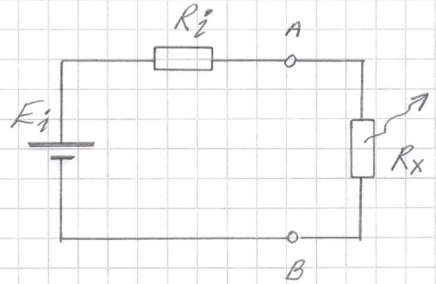
Lösningsförslag till tentamen TMEL08 Elteknika system 2023-03-17

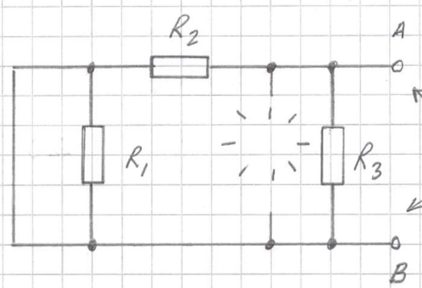
1. FÖR ATT LÖSA DEN HÄR UPPGIFTEN BEHÖVER TVÅPOLSSATSEN ANVÄNDAS.



$P = P_{MAX}$ OM $R_x = R_i$

OCH $P_{MAX} = \dfrac{E_i^2}{4R_i}$

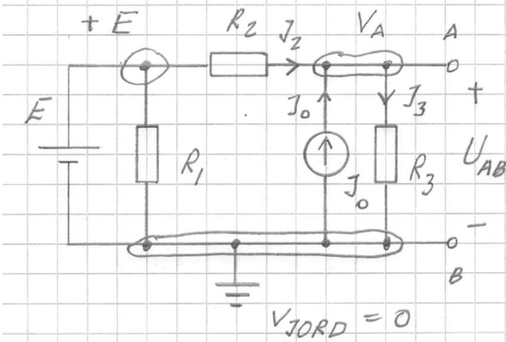
a) NOLLSTÄLL ALLA STRÖM- OCH SPÄNNINGS-KÄLLOR. BERÄKNA R_i MELLAN A OCH B.



$$R_i = \frac{R_3 \cdot R_2}{R_3 + R_2} \Rightarrow R_i \approx 1{,}4\,\Omega \quad (1{,}43)$$

ALLTSÅ $P = P_{MAX}$ OM $\underline{\underline{R_x \approx 1{,}4\,\Omega}}$

b) $E_i = U_{ABO}$ (TVÅPOLENS TOMGÅNGSSPÄNNING)



$U_{ABO} = V_A - V_{JORD} = E_i$

$$J_2 + J_0 - J_3 = 0 \rightarrow$$

$$\frac{E - V_A}{R_2} + J_0 - \frac{V_A - 0}{R_3} = 0 \Rightarrow V_A \approx +5{,}4\text{ V} \quad (5{,}43)$$

$$P_{MAX} = \frac{E_i^2}{4R_i} \Rightarrow \underline{\underline{P_{MAX} \approx 5{,}2\text{ W}}}$$

2a) OM KONDENSATORN ÄR BORTKOPPLAD

$$\mathbb{J} = \frac{U}{R + j\omega L}$$

$$\mathbb{J} = \frac{230\sqrt{2}\cdot e^{j0^\circ}}{24 + j\,314\cdot 0{,}10} \approx 5{,}8\sqrt{2}\,e^{-j53^\circ}\ \text{A}$$

$$\underline{i(t) = 5{,}8\sqrt{2}\sin(314\cdot t - 53^\circ)}\ \text{A}$$

$$P = R\cdot J^2 \rightarrow P = 24\cdot 5{,}8^2 \approx \underline{0{,}81\ \text{kW}}$$

$$Q = Q_L = \omega L\cdot J^2 \rightarrow Q = 314\cdot 0{,}10\cdot 5{,}8^2 \approx \underline{1{,}1\ \text{kVAr}}$$

2b) OM KONDENSATORN ÄR INKOPPLAD

$Q = Q_L - Q_C$ DÄR

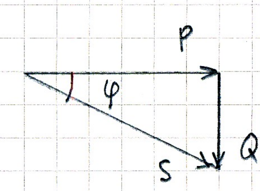
$$Q_C = \frac{U^2}{X_C} = \Big/ X_C = \frac{1}{\omega C} \Big/ = \omega C U^2$$

$$Q_C = 314 \cdot 150 \cdot 10^{-6} \cdot 230^2 = 2{,}5 \text{ kVAr}$$

$$Q = 1{,}1 - 2{,}5 \approx \underline{-1{,}4 \text{ kVAr}}$$

STRÖMMEN GENOM R OCH L PÅVERKAS INTE DÅ C KOPPLAS IN DVS. P ÄR DENSAMMA SOM FÖRUT.

$$\underline{P = 0{,}81 \text{ kW}}$$



SKENBARA EFFEKTEN

$$S = \sqrt{P^2 + Q^2} \Rightarrow S \approx 1{,}6 \text{ kVA}$$

$$S = U \cdot I \Rightarrow 1{,}6 \cdot 10^3 = 230 \cdot I \rightarrow I = 7{,}0 \text{ A}$$

$$\tan\varphi = \frac{Q}{P} \rightarrow \varphi \approx -60^\circ$$

$$\varphi = \arg U - \arg I \qquad -60^\circ = 0^\circ - \arg I$$

$$\rightarrow \arg I = 60^\circ$$

ALLTSÅ $\underline{i(t) \approx 7{,}0\sqrt{2}\sin(314 \cdot t + 60^\circ) \text{ A}}$

3a)

$$\frac{N_1}{N_2} = \frac{\hat{U}_1}{\hat{U}_2} = \frac{\hat{U}_1}{U_C + 2\cdot 0{,}70}$$

$$\Rightarrow \frac{N_1}{N_2} = \frac{230\sqrt{2}}{12 + 1{,}4} \approx \underline{\underline{24}}$$

3b)

$$U_C - R\cdot J_R - U_Z = 0 \quad \ldots (1)$$

$$P_{Z\,MAX} = U_Z \cdot J_{Z\,MAX} \quad \ldots (2)$$

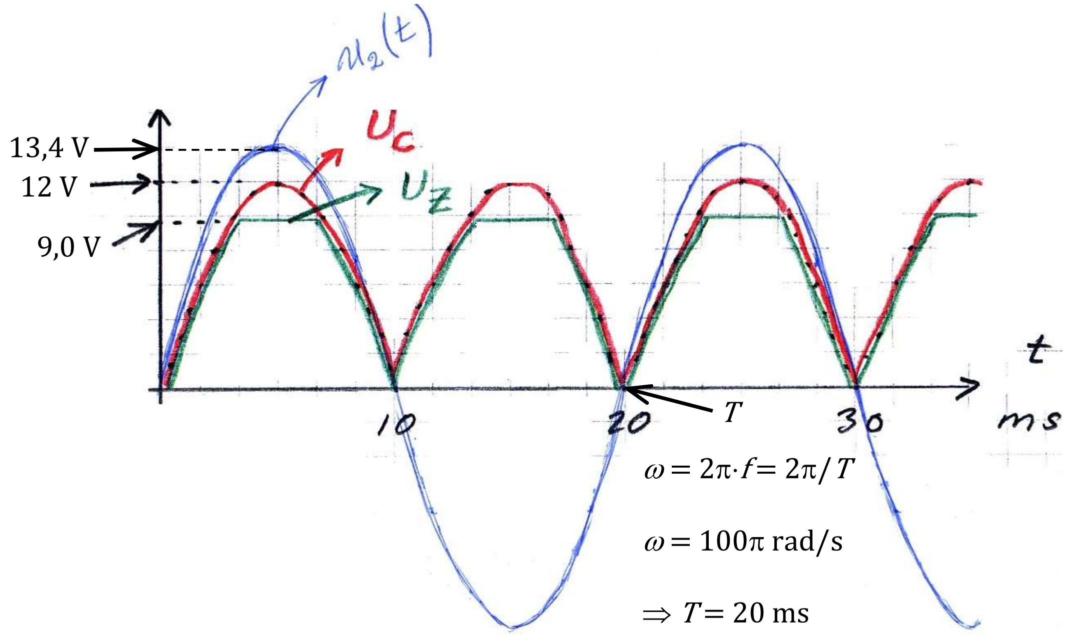
$$(2) \Rightarrow 2{,}0 = 9{,}0 \cdot J_{Z\,MAX} \Rightarrow J_{Z\,MAX} \approx 0{,}22\,A$$

NÄR LAST SAKNAS BLIR J_Z MAXIMAL OCH LIKA MED J_R.

$$(1) \Rightarrow 12 - R\cdot 0{,}22 - 9{,}0 = 0$$

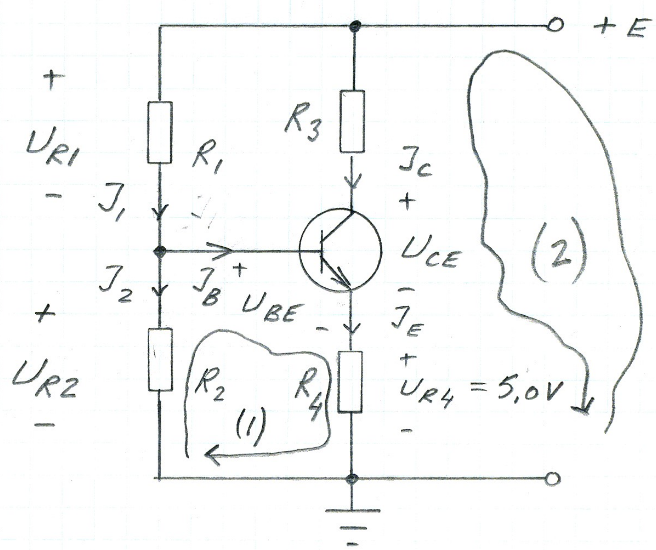
$$\Rightarrow \underline{\underline{R = 13{,}5\ \Omega}} \quad (R_{MIN})$$

3c) Tidsdiagram för $u_2(t)$, U_C och U_Z då glättningskondensatorn gått sönder:



4a)

LIKSTRÖMSSCHEMA



$$+U_{R2} - U_{BE} - U_{R4} = 0 \quad \ldots \quad (1)$$

$$(1) \Rightarrow U_{R2} = 5{,}7 \text{ V}$$

$$U_{R1} = E - U_{R2} \Rightarrow U_{R1} = 4.3 \text{ V}$$

$$J_1 = \frac{U_{R1}}{R_1} \Rightarrow J_1 = 159 \ \mu A$$

$$J_E = J_B + J_C = J_B + h_{FE} J_B$$

$$J_E = \frac{U_{R4}}{R_4} \Rightarrow J_E = 5{,}0 \text{ mA}$$

$$\Rightarrow 0{,}0050 = J_B + 300 J_B \Rightarrow J_B = 16{,}6 \ \mu A$$

$$J_2 = J_1 - J_B \Rightarrow J_2 = 143 \ \mu A$$

$$R_2 = \frac{U_{R2}}{J_2} \Rightarrow \underline{R_2 \approx 40 \text{ k}\Omega}$$

4b)

$$+E - R_3 I_C - U_{CE} - U_{R4} = 0 \quad \ldots (2)$$

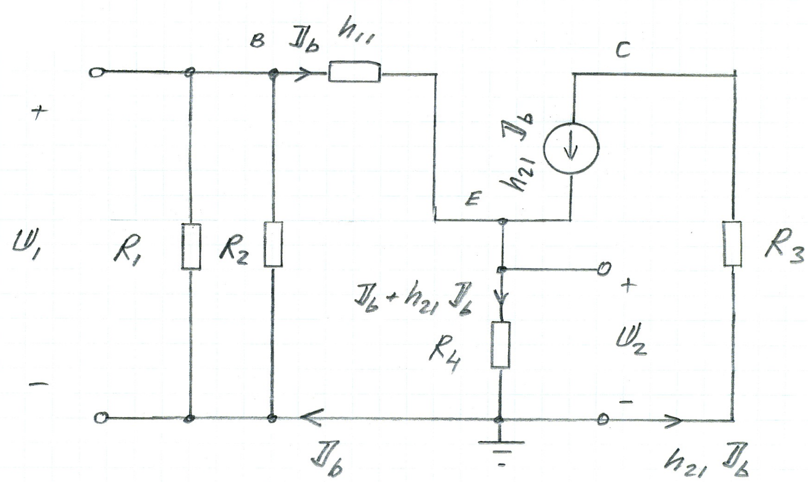
$$I_C = h_{FE} I_B \rightarrow \underline{I_C \approx 5{,}0 \text{ mA}}$$

$$(2) \Rightarrow \quad +10 - 100 \cdot 0{,}0050 - U_{CE} - 5{,}0 = 0$$

$$\Rightarrow \quad \underline{U_{CE} \approx 4{,}5 \text{ V}}$$

4c)

EKVIVALENT SIGNALSCHEMA



$$F = \frac{U_2}{U_1} \quad \ldots (3)$$

$$U_1 = h_{11} I_b + R_4 (I_b + h_{21} I_b) \quad \ldots (4)$$

$$U_2 = R_4 (I_b + h_{21} I_b) \quad \ldots (5)$$

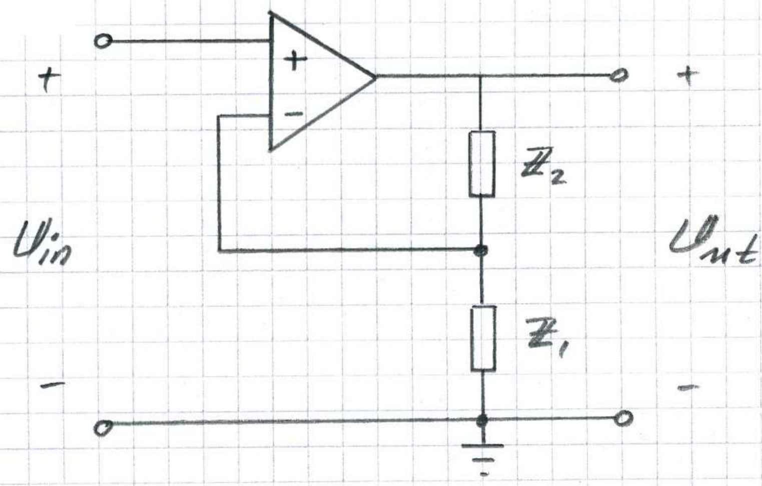
$$(4) \ \& \ (5) \text{ INS I } (3) \rightarrow \underline{F \approx 1{,}0}$$

$$Z_{in} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{U_1 / I_b} \right)^{-1}$$

$$(4) \rightarrow \quad U_1 / I_b = h_{11} + R_4 (1 + h_{21})$$

$$\Rightarrow \quad \underline{Z_{in} \approx 15 \text{ k}\Omega}$$

5.



$$\frac{U_{ut}}{U_{in}} = 1 + \frac{Z_2}{Z_1} \quad \text{DÄR} \quad Z_1 = R_1$$

$$\text{OCH} \quad Z_2 = \frac{\frac{1}{j\omega C} \cdot R_2}{\frac{1}{j\omega C} + R_2} = \frac{R_2}{1 + j\omega C R_2}$$

$$\underline{\frac{U_{ut}}{U_{in}}} = 1 + \frac{R_2}{R_1\left(1 + j\omega C R_2\right)} =$$

$$= \; \dots\dots \; = \frac{R_1 + R_2}{R_1} \cdot \frac{1 + j\omega C \cdot \frac{R_1 R_2}{R_1 + R_2}}{1 + j\omega C R_2}$$

$$\left|\frac{U_{ut}}{U_{in}}\right| = \frac{R_1+R_2}{R_1} \cdot \frac{\sqrt{1^2+\left(\omega C \cdot \frac{R_1 R_2}{R_1+R_2}\right)^2}}{\sqrt{1^2+\left(\omega C R_2\right)^2}}$$

$R_1 = 1{,}0\ k\Omega$, $R_2 = 100\ k\Omega$ och $C = 2{,}7\ nF$

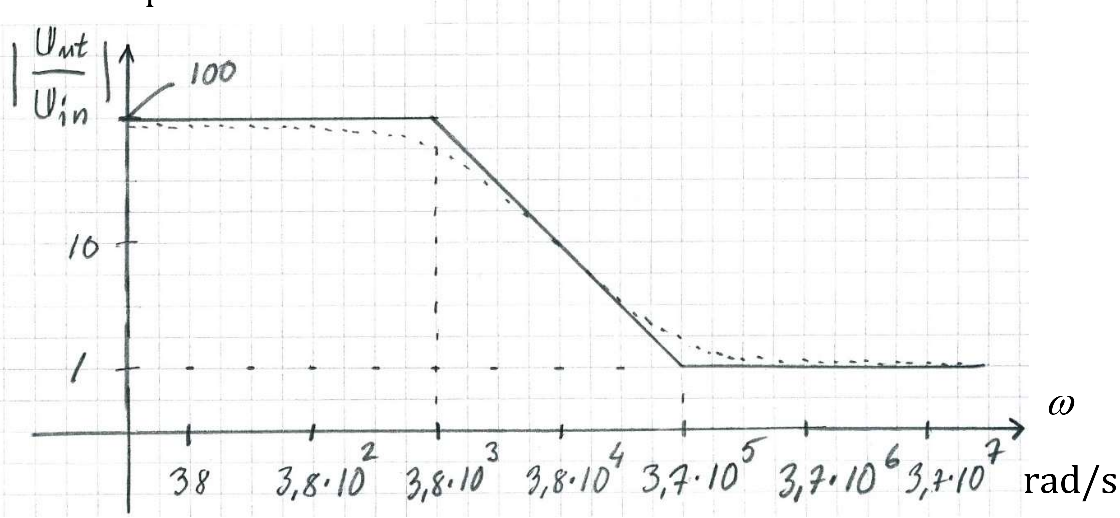
$$\Rightarrow \left|\frac{U_{ut}}{U_{in}}\right| \approx 100 \cdot \frac{\sqrt{1^2+\left(\frac{\omega}{3{,}7 \cdot 10^5}\right)^2}}{\sqrt{1^2+\left(\frac{\omega}{3{,}8 \cdot 10^3}\right)^2}}$$

$$\omega << 3{,}8 \cdot 10^3\ \frac{RAD}{s} \rightarrow \left|\frac{U_{ut}}{U_{in}}\right| \approx 100$$

$$3{,}8 \cdot 10^3 << \omega << 3{,}7 \cdot 10^5 \rightarrow \left|\frac{U_{ut}}{U_{in}}\right| \approx \frac{3{,}8 \cdot 10^5}{\omega}$$

$$\omega >> 3{,}7 \cdot 10^5\ \frac{RAD}{s} \rightarrow \left|\frac{U_{ut}}{U_{in}}\right| \approx 1{,}0$$

Amplitudkurva



$$\arg U_{ut} - \arg U_{in} = \arg\left(\frac{U_{ut}}{U_{in}}\right) =$$

$$= \arg\left(\frac{R_1+R_2}{R_1} \cdot \frac{1 + j\omega C \cdot \frac{R_1 R_2}{R_1+R_2}}{1 + j\omega C R_2}\right) =$$

$$= \arg\left(\frac{R_1+R_2}{R_1}\right) + \arg\left(1 + j\omega C \cdot \frac{R_1 R_2}{R_1+R_2}\right) -$$

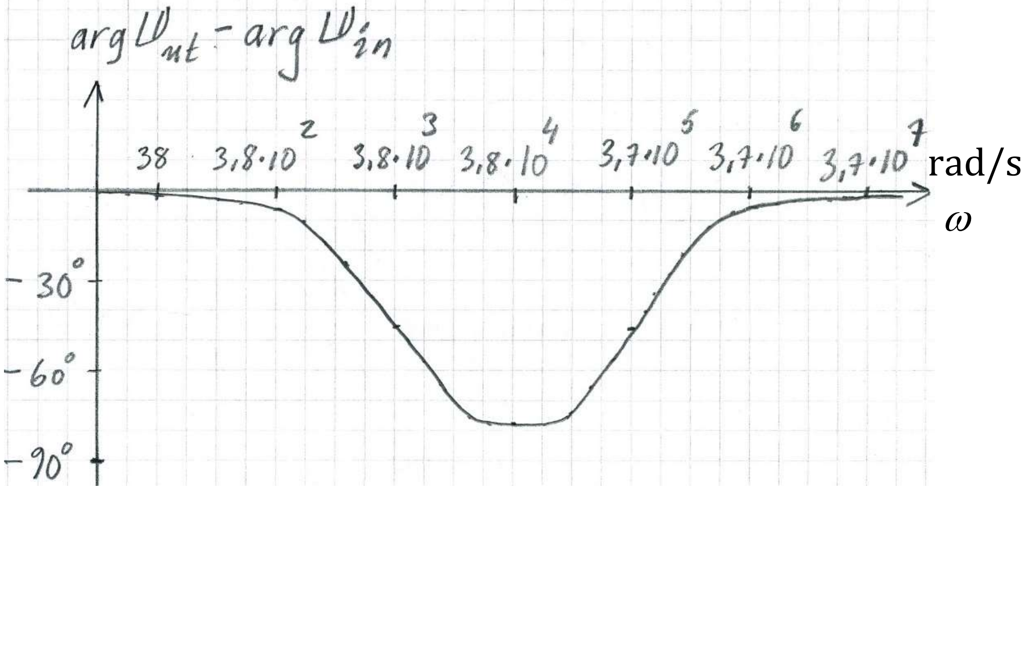
$$- \arg\left(1 + j\omega C R_2\right) =$$

$$= 0 + \arctan\left(\omega C \cdot \frac{R_1 R_2}{R_1+R_2}\right) - \arctan\left(\omega C R_2\right) \approx$$

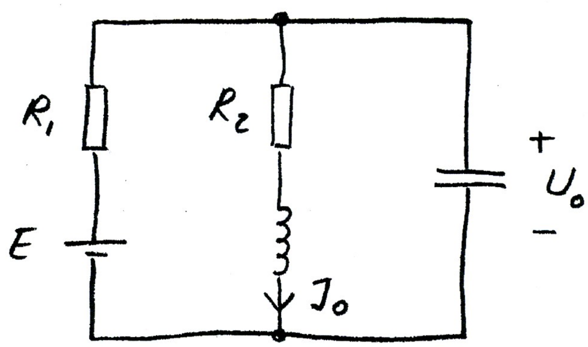
$$\approx \arctan\left(\frac{\omega}{3{,}7 \cdot 10^5}\right) - \arctan\left(\frac{\omega}{3{,}8 \cdot 10^3}\right)$$

ω (RAD/s)	$\arg U_{ut} - \arg U_z$
38	$-1°$
$3{,}8 \cdot 10^2$	$-6°$
$3{,}8 \cdot 10^3$	$-44°$
$3{,}8 \cdot 10^4$	$-78°$
$3{,}7 \cdot 10^5$	$-44°$
$3{,}7 \cdot 10^6$	$-6°$
$3{,}7 \cdot 10^7$	$-1°$

FASKURVA:



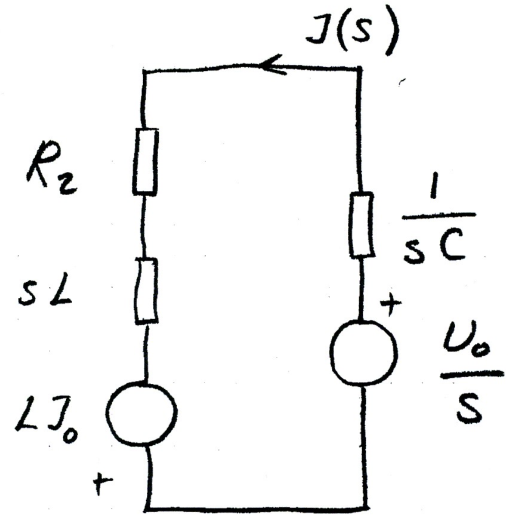
6. BEGYNNELSEVILLKOR $(t < 0)$



$$J_0 = \frac{E}{R_1 + R_2} \Rightarrow J_0 = 6{,}0 \text{ mA}$$

$$U_0 = E \cdot \frac{R_2}{R_1 + R_2} \Rightarrow U_0 = 6{,}0 \text{ V}$$

OPERATORSCHEMA $(t \geq 0)$



$$J(s) = \frac{LJ_0 + \frac{U_0}{s}}{sL + R_2 + \frac{1}{sC}} \Rightarrow$$

$$\Rightarrow I(s) = \frac{6\cdot 10^{-6} + \frac{6{,}0}{s}}{s\cdot 10^{-3} + 10^{3} + \frac{1}{s\cdot 2{,}0\cdot 10^{-9}}} =$$

$$= 6{,}0\cdot 10^{-3}\cdot \frac{s + 10^{6}}{s^{2} + s\cdot 10^{6} + 0{,}5\cdot 10^{12}} =$$

$$= 6{,}0\cdot 10^{-3}\cdot \frac{(s+0{,}5\cdot 10^{6}) + 0{,}5\cdot 10^{6}}{(s+0{,}5\cdot 10^{6})^{2} + (0{,}5\cdot 10^{6})^{2}}$$

$\Rightarrow$

$$i(t) = 6{,}0\cdot e^{-0{,}5\cdot 10^{6}t}\left(\cos 0{,}5\cdot 10^{6}t + \sin 0{,}5\cdot 10^{6}t\right)\ \text{mA}$$

eller

$$i(t) = 6{,}0\sqrt{2}\cdot e^{-0{,}5\cdot 10^{6}t} sin\left(0{,}5\cdot 10^{6}t + \frac{\pi}{4}\right)\ \text{mA}$$