 = 2{,}004 \cdot 10^{4}$

$L = 2{,}829 \cdot 10^{-3}$

$C = 4{,}0575 \cdot 10^{-9}$

$$\frac{1}{LC} - \frac{R_1}{R_3 LC} = \frac{R_3 - R_1}{LCR_3} = 8{,}6967 \cdot 10^{10} \text{ рад/с}$$

III

$$\frac{1}{R_1 C} + \frac{1}{R_3 C} + \frac{R_1}{R_2 R_3 C} - \frac{R_1}{L} =$$

$$V_1: \quad \frac{V_1 - e}{R_1} + \frac{V_1 - V_2}{R_2} + \frac{1}{L}\int_{-\infty}^{t} (V_1 - V_2)\, d\tau = 0$$

$$V_2: \quad \frac{V_2 - V_1}{R_2} + \frac{1}{L}\int_{-\infty}^{t} (V_2 - V_1)\, d\tau + \frac{V_2}{R_3} + C\frac{dV_2}{dt} = 0$$

$$\frac{1}{R_1}\frac{dV_1}{dt} - \frac{1}{R_1}\frac{de}{dt} + \frac{1}{R_2}\frac{dV_1}{dt} - \frac{1}{R_2}\frac{dV_2}{dt} + \frac{1}{L}(V_1 - V_2) = 0$$

$$\frac{1}{R_2}\frac{dV_2}{dt} - \frac{1}{R_2}\frac{dV_1}{dt} + \frac{1}{L}(V_2 - V_1) + \frac{dV_2}{dt R_3} + C\frac{d^2V_2}{dt^2} = 0$$

$$\text{I} \quad \frac{pV_1}{R_1} - \frac{pe}{R_1} + \frac{pV_1}{R_2} - \frac{pV_2}{R_2} + \frac{V_1}{L} - \frac{V_2}{L} = 0$$

$$\text{II} \quad \frac{pV_2}{R_2} - \frac{pV_1}{R_2} + \frac{V_2}{L} - \frac{V_1}{L} + \frac{pV_2}{R_3} + C\frac{d^2V_2}{dt^2} = 0$$

Cp^2V_2

$V.$

$V_L = V_1 - V_2$ для I $\Rightarrow V_1 = V_L + V_2$.

подставляем:

$$\frac{pV_L}{R_1} + \frac{pV_2}{R_1} - \frac{pe}{R_1} + \frac{pV_L}{R_2} + \cancel{\frac{pV_2}{R_2}} - \cancel{\frac{pV_2}{R_2}} + \frac{V_L}{L} + \cancel{\frac{V_2}{L}} - \cancel{\frac{V_2}{L}} = 0$$

$$\cancel{\frac{pV_2}{R_2}} - \frac{pV_L}{R_2} - \cancel{\frac{pV_2}{R_2}} + \cancel{\frac{V_2}{L}} - \frac{V_L}{L} - \cancel{\frac{V_2}{L}} + \frac{pV_2}{R_3} + Cp^2V_2 = 0$$

$$\text{I} \quad \frac{pV_L}{R_1} + \frac{pV_2}{R_1} - \frac{pe}{R_1} + \frac{pV_L}{R_2} + \frac{V_L}{L} = 0$$

$$\text{II} \quad -\frac{pV_L}{R_2} - \frac{V_L}{L} + \frac{pV_2}{R_3} + Cp^2V_2 = 0$$

$$\frac{pV_L}{R_1} + \frac{pV_L}{R_2} + \frac{V_L}{L} + p\frac{V_2}{R_1} - \frac{pe}{R_1} = 0$$

$$-\frac{pV_L}{R_2} - \frac{V_L}{L} + p\frac{V_2}{R_3} + p^2 C V_2 = 0$$

из I $\quad p\dfrac{V_2}{R_1} = \dfrac{pe}{R_1} - V_L\left(\dfrac{p}{R_1} + \dfrac{p}{R_2} + \dfrac{1}{L}\right)$

$V_2 = e - V_L\left(1 + \dfrac{R_1}{R_2} + \dfrac{R_1}{pL}\right)$

подставлем V_2 из I в II.

$$V_2 = e - V_L\left(1+\frac{R_1}{R_2}+\frac{R_1}{pL}\right)$$

$$\text{II}\quad -\frac{pV_L}{R_2} - \frac{V_L}{L} + \frac{pV_2}{R_3} + p^2CV_2 = 0$$

$$-\frac{pV_L}{R_2} - \frac{V_L}{L} + \frac{e}{R_3} - V_L\left(\frac{1}{R_3}+\frac{R_1}{R_2R_3}+\frac{1}{pR_1R_3L}\right) + p^2Ce - p^2CV_L\left(1+\frac{R_1}{R_2}+\frac{1}{pR_1L}\right) = 0$$

$$\frac{pV_L}{R_2}+\frac{V_L}{L}+V_L\left(\frac{1}{R_3}+\frac{R_1}{R_2R_3}+\frac{1}{pR_1R_3L}\right) + V_L\left(p^2C+\frac{p^2CR_1}{R_2}+\frac{pC}{R_1L}\right) = \frac{e}{R_3}+p^2Ce$$

$$\frac{pV_L}{R_2}+\frac{V_L}{L}+\frac{V_L}{R_3}+\frac{R_1V_L}{R_2R_3}+\frac{V_L}{pR_1R_3L}$$

$$\text{II}\quad -\frac{pV_L}{R_2}-\frac{V_L}{L}+\frac{pe}{R_3}-\frac{pV_L}{R_3}-\frac{pV_LR_1}{R_2R_3}-\frac{pR_1V_L}{R_3L}+p^2Ce-p^2CV_L-$$

$$-\frac{p^2CR_1}{R_2}-\frac{pCV_LR_1}{L}=0$$

$$-\frac{pV_L}{R_2}-\frac{V_L}{L}-\frac{pV_L}{R_3}\left(1+\frac{R_1}{R_2}+\frac{R_1}{pL}\right) - p^2CV_L\left(1+\frac{R_1}{R_2}+\frac{R_1}{pL}\right) = -\frac{pe}{R_3}-p^2Ce$$

$$\frac{pV_L}{R_2}+\frac{V_L}{L}+\frac{pV_L}{R_3}\left(1+\frac{R_1}{R_2}+\frac{R_1}{pL}\right)+p^2CV_L\left(1+\frac{R_1}{R_2}+\frac{R_1}{pL}\right) = \frac{pe}{R_3}+p^2Ce.$$

$$\frac{pV_L}{R_2}+\frac{V_L}{L}+\frac{pV_L}{R_3}+\frac{pR_1V_L}{R_2R_3}+\frac{R_1V_L}{R_3L}+p^2CV_L+\frac{p^2CR_1V_L}{R_2}+\frac{pCR_1V_L}{L}=\frac{pe}{R_3}+p^2Ce.$$

$$p\frac{V_L}{R_2C}+\frac{V_L}{LC}+p\frac{V_L}{R_3C}+p\frac{R_1V_L}{R_2R_3C}+\frac{R_1V_L}{R_3LC}+p^2V_L+\frac{p^2R_1V_L}{R_2}+\frac{pR_1V_L}{L}=\frac{pe}{R_3C}+p^2e$$

$$p^2\left(V_L+\frac{R_1V_L}{R_2}\right)+p\left(\frac{V_L}{R_2C}+\frac{V_L}{R_3C}+\frac{R_1V_L}{R_2R_3C}+\frac{R_1V_L}{L}\right)+\frac{V_L}{LC}+\frac{R_1V_L}{R_3LC}=\frac{pe}{R_3C}+p^2e$$

$$p^2\left(1+\frac{R_1}{R_2}\right)+p\left(\frac{1}{R_2C}+\frac{R_1}{R_2R_3C}+\frac{R_1}{L}\right)+\left(\frac{1}{LC}+\frac{R_1}{R_3LC}\right)=0$$

$$p^2+p\left(\frac{\frac{1}{R_2C}+\frac{1}{R_3C}+\frac{R_1}{R_2R_3C}+\frac{R_1}{L}}{1+\frac{R_1}{R_2}}\right)+\left(\frac{\frac{1}{LC}+\frac{R_1}{R_3LC}}{1+\frac{R_1}{R_2}}\right)=0 \quad ✓$$

$2\alpha = 36852{,}1$ ✓

$\alpha = 18426{,}1 = 1{,}8426\cdot10^4$

$\omega_0^2 = 8{,}7118\cdot10^{10}$ ✓

$\omega_0 = 2{,}95158\cdot10^5$ рад/с

„In-Out"

IV

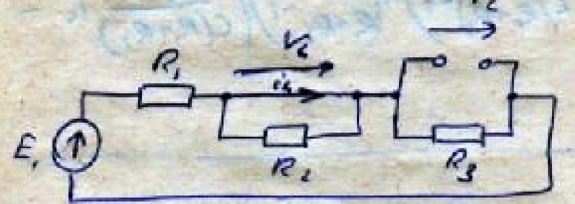
$$\frac{d^2V_L}{dt^2}\left(1+\frac{R_1}{R_2}\right) + \frac{dV_L}{dt}\left(\frac{1}{R_2C}+\frac{1}{R_3C}+\frac{R_1}{R_2R_3C}+\frac{R_1}{L}\right) + V_L\left(\frac{1}{LC}+\frac{R_1}{R_3LC}\right) = \frac{d^2e}{dt^2}+\frac{de}{dt}\cdot\frac{1}{R_3C}$$

$$p_{1,2} = \underbrace{-1{,}84261\cdot10^4}_{\alpha} \pm j\,\underbrace{2{,}9458\cdot10^5}_{\beta}$$

$R_3 = R_2$

$\cancel{\frac{d^2V_L}{dt^2}}$

Поиск НУ.



$J_L = i_L(0^-) = \frac{E_1}{R_1+R_3}$;
$V_C = v_C(0^-) = E_1\cdot\frac{R_3}{R_1+R_3}$; } независимые НУ в момент времени 0−

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

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

$$V_L = E - R_1\frac{E+J_LR_2-V_C}{R_1+R_2} - V_C;$$

$$\cancel{V_L(0^-) = E_1 - R_1\frac{E_1+\frac{E_1R_2}{R_1+R_3}-\frac{E_1R_3}{R_1+R_3}}{R_1+R_2} - \frac{E_1R_3}{R_1+R_3}}$$

$$V_L(0^-) = E_1 - \frac{E_1R_1}{R_1+R_2} - \frac{E_1R_2R_1}{(R_1+R_2)(R_1+R_3)} + \frac{E_1R_3R_1}{(R_1+R_2)^2} - \frac{E_1R_3}{R_1+R_3}$$

$$\cancel{V_L(0^-) = (R_1+R_2)^2(R_1+R_3)E_1 - E}$$

$$V_L(0^+) = E_2 - \frac{R_1}{R_1+R_2}\left(E_2+\frac{E_1R_2}{R_1+R_3}-\frac{E_1R_3}{R_1+R_3}\right) - \frac{E_1R_3}{R_1+R_3} =$$

$$= E_2 - \frac{R_1}{R_1+R_2}\left(\frac{R_1E_2+R_3E_2+E_1R_2-E_1R_3}{R_1+R_3}\right) - \frac{E_1R_3}{R_1+R_3}$$

$$= E_2 - \frac{R_1(E_1R_2-E_1R_3+E_2R_1+E_2R_3)}{(R_1+R_2)(R_1+R_3)} - \frac{E_1R_3}{R_1+R_3} =$$

$$\frac{\cancel{R_1^2E_2} + R_1R_2E_2 + R_2R_3E_2 + \cancel{R_1R_3E_2} - R_1R_2E_1 + \cancel{R_1R_3E_1} - \cancel{R_1^2E_2} - \cancel{R_1R_3E_2} - \cancel{R_1R_3E_1} - R_3^2E_1}{(R_1+R_2)(R_1+R_3)} =$$

(7)

$$(8) = \frac{R_1R_2E_2 + R_2R_3E_2 + \cancel{R_1R_3E_2} - R_1R_2E_1 - \cancel{R_1R_3E_2} - R_3^2E_1}{(R_1+R_2)(R_1+R_3)} =$$

$$V_L(0^+) = \frac{E_1(-R_3^2-R_1R_2)+E_2(R_1R_2+R_2R_3)}{\ldots}$$

$$V_L = E - \frac{R_1 E}{R_1+R_2} - \frac{R_2}{R_1+R_2} J_L + \frac{1}{R_1+R_2} V_c - V_c$$

$$V_L = E - \frac{R_1 E}{R_1+R_2} - \frac{R_2}{R_1+R_2} J_L + \left(\frac{1}{R_1+R_2} - 1\right) V_c$$

$$(0^+)\ \frac{dV_L}{dt} = \underbrace{\frac{dE_2}{dt}}_{0} - \frac{R_1}{R_1+R_2} \underbrace{\frac{dE_2}{dt}}_{0} - \frac{R_2}{R_1+R_2}\frac{dJ_L}{dt} + \left(\frac{1}{R_1+R_2} - 1\right)\frac{dV_c}{dt}$$

$$\frac{dV_L(0^+)}{dt} = -\frac{R_2}{R_1+R_2}\frac{dJ_L}{dt} + \left(\frac{1}{R_1+R_2} - 1\right)\frac{dV_c}{dt};$$

$$\boxed{\frac{dV_L(0^+)}{dt} = -\frac{R_2}{R_1+R_2}\left(-\frac{R_1 R_2}{L(R_1+R_2)} i_L - \frac{R_2}{L(R_1+R_2)} V_c + \frac{R_2}{L(R_1+R_2)} E_2\right) + \left(\frac{1}{R_1+R_2} - 1\right)\left(\frac{R_2}{C(R_1+R_2)} i_L - \frac{R_1+R_2+R_3}{CR_3(R_1+R_2)} V_c + \frac{1}{C(R_1+R_2)} E_2\right);}$$

Зависимое НУ

$$V_L(t) = K e^{(-\alpha + j\beta)t} + K^* e^{(-\alpha - j\beta)t} = 2\operatorname{Re} K \ldots \frac{E_1(\cancel{R_3^2} - R_1R_2) + E_2(R_1R_2 + R_1R_3)}{(R_1+R_3)(R_1+R_3)}$$

$$V_L(t) = E_2 - \frac{R_1}{R_1+R_2}\left(\frac{E_1R_2 - E_1R_3 + E_2R_1 + E_2R_3}{R_1+R_3}\right) - \frac{E_1R_3}{R_1+R_3} =$$

$$= \frac{E_2(R_1+R_2)(R_1+R_3) - R_1(E_1R_2 - E_1R_3 + E_2R_1 + E_2R_3) - (R_1+R_2)(E_1R_3)}{(R_1+R_2)(R_1+R_3)} =$$

$$= \frac{\cancel{R_1^2E_2} + R_1R_2E_2 + \cancel{R_1R_3E_2} + R_2R_3E_2 - R_1R_2E_1 + \cancel{R_1R_3E_1} - \cancel{R_1^2E_2} - \cancel{R_1R_3E_2} - \cancel{R_1R_3E_1} - R_2R_3E_1}{(R_1+R_2)(R_1+R_3)} =$$

$$= \frac{R_1R_2E_2 + R_2R_3E_2 - R_1R_2E_1 - R_2R_3E_1}{(R_1+R_2)(R_1+R_3)} = \frac{E_2R_2\cancel{(R_1+R_3)} - E_1R_2\cancel{(R_1+R_3)}}{(R_1+R_2)\cancel{(R_1+R_3)}} =$$

$$= \frac{E_2R_2 - E_1R_2}{R_1+R_2}$$

$$\boxed{V_L(t) = \frac{E_2R_2 - E_1R_2}{R_1+R_2} \qquad V_L = 56{,}9012.}$$

Зависимое НУ в момент времени 0^+ (одно из двух

8

$$\frac{dV_L}{dt} = -\frac{R_2}{R_1+R_2}\cdot\frac{di_L}{dt} + \left(\frac{1}{R_1+R_2}-1\right)\cdot\frac{dV_C}{dt} =$$

$$= -\frac{R_2}{R_1+R_2}\left(\frac{-R_1R_2\cdot i_L - R_2V_C + R_2E_2}{L(R_1+R_2)}\right) + \left(\frac{1}{R_1+R_2}-1\right)\cdot\left(\frac{R_2R_3\,i_L - (R_1+R_2+R_3)V_C + R_3E_2}{CR_3(R_1+R_2)}\right) =$$

$$= \frac{R_2}{R_1+R_2}\left(\frac{\frac{R_1R_2E_1}{R_1+R_3} + \frac{R_2R_3E_1}{R_1+R_3} - R_2E_2}{L(R_1+R_2)}\right) + \left(\frac{1}{R_1+R_2}-1\right)\cdot\left(\frac{\frac{R_2R_3E_1}{R_1+R_3} - \frac{(R_1+R_2+R_3)R_3E_1}{R_1+R_3} + R_3E_2}{CR_3(R_1+R_2)}\right)$$

$$I_L = \frac{E_1}{R_1+R_3}$$

$$V_C = \frac{E_1R_3}{R_1+R_3}$$

$$\boxed{\frac{dV_L}{dt} = -7{,}19831 \text{ – [illegible] } 0^+ \text{ ([illegible])}}$$

$$\frac{di_L}{dt} = -\frac{R_1R_2\cdot I_L}{L(R_1+R_2)} - \frac{R_2V_C}{L(R_1+R_2)} + \frac{R_2E_2}{L(R_1+R_2)}$$

$$\frac{dV_C}{dt} = \frac{R_2I_L}{C(R_1+R_2)} - \frac{(R_1+R_2+R_3)V_C}{CR_3(R_1+R_2)} + \frac{E_2}{C(R_1+R_2)}$$

$$\cancel{R_2E}\cdot\frac{R_2E_1}{C(R_1+R_2)(R_1+R_3)} - \frac{(R_1+R_2+R_3)\cancel{R_2}E_1R_3}{CR_3(R_1+R_2)(R_1+R_3)} + \frac{E_2}{C(R_1+R_2)} =$$

$$= \cancel{\frac{R_2R_3E_1 - (R_1+R_2+R_3)E_1R_3 + (R_1+R_3)R_3E_2}{CR_3(R_1+R_2)(R_1+R_2)}}$$

$$= \frac{R_2E_1 - (R_1+R_2+R_3)E_1 + (R_1+R_3)E_2}{C(R_1+R_2)(R_1+R_2)} =$$

$$\frac{dV_L}{dt} = -7{,}19831 = -7{,}19831\cdot10^5$$

$V_L = 56{,}9012$.

$\mathrm{Re}\,K = 28{,}4506$ $\qquad K = 28{,}4506 - j\,0{,}557805$

$\mathrm{Im}\,K = -0{,}557805$

$A_0 = 28{,}4561\cdot2 = 56{,}9121$ $\qquad \varphi_0 = \arg K = \mathrm{atan}\left(-\frac{0{,}557805}{28{,}4506}\right) = -1{,}55119$

$$V_L(t) = 56{,}9121\cdot e^{-1{,}84261\cdot10^4 t}\cos\left(2{,}9458\cdot10^5 t - 1{,}55119\right)$$

(градусы) $\qquad 1{,}55119° = 0{,}027073$ рад

по графику: $T = \frac{-1{,}55\cdot10^{-5} + 1{,}22\cdot10^{-4}}{5} = 2{,}13\cdot10^{-5}$ с. $f_0 = 4{,}69\cdot10^4$ Гц. – [illegible]

$$V_L^+ = E_2 - \frac{R_1 E_2}{R_1+R_2} - \frac{R_2}{R_1+R_2} J_L + \left(\frac{1}{R_1+R_2} - 1\right) V_C$$

$$\frac{dV_L}{dt} = \underbrace{\frac{dE_2}{dt}}_{0} - \frac{R_1}{R_1+R_2}\underbrace{\frac{dE_2}{dt}}_{0} - \frac{R_2}{R_1+R_2}\frac{di_L}{dt} + \left(\frac{1}{R_1+R_2}-1\right)\frac{dV_C}{dt};$$

$$\frac{dV_L}{dt} = -\frac{R_2}{R_1+R_2}\frac{di_L}{dt} + \frac{1}{R_1+R_2}\frac{dV_C}{dt} - \frac{dV_C}{dt}$$

$$\frac{dV_L}{dt} = -\frac{R_2}{R_1+R_2}\left(-\frac{R_1R_2}{L(R_1+R_2)} i_L - \frac{R_2}{L(R_1+R_2)} V_C + \frac{R_2}{L(R_1+R_2)}E_2\right) +$$

$$+\left(\frac{1}{R_1+R_2}-1\right)\left(\frac{R_2}{C(R_1+R_2)} i_L - \frac{R_1+R_2+R_3}{CR_3(R_1+R_2)} V_C + \frac{1}{C(R_1+R_2)}E_2\right);$$

$$\frac{dV_L}{dt} = \frac{R_2}{R_1+R_2}\cdot\frac{R_1R_2 i_L - R_2V_C + R_2E_2}{L(R_1+R_2)} + \left(\frac{1}{R_1+R_2}-1\right)\left(\frac{R_2R_3i_L - (R_1+R_2+R_3)V_C + R_3E_2}{CR_3(R_1+R_2)}\right)$$

$$\frac{dV_L}{dt} = \frac{R_1R_2^2 i_L - R_2^2 V_C + R_2^2E_2}{L(R_1+R_2)^2} + \frac{(1-R_1-R_2)(R_2R_3i_L - R_1V_C - R_2V_C - R_3V_C + R_3E_2)}{CR_3(R_1+R_2)^2}$$

$$\frac{dV_L}{dt} = \frac{R_1R_2^2 i_L - R_2^2V_C + R_2^2E_2}{L(R_1+R_2)^2} + R_2R_3i_L - R_1V_C - R_2V_C - R_3V_C + R_3E_2 - R_2R_3R_1 i_L + R_1^2V_C + R_1R_2V_C +$$

$$+ R_3R_1V_C - R_3R_1E_2 + R_2^2R_3 i_L$$

$$\frac{dV_L}{dt} = \frac{R_2}{R_1+R_2}\left(\frac{\frac{R_1R_2E_1}{R_1+R_3} - \frac{R_2E_1R_3}{R_1+R_3} + R_2E_2}{L(R_1+R_2)}\right) +$$

$$\left(\frac{1}{R_1+R_2}-1\right)$$

$$+ (\cancel{1-R_1}-R_2)\left(\frac{\frac{R_2R_3E_1}{R_1+R_3} - \frac{(R_1+R_2+R_3)E_1R_3}{R_1+R_3} + R_3E_2}{CR_3(R_1+R_2)}\right)$$

В соответствии с математикой 5:

$$(0^+)\frac{dV_L}{dt} = \cancel{-1{,}90023\cdot 10^{10}} - 71983,$$

$$(0^+)\ V_L = 56{,}9012.$$

VI

$$\boxed{\mathrm{Re}K = \frac{E_2R_2 - E_1R_2}{2(R_1+R_2)} = \frac{R_2\Delta E}{2(R_1+R_2)};}$$

$$J_L = \frac{E_1}{R_1+R_3}$$

$$V_c = E_1 \cdot \frac{R_3}{R_1+R_3}$$

$$V_L = E_2 - \frac{R_1E_2}{R_1+R_2} - \frac{R_2}{R_1+R_2}J_L + \left(\frac{1}{R_1+R_2} - 1\right)V_c$$

$$\frac{dV_L}{dt} = -\frac{R_2}{R_1+R_2}\frac{di_L}{dt} + \left(\frac{1}{R_1+R_2} - 1\right)\frac{dV_c}{dt}$$

$$\frac{dV_L}{dt} = +\frac{R_2}{R_1+R_2}\left(\frac{R_1R_2}{L(R_1+R_2)}i_L + \frac{R_2}{L(R_1+R_2)}V_c + \frac{R_2E_2}{L(R_1+R_2)}\right) + \left(\frac{1}{R_1+R_2} - 1\right)\left(\frac{R_2}{C(R_1+R_2)}i_L - \frac{R_1+R_2+R_3}{CR_3(R_1+R_2)}V_c + \frac{E_2}{C(R_1+R_2)}\right)$$

$$\frac{dV_L}{dt} = \frac{R_2}{R_1+R_2}\left(\frac{R_1R_2i_L + R_2V_c + R_2E_2}{L(R_1+R_2)}\right) + \left(\frac{1-R_1-R_2}{R_1+R_2}\right)\left(\frac{R_3R_2i_L - (R_1+R_2+R_3)V_c + R_3E_2}{CR_3(R_1+R_2)}\right)$$

$$\frac{dV_L}{dt} = \frac{R_1R_2^2i_L + R_2^2V_c + R_2^2E_2}{L(R_1+R_2)^2} + \frac{(1-R_1-R_2)R_3R_2i_L - (1-R_1-R_2)(R_1+R_2+R_3)V_c + (1-R_1-R_2)R_3E_2}{CR_3(R_1+R_2)^2}$$

$$\frac{dV_L}{dt} = \frac{CR_3R_1R_2^2i_L + CR_3R_2^2V_c + CR_3R_2^2E_2 + (1-R_1-R_2)R_3R_2Li_L - (1-R_1-R_2)(R_1+R_2+R_3)LV_c + (1-R_1-R_2)R_3LE_2}{CR_3L(R_1+R_2)^2}$$

$$\frac{dV_L}{dt} = \frac{i_L\left(CR_3R_1R_2^2 + (1-R_1-R_2)R_3R_2L\right) + V_c\left(CR_3R_2^2 - (1-R_1-R_2)(R_1+R_2+R_3)L\right) + E_2\left(CR_3R_2^2 + (1-R_1-R_2)R_3L\right)}{CR_3L(R_1+R_2)^2}$$

$$\frac{dV_L}{dt} = (\mathrm{Re}K + j\,\mathrm{Jm}K)(-\alpha + j\beta)e^{(-\alpha+j\beta)t} + (\mathrm{Re}K - j\,\mathrm{Jm}K)(-\alpha - j\beta)e^{(-\alpha-j\beta)t} =$$

$$(t=0^+) = -2\alpha\,\mathrm{Re}K - 2\beta\,\mathrm{Jm}K$$

$$\frac{dV_L}{dt} = -2\alpha\,\mathrm{Re}K - 2\beta\,\mathrm{Jm}K$$

$$V_L(t) = A_0 e^{-\alpha t}\cos(\beta t + \varphi_0)$$

$$A_0 = 2|K|$$

$$\varphi_0 = \arg K.$$

$$\frac{dV_L}{dt} = -2\alpha\frac{R_2\Delta E}{2(R_1+R_2)} - 2\beta\,\mathrm{Jm}K$$

$$\frac{dV_L}{dt} = -\frac{\alpha R_2\Delta E}{R_1+R_2} - 2\beta\,\mathrm{Jm}K$$

$$\mathrm{Jm}K = \frac{-\frac{\alpha R_2\Delta E}{R_1+R_2} - \frac{dV_L}{dt}}{2\beta}$$

$$T_c = \frac{1{,}08\cdot10^{-5} \div 11{,}62\cdot10^{-5}}{5} = \frac{10{,}54}{5}\cdot10^{-5} = 2{,}108\cdot10^{-5}$$

$1{,}9\cdot10^{-5} \div 7{,}2\cdot10^{-5}$

$1/\alpha = (7{,}2 - 1{,}9)\cdot10^{-5} = 5{,}3\cdot10^{-5}$ s

$\alpha = 0{,}188679\cdot10^{5} = 1{,}88679\cdot10^{4}$

$f_0 = 0{,}4743\cdot10^{5} = 4{,}743\cdot10^{4}$

$\omega_0 = 2\pi f_0 = 2{,}97860\cdot10^{5}$ rad/s

$Q = \frac{\omega_0}{2\alpha} = \frac{2{,}97860}{2\cdot0{,}188679} = 7{,}8933 \approx 8.$

$2\alpha = \Delta\omega$

1) анализ ~~Ду~~. динам. ур.
2) сравнить характеристики разд. контура.
3) провести анализ реакции. (график).

VII

Заключение.

$(0^-)\, i_L = -0{,}000946461$ $\qquad \dfrac{di_L}{dt} = 20113{,}6$

$(0^-)\, v_C = -18{,}9671$

$(0^+)\, v_C = 56{,}9012$ $\qquad \dfrac{dv_C}{dt} = 699787$

$(0^+)\, \dfrac{dv_L}{dt} = -719836$

$Re\,K = 28{,}4506$

$Im\,K = -0{,}557805$ $\qquad \alpha = 1{,}04261 \cdot 10^4$

$2|K| = 56{,}9121$ $\qquad \beta = 2{,}9458 \cdot 10^5$

$\arg K = -1{,}55119^\circ = -0{,}027073$ рад → график схема запаздывает.