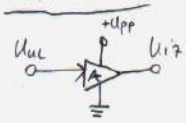
MASOVNE instrukcije - ELEKTRONIKA

POJAČALA



$U_{iz} = A \cdot U_{ul}$

$U_{ul} = 4V$, $A = 5$ } $U_{iz} = 20V$ (10) ; $U_{pp} = 10V$

$U_{ul} = 4V$, $A = 1,5$ } $U_{iz} = 6V$ ✓

4 tipa pojačala

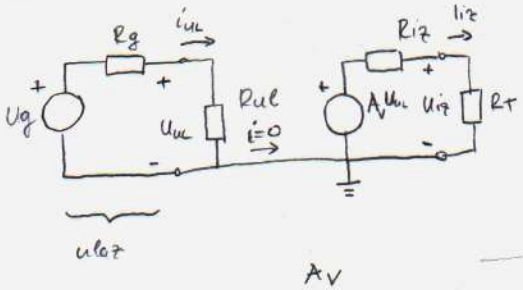
Naponski → Naponski

Strujni → Strujni

N → S

S → N

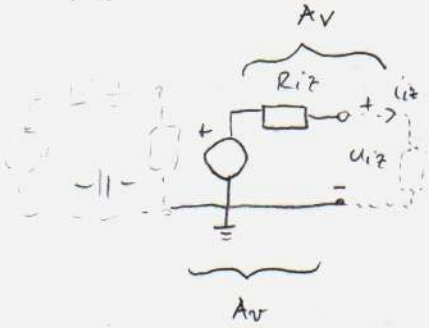
Naponsko pojačalo



A_v – pojačanje neopterećenog trošila

A_V – pojačanje opterećenog trošila

$A = \frac{U_{iz}}{U_{ul}}$



$A_V = \frac{U_{iz}}{U_{ul}}$

$U_{iz} = i_{iz} \cdot R_T = \frac{A_v \cdot U_{ul}}{R_T + R_{iz}} \cdot R_T$

$A_V = \frac{A_v U_{ul}}{U_{ul}} \cdot \frac{R_T}{R_T + R_{iz}}$

$\Rightarrow \boxed{A_V = A_v \frac{R_T}{R_T + R_{iz}}}$ → primarno pojačanje

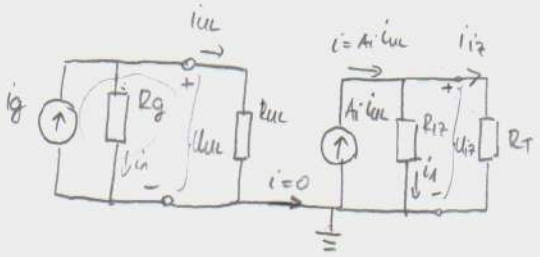
$A_I = \frac{i_{iz}}{i_{ul}} = \frac{\frac{1}{R_T} U_{iz}}{\frac{1}{R_{ul}} U_{ul}} \Rightarrow \boxed{A_I = A_v \frac{R_{ul}}{R_T}}$ – strujno pojačanje

$A_{vg} = \frac{U_{iz}}{U_g}$ → $A_{vg} = \frac{U_{iz}}{\frac{R_{ul}+R_g}{R_{ul}} \cdot U_{ul}}$ → $\boxed{A_{vg} = A_v \frac{R_{ul}}{R_{ul}+R_g}}$

$U_{ul} = i_{ul} \cdot R_{ul} = \frac{U_g}{R_{ul}+R_g} \cdot R_{ul} \rightarrow U_g = \frac{R_{ul}+R_g}{R_{ul}} \cdot U_{ul}$

pojačanje izvora

Strujno pojačalo



$$A_I = \frac{i_{iz}}{i_{UL}}$$

$$A_i i_{UL} = i_A + i_{iz} = \frac{R_T + R_{iz}}{R_{iz}} i_{iz} \rightarrow i_{iz} = A_i i_{UL} \frac{R_{iz}}{R_{iz} + R_T}$$

$$i_A R_{iz} = i_{iz} R_T \Rightarrow i_A = \frac{R_T}{R_{iz}} i_{iz}$$

$$\Rightarrow \boxed{A_I = A_i \frac{R_{iz}}{R_{iz} + R_T}}$$

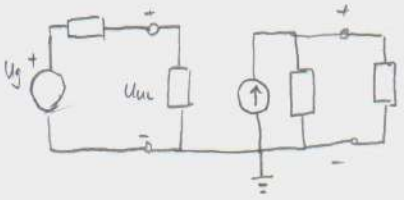
$$A_V = \frac{u_{iz}}{u_{UL}} = \frac{i_{iz} R_T}{i_{UL} R_{UL}} \Rightarrow \boxed{A_V = A_I \frac{R_T}{R_{UL}}}$$

$$A_{Ig} = \frac{i_{iz}}{i_g}$$

$$i_g = i_A + i_{UL} = i_{UL} \frac{R_g + R_{UL}}{R_g}$$

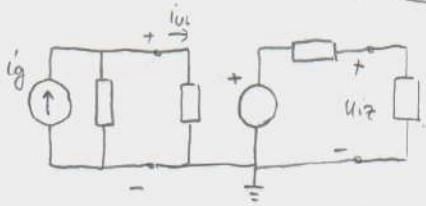
$$i_A R_g = i_{UL} R_{UL} \rightarrow i_A = \frac{R_{UL}}{R_g} i_{UL}$$

$$\Rightarrow \boxed{A_{Ig} = A_I \frac{R_g}{R_g + R_{UL}}}$$



$$G_M = \frac{i_{iz}}{u_{UL}}$$

$$A = V \cdot X \rightarrow X = \frac{A}{V}$$

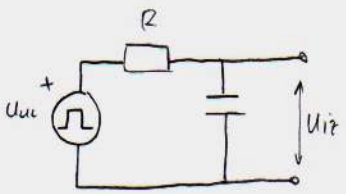


$$R_M = \frac{u_{iz}}{i_{UL}}$$

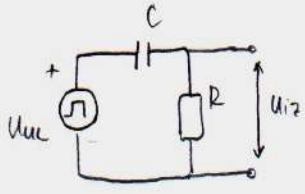
$$V = A \cdot X \Rightarrow X = \frac{V}{A}$$

otporno pojačalo

CR/RC MREŽE



•RC-MREŽA



•CR - MREŽA

→ napon u odredenim vremenskim trenucima?

$\tau = R \cdot C$ (najčešće u ms)

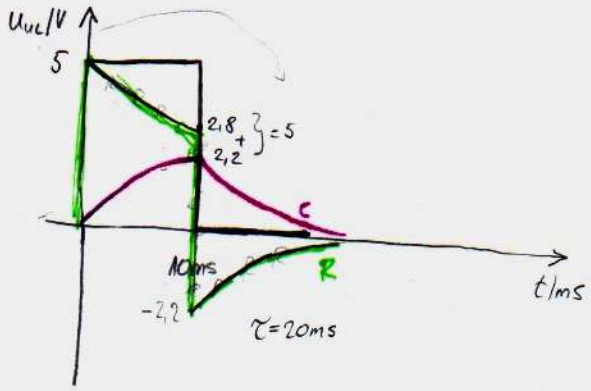
$U_{ul} = U_R + U_c$

$U_c(t) = \Delta U \left(1 - e^{-\frac{\Delta t}{\tau}}\right) + U_{c\emptyset}$

EKSPONENCIJALA

$\Delta U = U_{ul} - U_{c\emptyset}$

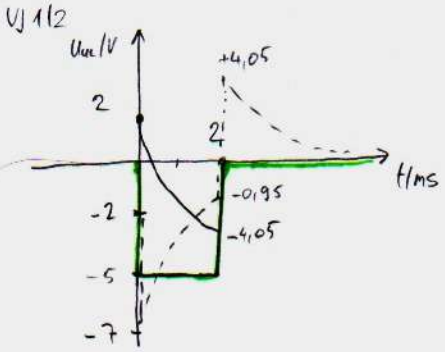
napon kondenzatora u prethodnom stanju

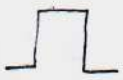


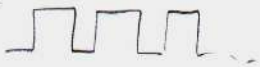
10^- $U_{ul} = 5V$

10^+ $U_{ul} = 0V$

VJ 1/2



pravokutni impuls 

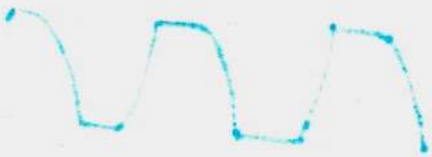
signal 

$C = 1\mu F$, $R = 1k\Omega$ } $\tau = 1ms$

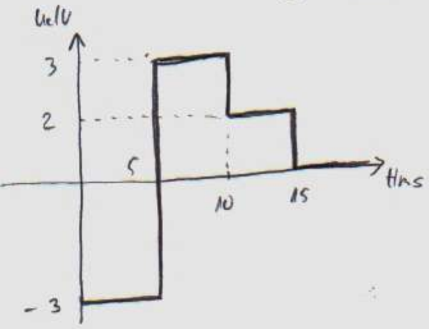
$U_c(0) = 2V$

	U_{ul}	U_c	U_R
$t=0^-$	0	2	-2
$t=0^+$	-5	2	-7
$t=2^-$	-5	-4,05	-0,95
$t=2^+$	0	-4,05	+4,05
		RC-mj	CR-ms

$U_c(12) = \left((-5) - (2)\right) \cdot \left(1 - e^{-\frac{2}{1}}\right) + 2 = -4,05$



CR-mreža



$C = 1\mu F$, $R = 5{,}6\,k\Omega$ } $\tau = 5{,}6\,ms$

	U_{ul}/V	U_C/V	U_R/V
$t=0^-$	0	0	0
$t=0^+$	-3	0	-3
$t=3$	-3	-1,24	-1,76
$t=5^-$	-3	-1,77	-1,23
$t=5^+$	5	-1,77	6,77
$t=9$	5	1,68	3,32
$t=10^-$	5	2,22V	2,78V
$t=10^+$	2	2,22V	-0,22
$t=12$	2		
$t=15^-$			
$t=15^+$			
$t=21$			

početni na kondenzatoru

$u_C(3) = ((-3)-0)(1-e^{-\frac{3}{5,6}}) + 0 = -1{,}24V$

$u_C(5) = ((-3)-0)(1-e^{-\frac{5}{5,6}}) + 0 = -1{,}77V$

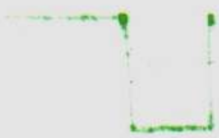
ili ‖

$u_C(5) = ((-3)-(-1{,}24))(1-e^{-\frac{2}{5,6}}) + (-1{,}24)$

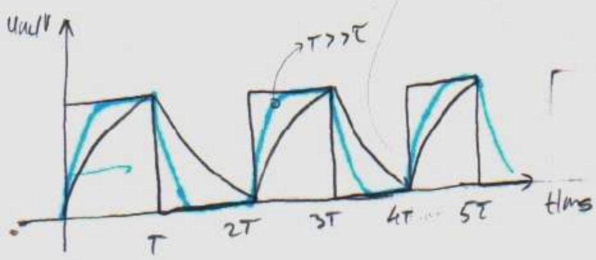
$u_C(9) = ((5)-(-1{,}77))(1-e^{-\frac{4}{5,6}}) + (-1{,}77) = 1{,}68V$

$u_C(10) = ((5)-(-1{,}77))(1-e^{-\frac{5}{5,6}}) + (-1{,}77) = 2{,}22V$

$u_C(12) = ((2)-(2{,}22))(1-e^{-\frac{2}{5,6}}) + 2{,}22 = 2{,}15V$



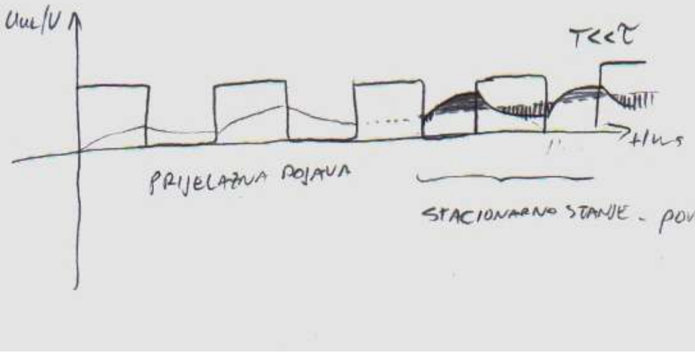
⇒ punjenje i pražnjenje kondenzatora



$U_C = U(1-e^{-\frac{t}{\tau}})$ $t = 5\tau$

$\Rightarrow u_C = U(1-e^{-5}) \approx 0{,}9991\,U$

$t = \tau \rightarrow U_C = 0{,}63U$

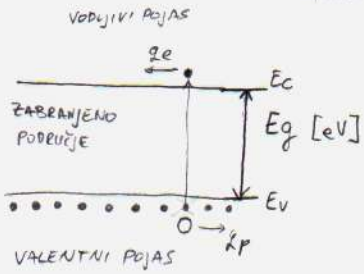


STACIONARNO STANJE - površine iznad i ispod moraju biti jednake

ELEKTRIČKA SVOJSTVA POLUVODIČA

- usmjereno gibanje naboja
  - elektroni • - n
  - šupljine o - p

- τ - vrijeme rekombinacije



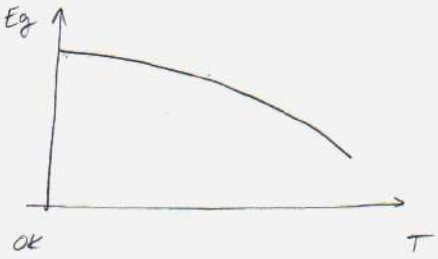
$T = \phi K = -273{,}15\ °C$

$q = 1{,}602 \cdot 10^{-9} [C = As]$

$i = \frac{dQ}{dt}$ $\quad 2e = -1{,}602 \cdot 10^{-19} C$

$2p = 1{,}602 \cdot 10^{-19} C$

n_i - broj slobodnih nositelja naboja



Širina zabranjenog pojasa

$E_G(T) = E_{g0} + aT$ [eV]

KELVIN

$n_i = C \cdot T^{\frac{3}{2}} \exp\left(-\frac{E_g}{2E_T}\right)$ $[cm^{-3}]$

$n_i = C_1 T^{\frac{3}{2}} \exp\left(-\frac{E_{g0}'}{2E_T}\right)$ $[cm^{-3}]$

$e^{(\ )}$

$E_T = k \cdot T = \frac{T}{11600}$

Boltzmanova konstanta

1.) ČISTI POLUVODIČ

$n_0 = p_0$

$n_i^2 = n \cdot p$ → broj šupljina

broj elektrona

$n_i^2 = n_0 \cdot n_0 \rightarrow n_0 p_0 = n_i^2$

2) DOPIRANI POLUVODIČ

n-tip (dopiran elektronima, N_D - donor)

p-tip (dopiran šupljinama, N_A - akceptori)

npr. $N_D = 4 \cdot 10^{15} cm^{-3}$, $N_A = 1 \cdot 10^{15} cm^{-3}$ $\Big\} N_D = 3 \cdot 10^{15} cm^{-3}$

$n_{on} = \frac{(N_D - N_A) + \sqrt{(N_D - N_A)^2 + 4n_i^2}}{2}$

$n_{on} = \frac{N_D + \sqrt{N_D^2 + 4n_i^2}}{2}$

$p_{op} = \frac{N_A + \sqrt{N_A^2 + 4n_i^2}}{2}$

$p_{on} = \frac{n_i^2}{n_{on}}$

$n_{op} = \frac{n_i^2}{p_{op}}$

Primjer $T = 300K$

$C_1 = 3{,}07 \cdot 10^{16}\ K^{-\frac{3}{2}} cm^{-3}$

$E_{g0}' = 1.196$

$N_D = 5 \cdot 10^{10}\ cm^{-3}$

N-tip! → n_{on}, p_{on} = ?

$n_i = 1{,}45 \cdot 10^{10} cm^3$

$n_{on} = \frac{N_D + \sqrt{N_D^2 + 4n_i^2}}{2} = 5{,}39 \cdot 10^{10} cm^{-3}$

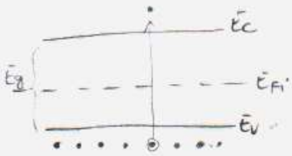
$p_{on} = \frac{n_i^2}{n_{on}} = 3{,}9 \cdot 10^9 cm^{-3}$

$N_D =$

⇒ FERMIJEVA ENERGIJA - E_F

- kod intrinzičnog poluvodiča $(n=p)$

$$E_{Fi} = E_{Fi} = \frac{E_G}{2} = \frac{E_V + E_C}{2}$$



$$n_0 = N_C \exp\left(\frac{E_F - E_C}{E_T}\right) = n_i \exp\left(\frac{E_F - E_{Fi}}{E_T}\right)$$

$$p_0 = N_V \exp\left(\frac{E_V - E_F}{E_T}\right) = n_i \exp\left(\frac{E_{Fi} - E_F}{E_T}\right)$$

$E_T = \frac{T}{11600}$

$\frac{E_g}{2}$

$N_C = N_V = C \cdot T^{\frac{3}{2}}$

$\vec{J} = \sigma \cdot \vec{F}$ - gustoća struje $[A/cm^2]$

↓ vodljivost

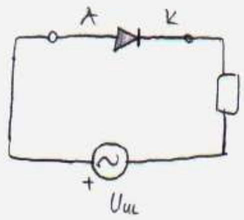
$I = J \cdot S \; [A]$

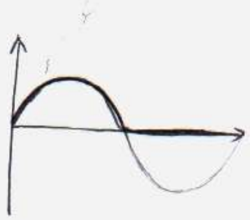
pokretljivost $[cm^2/Vs]$

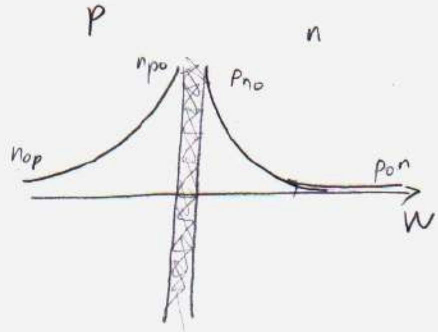
$\sigma = q(n_0 \mu_n + p_0 \mu_p)$

n_0 – broj elektrona na T, p_0 – broj šupljina na T

PN DIODE

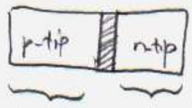






I_s – struja zasićenja

$U_K = U_T \ln\left(\frac{n_{on}\, p_{op}}{n_i^2}\right)$

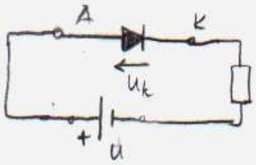


$I = I_s \cdot \left(e^{\frac{u}{m U_T}} - 1\right)$

$I_s = q S \left(D_n \frac{n_{op}}{(W_p L_n)} + D_p \frac{p_{on}}{(W_n L_p)}\right)$ — L_n W_n, L_p W_p

zasićenja

npr: $W_n >> L_p$, $W_p >> L_n$



$U_{TOT} = U_K - U_{AK}$

totalni napon na diodi; U_{AK} = U

Dinamički otpor kroz diodu $\boxed{r_d = \frac{u_d}{i_d}}$

① Ak. God. 2007/08?

$T = 450K$

$n = 10^{14} cm^{-3}$

$n_i' = c_1 T^{\frac{3}{2}} \exp\left(-\frac{E_{g0}'}{2E_T}\right) = 5,91 \cdot 10^{13}$ $\quad p = \frac{n_i^2}{n} = \frac{(5,91 \cdot 10^{13})^2}{10^{14}} = 3,3.49 \cdot 10^{13} cm^{-3}$

više elektrona => n-tip

$$n = \frac{N_D + \sqrt{N_D^2 + 4n_i^2}}{2}$$

$$(2n - N_D)^2 = N_D^2 + 4n_i^2$$

$$4n^2 - 4nN_D + N_D^2 = N_D^2 + 4n_i^2$$

$$N_D = \frac{n^2 - n_i^2}{n} = 6,5 \cdot 10^{19} cm^{-3}$$

$T = 300K$ $\quad n_i' = 1,45 \cdot 10^{10} cm^{-3}$

$n_i = n = p = 1,45 \cdot 10^{10} cm^{-3}$

$S = 5 mm^2$

$l = 1mm$

$$R = \rho \frac{l}{S}$$

$\sigma = 5mS/cm \rightarrow \rho = \frac{1}{\sigma}$

$\sigma = \frac{5 \cdot 1 \cdot 10^{-3} S}{10mm} = 5 \cdot 10^{-4} S/mm$

$\rho = \frac{1}{5 \cdot 10^{-4}} = 2 \cdot 10^3 \Omega mm$