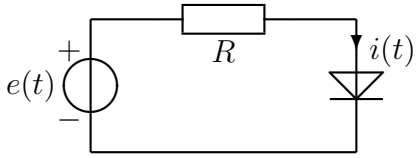
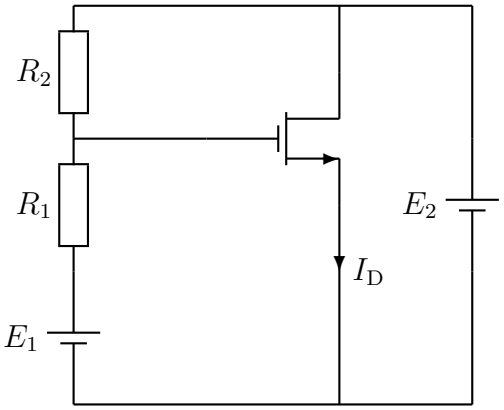
ELEC–C4210 SÄHKÖTEKNIIKKA JA ELEKTRONIIKKA Kimmo Silvonen

2. välikoe 5.12.2022.
2. mellanförhör 5.12.2022.

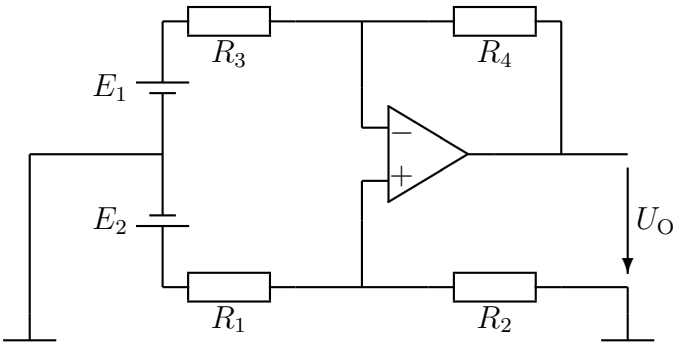
1. Laske likimain diodin maksimivirta $i(t)$.
1. Beräkna strömmen $i(t)$.
$R = 760\ \Omega$, $e(t) = 1000\ \sin \omega t$ V, $n = 2$, $U_T = 25$ mV, $I_\mathrm{S} = 4$ nA.



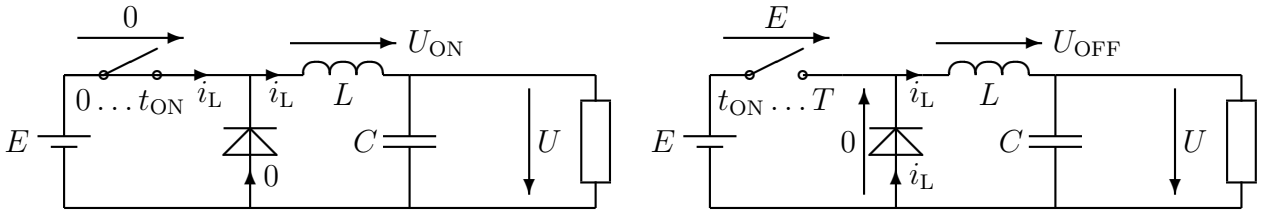
2. Laske virta I_D.
2. Beräkna strömmen I_D.
$E_1 = 5$ V, $E_2 = 8$ V, $R_1 = R_2 = 100$ kΩ, $U_\mathrm{t} = 2$ V, $K = 0{,}1\ \frac{\mathrm{mA}}{\mathrm{V}^2}$.



3. Laske jännite U_O.
3. Beräkna spänningen U_O.
$R_1 = 10$ kΩ, $R_2 = 22$ kΩ, $R_3 = 10$ kΩ, $R_4 = 22$ kΩ, $E_1 = 100$ mV, $E_2 = 200$ mV.



4. SMPS: Laske jännite U
4. SMPS: Beräkna spänningen U
$E = 15$ V, $U_\mathrm{ON} = L\,\frac{\Delta i_\mathrm{L}}{t_\mathrm{ON}}$, $U_\mathrm{OFF} = -L\,\frac{\Delta i_\mathrm{L}}{t_\mathrm{OFF}}$, $t_\mathrm{ON} = 0{,}6\ \mu$s, $t_\mathrm{OFF} = 0{,}4\ \mu$s, $\Delta i_\mathrm{L} = 0{,}1$ A.



Vänd! Resultat och svar kan hittas i MyCo.
Käännä! Ratkaisut ja tulokset tulevat MyCoon. Hyvää joulua, t. X

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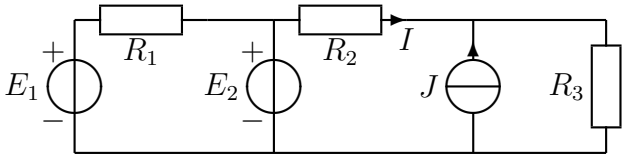
Tentti 5.12.2022: tehtävät 2 ja 4 (2. välikokeesta) sekä lisäksi tehtävät 6 ja 7.
Examen 5.12.2022: uppgifterna nummer 2 och 4 (från 2. mellanförhöret) samt 6 och 7.

6. Laske virta I.

6. Beräknä strömmen I.

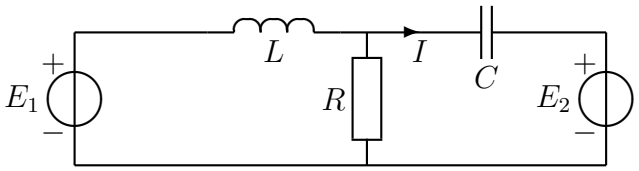
$J = 3$ A, $E_1 = 10$ V, $E_2 = 5$ V, $R_1 = 2{,}5\ \Omega$, $R_2 = 5\ \Omega$, $R_3 = 5\ \Omega$.



7. Laske virta I.

7. Beräkna strömmen I.

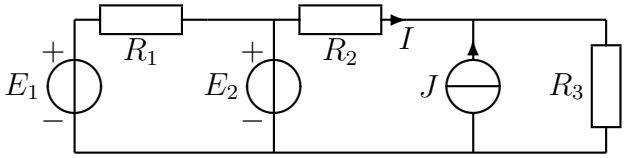
$L = 0{,}5$ H, $R = 4\ \Omega$, $C = 0{,}5$ F, $\omega = 2\ \frac{\text{rad}}{\text{s}}$, $E_1 = 20\angle 0°$ V, $E_2 = (10 + \text{j}10)$ V.



6. Laske virta I.

6. Beräknä strömmen I.

$J = 3$ A, $E_1 = 10$ V, $E_2 = 5$ V, $R_1 = 2{,}5\ \Omega$, $R_2 = 5\ \Omega$, $R_3 = 5\ \Omega$.



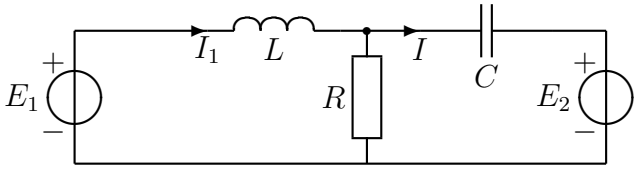
$$-E_2 + R_2 I + R_3(I + J) = 0 \tag{1}$$

$$\Rightarrow I = \frac{E_2 - R_3 J}{R_2 + R_3} = \frac{5 - 5J}{5 + 5} = -1 \text{ A} \tag{2}$$

7. Laske virta I.

7. Beräkna strömmen I.

$L = 0{,}5$ H, $R = 4\ \Omega$, $C = 0{,}5$ F, $\omega = 2\ \frac{\text{rad}}{\text{s}}$, $E_1 = 20\angle 0°$ V, $E_2 = (10 + \text{j}10)$ V.



$$-E_1 + \text{j}\omega L I_1 + R(I_1 - I) = 0 \Rightarrow I_1 = \frac{E_1 + RI}{\text{j}\omega L + R} \tag{3}$$

$$-R(I_1 - I) + \frac{1}{\text{j}\omega C}\, I + E_2 = 0 \tag{4}$$

$$-R\left(\frac{E_1 + RI}{\text{j}\omega L + R}\right) + RI + \frac{1}{\text{j}\omega C}\, I + E_2 = 0 \tag{5}$$

$$-RE_1 - R^2 I + (\text{j}\omega L + R)\left(RI + \frac{1}{\text{j}\omega C}\, I + E_2\right) = 0 \tag{6}$$

$$-R^2 I + \text{j}\omega L\left(RI + \frac{1}{\text{j}\omega C}\, I + E_2\right) + R\left(RI + \frac{1}{\text{j}\omega C}\, I + E_2\right) = RE_1 \tag{7}$$

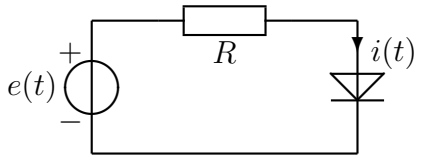
$$\text{j}\omega LRI + \frac{L}{C}\, I + R\,\frac{1}{\text{j}\omega C}\, I = RE_1 - RE_2 - \text{j}\omega L\, E_2 \tag{8}$$

$$I = \frac{RE_1 - RE_2 - \text{j}\omega L\, E_2}{\text{j}\omega LR + \frac{L}{C} + R\,\frac{1}{\text{j}\omega C}} = \frac{\text{j}\omega CR(E_1 - E_2) + \omega^2 LC\, E_2}{-\omega^2 LCR + \text{j}\omega L + R} \tag{9}$$

$$= \frac{4\text{j}(20 - 10 - \text{j}10) + 10 + \text{j}10}{4 - 4 + \text{j}} \tag{10}$$

$$= \frac{50 + \text{j}50}{\text{j}} = 50 - 50\text{j} = 70{,}7\angle -45° \text{ A} \tag{11}$$

1. Laske likimain diodin maksimivirta $i(t)$.
1. Beräkna strömmen $i(t)$.
$R = 760\ \Omega$, $e(t) = 1000\ \sin \omega t$ V, $n = 2$, $U_T = 25$ mV, $I_\mathrm{S} = 4$ nA.

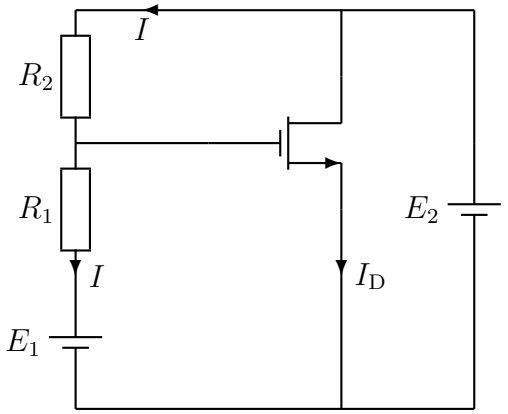


$$-e(t) + Ri(t) + u(t) = 0 \Rightarrow i(t) = \frac{e(t) - u(t)}{R} \approx \frac{e(t)}{R} = 1{,}3\ \mathrm{A} \tag{12}$$

Tasasuuntausdiodi 1N 4007 kestää 1000 voltin estosuuntaisen jännitteen, mutta vain $I = 1$ A virran, joten diodi ei kestä tässä kytkennässä. Tämä oli varsinaisesti tehtävän opetus ja motivaatio. Tarkemmin iteroimalla:

$$-e(t) + RI_\mathrm{S}\,\mathrm{e}^{\frac{u(t)}{nU_T}} + u(t) = 0 \tag{13}$$
$$-\hat{e} + RI_\mathrm{S}\,\mathrm{e}^{20\hat{u}} + \hat{u} = 0 \tag{14}$$
$$\hat{u} = \hat{e} - RI_\mathrm{S}\,\mathrm{e}^{20\hat{u}} = 1000 - 3{,}04\mu\,\mathrm{e}^{20\hat{u}} = 1{,}014\ \mathrm{V} \tag{15}$$
$$\hat{i} = \frac{1000 - 1{,}014}{760} \approx 1{,}314\ \mathrm{A} \tag{16}$$

2. Laske virta I_D.
2. Beräkna strömmen I_D.
$E_1 = 5$ V, $E_2 = 8$ V, $R_1 = R_2 = 100$ kΩ, $U_\mathrm{t} = 2$ V, $K = 0{,}1\ \frac{\mathrm{mA}}{\mathrm{V}^2}$.

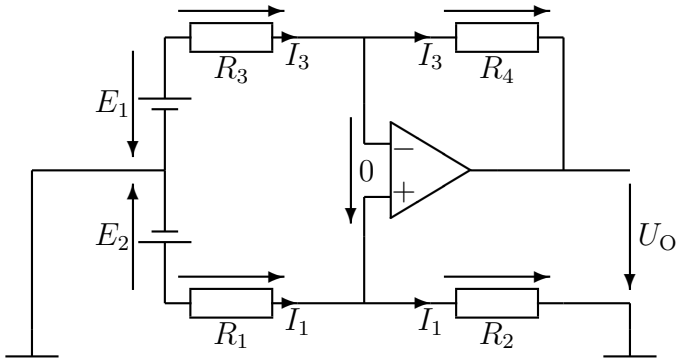


$$-E_1 - (R_1 + R_2)I + E_2 = 0 \Rightarrow I = \frac{E_2 - E_1}{R_1 + R_2} = \frac{3}{200\mathrm{k}} \tag{17}$$
$$U_\mathrm{GS} = E_1 + R_1 I = 5 + \frac{300\mathrm{k}}{200\mathrm{k}} = 6{,}5\ \mathrm{V} \tag{18}$$
$$U_\mathrm{DS} = E_2 = 8\ \mathrm{V} \geq U_\mathrm{GS} - U_\mathrm{t} \tag{19}$$
$$I_\mathrm{D} = K(U_\mathrm{GS} - U_\mathrm{t})^2 \tag{20}$$
$$I_\mathrm{D} = K(6{,}5 - 2)^2 = 2{,}025\ \mathrm{mA} \tag{21}$$

3. Laske jännite U_O.

3. Beräkna spänningen U_O.

$R_1 = 10\ \mathrm{k\Omega}$, $R_2 = 22\ \mathrm{k\Omega}$, $R_3 = 10\ \mathrm{k\Omega}$, $R_4 = 22\ \mathrm{k\Omega}$, $E_1 = 100\ \mathrm{mV}$, $E_2 = 200\ \mathrm{mV}$.



$$-E_2 + R_1 I_1 + R_2 I_1 = 0 \Rightarrow I_1 = \frac{E_2}{R_1 + R_2} \tag{22}$$

$$-E_1 + R_3 I_3 + 0 - R_1 I_1 + E_2 = 0 \Rightarrow I_3 = \frac{E_1 - E_2 + R_1 I_1}{R_3} \tag{23}$$

$$-E_1 + R_3 I_3 + R_4 I_3 + U_\mathrm{O} = 0 \tag{24}$$

$$\Rightarrow U_\mathrm{O} = E_1 - (R_3 + R_4) I_3 = E_1 - (R_3 + R_4)\,\frac{E_1 - E_2 + R_1 I_1}{R_3} \tag{25}$$

$$U_\mathrm{O} = E_1 - \frac{R_3 + R_4}{R_3}\,(E_1 - E_2) - (R_3 + R_4)\,\frac{R_1}{R_3}\,\frac{E_2}{R_1 + R_2} \tag{26}$$

$$U_\mathrm{O} = \frac{R_3 + R_4}{R_3}\,E_2 - \frac{R_4}{R_3}\,E_1 - (R_3 + R_4)\,\frac{R_1}{R_3}\,\frac{E_2}{R_1 + R_2} \tag{27}$$

$$U_\mathrm{O} = \left(\frac{R_3 + R_4}{R_3} - \frac{R_1}{R_3}\frac{R_3 + R_4}{R_1 + R_2}\right)\,E_2 - \frac{R_4}{R_3}\,E_1 \tag{28}$$

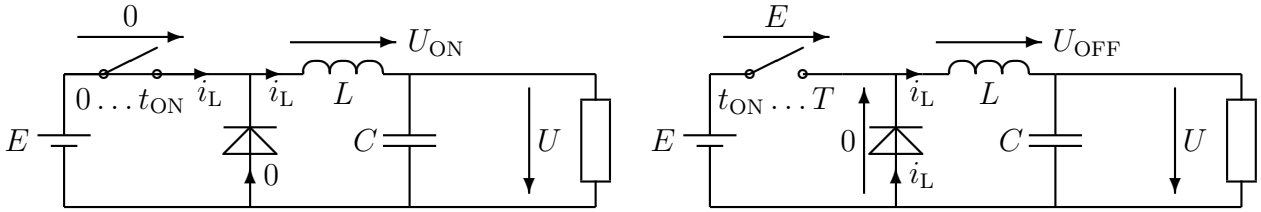
$$U_\mathrm{O} = \frac{1 + \frac{R_4}{R_3}}{1 + \frac{R_1}{R_2}}\,E_2 - \frac{R_4}{R_3}\,E_1 \tag{29}$$

$$U_\mathrm{O} = \frac{R_2}{R_1 + R_2}\,\frac{R_4 + R_3}{R_3}\,E_2 - \frac{R_4}{R_3}\,E_1 = 2{,}2(E_2 - E_1) = 220\ \mathrm{mV} \tag{30}$$

4. Laske jännite U

4. Beräkna spänningen U

$E = 15\ \mathrm{V}$, $U_\mathrm{ON} = L\,\frac{\Delta i_\mathrm{L}}{t_\mathrm{ON}}$, $U_\mathrm{OFF} = -L\,\frac{\Delta i_\mathrm{L}}{t_\mathrm{OFF}}$, $t_\mathrm{ON} = 0{,}6\ \mu\mathrm{s}$, $t_\mathrm{OFF} = 0{,}4\ \mu\mathrm{s}$, $\Delta i_\mathrm{L} = 0{,}1\ \mathrm{A}$.



$$U_\mathrm{ON} = E - 0 - U = L\,\frac{\Delta i_\mathrm{L}}{t_\mathrm{ON}} \Rightarrow L\Delta i_\mathrm{L} = (E - U)t_\mathrm{ON} \tag{31}$$

$$U_\mathrm{OFF} = -0 - U = -L\,\frac{\Delta i_\mathrm{L}}{t_\mathrm{OFF}} \Rightarrow \Delta L i_\mathrm{L} = (U)t_\mathrm{OFF} \tag{32}$$

$$(E - U)t_\mathrm{ON} = U t_\mathrm{OFF} \tag{33}$$

$$U = \frac{t_\mathrm{ON}}{t_\mathrm{ON} + t_\mathrm{OFF}}\,E = 9\ \mathrm{V} \tag{34}$$