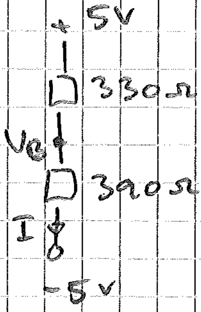
K4 a) Diod spärrar



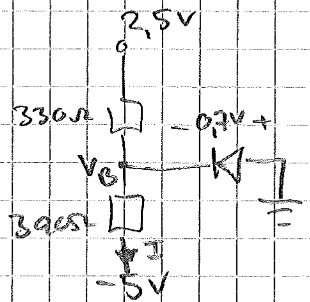
$$\underline{\underline{I}} = \frac{10}{330+390} = \underline{\underline{13{,}9\text{ mA}}}$$

$$\underline{\underline{V_B}} = -5 + 390 \cdot I =$$

$$= -5 + 390 \cdot 13{,}9 \cdot 10^{-3} = \underline{\underline{0{,}417\text{ V}}}$$

---

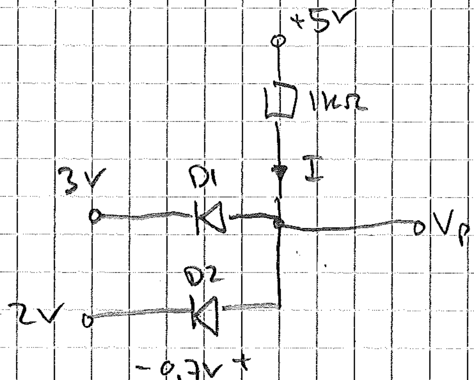
b) Diod leder



$$\underline{\underline{V_B}} = \underline{\underline{-0{,}7\text{ V}}}$$

$$\underline{\underline{I}} = \frac{V_B - (-5)}{390} = \frac{-0{,}7+5}{390} = \underline{\underline{11{,}0\text{ mA}}}$$

K6



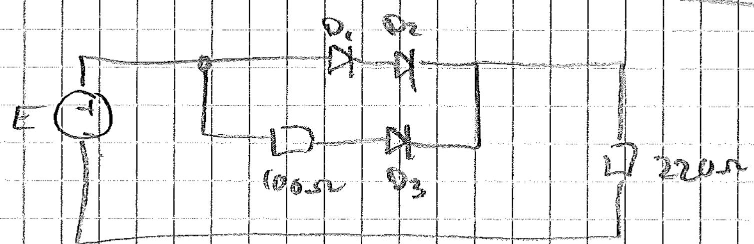
D2 leder

D1 spärrar

$$\underline{\underline{V_p}} = 2 + 0{,}7 = \underline{\underline{2{,}7\text{ V}}}$$

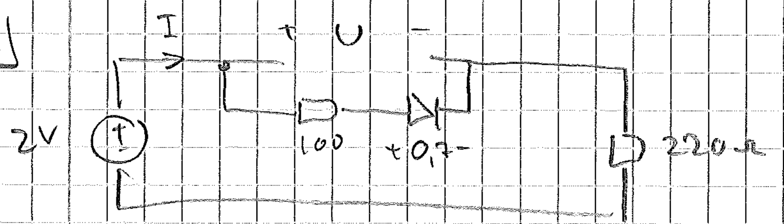
$$\underline{\underline{I}} = \frac{5 - V_p}{1000} = \frac{5-2{,}7}{1000} = \underline{\underline{2{,}3\text{ mA}}}$$

K7



D_3 leder då $E > 0{,}7$V

a)



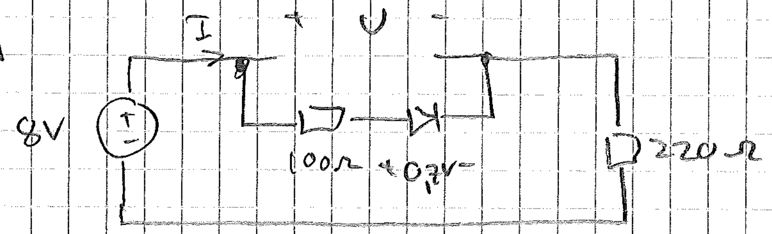
$$\underline{\underline{I}} = \frac{2-0{,}7}{100+220} = \underline{\underline{4{,}06\text{ mA}}}$$

$$U = 0{,}7 + 100 I = 1{,}11\text{ V}$$

$U < 2 \cdot 0{,}7 \Rightarrow$

D_2 o D_3 leder ej $\Rightarrow$ $\underline{\underline{I_D = 0}}$

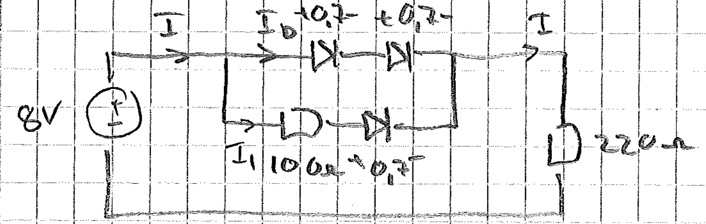
K7 | b |



$$I = \frac{8-0{,}7}{100+220} = 22{,}81 \text{ mA}$$

$$U = 0{,}7 + 100I = 2{,}98 \text{V}$$

$U > 2 \cdot 0{,}7\text{V} \Rightarrow D_1$ o D_2 leder



$$\underline{\underline{I}} = \frac{8-0{,}7-0{,}7}{220} = \underline{\underline{30 \text{ mA}}}$$

$$I_1 = \frac{0{,}7}{100} = 7 \text{ mA}$$

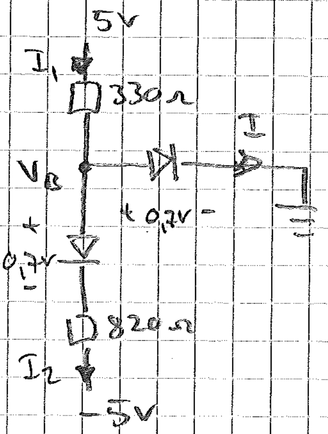
$$\underline{\underline{I_D}} = I - I_1 = 30 - 7 = \underline{\underline{23{,}0 \text{ mA}}}$$

K8 Diod leder då $u(t) > 0,7V$

Då gäller $v(t) = u(t) - 0,7V$

Se facit för figur

K9 Dioder leder



$$\underline{\underline{V_B}} = \underline{\underline{+0,7V}}$$

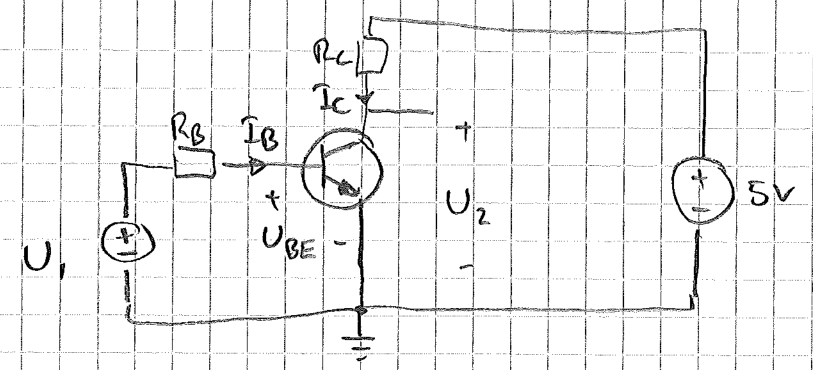
$$I_1 = \frac{5-0,7}{330} = 13,0 \text{ mA}$$

$$I_2 = \frac{(V_B-0,7)-(-5)}{820} = \frac{5}{820} = 6,1 \text{ mA}$$

$$\underline{\underline{I}} = I_1 - I_2 = 13,0 - 6,1 = \underline{\underline{6,9 \text{ mA}}}$$

K

1



$R_B = 120\ k\Omega \quad R_C = 1\ k\Omega \quad h_{fe} = 100 \quad U_1 = 4V \quad U_{BE} = 0{,}7\ V$

a) $U_1 - R_B I_B - U_{BE} = 0$ (1) $\Rightarrow$

$$I_B = \frac{U_1 - U_{BE}}{R_B} = \frac{4 - 0{,}7}{120 \cdot 10^3} = 27{,}5\ \mu A$$

$$I_C = h_{fe} \cdot I_B = 100 \cdot 27{,}5\ \mu A = 2{,}75\ mA$$

$5 - R_C I_C - U_2 = 0$ (2) $\Rightarrow$

$$\underline{\underline{U_2}} = 5 - R_C I_C = 5 - 1000 \cdot 2{,}75 \cdot 10^{-3} = \underline{\underline{2{,}25\ V}}$$

---

b) Ur (2) $I_C = \frac{5 - U_2}{R_C} = \frac{5 - 3{,}8}{1000} = 1{,}2\ mA$

$$I_B = \frac{I_C}{h_{FE}} = \frac{1{,}2\ mA}{100} = 12\ \mu A$$

Ur (1) $\underline{\underline{U_1}} = U_{BE} + R_B I_B = 0{,}7 + 120 \cdot 10^3 \cdot 12 \cdot 10^{-6} = \underline{\underline{2{,}14\ V}}$

---

c) Bottnad $\Rightarrow$ $U_2 = U_{CEsat} = 0{,}1\ V$

Ur (2) $I_C = \frac{5 - U_2}{R_C} = \frac{5 - 0{,}1}{1000} = 4{,}9\ mA$

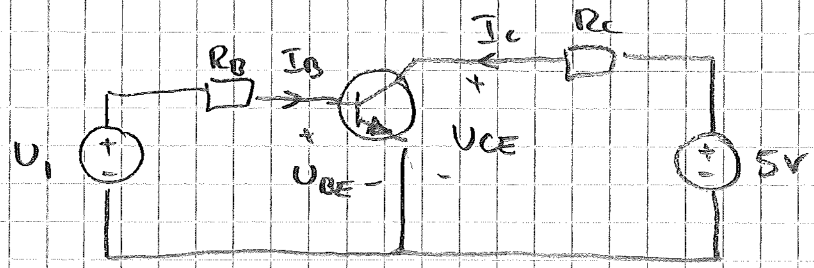
$$I_B = \frac{I_C}{h_{FE}} = \frac{4{,}9\ mA}{100} = 49\ \mu A$$

Ur (1) $\underline{\underline{U_1}} = U_{BE} + R_B I_B = 0{,}7 + 120 \cdot 10^3 \cdot 49 \cdot 10^{-6} = \underline{\underline{6{,}58\ V}}$

Även högre sp ger bottnad transistor $\Rightarrow$ $\underline{\underline{U_1 \geq 6{,}58\ V}}$

K

(2)



$R_B = 100\,k\Omega \quad R_C = 2{,}2\,k\Omega \quad h_{FE} = 100 \quad U_{BE} = 0{,}7V$

$U_{CEsat} = 0{,}1V$

a) $U_1 - R_B I_B - U_{BE} = 0 \Rightarrow$

$$I_B = \frac{U_1 - U_{BE}}{R_B} = \frac{2-0{,}7}{100\cdot 10^3} = 13\,\mu A$$

$$\underline{\underline{I_C}} = h_{FE}\cdot I_B = 100\cdot 13\,\mu A = \underline{\underline{1{,}3\,mA}}$$

Kontroll $U_{CE} + R_c I_C - 5 = 0 \Rightarrow$

$U_{CE} = 5 - R_c I_C = 5 - 2200\cdot 1{,}3\cdot 10^{-3} = 2{,}14\,V$

$U_{CE} > 0{,}1V \Rightarrow$ Ej bottnad

---

b) $$I_B = \frac{U_1 - U_{BE}}{R_B} = \frac{10-0{,}7}{100\cdot 10^3} = 93\,\mu A$$

$I_C = h_{FE}\cdot I_B = 100\cdot 93\,\mu A = 9{,}3\,mA$

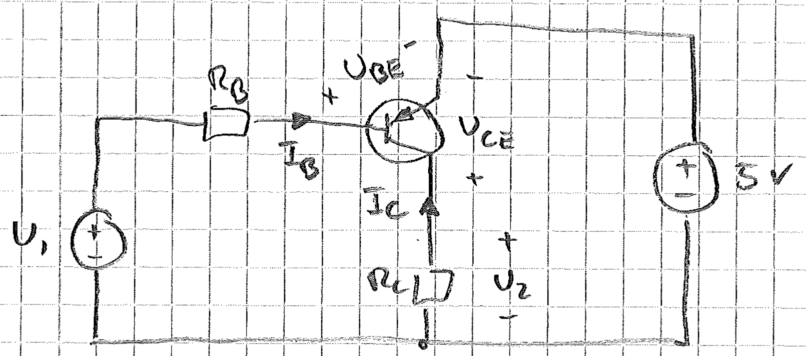
Kontroll $U_{CE} = 5 - R_c I_C = 5 - 2200\cdot 9{,}3\cdot 10^{-3} = -15{,}46\,V$

$U_{CE} \leq 0{,}1V \Rightarrow$ Bottnad $\Rightarrow U_{CE} = U_{CEsat} = 0{,}1V \Rightarrow$

$$\underline{\underline{I_C}} = \frac{5 - U_{CEsat}}{R_c} = \frac{5-0{,}1}{2200} = \underline{\underline{2{,}23\,mA}}$$

K

3



$R_B = 82\ k\Omega \quad R_C = 2{,}2\ k\Omega \quad h_{FE} = 100 \quad U_{BE} = -0{,}7V \quad U_2 = 2V$

$$I_C = -\frac{U_2}{R_C} = -\frac{2}{2200} = -0{,}909\ mA$$

$$I_B = \frac{I_C}{h_{FE}} = -\frac{0{,}909\ mA}{100} = -9{,}09\ \mu A$$

$$U_1 - R_B I_B - U_{BE} - 5 = 0$$

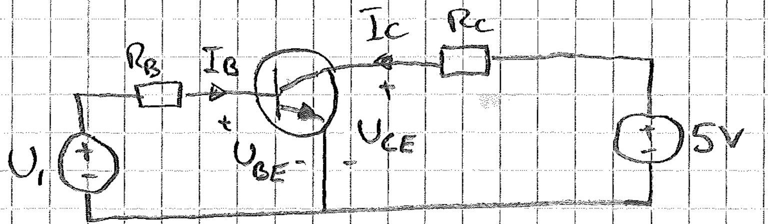
$$\underline{U_1} = R_B I_B + U_{BE} + 5 = 82 \cdot 10^3 \cdot (-9{,}09) \cdot 10^{-6} - 0{,}7 + 5 =$$

$$= \underline{\underline{3{,}55V}}$$

(33)

K

(4)



$R_C = 1\,k\Omega \quad U_1 = 5V \quad h_{FE} = 100 \quad U_{BE} = 0{,}7\ V \quad U_{CEsat} = 0{,}1\ V$

Transistor bottnad $\Rightarrow U_{CE} = U_{CEsat} = 0{,}1\,V$

$U_{CE} + R_C I_C - 5 = 0 \Rightarrow$

$I_C = \dfrac{5 - U_{CE}}{R_C} = \dfrac{5 - 0{,}1}{1000} = 4{,}9\ mA$

$I_B = \dfrac{I_C}{h_{FE}} = \dfrac{4{,}9\ mA}{100} = 49\ \mu A$

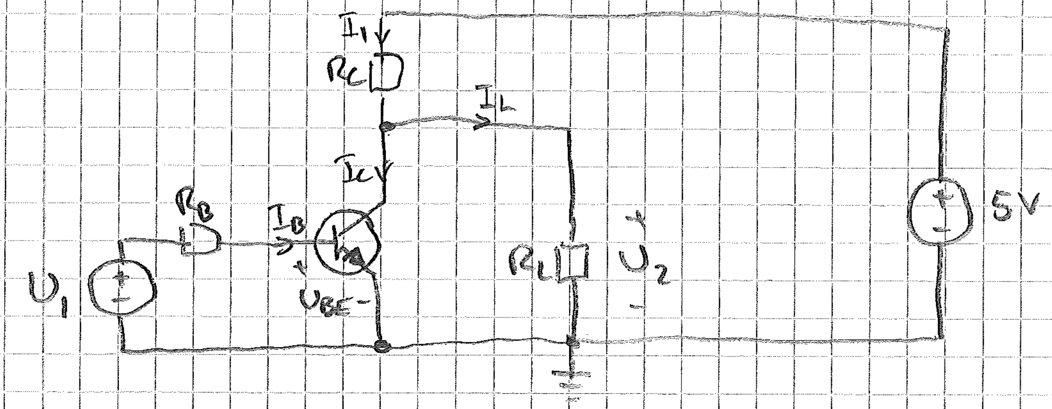
$U_{BE} + R_B I_B - U_1 = 0 \Rightarrow$

$\underline{\underline{R_B}} = \dfrac{U_1 - U_{BE}}{I_B} = \dfrac{5 - 0{,}7}{49 \cdot 10^{-6}} = \underline{\underline{87{,}8\ k\Omega}}$

Även $R_B < 87{,}8\ k\Omega$ ger bottnad transistor

K

5



$R_C = 1\,k\Omega \quad R_B = 100\,k\Omega \quad R_L = 10\,k\Omega \quad h_{FE} = 100 \quad U_2 = 3V \quad U_{BE} = 0{,}7V$

$$I_L = \frac{U_2}{R_L} = \frac{3}{10\,000} = 0{,}3\ mA$$

$$U_2 + R_C I_1 - 5 = 0 \Rightarrow$$

$$I_1 = \frac{5 - U_2}{R_C} = \frac{5-3}{1000} = 2\ mA$$

$$I_C = I_1 - I_L = 2 - 0{,}3 = 1{,}7\ mA$$

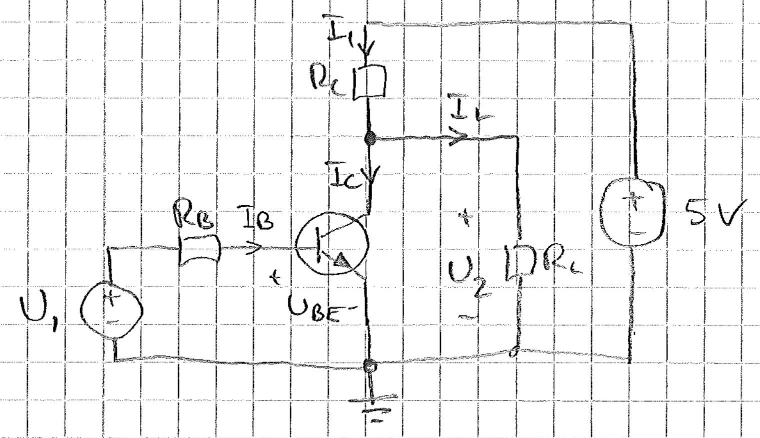
$$I_B = \frac{I_C}{h_{FE}} = \frac{1{,}7\,mA}{100} = 17\ \mu A$$

$$U_{BE} + R_B I_B - U_1 = 0 \Rightarrow$$

$$\underline{\underline{U_1}} = U_{BE} + R_B \cdot I_B = 0{,}7 + 100 \cdot 10^3 \cdot 17 \cdot 10^{-6} = \underline{\underline{2{,}4\ V}}$$

K

6



$R_C = 1k\Omega \quad R_L = 10k\Omega \quad U_1 = 5V \quad h_{FE} = 100 \quad U_{BE} = 0{,}7\ V$

Transistor bottnad $\Rightarrow U_2 = U_{CEsat} = 0{,}1\ V$

$$I_L = \frac{U_2}{R_L} = \frac{0{,}1}{10000} = 10\mu A$$

$U_2 + I_1 R_C - 5 = 0 \Rightarrow$

$$I_1 = \frac{5 - U_2}{R_C} = \frac{5 - 0{,}1}{1000} = 4{,}90\ mA$$

$$I_C = I_1 - I_L = 4{,}90\ mA - 10\mu A = 4{,}89\ mA$$

$$I_B = \frac{I_C}{h_{FE}} = \frac{4{,}89\ mA}{100} = 48{,}9\ \mu A$$

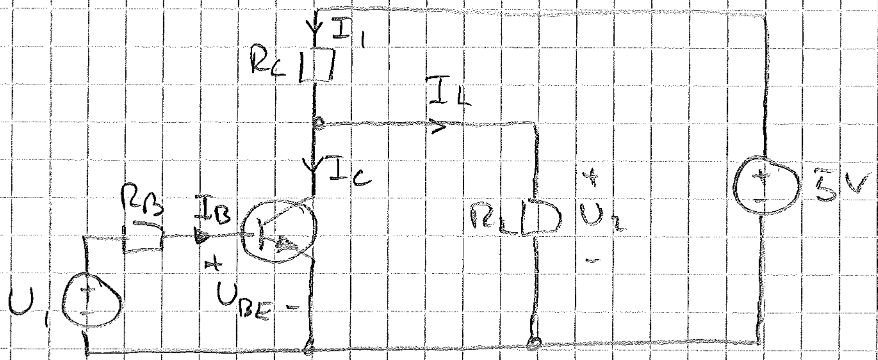
$U_{BE} + R_B I_B - U_1 = 0 \Rightarrow$

$$\underline{R_B} = \frac{U_1 - U_{BE}}{I_B} = \frac{5 - 0{,}7}{48{,}9 \cdot 10^{-6}} = \underline{87{,}9\ k\Omega}$$

Även lägre värde på R_B gör att transistor bottnar

K

7



$R_C = 1\,k\Omega \quad h_{FE} = 100 \quad U_{BE} = 0{,}7\,V$

$U_2 \geq 4{,}5\,V$ då $U_1 \leq 0{,}5\,V$

$U_1 \leq 0{,}7\,V \Rightarrow$ Transistor strypt $\Rightarrow I_B = 0 \Rightarrow I_C = 0$

$$I_1 = \frac{5 - U_2}{R_C} = \frac{5 - 4{,}5}{1000} = 0{,}5\,mA$$

$$I_L = I_1 = 0{,}5\,mA$$

$$\underline{\underline{R_L}} = \frac{U_2}{I_L} = \frac{4{,}5}{0{,}5 \cdot 10^{-3}} = \underline{\underline{9\,k\Omega}}$$

$U_2 \leq 0{,}2\,V$ då $U_1 \geq 4{,}5\,V$

$U_1 > 0{,}7\,V \Rightarrow$ Transistor leder

$$I_L = \frac{U_2}{R_L} = \frac{0{,}2}{9000} = 22{,}2\,\mu A$$

$$I_1 = \frac{5 - U_2}{R_C} = \frac{5 - 0{,}2}{1000} = 4{,}80\,mA$$

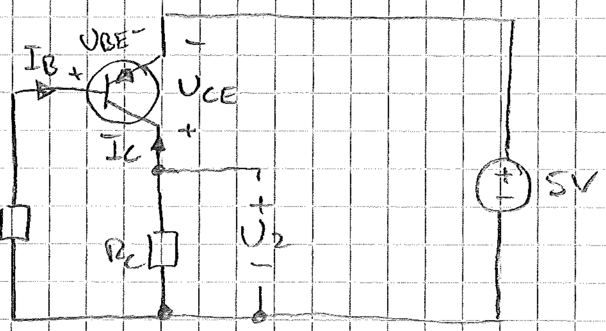
$$I_C = I_1 - I_L = 4{,}80\,mA - 22{,}2\,\mu A \approx 4{,}78\,mA$$

$$I_B = \frac{I_C}{h_{FE}} = \frac{4{,}78\,mA}{100} = 47{,}8\,\mu A$$

$$\underline{\underline{R_B}} = \frac{U_1 - U_{BE}}{I_B} = \frac{4{,}5 - 0{,}7}{47{,}8 \cdot 10^{-6}} = \underline{\underline{79{,}5\,k\Omega}}$$

K

8



$R_C = 1\,k\Omega \quad h_{FE} = 100 \quad U_{BE} = -0{,}7\,V \quad U_{CEsat} = -0{,}1\,V$

Bottnad transistor $\Rightarrow U_{CE} = U_{CEsat} = -0{,}1\,V$

$5 + U_{CE} + I_C R_C = 0 \Rightarrow$

$I_C = \dfrac{-5 - U_{CE}}{R_C} = \dfrac{-5-(-1)}{1000} = -4{,}9\,mA$

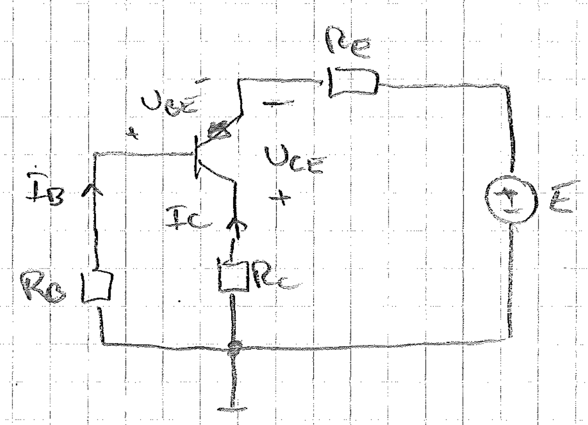
$I_B = \dfrac{I_C}{h_{FE}} = \dfrac{-4{,}9\,mA}{100} = -49\,\mu A$

$5 + U_{BE} + R_B I_B = 0 \Rightarrow$

$\underline{\underline{R_B}} = \dfrac{-5 - U_{BE}}{I_B} = \dfrac{-5-(-0{,}7)}{-49 \cdot 10^{-6}} = \underline{\underline{87{,}7\,k\Omega}}$

K

9



$E = 10V$

$R_E = 1{,}2k\Omega$

$R_C = 1{,}2k\Omega$

$h_{FE} = 20$

$U_{CE_{sat}} = -0{,}1V$

a) $R_B = 0$

$$\begin{cases} -U_{BE} - (I_B + I_C)R_E - E = 0 & (1) \\ -I_C R_C - U_{CE} - (I_B + I_C)R_E - E = 0 & (2) \\ U_{BE} = -0{,}7V \\ I_B = \frac{I_C}{h_{FE}} \end{cases} \Rightarrow$$

$$(1) \quad I_C = \frac{-U_{BE} - E}{R_E\left(1 + \frac{1}{h_{FE}}\right)} = \frac{0{,}7 - 10}{1200\left(1 + \frac{1}{20}\right)} = -7{,}38 \text{ mA}$$

$$(2) \quad U_{CE} = -E - I_C\left\{R_C + R_E\left(1 + \frac{1}{h_{FE}}\right)\right\} = 8{,}15V$$

$U_{CE} > U_{CE_{sat}} \Rightarrow$ Transistor bottnar

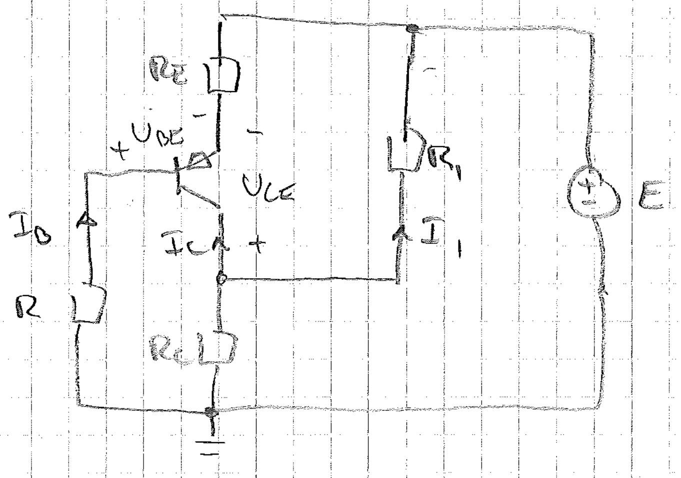
b)
$$\begin{cases} -R_B I_B - U_{BE} - (I_B + I_C)R_E - E = 0 & (1) \\ -I_C R_C - U_{CE} - (I_B + I_C)R_E - E = 0 & (2) \\ U_{BE} = -0{,}7V \\ I_B = \frac{I_C}{h_{FE}} \text{ vid bottningsgräns} \\ U_{CE} = -0{,}1V \end{cases} \Rightarrow$$

$$(2) \quad I_C = \frac{-E - U_{CE}}{R_C + R_E\left(1 + \frac{1}{h_{FE}}\right)} = \frac{-10 + 0{,}1}{1200 + 1200\left(1 + \frac{1}{20}\right)} = -4{,}02 \text{ mA}$$

$$(1) \quad R_B = \frac{-E - U_{BE} - R_E I_C\left(1 + \frac{1}{h_{FE}}\right)}{\frac{I_C}{h_{FE}}} = \frac{-10 + 0{,}7 - 1200 \cdot (-4{,}1 \cdot 10^{-3}) \cdot \left(1 + \frac{1}{20}\right)}{\frac{-4{,}1 \cdot 10^{-3}}{20}}$$

$= 20{,}2 \text{ k}\Omega \quad \Rightarrow R_B < 20{,}2 \text{ k}\Omega$

K
10



$R_C = 1\,k\Omega$
$R_E = 200\,\Omega$
$R_1 = 2\,k\Omega$
$h_{FE} = 100$
$E = 12V$
$U_{BE} = -0{,}7V$
$U_{CEsat} = -0{,}1V$
$U_{CE} = -6V$

$$\begin{cases} -(I_C+I_1)R_C - U_{CE} - (I_C+I_B)R_E - E = 0 & \text{①} \\ -(I_C+I_1)R_C - I_1R_1 - E = 0 & \text{②} \end{cases} \Rightarrow$$

② $\left\{ I_1 = \dfrac{-E - I_CR_C}{R_1+R_C} \right.$ insatt ① ger:

$$-I_CR_C + \frac{R_C}{R_1+R_C}\cdot E + \frac{R_C^2}{R_1+R_C}\cdot I_C - I_C\left(1+\frac{1}{h_{FE}}\right)R_E - E - U_{CE} = 0$$

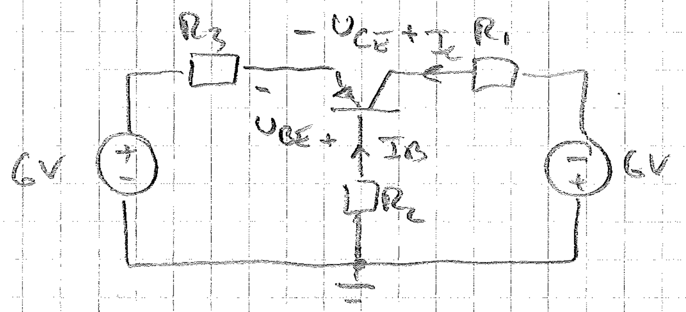
$$I_C = \frac{E\left(1-\frac{R_C}{R_1+R_C}\right)+U_{CE}}{\frac{R_C^2}{R_1+R_C} - R_C - R_E\left(1+\frac{1}{h_{FE}}\right)} = \frac{12\cdot 0{,}667-6}{-869} = -2{,}31\,mA$$

$$-I_BR - U_{BE} - (I_B+I_C)R_E - E = 0$$

$$\underline{\underline{R}} = \frac{-U_{BE} - I_C\left(\frac{1}{h_{FE}}+1\right)R_E - E}{\frac{I_C}{h_{FE}}} = \frac{0{,}7+2{,}31\cdot 10^{-3}(1{,}01)\cdot 200-12}{\frac{-2{,}31\cdot 10^{-3}}{100}} =$$

$$= \underline{\underline{470\,k\Omega}}$$

K 11



$R_1 = R_3 = 1{,}8\ k\Omega$

$h_{FE} = 30$

$U_{CE} = -6V$

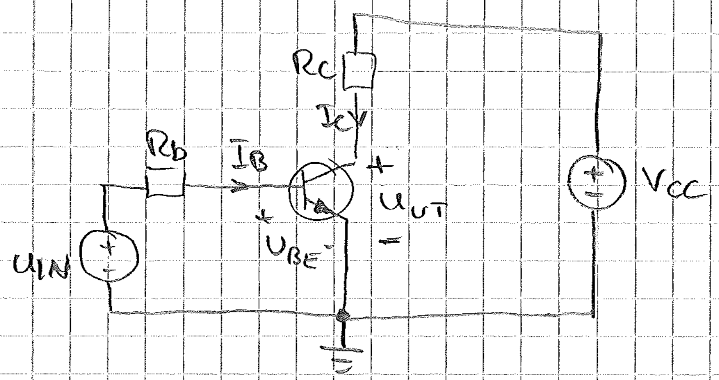
$U_{BE} = -0{,}7V$

$$\begin{cases} 6 + (I_B + I_C)R_3 + U_{BE} + I_B R_2 = 0 & (1) \\ 6 + (I_B + I_C)R_3 + U_{CE} + I_C R_1 + 6 = 0 & (2) \end{cases}$$

$$(2) \Rightarrow \quad I_C = \frac{-12 - U_{CE}}{R_1 + R_3\left(1 + \frac{1}{h_{FE}}\right)} = \frac{-12+6}{1800 + 1800\left(1 + \frac{1}{30}\right)} = -1{,}658\ mA$$

$$(1) \quad R_2 = \frac{-6 - U_{BE} - R_3 I_C\left(1 + \frac{1}{h_{FE}}\right)}{\frac{I_C}{h_{FE}}} = 41{,}4\ k\Omega$$

5.2



$V_{CC} = 12V \quad u_{IN} = 1{,}0V \quad R_b = 22k\Omega \quad R_c = 1k\Omega$

$U_{BE} = 0{,}7V \quad h_{FE} = 250$

$U_{BE} + R_b I_B - u_{IN} = 0 \Rightarrow$

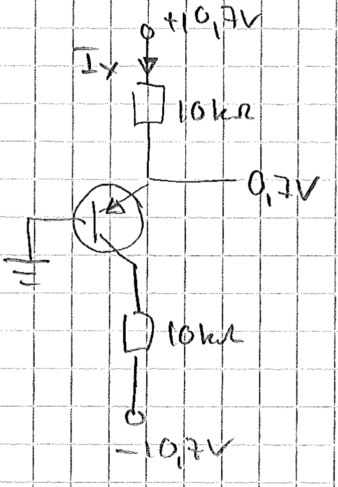
$I_B = \dfrac{u_{IN} - U_{BE}}{R_b} = \dfrac{1{,}0 - 0{,}7}{22 \cdot 10^3} = 13{,}6\ \mu A$

$I_C = h_{FE} \cdot I_B = 250 \cdot 13{,}6\mu A = 3{,}4\ mA$

$u_{UT} + R_C I_C - V_{CC} = 0 \Rightarrow$

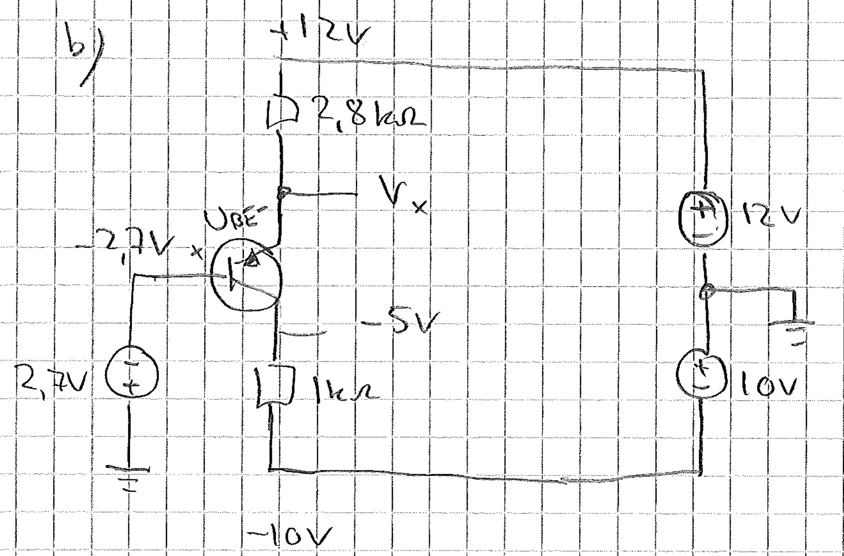
$\underline{\underline{u_{UT}}} = V_{CC} - R_C I_C = 12 - 1000 \cdot 3{,}4 \cdot 10^{-3} = \underline{\underline{8{,}6\,V}}$

5.3 a) h_{FE} mkt stor $\Rightarrow |I_C| = |I_E|$



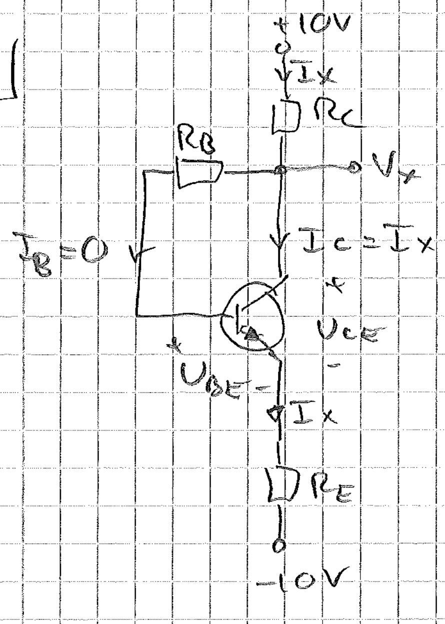
$$\underline{\underline{I_x}} = \frac{10,7-0,7}{10\,000} = \underline{\underline{1\text{ mA}}}$$

b)



Transistor leder $\Rightarrow \underline{\underline{V_x}} = -2,7 - U_{BE} = -2,7 - (-0,7) = \underline{\underline{-2,0V}}$

53 c



$R_C = R_B = R_E = 10\,k\Omega$

h_{FE} mkt stor

$U_{BE} = 0{,}7V$

Ur figur $U_{CE} \geq U_{BE} \Rightarrow$ Transistor ej bottnad $\Rightarrow$

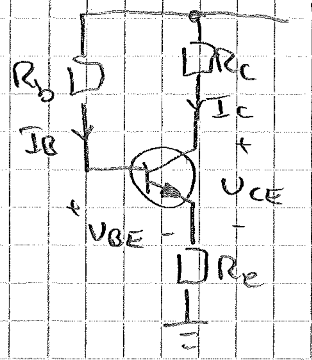
$I_B = \frac{I_C}{h_{FE}} \approx 0$ ty h_{FE} stor

$$-10 + R_E I_x + U_{BE} + 0 \cdot R_B + R_C I_x = 10$$

$$\underline{\underline{I_x}} = \frac{20 - U_{BE}}{R_E + R_C} = \frac{20 - 0{,}7}{20000} = \underline{\underline{0{,}965\ mA}}$$

$$\underline{\underline{V_x}} = 10 - R_C I_x = 10 - 10 \cdot 10^3 \cdot 0{,}965 \cdot 10^{-3} = \underline{\underline{0{,}35\ V}}$$

5.4



$V_{cc} = 6V$

$R_b = 200 k\Omega$

$R_c = 1{,}5 k\Omega$

$R_e = 1 k\Omega$

$U_{BE} = 0{,}7 V$

$V_{CEsat} = 0{,}2 V$

$$\begin{cases} R_e(I_B + I_c) + U_{CE} + R_c I_c = V_{cc} & (2) \\ R_e(I_B + I_c) + U_{BE} + R_b I_B = V_{cc} & (1) \\ I_B = \frac{I_c}{h_{FE}} & (3) \\ U_{BE} = 0{,}7V & (4) \end{cases}$$

Byt ordning

$$\begin{cases} R_e I_c \left(1 + \frac{1}{h_{FE}}\right) + U_{CE} + R_c I_c = V_{cc} & (2) \\ R_e I_c \left(1 + \frac{1}{h_{FE}}\right) + U_{BE} + R_b \frac{I_c}{h_{FE}} = V_{cc} & (1) \end{cases}$$

Byt ordning

$$\begin{cases} (1) \Rightarrow I_c = \dfrac{V_{cc} - U_{BE}}{R_e\left(1 + \frac{1}{h_{FE}}\right) + \frac{R_b}{h_{FE}}} \\ (2) \Rightarrow U_{CE} = V_{cc} - I_c \left(R_c + R_e\left(1 + \frac{1}{h_{FE}}\right)\right) \end{cases}$$

a) $h_{FE} = 100$

$$\underline{\underline{I_c}} = \frac{6 - 0{,}7}{1000\left(1 + \frac{1}{100}\right) + \frac{200 \cdot 10^3}{100}} = \underline{1{,}76 \text{ mA}}$$

$$\underline{\underline{U_{CE}}} = 6 - 1{,}76 \cdot 10^{-3}\left(1500 + 1000\left(1 + \frac{1}{100}\right)\right) = \underline{\underline{1{,}58 V}}$$

b) $h_{FE} = 200$

$$I_c = \frac{6 - 0{,}7}{1000\left(1 + \frac{1}{200}\right) + \frac{200 \cdot 10^3}{200}} = 2{,}64 \text{ mA}$$

$$U_{CE} = 6 - 2{,}64 \cdot 10^{-3}\left(1500 + 1000\left(1 + \frac{1}{200}\right)\right) = -0{,}61 V$$

$$U_{CE} < U_{CEsat} \Rightarrow \begin{cases} \text{Transistor bottnad} \\ (3) \text{ gäller } \underline{\text{ej}} \end{cases}$$

5.4 forts | b |

Bottnad transistor $\underline{\underline{U_{CE} = U_{CEsat} = 0{,}2V}}$

$$\begin{cases} R_e(I_B + I_C) + U_{CE} + R_C I_C = V_{CC} & (2) \\ R_e(I_B + I_C) + U_{BE} + R_b I_B = V_{CC} & (1) \\ U_{CE} = 0{,}2V \end{cases}$$

Byt

Eliminera I_B

$$(1) \Rightarrow I_B = \frac{V_{CC} - U_{BE} - R_E I_C}{R_E + R_b} \quad \text{insatt } (2)$$

$$\frac{R_e}{R_e + R_b}\left(V_{CC} - U_{BE} - R_e I_C\right) + R_e I_C + U_{CE} + R_C I_C = V_{CC}$$

$$I_C = \frac{V_{CC} - U_{CE} - \frac{R_e}{R_e + R_b}\left(V_{CC} - U_{BE}\right)}{R_C + R_e - \frac{R_e^2}{R_C + R_b}} =$$

$$= \frac{6 - 0{,}2 - \frac{1k}{201k}(6 - 0{,}7)}{1{,}5 \cdot 10^3 + 10^3 - \frac{1000^2}{1500 + 200000}} = 2{,}3 \text{ mA}$$

5.5

a) $I_B = -\frac{4{,}3}{450 \cdot 10^3} = -9{,}56\ \mu A$

$I_C = -\frac{2}{2000} = -1\ mA$

$\underline{\underline{h_{FE}}} = \frac{I_C}{I_B} = \underline{\underline{105}}$

b) $\left.\begin{array}{l} I_B = -\frac{(4{,}3-2{,}3)}{20000} = 0{,}1\ mA \\ I_B + I_C = -\frac{2{,}3}{230} = -10\ mA \end{array}\right\} \Rightarrow I_C = -9{,}9\ mA$

$\underline{\underline{h_{FE}}} = \frac{I_C}{I_B} = \underline{\underline{99}}$

c) $\begin{cases} 8{,}3 + 150 \cdot 10^3 \cdot I_B + 1000 \cdot (I_B + I_C) = 0 \\ 9 - (I_C + I_B)1000 = 10 \end{cases} \Rightarrow I_C = \frac{-1 - 1000 I_B}{1000} = -I_B - 10^{-3}$

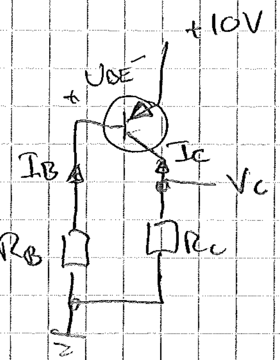
$8{,}3 + 150 \cdot 10^3 I_B + 1000 I_B - 1000 I_B - 1 = 0$

$I_B = \frac{-7{,}3}{150 \cdot 10^3} = -48{,}7\ \mu A$

$I_C = -I_B - 10^{-3} = 48{,}7 \cdot 10^{-6} - 10^{-3} = -951\ \mu A$

$\underline{\underline{h_{FE}}} = \frac{I_C}{I_B} = \underline{\underline{19{,}5}}$

5,6



$R_B = 100\,k\Omega$

$U_{BE} = -0{,}7\,V$

$$-R_B I_B - U_{BE} = 10 \Rightarrow I_B = \frac{-U_{BE} - 10}{R_B} = \frac{0{,}7 - 10}{100 \cdot 10^3} = -93\,\mu A$$

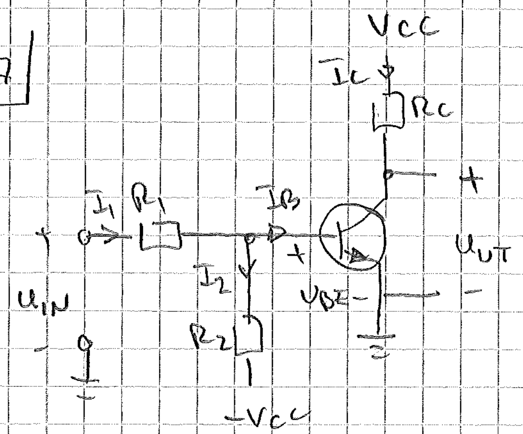
a) $I_C = h_{FE} I_B = -50 \cdot 93\,\mu A = -4{,}65\,mA$

$$V_C = -R_C I_C \Rightarrow \underline{\underline{R_C}} = -\frac{V_C}{I_C} = \frac{5}{4{,}65 \cdot 10^{-3}} = \underline{\underline{1075\,\Omega}}$$

b) $I_C = h_{FE} \cdot I_B = -100 \cdot 93\,\mu A = -9{,}3\,mA$

$\underline{\underline{V_C}} = -R_C I_C = 1075 \cdot 9{,}3 \cdot 10^{-3} = \underline{\underline{10\,V}}$ ca transistor är bottnad.

5,7



$U_{BE} = 0{,}7\,V$

$U_{CEsat} = 0{,}2\,V$

$h_{FE} = 75$

$R_1 = 15\,k\Omega \quad R_2 = 100\,k\Omega \quad R_C = 2{,}2\,k\Omega$

$V_{CC} = 12\,V$

$U_{BE} - R_2 I_2 = -V_{CC} \Rightarrow$

$$I_2 = \frac{V_{CC} + U_{BE}}{R_2} = \frac{12 + 0{,}7}{100 \cdot 10^3} = 127\,\mu A$$

$U_{BE} + R_1 I_1 = u_{IN} \Rightarrow$

$$I_1 = \frac{u_{IN} - u_{BE}}{R_1} =$$

$$I_B = I_1 - I_2 = \frac{u_{IN}}{R_1} - \frac{0{,}7}{15000} - 127\,\mu A = \frac{u_{IN}}{15000} - 174 \cdot 10^{-6}$$

5.7 forts

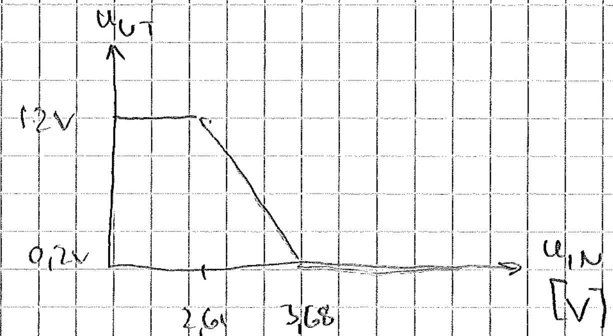
$$u_{UT} = V_{CC} - I_C R_C = V_{CC} - R_C h_{FE} \cdot I_B =$$

$$= 12 - R_C h_{FE} \left(\frac{u_{IN}}{15000} - 174 \cdot 10^{-6} \right) =$$

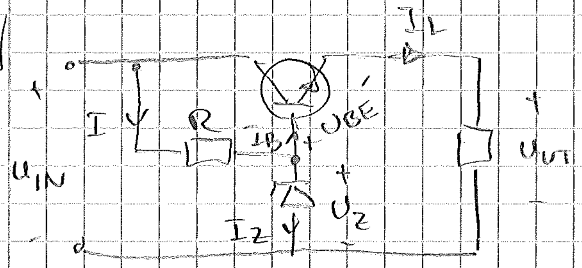
$$= 40{,}71 - 11\, u_{IN} \qquad \text{för} \quad 0{,}2V \leq u_{UT} \leq 12V$$

$$12 = 40{,}71 - 11\, u_{IN} \Rightarrow u_{IN} = 2{,}61 \text{ V}$$

$$0{,}2 = 40{,}71 - 11\, u_{IN} \Rightarrow u_{IN} = 3{,}68 \text{ V}$$



5.11



$35 \leq u_{IN} \leq 45 \text{ V}$

$u_{UT} = 25 \text{ V}$

$0 \leq I_L \leq 500 \text{ mA}$

$U_{BE} = 0{,}6 \text{ V} \quad h_{FE} = 30$

$I_Z \geq 5 \text{ mA}$

a) $\underline{\underline{U_Z}} = U_{UT} + U_{BE} = \underline{\underline{25{,}6 \text{ V}}}$

b) $I_{B_{max}} = \dfrac{I_{L_{max}}}{h_{FE}} = \dfrac{500 \text{ mA}}{30} = 16{,}7 \text{ mA}$

R ska alltid kunna ge strömmen $I = I_{B_{max}} + I_{Z_{min}} = 21{,}7 \text{ mA}$

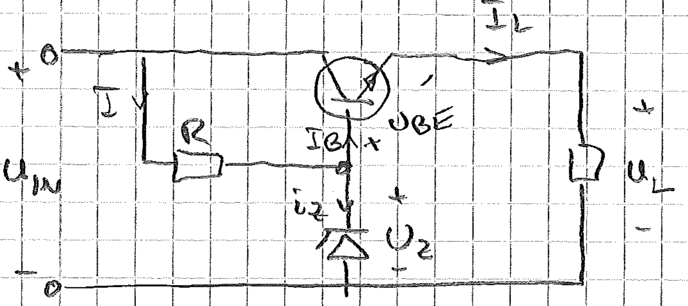
$$\underline{\underline{R_{max}}} = \frac{U_{IN_{min}} - U_Z}{I} = \frac{35 - 25{,}6}{21{,}7 \cdot 10^{-3}} = \underline{\underline{433\ \Omega}}$$

c) $\underline{\underline{P_{max}}} = (u_{IN_{max}} - u_{UT}) \cdot I_{L_{max}} = (45 - 25{,}6) \cdot 0{,}5 = \underline{\underline{9{,}7 \text{ W}}}$

d) Störst effekt i zener då I_L minimal och u_{IN} maximal

$I_{max} = \dfrac{u_{IN_{max}} - u_Z}{R} = \dfrac{45 - 25{,}6}{433} = 44{,}8 \text{ mA} \quad P_{Z_{max}} = U_Z \cdot I_{max} = 1{,}15 \text{ W}$

5.12



$u_{IN} = 20\ V$

Transistor: $U_{BE} = 0{,}7\ V \quad h_{FE} = 40 \quad P_{f_{max}} = 30\ W$

Zener: $U_Z = 11{,}0\ V \quad i_{Z_{min}} = 10\ mA \quad P_{Z_{max}} = 1{,}0\ W$

$R = 80\ \Omega$

$\underline{\underline{U_L}} = U_Z - U_{BE} = 11{,}0 - 0{,}7 = \underline{\underline{10{,}3\ V}}$

$I_{L_{min}}$ begränsas av hur mycket ström zenerdiod tål

$$I_{Z_{max}} = \frac{P_{Z_{max}}}{U_Z} = \frac{1{,}0}{11{,}0} = 90{,}9\ mA$$

$$I = \frac{U_{IN} - U_Z}{R} = \frac{20 - 11}{80} = 112{,}5\ mA$$

$$I_{B_{min}} = I - I_{Z_{max}} = 112{,}5 - 90{,}9 = 21{,}6\ mA$$

$$\underline{\underline{I_{L_{min}}}} = I_{B_{min}} + I_C = I_{B_{min}}(1 + h_{FE}) = 21{,}6 \cdot 10^{-3}(1+40) = \underline{\underline{0{,}886\ A}}$$

$I_{L_{max}}$ kan begränsas av $P_{f_{max}}$ eller $i_{Z_{min}}$

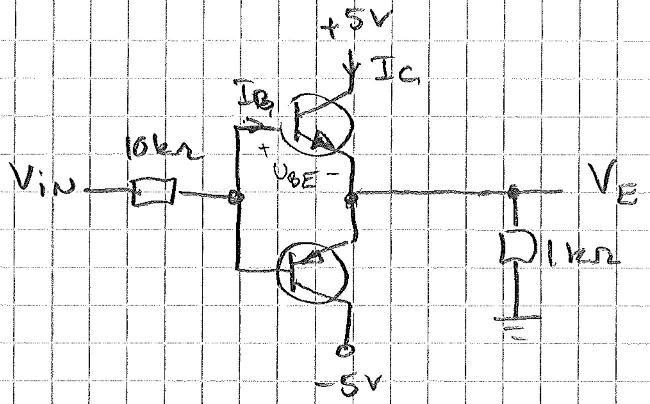
$$P_{f_{max}} = (U_{IN} - U_L) I_{L_{max}} \Rightarrow \underline{\underline{I_{L_{max}}}} = \frac{P_{f_{max}}}{U_{IN} - U_L} = \frac{30}{9{,}7} = \underline{\underline{3{,}09\ A}}$$

$$I_{B_{max}} = I - I_{Z_{min}} = 112{,}5 - 10 = 102{,}5\ mA$$

$$I_{L_{min}} = I_{B_{max}}(1 + h_{FE}) = 102{,}5 \cdot 10^{-3}(1+40) = 4{,}2\ A$$

$P_{f_{max}}$ begränsar. $\Rightarrow \underline{\underline{0{,}886\ A \le I_L \le 3{,}09\ A}}$

5.17



$B = h_{FE} = 100$

$|U_{BE}| = 0{,}7V$

a) $V_{IN} = 0 \Rightarrow$ Båda transistorer spärrar $\Rightarrow V_E = 0$

b) $V_{IN} = +3V \Rightarrow$ NPN leder PNP spärrar

$$\begin{cases} 3 - 10 \cdot 10^3 I_B - U_{BE} - (I_B + I_C) \cdot 10^3 = 0 \\ I_C = h_{FE} \cdot I_B \end{cases} \Rightarrow$$

$$3 - U_{BE} - 10 \cdot 10^3 I_B - I_B(1 + h_{FE}) \cdot 10^3 = 0$$

$$I_B = \frac{3 - U_{BE}}{10 \cdot 10^3 + (1 + h_{FE}) \cdot 10^3} = \frac{3 - 0{,}7}{10 \cdot 10^3 + 101 \cdot 10^3} =$$

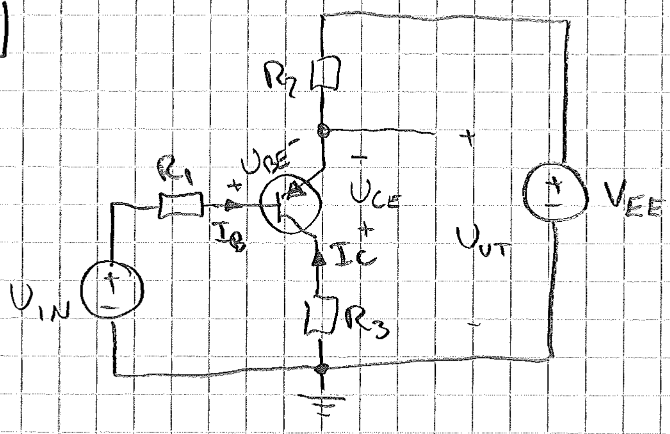
$$= 20{,}72 \, \mu A$$

$$V_E = (I_B + I_C) \cdot 1k\Omega = I_B(1 + h_{FE}) \cdot 10^3 = 20{,}72 \cdot 10^{-6} \cdot (101) \cdot 10^3 =$$

$$= 2{,}09 V$$

c)

5.18



$V_{EE} = 10V$

$R_1 = 15 k\Omega$

$R_2 = R_3 = 1 k\Omega$

$U_{BE} = -0,7V$

$U_{CEsat} = 0 V$

$h_{FE} = 25$

$$U_{IN} - R_1 I_B - U_{BE} - R_2(I_B + I_C) - V_{EE} = 0 \quad (1)$$

$$V_{EE} + R_2(I_B + I_C) + U_{CE} + R_3 I_C = 0 \quad (2)$$

ur (1) $$U_{IN} - R_1 \frac{I_C}{h_{FE}} - U_{BE} - R_2 I_C \left(1 + \frac{1}{h_{FE}}\right) - V_{EE} = 0$$

$$I_C = \frac{U_{IN} - U_{BE} - V_{EE}}{\frac{R_1}{h_{FE}} + R_2\left(1 + \frac{1}{h_{FE}}\right)} \quad (3)$$

ur (2) $$U_{CE} = -V_{EE} - I_C\left(R_3 + R_2\left(1 + \frac{1}{h_{FE}}\right)\right) \quad (4)$$

---

a) $U_{IN} = 7,5V$

ur (3) $$I_C = \frac{7,5 - (-0,7) - 10}{\frac{15000}{25} + 1000\left(1 + \frac{1}{25}\right)} = -1,10 \text{ mA}$$

$$\underline{\underline{U_{UT}}} = V_{EE} + R_2(I_C + I_B) = V_{EE} + R_2 I_C \left(1 + \frac{1}{h_{FE}}\right) =$$

$$= 10 + 1000 \cdot (-1,10 \cdot 10^{-3})\left(1 + \frac{1}{25}\right) = \underline{\underline{8,86V}}$$

$\boxed{5.18b}$ $U_{CE} = 0$

Ur ④ $I_C = \dfrac{-V_{EE} - U_{CE}}{R_3 + R_2\left(1 + \frac{1}{h_{FE}}\right)} =$

$= \dfrac{+10 - 0}{1000 + 1000\left(1 + \frac{1}{25}\right)} = -4{,}90\ mA$

Ur ① $\underline{\underline{U_{IN}}} = V_{EE} + U_{BE} + I_C\left(\dfrac{R_1}{h_{FE}} + R_2\left(\dfrac{1}{h_{FE}} + 1\right)\right) =$

$= 10 - 0{,}7 - 4{,}90 \cdot 10^{-3}\left(\dfrac{15000}{25} + 1000\left(\dfrac{1}{25} + 1\right)\right) =$

$= \underline{\underline{1{,}26\ V}}$

53

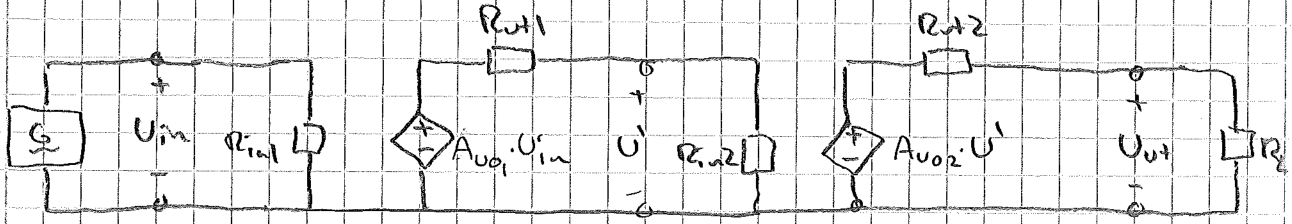
7.1 a) $A_p = \frac{P_{ut}}{P_{in}} = \frac{230 \cdot 10^{-3}}{1{,}3 \cdot 10^{-6}} = 177\,000$

b) $A_p = \frac{P_{ut}}{P_{in}} = \frac{600 \cdot 10^{-3}}{265 \cdot 10^{-9}} = 2{,}3 \cdot 10^{6}$

7.2 a) $|A_u| = \frac{|U_{ut}|}{|U_{in}|} = \frac{50 \cdot 10^{-3}}{2 \cdot 10^{-3}} = 25$

b) $|A_u| = \frac{|U_{ut}|}{|U_{in}|} = \frac{12 \cdot 10^{-3}}{15 \cdot 10^{-3}} = 0{,}8$

7.6



$R_{in1} = 800\,\Omega \quad A_{uo1} = 100 \quad R_{ut1} = 1{,}2\,k\Omega \quad R_{in2} = 350\,\Omega \quad A_{uo2} = 150$

$R_{ut2} = 880\,\Omega$

a) $R_L = 1{,}3\,k\Omega$

$$\begin{cases} U_{ut} = \frac{R_L}{R_L + R_{ut2}} \cdot A_{uo2} \cdot U' \\ U' = \frac{R_{in2}}{R_{in2} + R_{ut1}} \cdot A_{uo1} \cdot U_{in} \end{cases} \Rightarrow$$

$$U_{ut} = \frac{R_L}{R_L + R_{ut2}} \cdot A_{uo2} \cdot \frac{R_{in2}}{R_{in2} + R_{ut1}} \cdot A_{uo1} \cdot U_{in}$$

$$\underline{\underline{A_u}} = \frac{U_{ut}}{U_{in}} = \frac{R_L}{R_L + R_{ut2}} \cdot A_{uo2} \cdot \frac{R_{in2}}{R_{in2} + R_{ut1}} A_{uo1} = \quad 1$$

$$= \frac{1300}{1300 + 880} \cdot 150 \cdot \frac{350}{350 + 1200} \cdot 100 = \underline{\underline{2020}}$$

7.6 b) Ur (1)

$$2500 = \frac{R_L}{R_L+880} \cdot 150 \cdot \frac{350}{350+1200} \cdot 100$$

$$0,738 = \frac{R_L}{R_L+880}$$

$$0,738 R_L + 649,5 = R_L$$

$$R_L = \frac{649,5}{1-0,738} = 2479$$

Då R_L ökar ökar A_v $\Rightarrow$ $\underline{\underline{R_L \geq 2479\ \Omega}}$

---

c) $$A_p = \frac{P_{ut}}{P_{in}} = \frac{\frac{U_{ute}^2}{R_L}}{\frac{U_{ine}^2}{R_{inl}}} = \left(\frac{U_{ute}}{U_{ine}}\right)^2 \cdot \frac{R_{inl}}{R_L} = A_v^2 \cdot \frac{R_{inl}}{R_L}$$

Ur (1) $$A_v = \frac{R_L}{R_L+880} \cdot 150 \cdot \frac{350}{350+1200} \cdot 100 = \frac{R_L}{R_L+880} \cdot 3387$$

$$A_p = A_v^2 \cdot \frac{R_{inl}}{R_L} = \left(\frac{R_L}{R_L+880}\right)^2 \cdot 3387^2 \cdot \frac{800}{R_L} =$$

$$= \frac{R_L}{(R_L+880)^2} \cdot 9,177 \cdot 10^9$$

Givet $\underline{A_p \geq 60\ dB} = 10^{\frac{60}{10}} = \underline{10^6}$ $\quad \underline{\underline{A_p \geq 10^6}}$

Räkna gränserna då $A_p = 10^6$

$$10^6 = \frac{R_L}{(R_L+880)^2} \cdot 9,177 \cdot 10^9$$

$$(R_L+880)^2 = R_L \cdot 9177$$

$$R_L^2 - 7417 R_L + 774400 = 0$$

7.6, c) forts

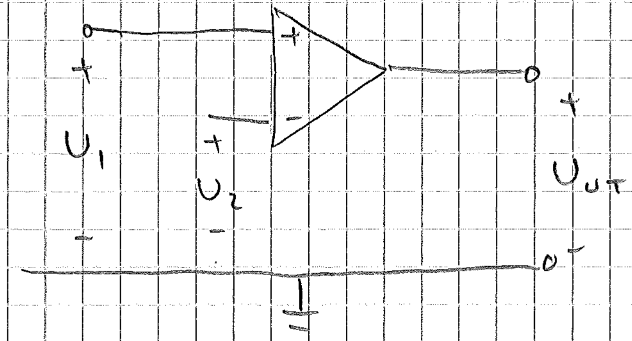
$$R_L = \frac{7417}{2} \pm \sqrt{\left(\frac{7417}{2}\right)^2 - 774400} =$$

$$= \begin{cases} 7311\ \Omega \\ 106\ \Omega \end{cases}$$

Max effektförstärkning fås vid effektanpassning d v s $R_L = R_{utz} = 880\ \Omega$. $\Rightarrow$

$A_p > 10^6$ då $106\ \Omega < R_L < 7311\ \Omega$

7.8



(1) $U_{UT} = A_{UCM} \cdot U_{CM} + A_{UDM} U_{DM}$ $\qquad U_{CM} = \frac{U_1 + U_2}{2}$ $\qquad U_{DM} = U_1 - U_2$

Mätning 1 $\qquad U_{CM} = \frac{6{,}02 + 5{,}98}{2} = 6{,}0\text{ V}$

$U_{DM} = 6{,}02 - 5{,}98 = 0{,}04\text{ V}$ $\qquad U_{UT} = 4{,}12\text{ V}$

Mätning 2 $\qquad U_{CM} = \frac{0{,}03 - 0{,}03}{2} = 0$ $\qquad U_{UT} = 6{,}00\text{ V}$

$U_{DM} = 0{,}03 - (-0{,}03) = 0{,}06\text{ V}$

Mätningar insatt i (1) ger

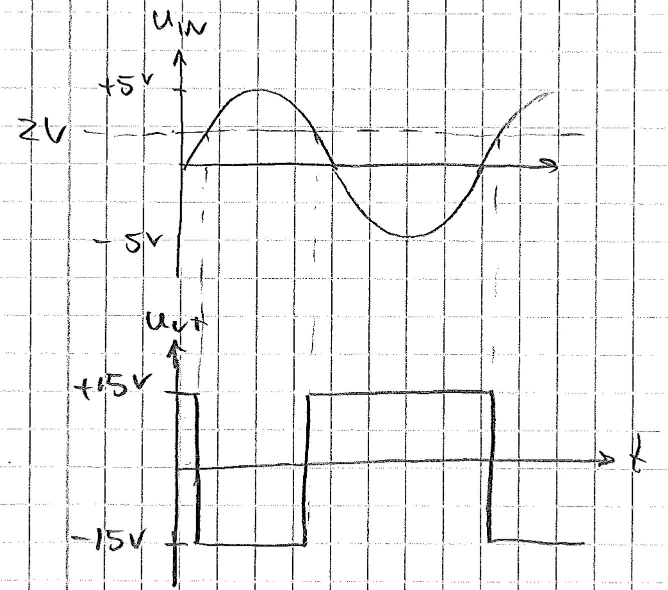
$$\begin{cases} 6{,}0\, A_{UCM} + 0{,}04\, A_{UDM} = 4{,}12 \\ 0 \cdot A_{UCM} + 0{,}06\, A_{UDM} = 6{,}00 \end{cases} \Rightarrow \begin{aligned} A_{UDM} &= 100 \\ A_{UCM} &= 0{,}02 \end{aligned}$$

$$\underline{\underline{CMRR}} = 20 \log \left| \frac{A_{UDM}}{A_{UCM}} \right| = 20 \log \left| \frac{100}{0{,}02} \right| = \underline{\underline{74\text{ dB}}}$$

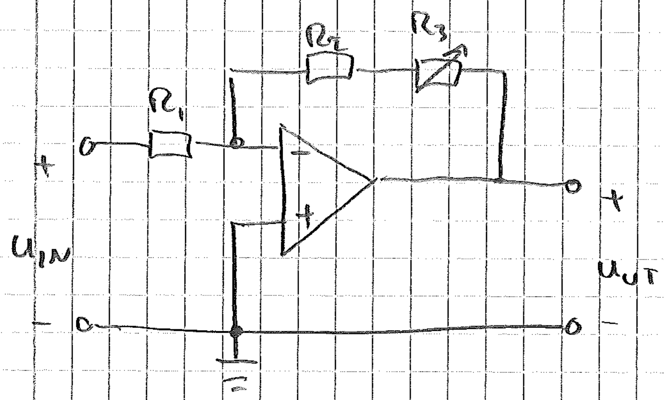
9.1 Komparator

$u_{UT} = +15V$ då $u_{in} < 2V$

$u_{UT} = -15V$ då $u_{IN} > 2V$



9.2



Inverterande koppling $\Rightarrow$ $A_v = -\dfrac{R_2+R_3}{R_1}$

$$|A_v| = \frac{R_2+R_3}{R_1}$$

$$|A_v|_{min} = \frac{2200+0}{2200} = 1$$

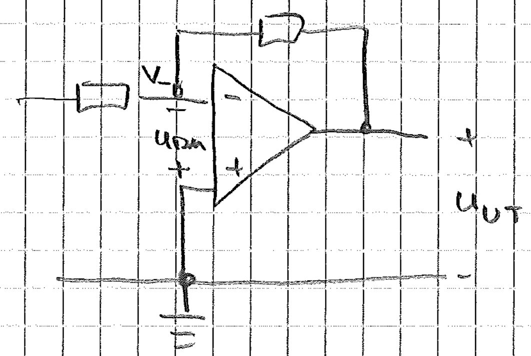
$$|A_v|_{max} = \frac{2200+100000}{2200} = 46,5$$

9.3 Icke-inverterande koppling

$$A_u = \frac{10R + R}{R} = 11$$

$$\underline{\underline{u_{UT}}} = A_u \cdot u_{IN} = 11 \cdot 200\,mV = \underline{\underline{2{,}2\,V}}$$

9.4



$$A_{u0} = 10\,000$$

$$u_{UT} = A_{u0} \cdot u_{DM} \Rightarrow$$

$$u_{DM} = \frac{u_{UT}}{A_{u0}}$$

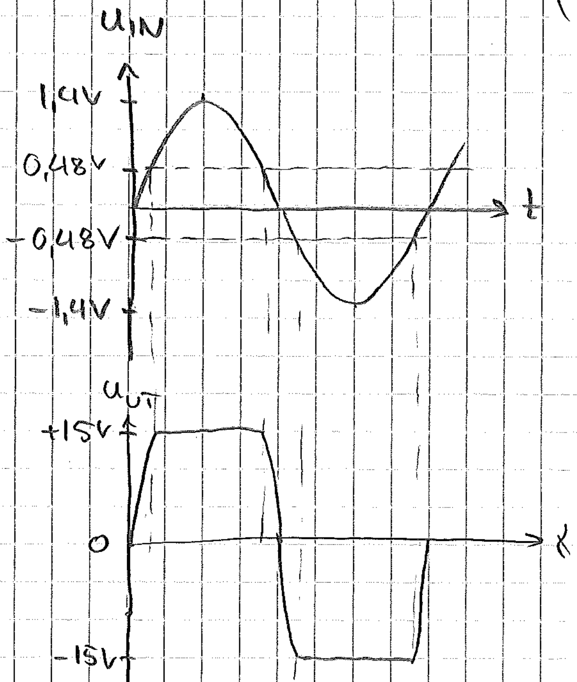
$$V_- = -u_{DM} = -\frac{u_{UT}}{A_{u0}}$$

$$\text{Max } V_- \Rightarrow \underline{\underline{V_-}} = -\frac{u_{UT\,min}}{A_{u0}} = -\frac{-12}{10000} = \underline{\underline{1{,}2\,mV}}$$

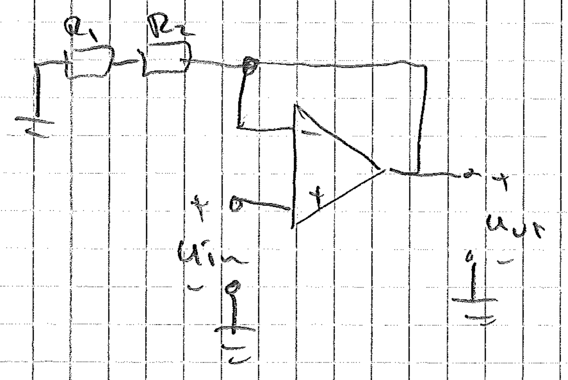
9.5 Icke inverterande koppling

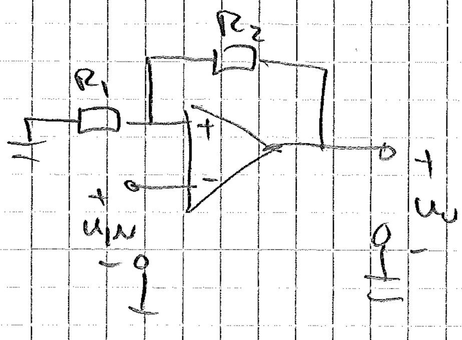
$$\underline{A_u} = \frac{R_1+R_2}{R_1} = \frac{1+30}{1} = \underline{31}$$

Förstärkaren överstyrs då
$$\begin{cases} u_{in} = \dfrac{u_{UTmax}}{A_u} = \dfrac{15}{31} = 0{,}48\ V \\ u_{in} = \dfrac{u_{UTmin}}{A_u} = \dfrac{-15}{31} = -0{,}48\ V \end{cases}$$



9.6 Icke Inverterande koppling





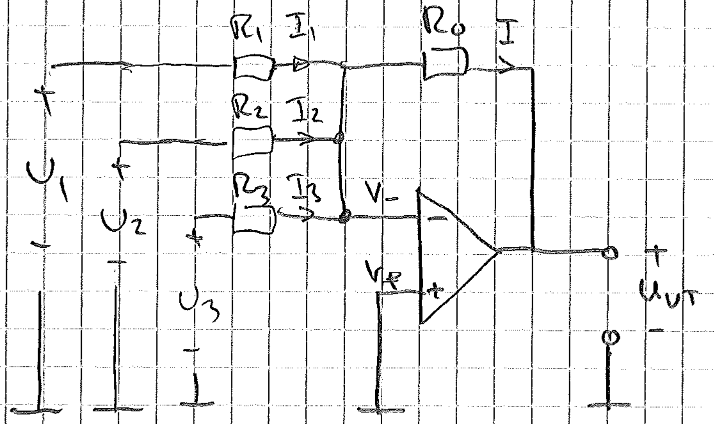
$R_1 = 100\ \Omega$

$R_2 = 10\ k\Omega$

$$\underline{A_{umin}} = \frac{0+(R_1+R_2)}{R_1+R_2} = \underline{1}$$

$$\underline{A_{umax}} = \frac{R_1+R_2}{R_1} = \frac{100+10000}{100} = \underline{101}$$

9.10



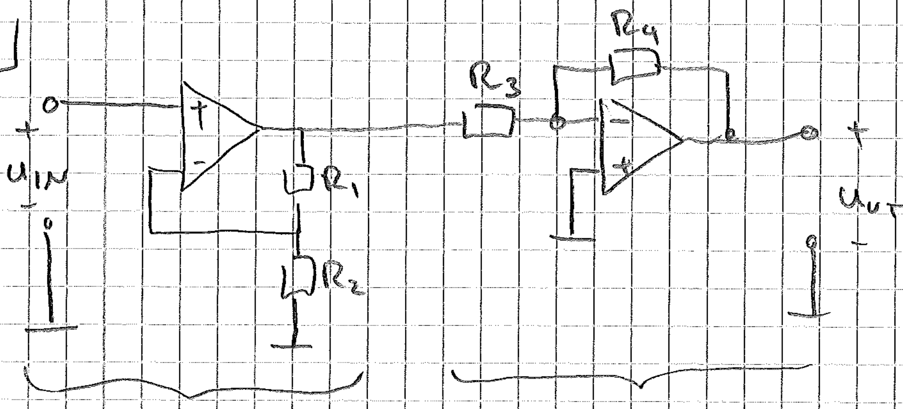
Ideal OP negativt återkopplad: $V_- = V_+ = 0$

$$I = I_1 + I_2 + I_3 = \frac{U_1}{R_1} + \frac{U_2}{R_2} + \frac{U_3}{R_3}$$

$$\underline{\underline{U_{UT}}} = -R_0 \cdot I = -\left(\frac{R_0}{R_1}U_1 + \frac{R_0}{R_2}U_2 + \frac{R_0}{R_3}U_3\right) =$$

$$= -\left(\frac{10k}{5k} \cdot 1{,}2V + \frac{10k}{10k} \cdot (-3{,}5V) + \frac{10k}{20k} \cdot 2{,}8V\right) = \underline{\underline{-0{,}3V}}$$

9.11



Icke inverterande

$$A_{u_1} = \frac{R_1 + R_2}{R_2}$$

Inverterande

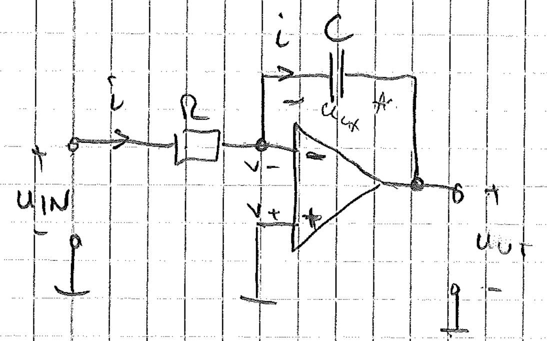
$$A_{u_2} = -\frac{R_4}{R_3}$$

Totalt $$\underline{\underline{A_u}} = A_{u_1} \cdot A_{u_2} = -\frac{R_1 + R_2}{R_2} \cdot \frac{R_4}{R_3} = -\frac{39k + 2{,}2k}{2{,}2k} \cdot \frac{39k}{2{,}2k} =$$

$$= \underline{\underline{-332}}$$

9.14

(a)



$R = 1\,k\Omega$

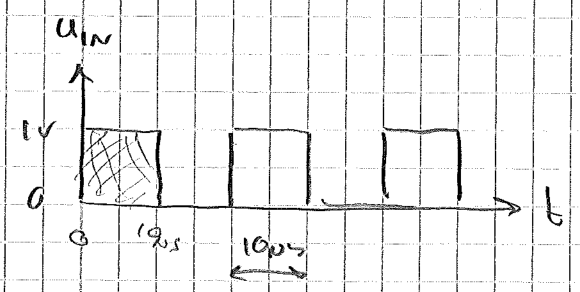
$C = 1\mu F$

Ideal op, neg. återkopplad $\Rightarrow$ $V_- = V_+ = 0$

$i_+ = i_- = 0$

$$\begin{cases} i = \dfrac{u_{in}}{R} \\ i = -C\dfrac{du_{UT}}{dt} \end{cases} \Rightarrow \frac{du_{UT}}{dt} = -\frac{1}{RC}u_{IN} \Rightarrow$$

$$u_{UT} = -\frac{1}{RC}\int_{-\infty}^{t} u_{in}\,dt$$



1 puls på 10µs ändrar utsignalen $\Delta u_{UT} = -\dfrac{1}{RC}\displaystyle\int_0^{10\mu s} 1\,dt =$

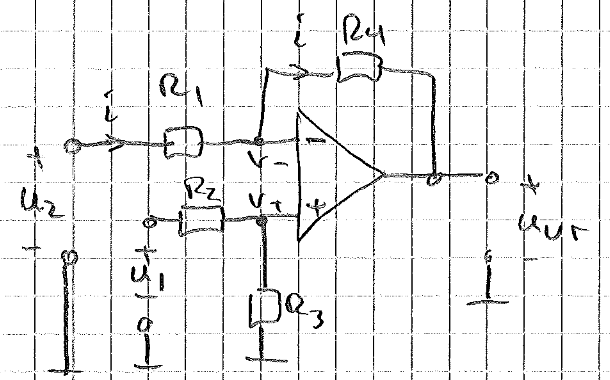
$$= -\frac{1}{RC}\cdot 10\cdot 10^{-6} =$$

$$= -\frac{1}{10^3\cdot 10^{-6}}\cdot 10\cdot 10^{-6} = -0{,}01V$$

För att ändra utsignal 1 V

krävs $\dfrac{1V}{0{,}01V/\text{puls}} = \underline{\underline{100 \text{ pulser}}}$

9.17



a) $R_1 = R_2 = 100\,\Omega$

$R_3 = R_4 = 100\,k\Omega$

FS $u_{UT} = \frac{R_4}{R_1}(u_2 - u_1)$

$$\underline{\underline{A_{u_{DM}}}} = \frac{u_{UT}}{u_2 - u_1} = \frac{R_4}{R_1} = \frac{100 \cdot 10^3}{100} = \underline{\underline{1000}}$$

b) $R_1 = 100\,\Omega$ $R_2 = 98\,\Omega$ $R_3 = 102\,k\Omega$ $R_4 = 100\,k\Omega$

Ideal OP neg återkoppl $V_+ = V_-$

$$V_+ = \frac{R_3}{R_3 + R_2} \cdot u_1 \quad (1)$$

$$\frac{u_2 - V_-}{R_1} = \frac{V_- - u_{UT}}{R_4} \Rightarrow V_- = \frac{R_4}{R_1 + R_4} u_2 + \frac{R_1}{R_1 + R_4} \cdot u_{UT} \quad (2)$$

$V_+ = V_-$ ger

$$\frac{R_3}{R_3 + R_2} \cdot u_1 - \frac{R_4}{R_1 + R_4} \cdot u_2 = \frac{R_1}{R_1 + R_4} u_{UT} \Rightarrow$$

$$0{,}99904\, u_1 - 0{,}99900\, u_2 = 0{,}000999\, u_{UT}$$

$$u_{UT} = 1000{,}040\, u_1 - 1000{,}000\, u_2$$

Ur FS $u_{UT} = A_{u_{DM}} u_{DM} + A_{u_{CM}} \cdot u_{CM} = A_{u_{DM}}(u_1 - u_2) + A_{u_{CM}} \frac{u_1 + u_2}{2}$

$$= \left(A_{u_{DM}} + \frac{A_{u_{CM}}}{2}\right) u_1 - \left(A_{u_{DM}} - \frac{A_{u_{CM}}}{2}\right) u_2$$

9,17 Forts

(63)

$$\text{ID} \begin{cases} A_{vDM} + \dfrac{A_{vcm}}{2} = 1000{,}040 & (3) \\ A_{vDM} - \dfrac{A_{vcm}}{2} = 1000{,}000 & (4) \end{cases}$$

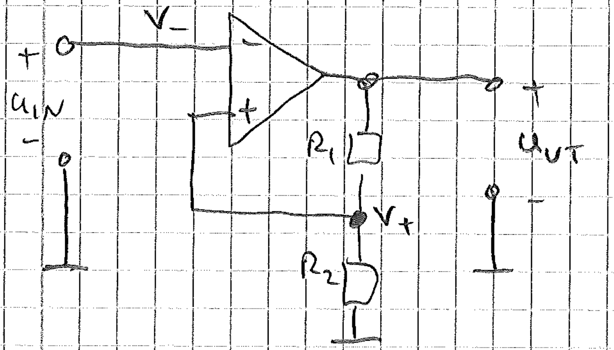
$(3)+(4) \Rightarrow A_{vDM} = 1000{,}020$

$(3)-(4) \Rightarrow A_{vcm} = 0{,}040$

$$\underline{\underline{CMRR}} = 20\log\left|\frac{A_{vDM}}{A_{vcm}}\right| = 20\log\left|\frac{1000{,}020}{0{,}040}\right| = \underline{\underline{88\,dB}}$$

9.18

a)



$u_{UT_{max}} = +15V$

$u_{UT_{min}} = -15V$

$R_1 = 10\,k\Omega$ $R_2 = 1,5\,k\Omega$

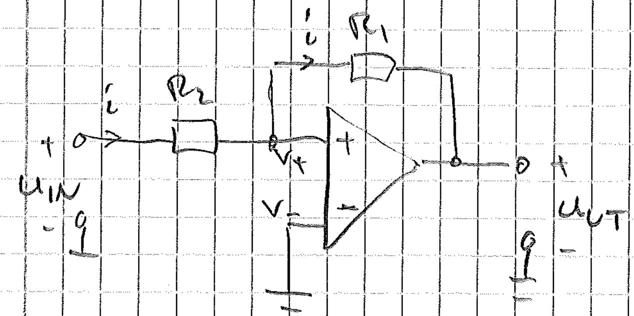
Antag $u_{UT} = U_{UT_{max}} = +15V$

$$\underline{\underline{V_+}} = \frac{R_2}{R_1+R_2} \cdot u_{UT_{max}} = \frac{1,5k}{10k+1,5k} \cdot 15V = \underline{\underline{1,96V}}$$ Övre omslagsnivå

Antag $u_{UT} = u_{UT_{min}} = -15V$

$$\underline{\underline{V_+}} = \frac{R_2}{R_1+R_2} \cdot u_{UT_{min}} = \underline{\underline{-1,96V}}$$ Undre omslagsnivå

b)



$R_1 = 10\,k\Omega$

$R_2 = 1,5\,k\Omega$

Slår om då $V_+ = V_-$. I figur $\underline{\underline{V_- = 0}}$

Undre omslagsnivå

Antag $u_{ut} = u_{ut_{max}} = +15V$

$$u_{UT} = -R_1 \cdot i = -R_1 \frac{u_{IN}}{R_2} \Rightarrow$$

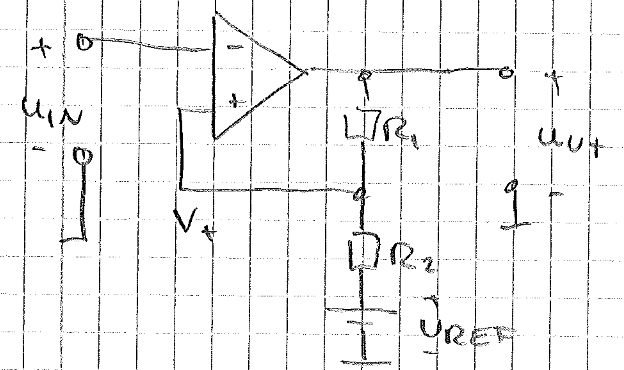
$$\underline{\underline{u_{in}}} = -\frac{R_2}{R_1} u_{ut} = -\frac{R_2}{R_1} U_{UT_{max}} = -\frac{1,5}{10} \cdot 15 = \underline{\underline{-2,25V}}$$

Övre omslagsnivå

Anta $U_{ut} = u_{ut_{min}} = -15V$

$$\underline{\underline{u_{in}}} = -\frac{R_2}{R_1} \cdot u_{UT_{min}} = \frac{1,5k}{10k} \cdot 15 = \underline{\underline{2,25V}}$$

9.19



$R_1 = 10\,k\Omega$

$u_{UTmax} = 15V$

$u_{UTmin} = -15V$

Övre omslagsnivå +5V då $u_{UT} = u_{UTmax} = +15V$

$$V_+ = U_{REF} + (u_{UTmax} - U_{REF}) \cdot \frac{R_2}{R_1 + R_2} \Rightarrow$$

$$5 = U_{REF} + (15 - U_{REF}) \cdot \frac{R_2}{R_1 + R_2} \quad (1)$$

Undre omslagsnivå +2V då $u_{UT} = u_{UTmin} = -15V$

$$V_+ = U_{ref} + (u_{UTmin} - U_{ref}) \cdot \frac{R_2}{R_1 + R_2}$$

$$2 = U_{ref} + (-15 - U_{ref}) \cdot \frac{R_2}{R_1 + R_2} \quad (2)$$

Ur (1) e (2) Lös ut $\begin{cases} U_{REF} = 3,89V \\ R_2 = 1,11\,k\Omega \end{cases}$