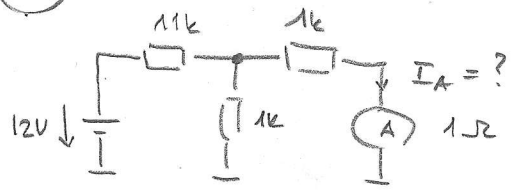
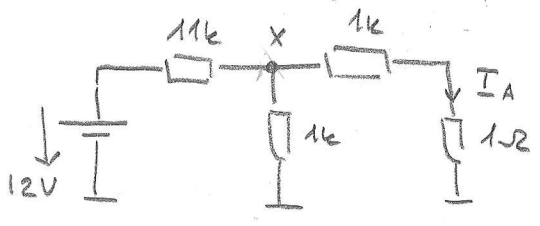


1a



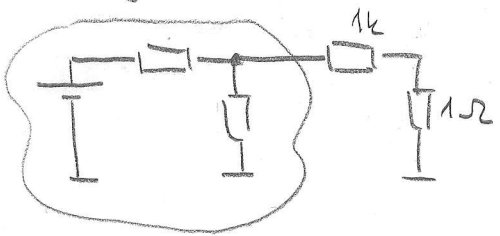
matručna rešitev:



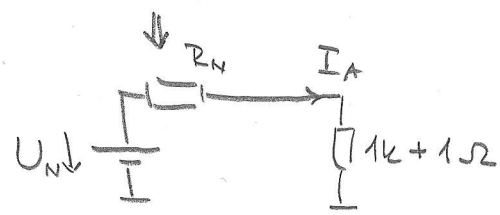
$$\frac{x-12V}{11k} + \frac{x}{1k} + \frac{x}{1k+1} = 0 \Rightarrow x = \frac{273}{253} = 0,52V$$

$$I_A = \frac{0,52V}{1001} = \underline{\underline{0,52mA}}$$

po bližnjici 1: Thevenin



$$R_N = 11k \parallel 1k = \frac{11k \cdot 1k}{11k + 1k} = 916 \Omega$$

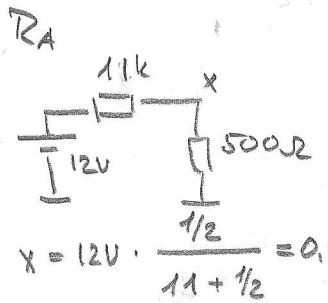
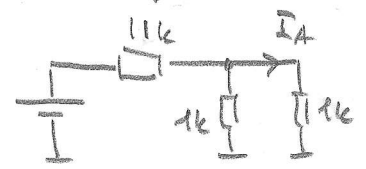


$$U_N = 12V \cdot \frac{1k}{1k + 11k} = 1V$$

$$I_A = \frac{U_N}{R_N + 1k + 1\Omega} = \underline{\underline{0,52mA}}$$

po bližnjici 2: približno

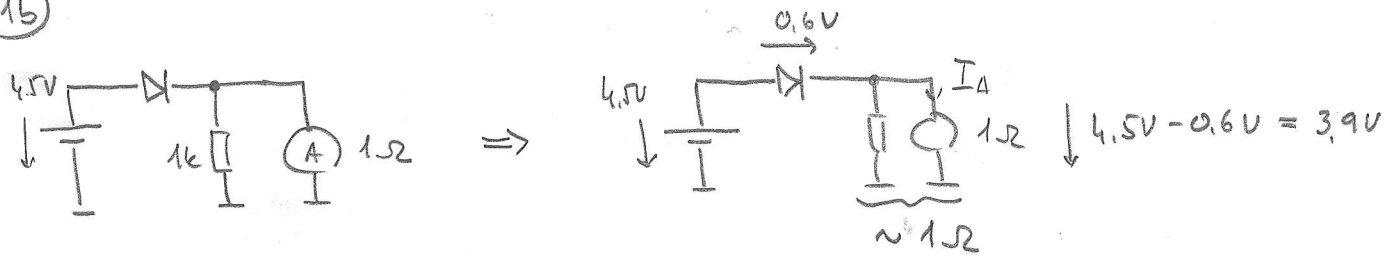
$R_{\text{ampermetra}} \ll 1k \Rightarrow$  zanemariti  $R_A$   
nova shema



$$x = 12V \cdot \frac{1/2}{11 + 1/2} = 0,52$$

$$\text{torej } I_A = \frac{x}{1k} = 0,52 mA$$

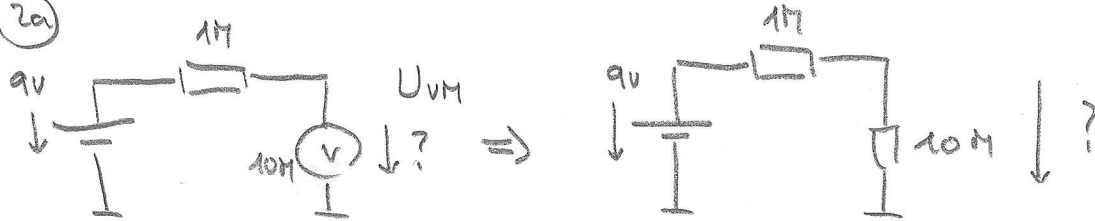
1b



$$I_A = \frac{3.9V}{1\Omega} = 3.9A$$

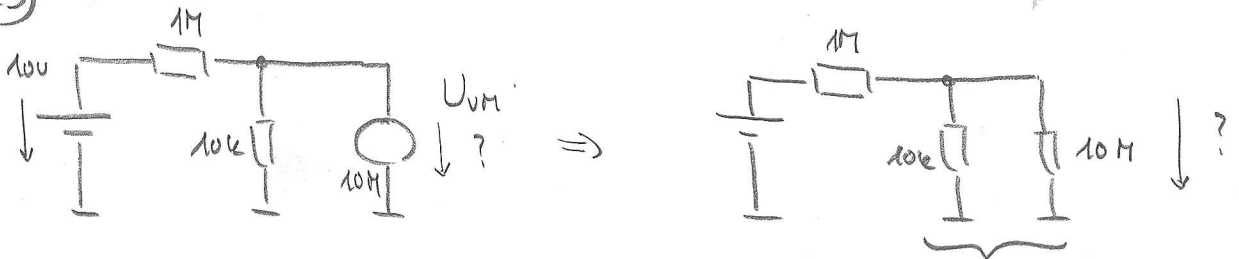
to je preveč za diodo, ži izpovni!

2a



$$U_{VM} = 9V \frac{10M}{10M + 1M} = 8.18V$$

2b

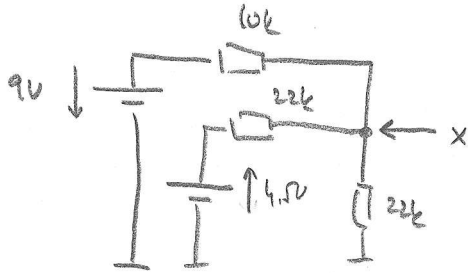
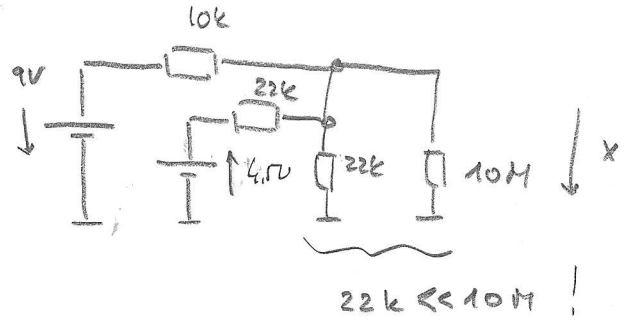
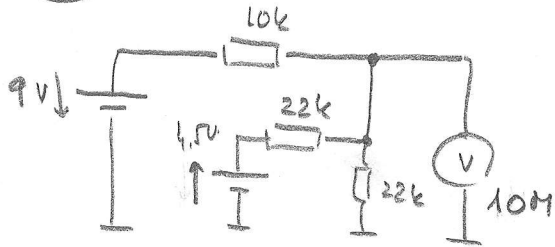


$$10k \parallel 10M \approx 10k$$

$$U_{VM} \approx 10V \frac{10k}{10k + 1M} \approx 99mV$$

$$U_{VM} = 10V \frac{10k \parallel 10M}{10k \parallel 10M + 1M} = \frac{9.99k \cdot 10V}{9.99k + 1M} = 0.0999V$$

2c

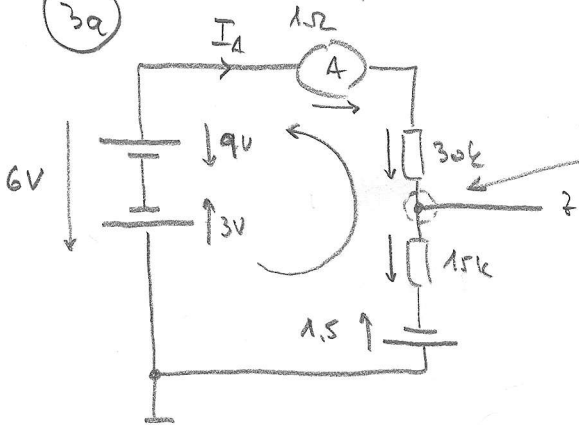


$$\frac{X - 9V}{10k} + \frac{X + 4.5V}{22k} + \frac{X}{22k} = 0$$

↓

$$\underline{X = +3.6V}$$

3a



$1\Omega \ll 30k \Rightarrow$  70% memori  $1\Omega$

$$\sum I = 0$$

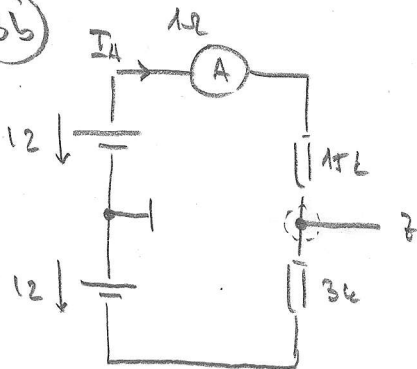
$$\frac{Z - (-1.5V)}{15k} + \frac{Z - 6V}{30k} = 0$$

↓

$$\underline{Z = 1V}$$

$$\underline{I_A} = \frac{6V - Z}{30k} = \frac{5V}{30k} = \underline{160\mu A}$$

3b



$1\Omega \ll 15k \Rightarrow$  70% memori  $1\Omega$

$$\sum I = 0$$

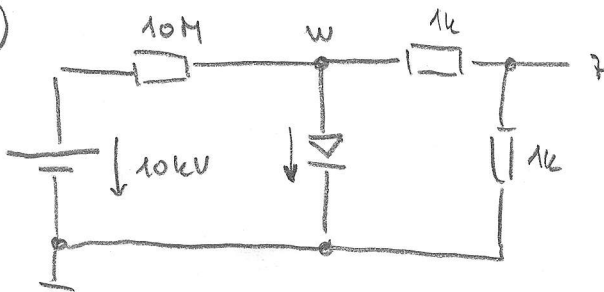
$$\frac{Z - 12V}{15k} + \frac{Z - (-12V)}{3k} = 0$$

↓

$$Z = -8V$$

$$I_A = \frac{12V - Z}{15k} = \frac{12V + 8V}{15k} = \underline{1.33mA}$$

3c

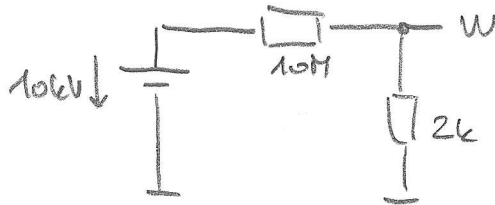


⇒ ali teče skozi diodo kolikoli?

1. NE: napetost Z manjšaja od 0.6V

2. DA: napetost Z je 0.6/2

test: napetost v točki W taktmet, če ni diode:



$$\Rightarrow W = 10 \text{ kV} \cdot \frac{2 \text{ k}}{10 \text{ M} + 2 \text{ k}} = \underline{\underline{1.999 \text{ V}}}$$

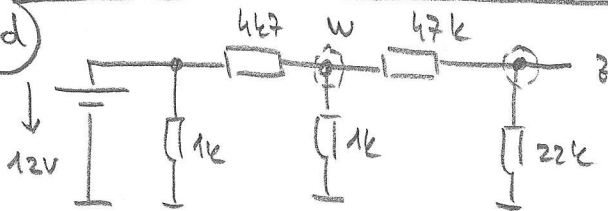
map. v W hi bila kraj > 0.6V

↓  
skozi diodo teče kolikoli

kraj velja 2

$$Z = 0.6 \text{ V} / 2 = \underline{\underline{0.3 \text{ V}}}$$

3d



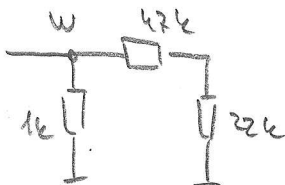
a) napišiti sistem: 2 vozl. en.  
za W in Z, napišiti sistem

$$W, Z$$

$$\left. \begin{aligned} \frac{W - 12 \text{ V}}{4 \text{ k}7} + \frac{W}{1 \text{ k}} + \frac{W - Z}{47 \text{ k}} &= 0 \\ \frac{Z - W}{47 \text{ k}} + \frac{Z}{22 \text{ k}} &= 0 \end{aligned} \right\} \Rightarrow$$

$$\underline{\underline{W, Z}}$$

približki: Z glavo



$$47 \text{ k} + 22 \text{ k} = 69 \text{ k} \gg 1 \text{ k}$$

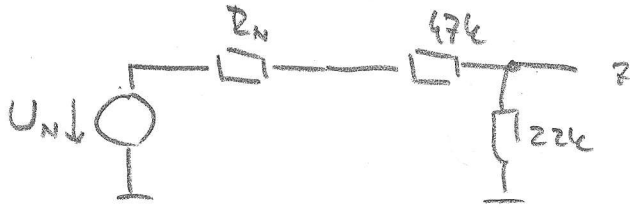
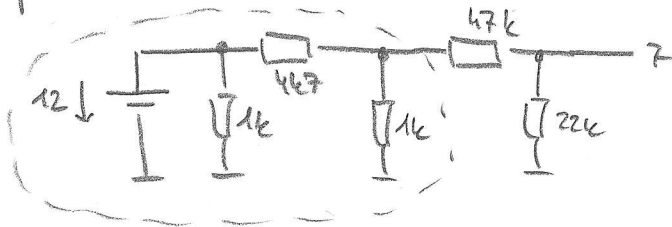
$$\text{kraj: } 1 \text{ k} \parallel 69 \text{ k} \approx 1 \text{ k}$$

$$\text{Zato: } W = 12 \cdot \frac{1 \text{ k}}{4 \text{ k}7 + 1 \text{ k}} = \underline{\underline{2.1 \text{ V}}}$$

in še:

$$Z = W \cdot \frac{22 \text{ k}}{47 \text{ k} + 22 \text{ k}} = \underline{\underline{0.67 \text{ V}}}$$

prbl: z Theveninom



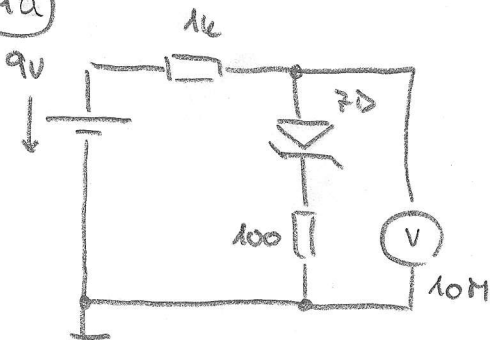
$$R_N = 1k \parallel 4k7 = 825 \Omega$$

$$U_N = 12 \frac{1k}{1k + 4k7} = 2.1V$$

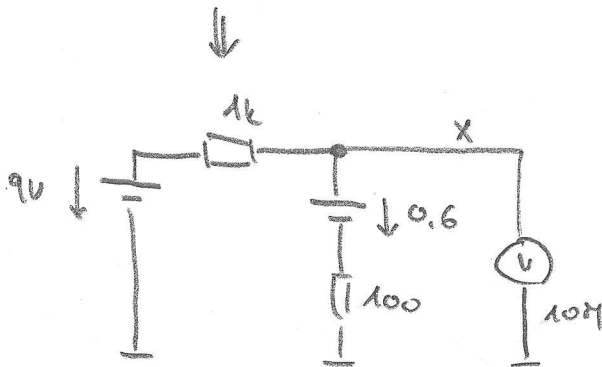
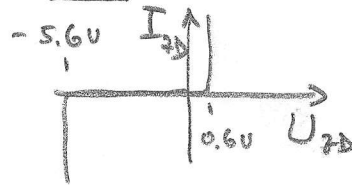
potem:

$$z = 2.1V \frac{22k}{22k + 47k + 825 \Omega} = \underline{\underline{0.66V}}$$

4a



① ZD je polarizirana v prevodni smeri  $\Rightarrow$  skrajno leče kol  
na njej je 0.6V



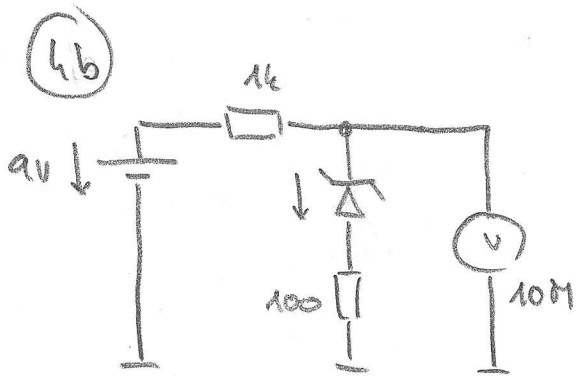
$$\sum I = 0$$

$\downarrow$

$$\frac{x-9}{1k} + \frac{x-0.6}{100} + \frac{x}{10M} = 0$$

7omelomni

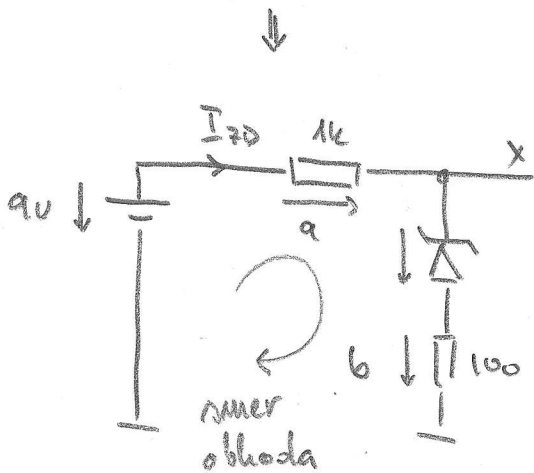
$$x = 1.36V$$



približje:  $10M \gg 100 \Omega$

$10M \gg 1k$

pri očitovanju zanemarljivo  
toda sledi: V Meter



7D je polarizirana v  
zaporni smeri; če sledimo me  
bi tekel tok, bi bila napetost  
v točki  $x = 9V$ , ma 7Diodi  
pa teh  $9V > U_{7D}$

↓  
torej teče tokoz: 7D vol, napetost  
ma mjej pa je  $U_{7D} = 5,6V$

$$I_{7D}: \sum U = 0$$

$$-9V + I_{7D} \cdot 1k + U_{7D} + I_{7D} \cdot 100 = 0$$

↓

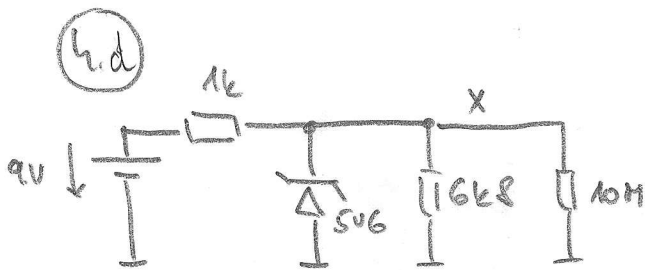
$$I_{7D} = 3,1mA$$

↓

$$b = I_{7D} \cdot 100 \Omega = 310mV$$

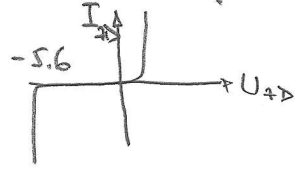
↓

$$x = b + U_{7D} = \underline{\underline{5,91V}}$$



$R_{VM} \gg 6k\Omega \Rightarrow$  zanemaranje tok  
skoz VM

① kolikšna je vrednost  $x$ , če skozi  $z$ -diodo ni toka?



$U > 5.6V \Rightarrow$  dioda prevaja, na  
mjej je tako 5.6V

$U < 5.6V \Rightarrow$  dioda ne prevaja,  
kot da je ni v vezju

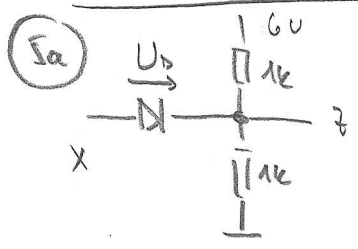
$$x = 9V \frac{6.8k}{6.8k + 1k} = 7.8V > 5.6V$$

$\Downarrow$   
zD prevaja, na mjej  
je dejansko 5.6V

$x = 5.6V$ , to merimo V-meter

skoz diodo teče tok:

$$I_{zD} = \frac{9V - 5.6V}{1k} - \frac{5.6V}{6.8k} = 2.58mA$$



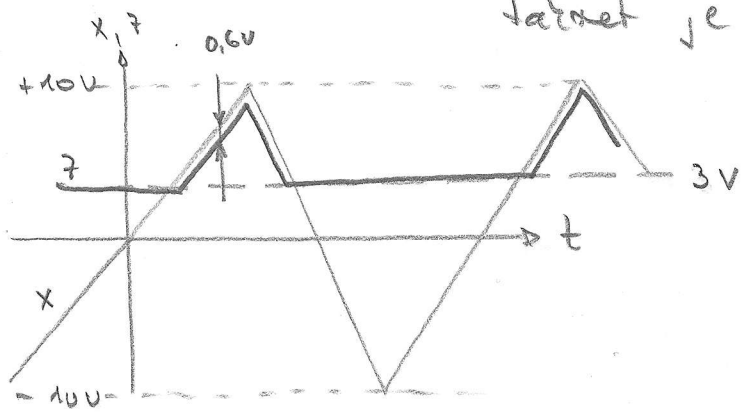
① če dioda ne prevaja, je  $z = \frac{6V}{2} = 3V$

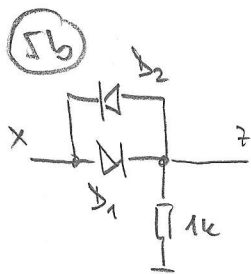
② dioda prevaja, kadar je:

$$x = U_D + 3V \Rightarrow U_D = x - 3V > 0.6V$$

$$x > 3.6V$$

talnet je  $z = x - 0.6V$





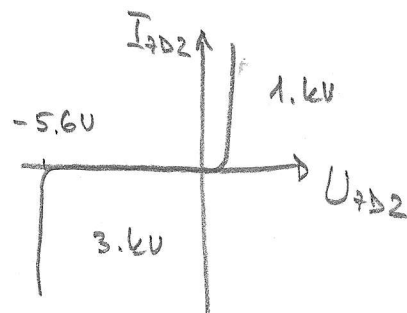
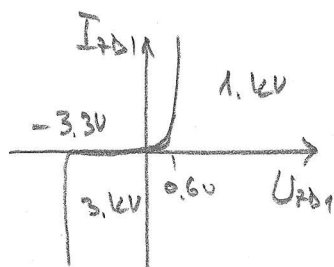
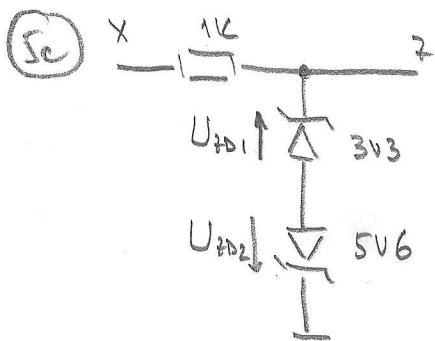
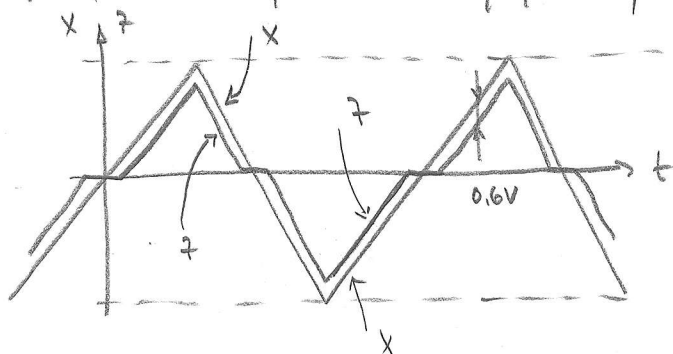
$D_1$  prevaja, če je na njej napetost  $\geq 0.6V$

$$x = U_{D1} + z$$

kar pomeni, da je  $D_2$  polarizirane v nevezni smeri, zato ne prevaja

kadar  $D_1$  prevaja, je torej  $z = x - 0.6V$

$D_2$  prevaja, kadar je na njej napetost  $-0.6V$ :

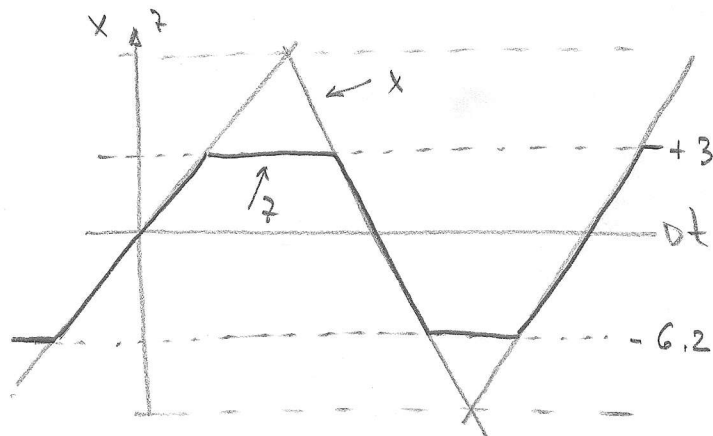


$$z = U_{D2} - U_{D1} = \begin{cases} z_{D1} : 0.6V & z_{D2} : 5.6V \\ \text{v. prevodi} & \text{v. nevezni} \\ \text{smeri} & \text{smeri} \\ \Rightarrow z = -0.6V - 5.6V \\ & = -6.2V \end{cases}$$

$$\begin{cases} z_{D1} : 3.3V & z_{D2} : 0.6V \\ \text{v. nevezni} & \text{v. prevodi} \\ \text{smeri} & \text{smeri} \\ \Rightarrow z = +3.3V + 0.6V \\ & = +3.9V \end{cases}$$

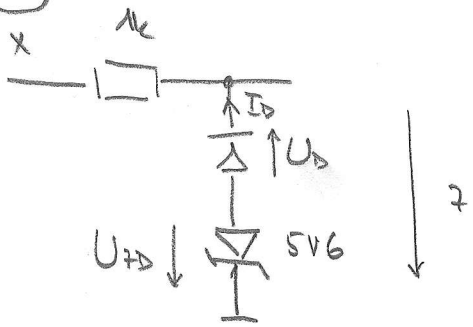
če je  $-6.2kx < 3.9V$   
nobena dioda ne prevaja

$$\Downarrow \\ z = x$$





5d



$$z = U_{7D} - U_D$$

tož  $I_D$  teče, kadar je

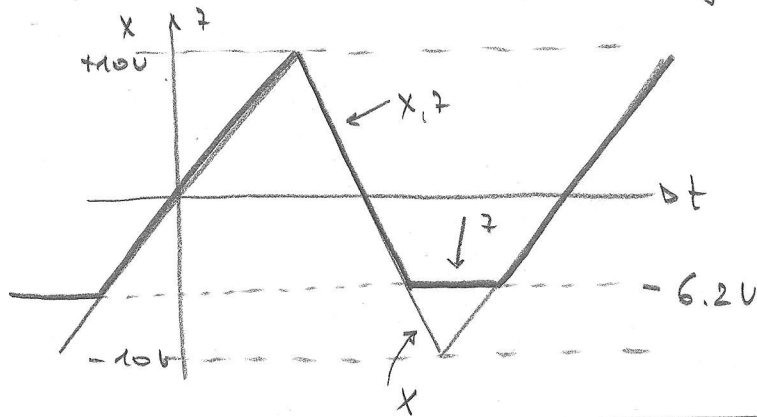
$$U_D \geq 0.6V \text{ in } U_{7D} \leq -5.6V$$

tonaj kadar je  $z \leq -5.6V - 0.6V$

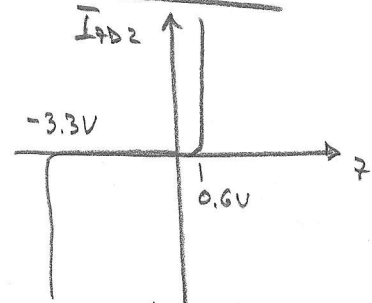
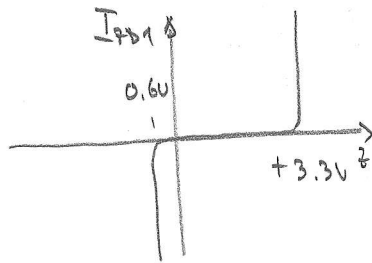
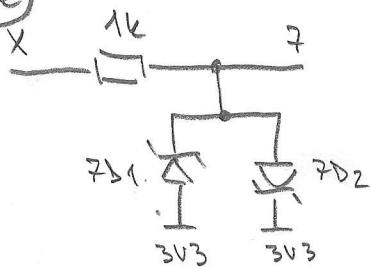
$$z \leq -6.2V$$

ta tož ledi pride le skozi upornik 1k od vhoda, tonaj teče tož le kakrat, ko je  $x \leq -6.2V$

za večje  $x$  tož ne teče, zato je kakrat  $z = x$



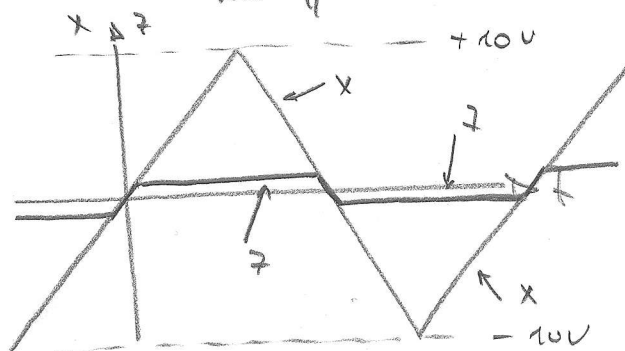
5e



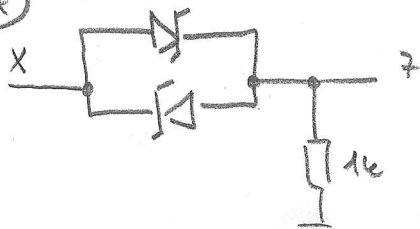
ker sta diodi vezani vzporedno (anti-paralelno)

- za  $z \geq 0.6V$  prevaja 7D2 in  $z$  ne more biti večji od 0.6V

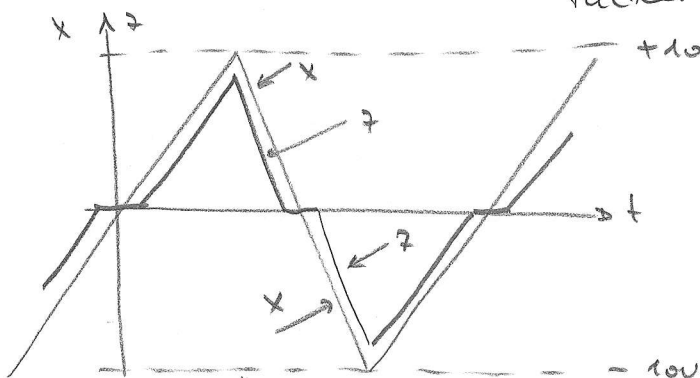
- za  $z \leq -3.3V$  prevaja 7D1 in  $z$  ne more biti manjši od -3.3V



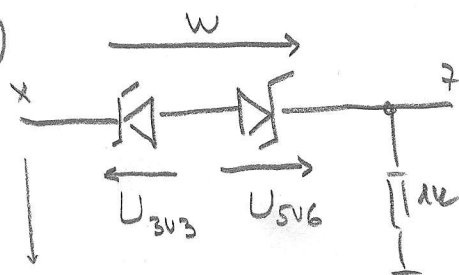
58



diodi sta spet vezani anti-paralelno  
 zato prevaja spornje ali spodnja,  
 če je ta napetost preko njih manj  
 +0.6V ali pod -0.6V  
 takrat je  $Z = X + 0.6V$  za  $X \leq -0.6V$   
 $Z = X - 0.6V$  za  $X \geq +0.6V$



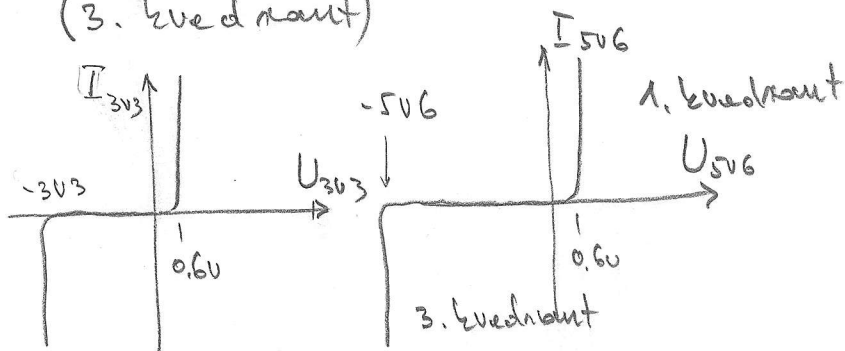
59



$$X + U_{3V3} = Z + U_{5V6}$$

- diodi sta vezani zaporedno, zato  
 ne napetosti ne njihju seštevek!

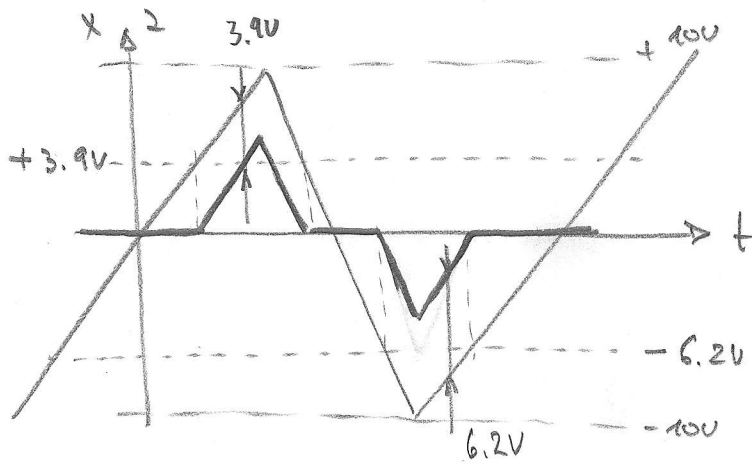
- ker sta vezani v obratnih smereh, ena deluje v  
 prevodni smeri (1. kvadrant), ena pa v zaporni smeri  
 (3. kvadrant)



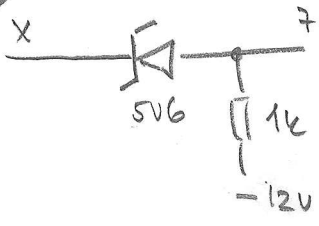
- obe diodi skupaj tvorj prevajata letnet, ko je napetost w  
 na njihju : a)  $3V3 + 0.6V = 3.9V$

$$b) -0.6V - 5.6V = -6.2V$$

ko sta ti meji preseženi, izhodne napetost Z  
 sledi vhodni napetosti +/- a, b po sliki



5b



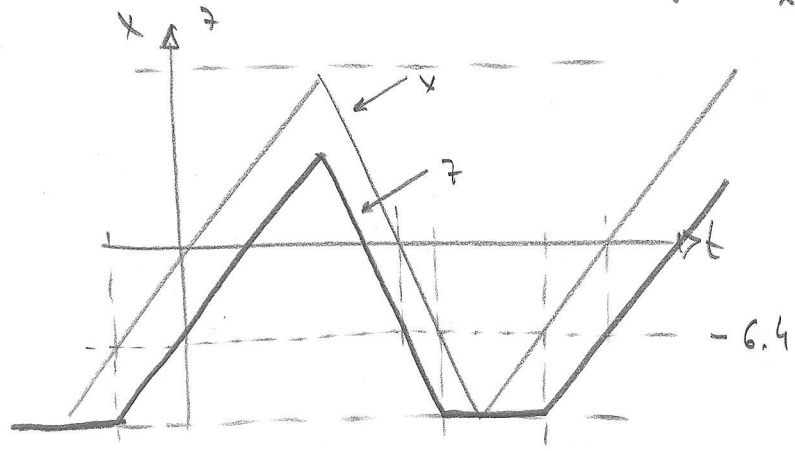
dioda prevaja, če je na njej  
nevarna napetost, večja od  $-5.6V$

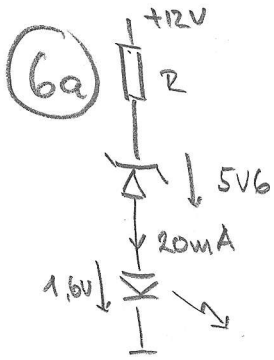
to ne opodi tokov, ko je

$$x > -12V + 5.6V = \underline{\underline{-6.4V}}$$

tokov je izh. napetost z enaka

$$z = x - 5.6V$$





$$R = \frac{12 - 1.6 - 5.6}{0.02} = 240 \Omega$$

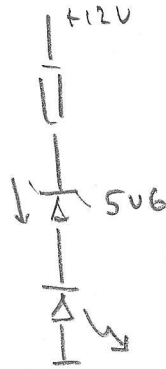
$$P_R = U_R \cdot I_R = 96 \text{ mW}$$

$$P_{ZD} = U_{ZD} \cdot I_{ZD} = 112 \text{ mW}$$

$$P_{LED} = U_{LED} \cdot I_{LED} = 32 \text{ mW}$$

zenerjeva dioda je polarizirana u zaporni smeri  
zato je na njeji napetost 5.6V čp teče  
strujajo toč

6b

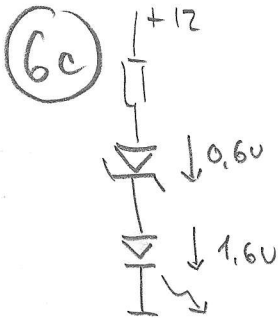


skoz LED

toč ne more

teči, ne j je

polarizirana u neverti smeri !  $P=0$



zenerjeva dioda je polarizirana u prevodni smeri,  
zato je na njeji napetost 0.6V

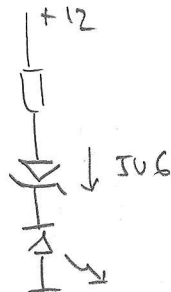
$$R = \frac{12 - 1.6 - 0.6}{0.02} = 490 \Omega$$

$$P_R = U_R \cdot I_R = 196 \text{ mW}$$

$$P_{ZD} = U_{ZD} \cdot I_{ZD} = 12 \text{ mW}$$

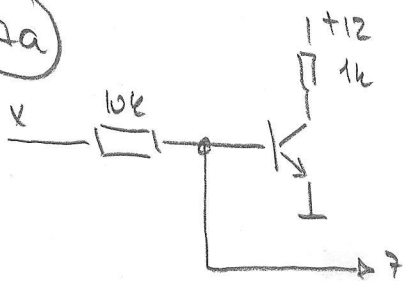
$$P_{LED} = U_{LED} \cdot I_{LED} = 32 \text{ mW}$$

6d

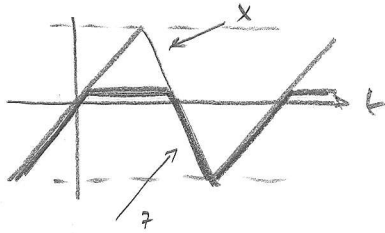
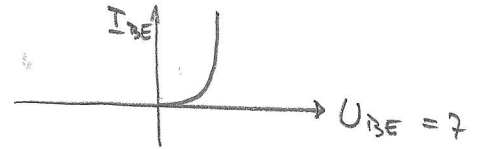


skoz LED toč ne teče, čer je  
polarizirana u zaporni smeri !  $P=0$

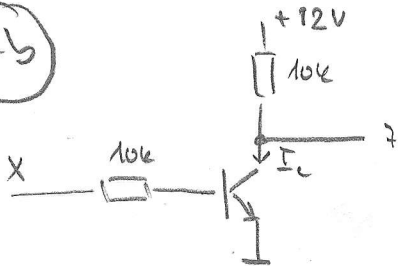
7a



npn B-E se obnaše kot dioda

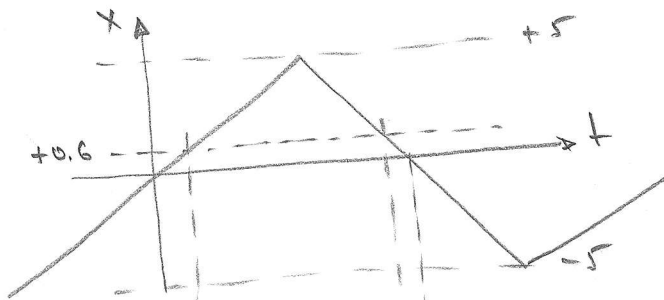


7b



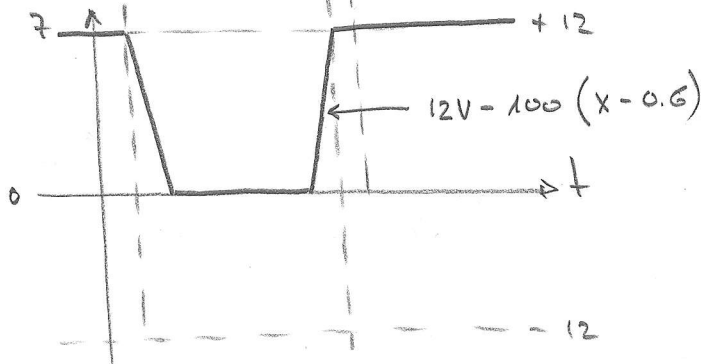
7a  $x > U_{BE} = 0.6V$  veljn

$$\begin{aligned}
 z &= 12V - I_c \cdot 10k \\
 &= 12V - \beta I_B \cdot 10k \\
 &= 12V - \beta \frac{x - 0.6}{10k} \cdot 10k \\
 &= 12V - \beta (x - 0.6)V
 \end{aligned}
 \left. \vphantom{\begin{aligned} z \\ &= 12V - \beta I_B \cdot 10k \\ &= 12V - \beta \frac{x - 0.6}{10k} \cdot 10k \\ &= 12V - \beta (x - 0.6)V \end{aligned}} \right\} z \geq 0!$$

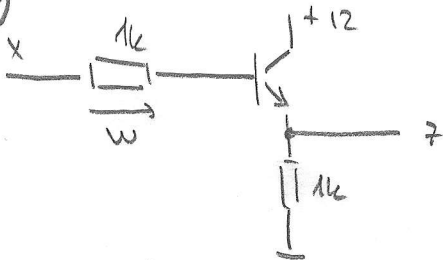


7a  $x < U_{BE} = 0.6V$  veljn

$$I_B = 0 \Rightarrow I_c = 0 \Rightarrow z = +12V$$



7c

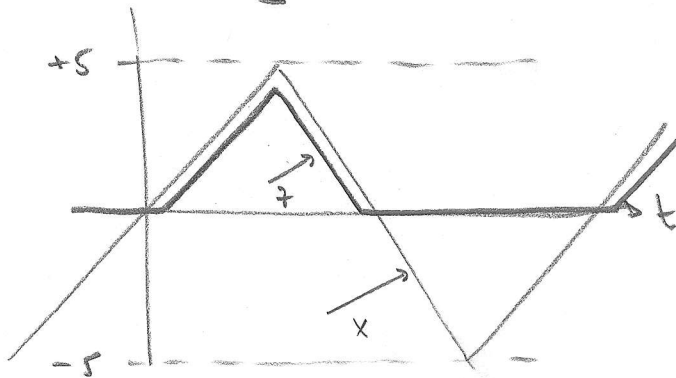


emitorski sledilnik

$$z = x - w - 0,6V ; w = 1k \cdot I_B$$

$$I_B = I_E / \beta$$

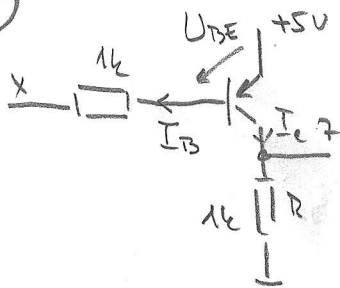
zanemariti



$$R_{IN} = 1k + \beta R_E$$

$$R_{OUT} = 1k / \beta$$

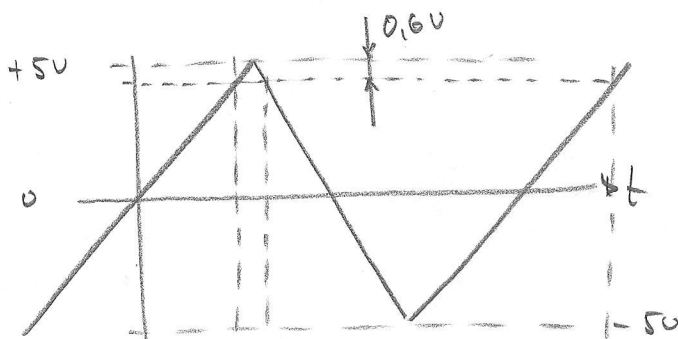
7d



pozor: PNP tranzistor

emitor je vezan na +5V

mimo toga je vezje dosta enemu od prejšnjih vezj



$I_B$  teče, če je  $U_{BE} \geq 0,6V$

$$\downarrow$$

$$I_B = \frac{5 - 0,6 - x}{1k} ; x < 5 - 0,6$$

zato teče toliko skozi kolektor

$$I_c = \beta I_B$$

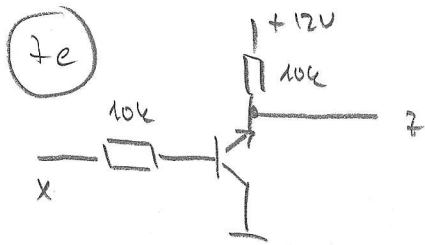
to pa povzroči padec napetosti na  $R = 1k$

$$z = I_c \cdot 1k$$

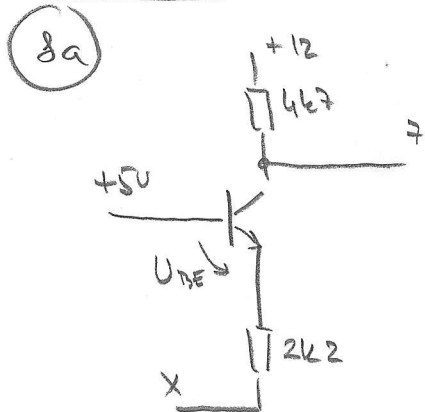
$$= \beta I_B \cdot 1k$$

$$= \beta \frac{5 - 0,6 - x}{1k} \cdot 1k$$

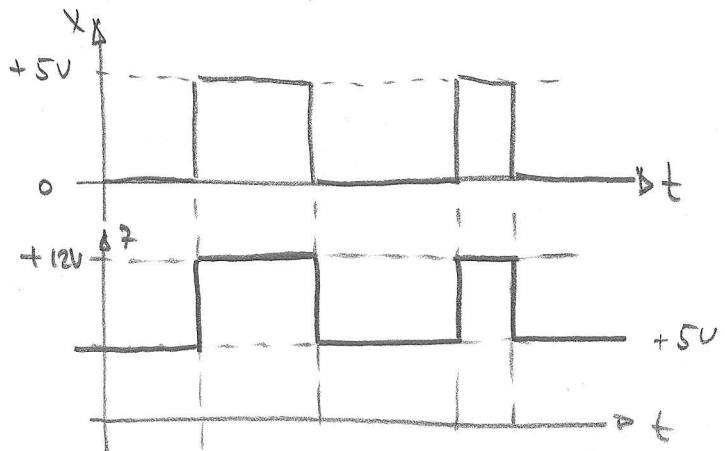
največja izh. napetost z je omejena s +5V



emitor in kolektor sta zamenjana, |  
tako verzij nismo bremenili.



level translator



a) tranzistor ne prevaja, če je  $U_{BE} < 0.6V \Rightarrow$  kadar je  $x > 5V - 0.6V$   
 tačnat skozi kolektor ni tla  $\Rightarrow$  padec napetosti na  $4k7 = 0$   
 $z = +12V$

b) če je  $x < 5V - 0.6V \Rightarrow$  teče iz emitorja tok, ki znašče

$$I_E = \frac{5 - 0.6}{2k2} = 2mA$$

ta tok prikaže skozi kolektor (večinoma,  $\beta = 100$ ) in  
 pušča padec napetosti na uporoku  $R_c = 4700 \Omega$

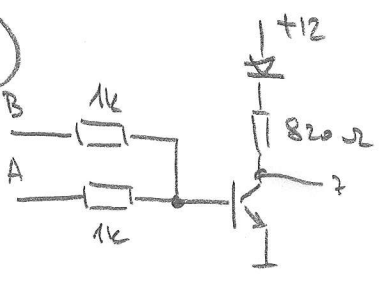
$$U_{zc} = I_E \cdot R_c = 2mA \cdot 4700 = 9.4V$$

torej bi morala biti izh. napetost  $z = 12 - 9.4 = 2.6V$

vedar: napetost na kolektorju ne more biti  
 bolj negativna od napetosti na  
 bazi, ker sicer tranzistor neha  
 prevajati  $\Rightarrow z = +5V$

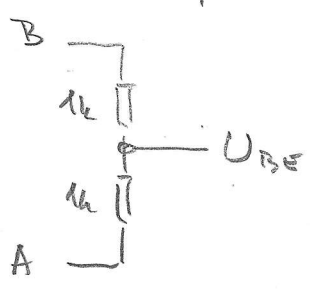
8b) podobne rešoge je že bila rešena

8c



- a) LED je pravilno obklojen, lahko sveh!
- b) LED sveh, če teče skozi kolektor tranzistorja tok
- c)  $I_c = \beta I_B$
- d) tok teče v bazo le, če je na njem  $U_{BE} > 0.6V$

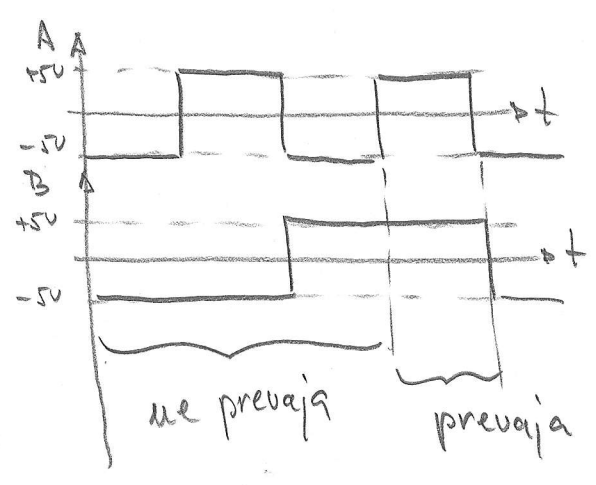
e) pogledajmo torej, kakšna je napetost  $U_{BE}$  za različne A, B pri tem se obnašajmo tako, kot da računamo nevezden delilnik napetosti



Možnosti:  
iz diagrama  
za A, B

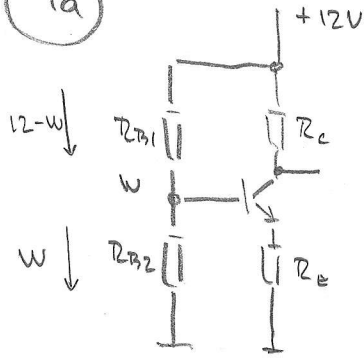
- $A = -5V, B = -5V \Rightarrow U_{BE} = -5V$
- $A = +5V, B = -5V \Rightarrow U_{BE} = 0V$
- $A = -5V, B = +5V \Rightarrow U_{BE} = 0V$
- $A = +5V, B = +5V \Rightarrow U_{BE} = +5V$

prevajaja!





9a



$$R_C/R_E = 5, \quad I_C \doteq I_E = 100 \mu A$$

izberimo:  $U_{RE} = 1V, \quad U_{RC} = 5V \Rightarrow z = 12V - 5V = \underline{7V}$

$$R_E = \frac{U_{RE}}{I_E} = 10k \Omega, \quad R_C = 50k \Omega$$

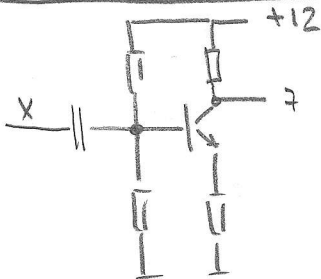
$$U_{BE} \doteq 0.6V \Rightarrow w = U_{RE} + 0.6V = \underline{1.6V}$$

izberimo: razmerje  $R_{B1}/R_{B2} = \frac{12-w}{w}$

$$R_{B1}/R_{B2} = 6.5$$

izberimo:  $R_{B2} = 10k \Rightarrow R_{B1} = 65k$

9b



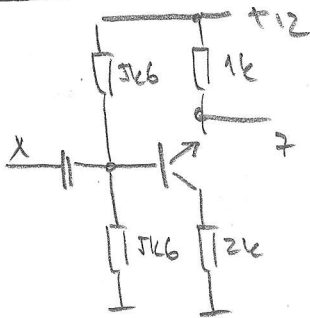
ojačenje  $\doteq R_C/R_E$ , če ohranimo

$R_E, R_{B1}$  in  $R_{B2}$

izprejame malce, moramo spreminiti le

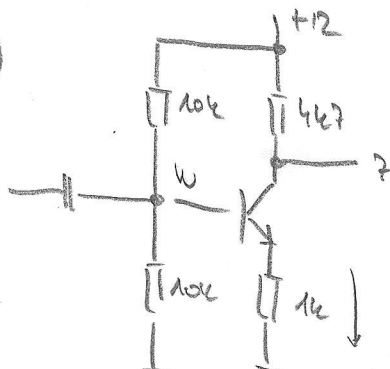
$$R_C = 3k \Omega$$

9c



emitor in kolektor sta zamenjana  
vezje verjetno ne deluje

9d



- topologija vezja je ok  
- preveri delovanje kolektora!

$$w = 12 \cdot \frac{10k}{10k + 4k7} = 6V$$

$$U_{RE} = w - 0.6V = 5.4V$$

$$I_E = \frac{U_{RE}}{R_E} = 5.4 \mu A$$

$$z = 12 - 4.7k \cdot I_E \leq 0 \Rightarrow \text{Bias mi ok!}$$

9d)

Zmanjšaj napetost na bazi (w) tako, da bo kolektorke napetost na približno 1/2 od 12V

$$7 = 7V = 12 - I_c \cdot R_c \Rightarrow I_c = \frac{12 - 7}{R_c} = 1.06 \mu A$$

↓

$$U_{RE} = R_E \cdot I_c = 1k \cdot 1.06 \mu A = 1V$$

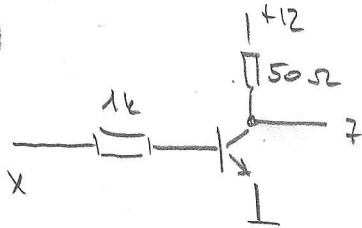
↓

$$W = U_{RE} + 0.6V = 1.6V$$

↓

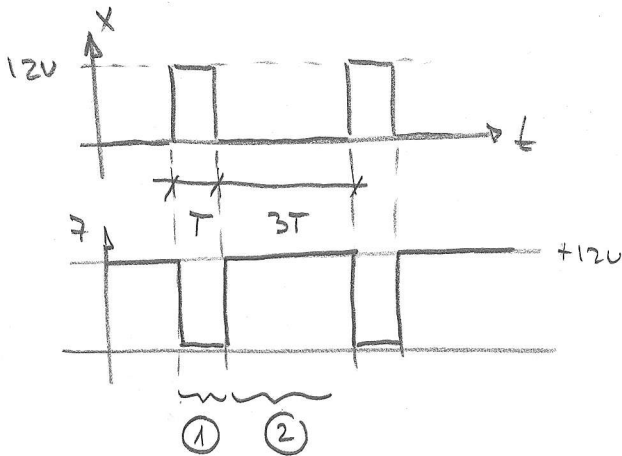
$$R_{B1} = 65k\Omega, \text{ glej 9a}$$

10a



$$P = U \cdot I$$

$$U_{CESAT} = 0.25V$$



$$\textcircled{1} \quad U_{CE1} = U_{CESAT}$$

$$I_{C1} = \frac{12 - U_{CE1}}{50} = 0.24A$$

$$P_1 = U_{CESAT} \cdot I_{C1} = 60mW$$

$$\textcircled{2} \quad U_{CE2} = 12V$$

$$I_{C2} = 0$$

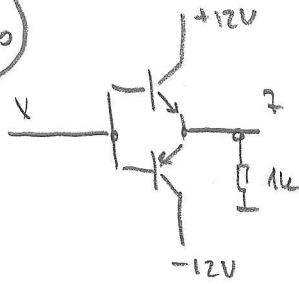
$$P_2 = 0$$

$$\langle P \rangle = (P_1 + P_2) / 4 = \underline{15mW}$$

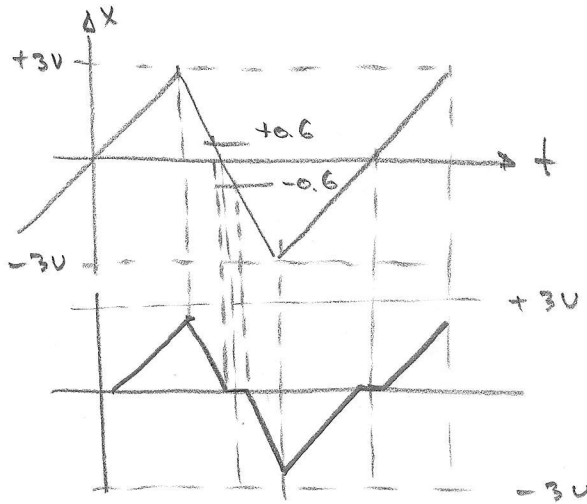
$$P_{50\Omega} = \begin{cases} 1: U_{50} = 12V, I_{50} = 0.24A \Rightarrow P_{50} = 2.88W \\ 2: U_{50} = 0V, I_{50} = 0A \Rightarrow P_{50} = 0 \end{cases}$$

$$\langle P_{50} \rangle = 2.88 / 4 = 0.72W$$

10b

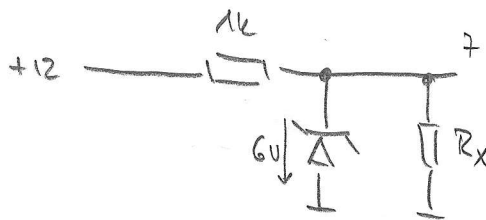


- a) zgotuji tr. prevaja, če je  $x > z + 0.6V$   
 b) spodnji tr. prevaja, če je  $x < z - 0.6V$   
 N a) nečja,  $z = x - 0.6V$   
 N b) nečja :  $z = x + 0.6V$

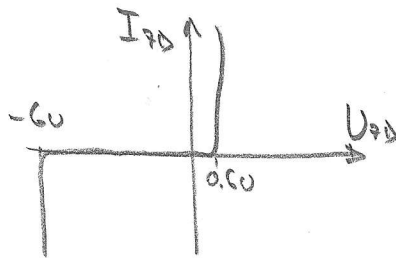


max. izh. napetost je  $3V - 0.6V$   
 min. " " je  $-3V + 0.6V$

10c



$z = 6V$  tabrat, ko izh. napetost definira zanesljiva dioda, ki je vezovana v zaporni smeri  
 torej tabrat, ko teče skozi zD tok



skozi  $R = 1k$  tabrat, ko je na izhodu  $z = 6V$  teče tok :

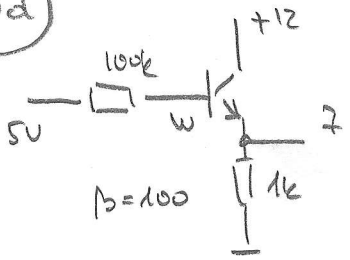
$$I_{1k} = \frac{12V - 6V}{1k} = 6mA$$

če ves ta tok izpine skozi  $R_x$ , ga nič ne ostane za zD in izhodna napetost z se zmanjša pod 6V

$$R_x = \frac{6V}{6mA} = 1k$$

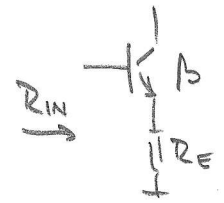
$R_x \geq 1k$  tako, da bo  $z = 6V$

10d

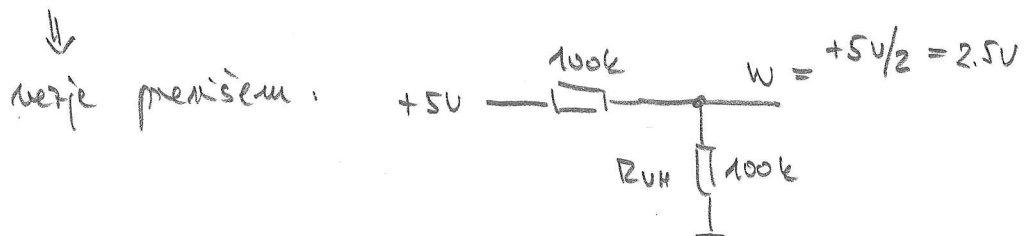


u zato teče tok, da prihaja s tokom  $Z=100k$   
 zato ostane na njem nekaj napetosti,  
 $U_B$  pa ni več +5V, zato je tudi  $Z < 5V$

določimo vhodno upornost u emitoru sledilnik

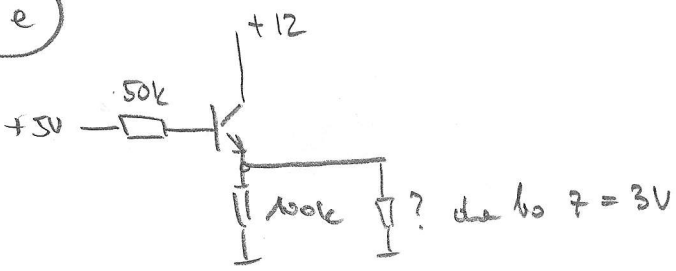


$\Rightarrow$  iz predavanj:  $R_{IN} = \beta R_E$   
 $= 100 \cdot 1k = 100k$



če je  $w = 2.5V$ , je na emitorju še 0.6V manj:  
 torej:  
 $Z = 2.5V - 0.6V = \underline{\underline{1.9V}}$

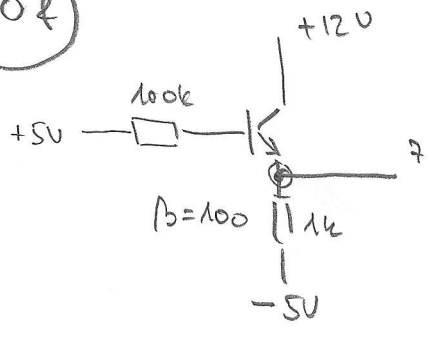
10e



mašo odlepamo, kot za 10d

- na  $Z$  bo 3V takt, ko bo  $w = 3.6V$ , takt ostane na  $Z = 50k$  1.4V, torej je vhodni tok  $I_B = 1.4V / 50k = 28\mu A$
- tok emitorja je torej  $\beta \cdot I_B = 2.8mA$
- od tega odteče tok  $Z = 100k\Omega$  tok  $I_{100k} = 3V / 100k = 30\mu A$
- torej ga za  $R_Z$  ostane še tokraj 2.8mA
- zato je upornost  $R_Z = \frac{3V}{2.8mA} = 1.07k\Omega$

10a



tolmet bmet slepauja, z matematiko

$$\sum I = 0$$

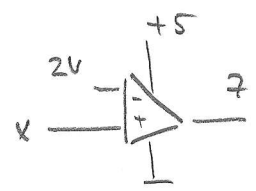
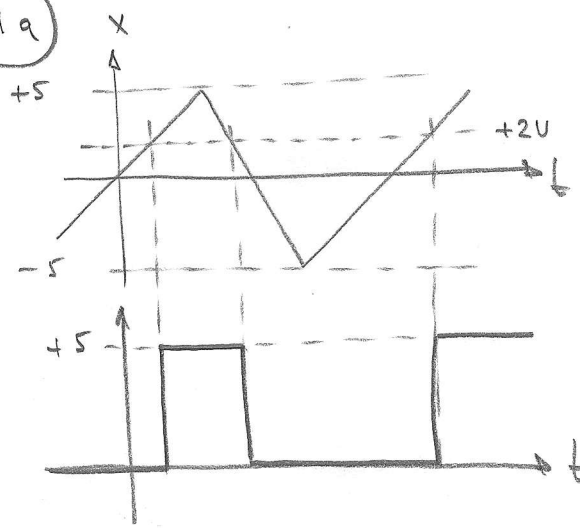
$$I_{RE} = I_E = \beta I_B$$

$$\frac{z - (-5)}{1k} = \beta I_B = \beta \frac{5 - (z + 0.6)}{100k}$$

$$100(z + 5) = 100(5 - z - 0.6)$$

$$2z = -0.6 \Rightarrow \underline{\underline{z = -0.3V}}$$

11a

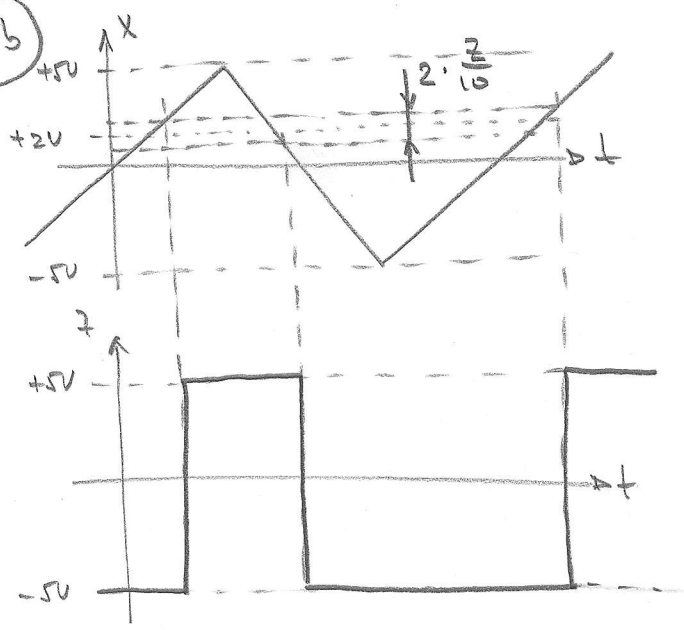


idealni OP

izh. napetosti  $z = \infty (x - 2)$   
 meandar  $-5V \leq z \leq +5V$

komparator, ni pomembne 0  
 uveruje 0

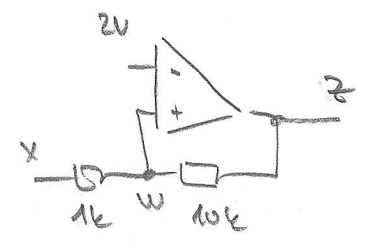
11b



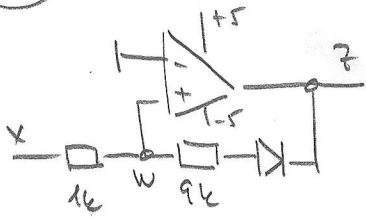
histereta:

$$W = \begin{cases} x + z/10 \\ x - z/10 \end{cases}$$

$$z = \pm 5V$$



11e

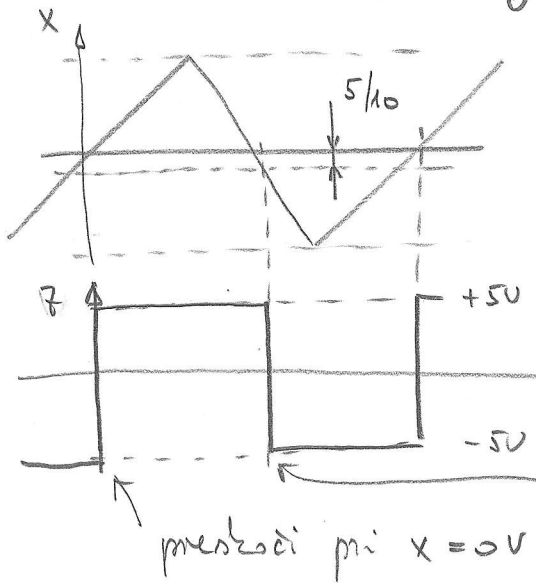


- pozitivna povratna vezava
- zaradi diode lahko kaže biti skoraj  $R=9k$  samo takrat, ko je  $z = -5V$

↓

- $w = x$  kadar je  $z = +5V$
- $w = x + z/10$  kadar je  $z = -5V$

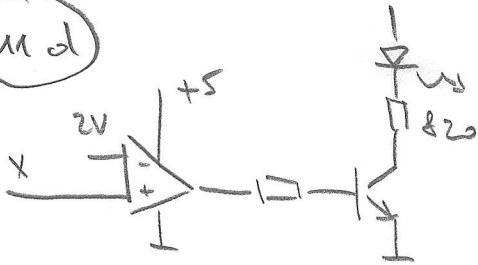
kistoreza deluje le na eno stran!



prestopi pri  $x = -0.5V$

prestopi pri  $x = 0V$

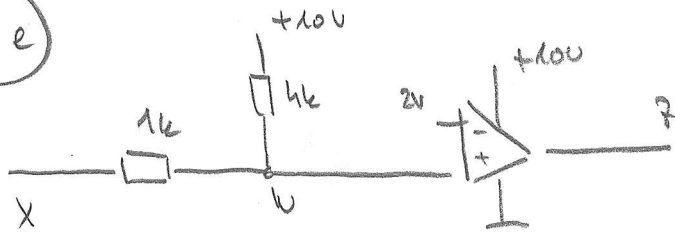
11d



LED svetli, če kaže skoraj TR toč; to je takrat, ko kaže toč v bazo TR; torej ko je izhodna napetost komparatorja +5V

LED svetli takrat, ko je  $x > 2V$ !

11 e



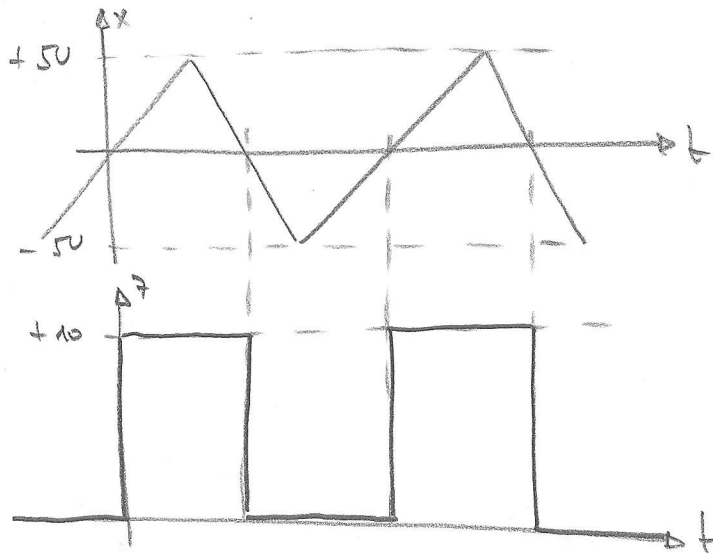
dobri najprej  $w$ , saj  $w$  primerjaš s  $+2V$ !

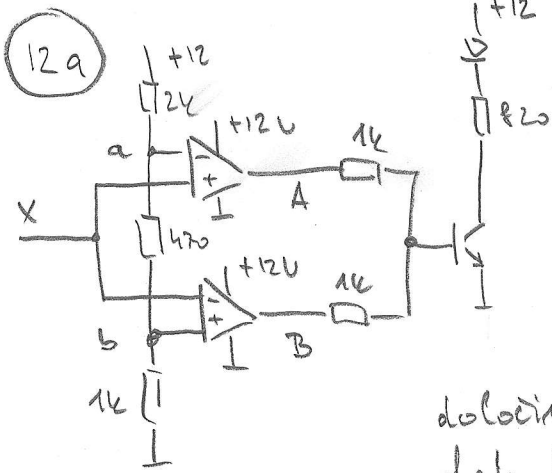
$$\frac{w-x}{1k} + \frac{w-10}{4k} = 0 \Rightarrow w = \frac{10+4x}{5} = 2 + 0,8x$$

$$z = +10V \text{ kadar je } w > 2 \Rightarrow 2 + 0,8x > 2$$

$$\underline{\underline{x > 0}}$$

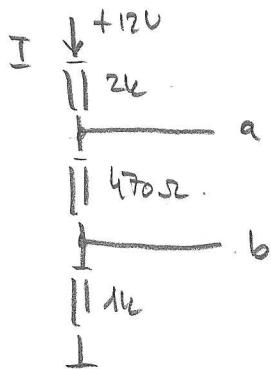
$$z = 0 \text{ kadar je } x < 0$$





- LED svetli, če teče u bazo TR  $12 \text{ k}\Omega$
- LED svetli, če je signal  $A = +12\text{V}$
- " " " " " "  $B = +12\text{V}$

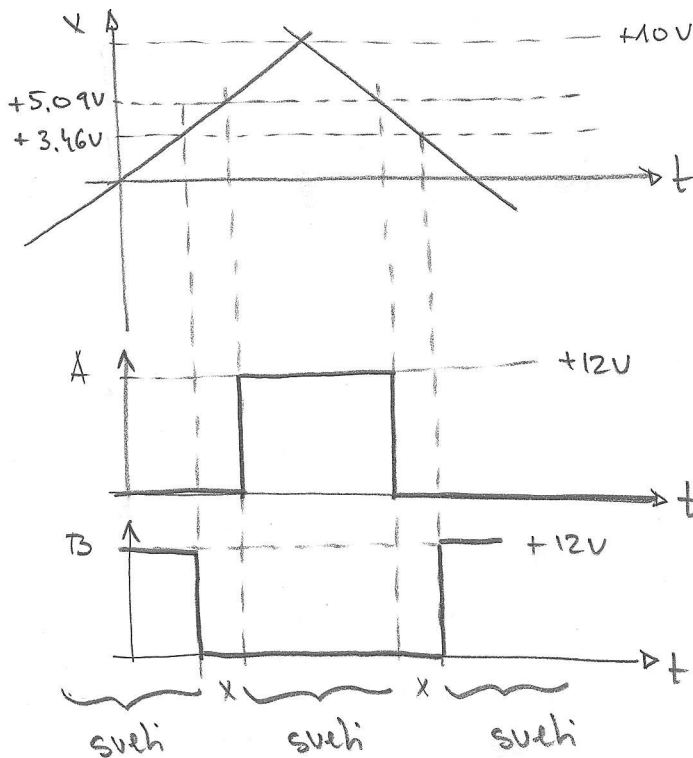
določimo napetosti a in b (referenčne vrednosti),  
obeh komparatorjev



$$I = \frac{12\text{V}}{2\text{k} + 470\Omega + 1\text{k}} = 3.46\mu\text{A}$$

$$b = I \cdot 1\text{k} = 3.46\text{V}$$

$$a = I(1\text{k} + 470\Omega) = 5.09\text{V}$$



$$\text{LED svetli: } \begin{cases} X > 5.09\text{V} \\ X < 3.46\text{V} \end{cases}$$

preveč ali premalo

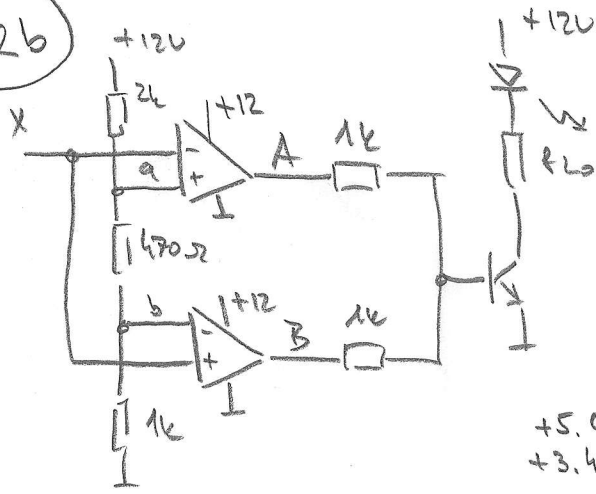
↓  
svetli

↓  
signal za

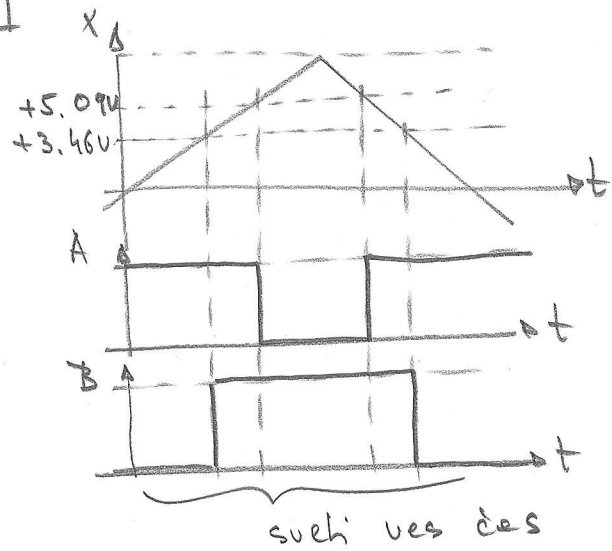
"malo je malo"



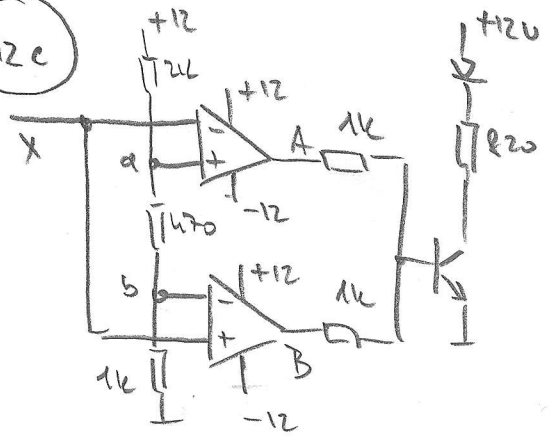
12b



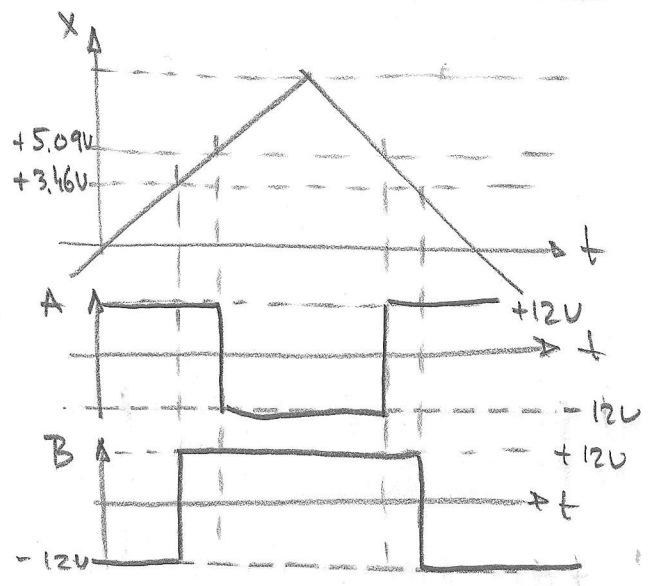
enako sklepanje:  
 - doloci a, b } pozor: vhodni v kump  
 - doloci A, B



12c



window detector



pozor: tolnat se A in B sestaveta, sej sta lahko +/- 12V!

- samo tolnat, ko sta oba +12 => LED suehi
- ce je en od njiju +12, en pa -12, je vsota 0 in LED ne suehi
- ce sta oba -12, je rezultat -12 in LED ne suehi

LED suehi, ko velja  $3.46V < X < 5.09V$