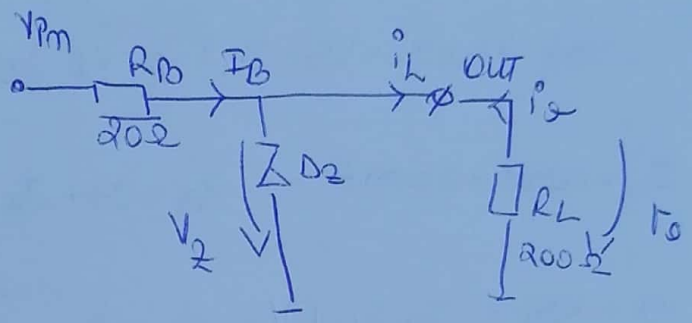
Seminar 9

Stabilizatoare liniare

(P1) D_Z: $V_Z = 5V$, $I_{Z,min} = 5mA$, $I_{Z,max} = 50mA$, $R_Z = 10\Omega$



$\frac{\Delta V_Z}{\Delta T} = 0,1V/°C$

(1) Tipul stabilizatorului: paralel

(2) $V_0 = ?$ a.î. $V_{im} = 6V$; $R_L = 200\Omega$

$-V_{im} + I_B R_B + V_Z = 0 \Rightarrow V_{im} = I_B R_B + V_Z \Rightarrow I_B = \frac{V_{im} - V_Z}{R_B}$

$\Rightarrow \boxed{I_B = 50mA} \Rightarrow V_Z = i_L \cdot R_L \Rightarrow I_L = \frac{5}{0,2} = 25mA \Rightarrow$

$\boxed{I_Z = 25mA}$

$\boxed{T1.2}$ $I_B = I_Z + I_L$

(3) $V_{i,min} = ?$ $R_L = 200\Omega$ $I_{Z,min} = 5mA$

$I_B = I_{Z,min} + I_L \Rightarrow \boxed{I_B = 5 + I_L}$

$-V_{im} + I_B R_B + \underbrace{I_L R_L}_{V_0} = 0 \Rightarrow$ $\quad V_{im} = I_B R_B + I_L R_L$

$V_{im} = (5 - I_L) \cdot R_B + I_L \cdot R_L$

$V_{im} = 5 \cdot 0{,}02 - I_L \cdot 0{,}02 + 0{,}2\, I_L$

$\Rightarrow \underbrace{V_{im} = 0{,}1 + 0{,}18\, I_L}$

$-V_{im} + 0{,}02 \cdot (5 - I_L) + V_Z = 0$

$I_L = \text{const} = 25\,mA \Rightarrow I_B = 25 + I_{Z,min} \Rightarrow \boxed{I_B = 30\,mA}$

$\Rightarrow -V_{im} + I_B R_B + V_Z = 0 \Rightarrow \boxed{V_{im} = 30 \cdot 0{,}02 + 5 \;\; V}$

(4) $I_{B,max} = 25 + I_{Z,max} = 25 + 50 = 75\,mA$

$-V_{im} + I_B R_B + V_Z = 0 \Rightarrow V_{im} = 6{,}5\,V$

(5) Fact de stabilizare

$S_T = \frac{\Delta V_0}{\Delta T} = \frac{\Delta V_Z}{\Delta T} = 0\,mV/°C$

(6) $R_L = ?$ a.î. $V_{im} = 6V \Rightarrow R_{L\,min}$

$V_Z = V_0 \Rightarrow R_L I_0 = 5V \Rightarrow I_0$ variază

$V_{im} = V_Z + I_B R_B \Rightarrow I_B = \frac{V_{IN} - V_Z}{R_B} = 50\,mA$

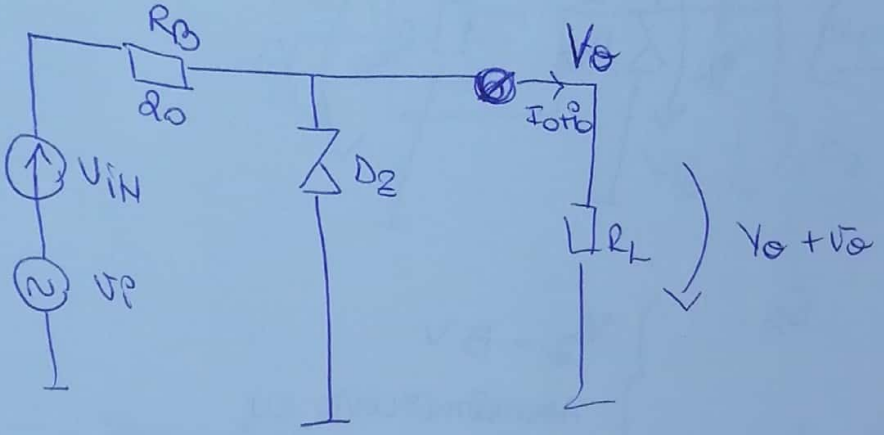
$I_B = I_L + I_Z \Rightarrow \frac{V_0}{I_0} = R_L \to \infty \Rightarrow R_{L\,max} \Rightarrow$

$I_Z = I_{Z,min} \Rightarrow I_L = 45\,mA$

(7)

$\Rightarrow R_{L,min} = \frac{V_0}{I_L} = \frac{1}{9}\,k\Omega$

(8) Factorul de stabilizare



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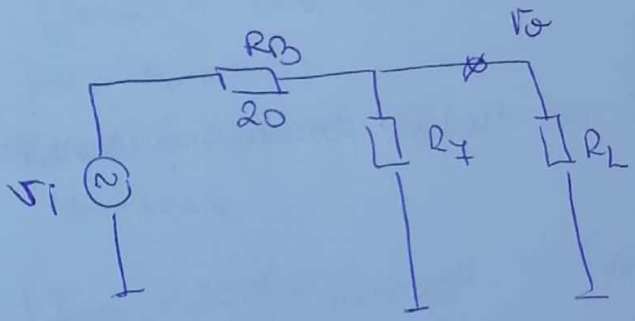


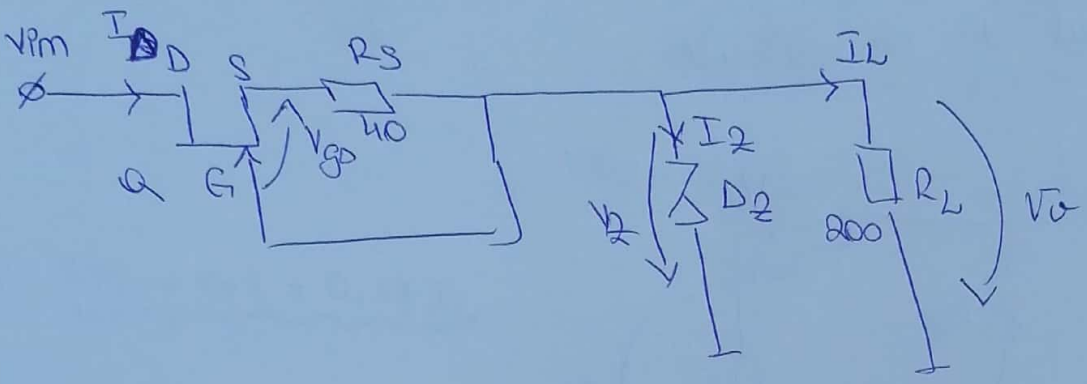
$$S = \frac{V_i}{V_o} = \frac{R_L \| R_L + R_B}{R_T + R_L} = \dots \quad \text{ft mic}$$

METODE DE CREȘTERE

① DZ cu rezistență mai mică

② Punem în paralel un condensator (C_∞)

Pb 2



Q:

$I_{DSS} = 200\ mA$
$V_T = -4\ V$
$r_{ds} = 10\ K\Omega$
$V_{DS,max} = 25V$

D2:

$V_Z = 5V$
Asemănătoare cu (P1)

(1) Stabilizator parametric cu diodă Zener și sursă de curent constantă: (Q, R_2)

(2) $V_o = V_Z = 5V \Rightarrow I_o = 25\ mA$ $\quad V_{DS\,min} = ?$

$V_{GS} = -R_S \cdot I_D$

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_T}\right)^2 \Rightarrow I_D = I_L + I_{Z,min} \Rightarrow \boxed{I_D = 30\ mA}$

$V_{GS} = -2V \Rightarrow V_{DS,min} = 4V$

$V_{IN} = V_{DS} + I_D R_S + V_o$

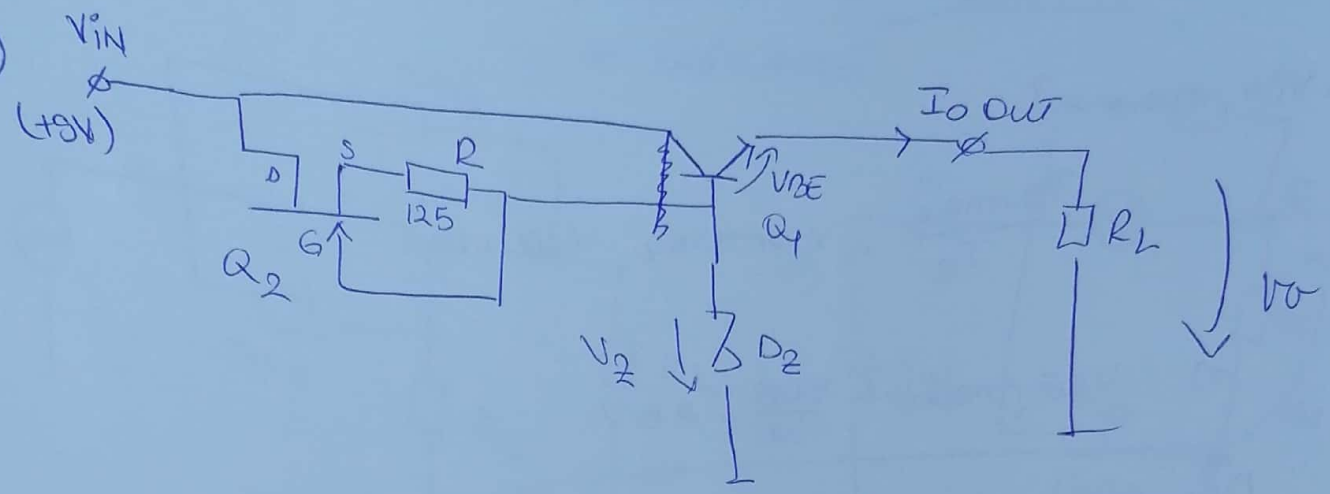
(5) $S_T = \frac{\Delta V_o}{\Delta T} = \frac{\Delta V_Z}{\Delta T} = 0\ mV/°C$

(6) și (7) Identic ca în (P1)

(8) $r_o = r_{ds}(1 + g_m \cdot R_S) \cdot R_{ds}$

Același calcule ca la (P1)

(P3)



Q_1: $V_{BE} = 0{,}6V$; $I_{C,max} = 750\,mA$; $P_{D,max} = 500\,mW$; $\beta_F = \beta_0 = 100$; $V_{CE,max} = 25V$; $V_A = 100V$

D_Z: $V_Z = 5{,}6V$; $I_{Z,min} = \ldots$ aceleași date

Q_2: $I_{DSS} = 32\,mA$; $V_T = -2V$; $r_{0,rds} = 50k\Omega$; $V_{DS,max} = 25V$

$I_O = I_D \cdot \beta_0$

(I_C)

$-V_{in} + V_{DS2} + I_D \cdot R + V_Z = 0$

$V_{GS} = I_D \cdot R \Rightarrow I_D = \frac{V_{GS}}{R}$

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_T}\right)^2 \Rightarrow V_{GS} = \ldots$

$\Rightarrow I_D > I_{Z,min}$

$V_O = V_Z - V_{BE} = 5V \Rightarrow I_O = \ldots$

$V_{in,min\,1} = V_O + V_{CE,min} = V_O + V_{BE} = 5{,}6V$

$V_{in,min\,2} = V_{BE} + V_O + I_D R + V_{DS,min} = 7{,}6V$

$V_{in,min} = \max \{ V_{in,min1}, V_{in,min2} \}$

a) $V_{in,max} = ?$

$$\frac{P_{D,max}}{I_C} = V_{in,max} - V_{CE\,max}$$

$$\Rightarrow V_{CE,max} = \frac{500}{20} = 25V$$

$V_{in,max1} = V_o + V_{CE,max1} = 30V$

$V_{in,max2} = V_o + V_{CE,max2} = 25V$

$V_{in,max3} = V_{DS\,max} + V_o + V_{BE} + \dots$?

$\Rightarrow V_{in,max} = \min \{ \dots \}$

(5) $S_T = \frac{\Delta V_o}{\Delta T} = \frac{\Delta}{\Delta T}(V_Z - V_{BE}) = \frac{\Delta V_Z}{\Delta T} - \frac{\Delta V_{BE}}{\Delta T} = 2\,mV/°C$

(6) $R_{L\,min} = ?$

$R_L \downarrow \Rightarrow I_o \uparrow$

$I_{o,max1} = I_{D,max} \cdot \beta \Rightarrow (I_D - I_{z,min}) \cdot \beta = 3 \cdot \beta = 300\,mA$

$I_{o,max2} = I_{C,max} = 250\,mA$

$I_{o,max} = \frac{P_{D,max}}{V_{CE1}} = \frac{P_{D,max}}{V_{IN} - V_o} = \frac{500}{4} = 125\,mA$

Deci $I_{o,max} = \min \{ \dots \} \Rightarrow R_{L,min} = \frac{V_o}{I_{o,max}} = 40\,\Omega$

(7) $R_{L,max} = ?$

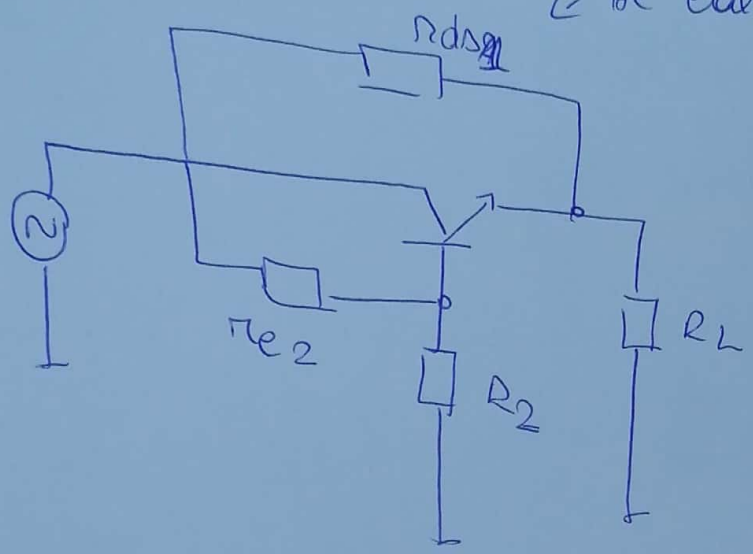
Daca $R_L \uparrow \Rightarrow I_o \downarrow$

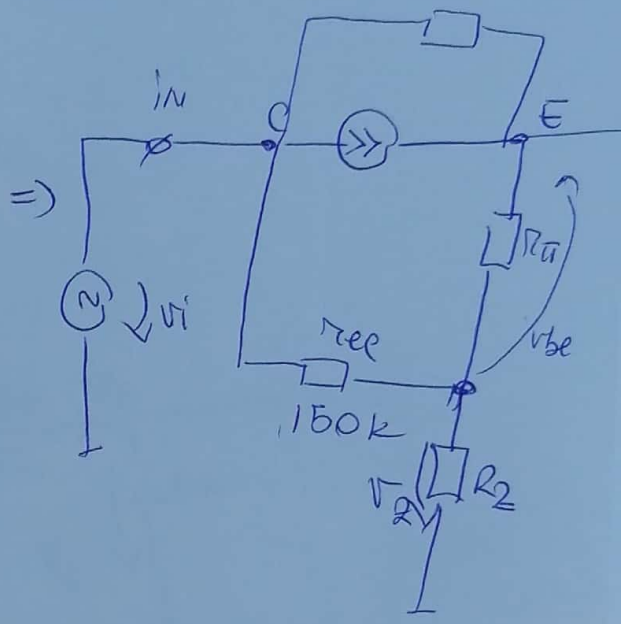
I_o poate fi 0 $\Rightarrow$ pentru stabilizatorul ideal

$R_{L,max} \to \infty$

⑧ $S = ?$

↙ de calculat ā





$r_{ds} = \frac{V_A}{I_E}$

$\frac{V_0}{V_i} = \frac{1}{S} \Rightarrow \frac{1}{S} = \frac{V_0}{V_2} \cdot \frac{V_2}{V_i} \cdots = \frac{R_2}{R_2 + r_{E2}} \simeq 15\,000$

$\Rightarrow V_2 = V_0 + V_{be} \Rightarrow V_2 \simeq V_{be}(1 + g_m R_2) = -V_0$

⑨ $R_0 = ?$

$r_E = \frac{r_\pi + R_2}{\beta + 1} \simeq \frac{1}{g_m} \Rightarrow \boxed{R_0 = \frac{1}{g_{m1}} \parallel r_{d1}}$

Seminar 10

→ Foaie cu formule → 2 pg.

STABILIZATOARE LINIARE

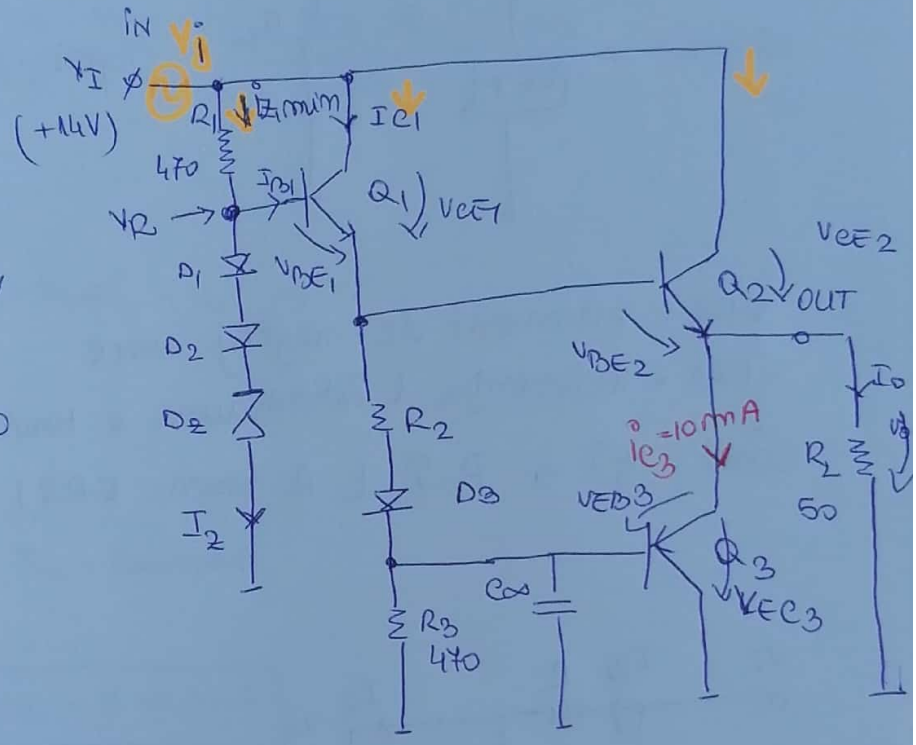
Pentru circuitul din figură se cunosc:

D_1, D_2, D_3: $\begin{cases} V_{D,ON} \simeq 0{,}45V \\ m = 1,\ V_{th} \simeq 25mV \end{cases}$

D_Z $\begin{cases} V_Z = 10V \\ I_{Z,min} = 2mA,\ R_Z \simeq 0 \end{cases}$

$Q_{1,2}$ $\begin{cases} V_{BE} = 0{,}45V \\ \beta_T = \beta_0 = 100 \\ V_{AQ_2} = 100V \end{cases}$

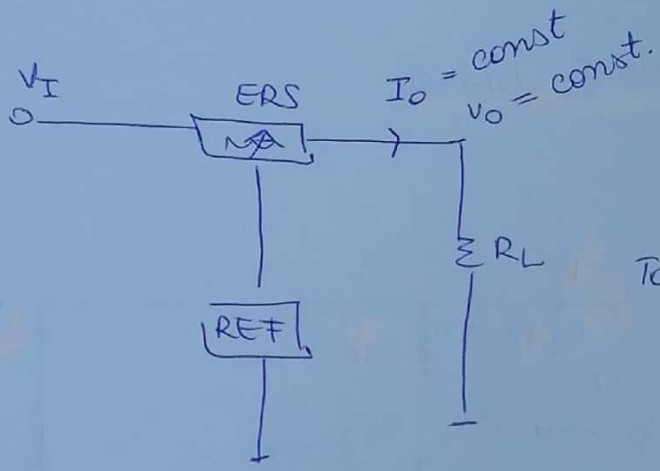
$Q_3 = \begin{cases} V_{EB} = 0{,}6V \\ \beta_T = \beta_0 = 200 \end{cases}$



1. Să se identifice tipul de stabilizare
2. Să se calculeze V_O și curenții prin circuit dacă $I_{C3} = 10_{mA}$
   Să se calculeze valoarea lui R_2
3. Deter. val minimă a tens de intrare, $V_{in,min}$
4. Să se calculeze S_T, dacă $\frac{\Delta V_Z}{\Delta T} \simeq 0\ mV/°C$, $\frac{\Delta V_{BE}}{\Delta T} = -2\ mV/°C$
5. Explicați funcționalitatea circuitului + rolul componentelor

6. Def factorul de stab. (S) la var tens de intrare.

(1) 2 Sch. bloc:

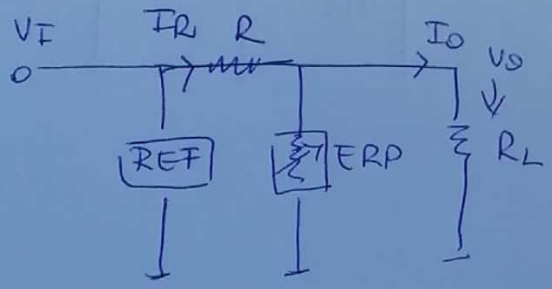


Topologia cu elem de reglaj serie

ERS = element de reglaj serie

REF = referința (întotdeauna o tensiune constantă)

când $V_I \uparrow \Rightarrow R \uparrow$ (R prin ERS) $\Rightarrow$ V_o const.



Topologia cu elem de reglaj paralel.

ERP = element de reglaj paralel

$V_I \uparrow \Rightarrow I_R \uparrow \Rightarrow R \downarrow$ (R prin ERP) $\Rightarrow$ V_o const

Q_2 = ERS
Q_3 = ERP
} $\Rightarrow$ STABILIZATOR liniar cu reglaj de tip serie-paralel

2.) Considerăm D_Z în STAB $\Rightarrow V_{DZ} = V_Z = 10V$

$D_{1,2,3}$ în CONDUCȚIE $\Rightarrow V_{D1,D2,D3} = 0,75V$

Pp. $Q_{1,2,3} \rightarrow$ RAN

T2K1: $V_I = I_Z \cdot R_1 + V_{D1} + V_{D2} + V_{DZ}$

$$I_Z = \frac{V_I - V_{D1} - V_{D2} - V_{DZ}}{R_1} = \frac{14 - 1,5 - 10}{470} = \frac{2,5}{470} \simeq 5,3mA$$

T2K: $RET = D_1, D_2, D_Z$

$V_{DZ} + V_{D1} + V_{D2} = V_{BE1} + V_{BE2} + V_O \Rightarrow$

$$\boxed{V_O = V_{DZ} = 10V}$$

$$I_O = \frac{V_O}{R_L} = \frac{10}{50} = 0,2\,A \Rightarrow I_O = 200\,mA$$

$$I_{C2} = I_O + I_{C3} \Rightarrow \boxed{I_{C2} = 210\,mA}$$

T2K Ia trece și prin R_2 și prin R_3

$-I_{C1}R_3 - V_{EB3} + V_O = 0 \Rightarrow -I_{C1} = -(V_{EB3} -$

$$I_{C1} = \frac{V_O - V_{EB3}}{R_3} = \frac{10 - 0,6}{470} \Rightarrow \boxed{I_{C1} = 20\,mA}$$

T2K: $V_{BE2} + V_{EB3} - V_{D3} - I_{C1}R_2 = 0$

$0,75 + 0,6 - 0,75 - 20 \cdot R_2 = 0$

$0,6 = 20 \cdot R_2 \Rightarrow R_2 = \frac{0,6}{20\,mA} \Rightarrow R_2 = \frac{0,6}{0,02}$ $0,02$

$$\boxed{R_2 = 30\Omega}$$

(3) $V_0 = const$

$V_R = const$

$V_{CE2_{sat}} = V_{BE2} = 0,745$ pt RAN

$V_{CE1,sat} = V_{BE1} = 0,745$ pt RAN

Pentru cazul 1: $V_{CE2\,sat} = V_{BE2} = 0,745V$

I2K: $V_{IN1min} = V_{CE2\,sat} + V_0$

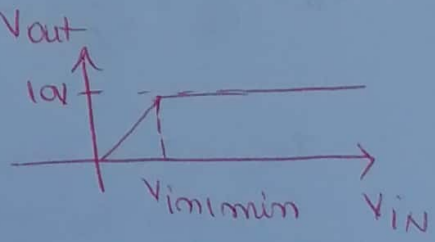
$V_{IN1min} = 0,745 + 10 = 10,745V$

Pt cazul 2: $V_{CE1\,sat} = V_{BE1} = 0,745V$

$V_{Im2min} = V_{CE1_{sat}} + I_{C2}R_2 + V_{D3} + I_{C2}R_3$ (V_{BE2}, V_0) $= 0,745 + 0,745 + 10$

~~$V_{Im2min} = 0,745 + 20 \cdot 10^{-3} \cdot 30 + 0,745 + 0,02 \cdot 470$~~

$V_{Im2min} = 1,5 + 10 = 11,5V$



Pt cazul 3: $I_2 = I_{2min} = 2mA$

$V_{Im3min} = I_{2,min} \cdot R_1 + V_{BE1} + V_{BE2} + V_0$

$V_{Im3min} = 1,5 + 10 + 0,94 = 12,44V$

$V_{IN\,min} = V_{Im1min} = 10,745V \rightarrow \max\{V_{in1min}, V_{in2min}, V_{in3min}\}$

(4) S_T = coef de variatie cu temperatura.

$$S_T = \frac{\Delta V_0}{\Delta T}$$

~~$V_O = V_{IN} = R_4 I_2 + V_{D1} + V_{D2} + V_{BE2}$~~

$\frac{\Delta V_D}{\Delta T} = -2\ mV/°C$

$-V_{D1} - V_{D2} - V_{D2} + V_{BE1} + V_{BE2} + V_O = 0$

$\Rightarrow V_O = V_{D2}$

$\frac{\Delta V_O}{\Delta T} = \frac{\Delta V_{D2}}{\Delta T} = 0\ mV/°C$ compensare ideală cu temp.

(5) Rolului componentelor:

- D_2, D_1, D_2 - referința
- Q_2 - ERS
- Q_3 - ERP
- D_1, D_2 - rolul de a compensa variația cu temperatura
- Q_1 - demultiplicator, multiplică curentul de bază a lui Q_2

• Dacă nu am avea diode $V_O = V_{D2} - 2V_{BE}$

$\frac{\Delta V_O}{\Delta T} = \frac{\Delta V_{D2}}{\Delta T} - \frac{2\Delta V_{BE}}{\Delta T}$

$\frac{\Delta V_O}{\Delta T} = 4\ mV/°C$

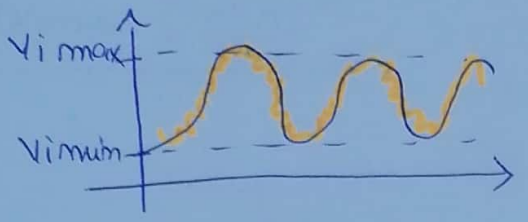
Funcționalitatea circuitului:

Dacă $V_I \uparrow \Rightarrow V_O$ tinde să crească

- $V_{BE2} + V_{BE1} = V_R - V_O \downarrow$
- $V_{EB3} \uparrow \Rightarrow I_{C3} \uparrow$
- $I_C = I_S \exp\left(\frac{V_{BE}}{V_{th}}\right)$

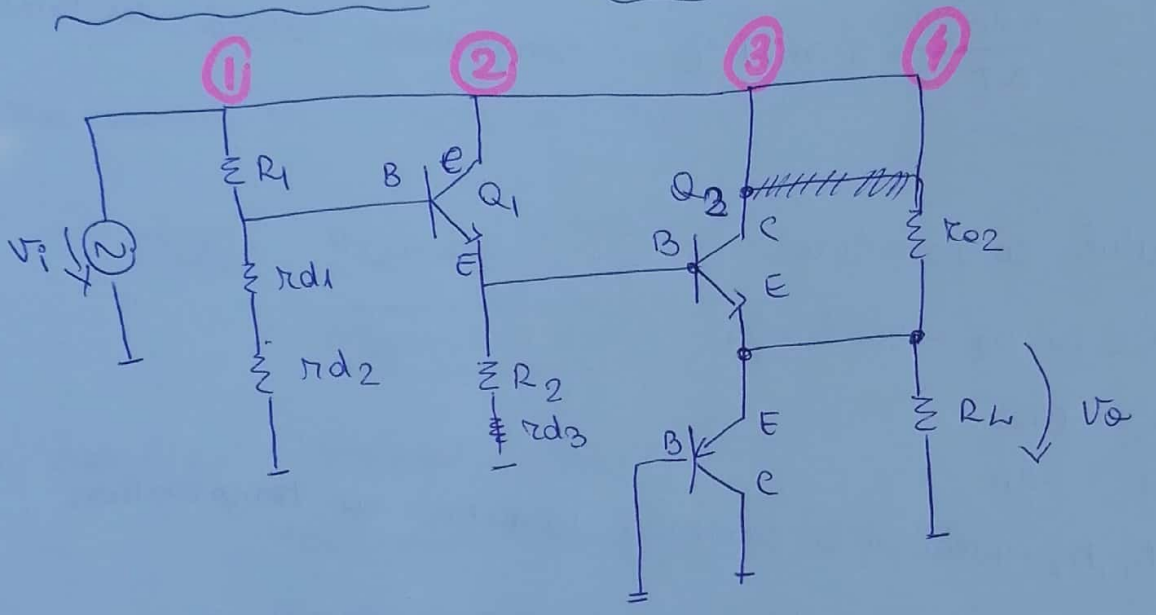
$I_O = I_{C2} - I_{C3} \downarrow \Rightarrow \boxed{V_O = R_L \cdot I_O \downarrow}$

(6) variația intrării este de 2 tipuri [intre $\{V_{I\,min}, V_{I\,max}\}$ = aleatoare; periodică (ripple) = variația alternatorului din sursă



$R_{diodă} = \frac{m V_{th}}{i_D}$ (r_d)

Schema în AC



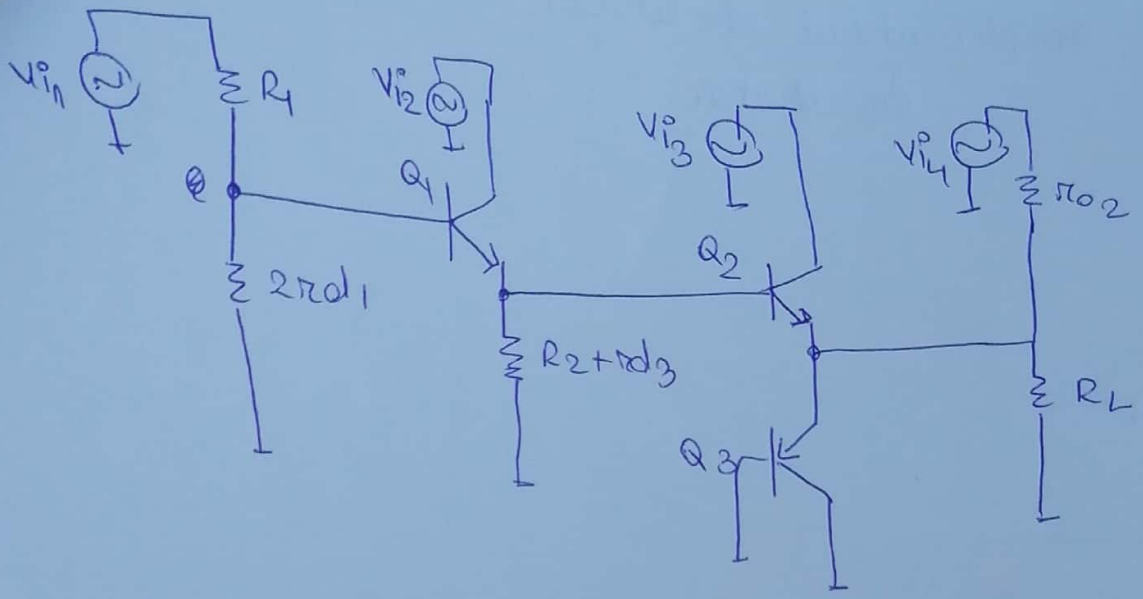
$$R_{o2} = \frac{V_{AQ2}}{I_{C2}} = \frac{100\ V}{210\ mA} \simeq 0{,}48\ k\Omega$$

$$r_{d1} = r_{d2} = \frac{m V_{th}}{I_{D1}} = \frac{0{,}025}{5\ mA} = 5\ \Omega$$

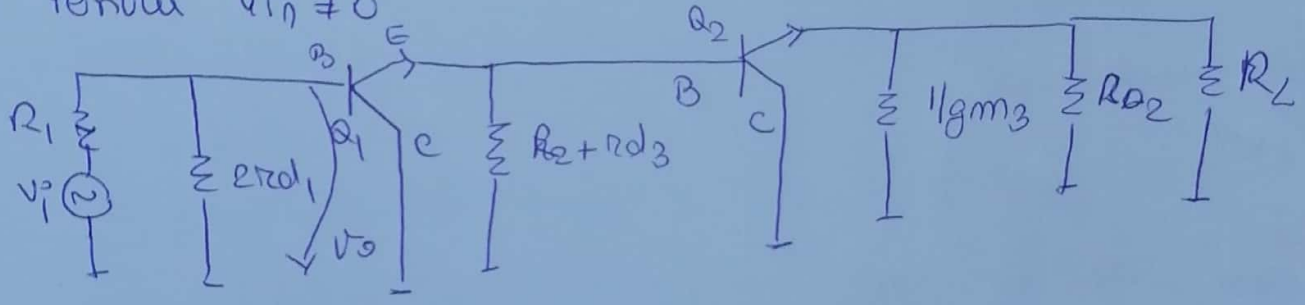
$$r_{d3} = \frac{0{,}025}{20\ mA} = 1{,}25\ \Omega$$

Pentru calculul lui S apl. T. suprapoziției:

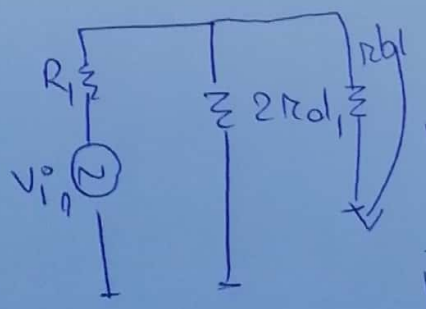
$$\frac{V_{o4}}{V_{i4}} = \frac{V_{o1}}{V_{in}}\Big|_{\substack{V_{in}\neq 0 \\ V_{i2-4}=0}} + \frac{V_{o2}}{V_{i2}}\Big|_{\substack{V_{i2}\neq 0 \\ V_{i1,3,4}=0}} + \frac{V_{o3}}{V_{i3}}\Big|_{\substack{V_{i3}\neq 0 \\ V_{i1,2,4}=0}} + \frac{V_{o4}}{V_{i4}}\Big|_{\substack{V_{i4}\neq 0 \\ V_{i1,2,3}=0}}$$



Pentru $v_{in} \neq 0$



$Q_1, Q_2 \rightarrow CC \rightarrow A_V = 1$



$$r_{bn} = r_{\pi n} + (\beta+1)\left[R_2 + r_{d_3} \| r_{b_2}\right]$$

$$r_{b_2} = r_{\pi_2} + (\beta+1)\left(r_{o_2} \| R_L \| \frac{1}{g_{m_3}}\right)$$

$$\boxed{r_{b_1} = 3k\Omega}$$

$$\boxed{r_{b_2} = 0{,}25k\Omega}$$

$$\frac{v_{on}}{v_{in}} \approx \frac{2r_{d_1} \| r_{b_1}}{R_1 + (2r_{d_1} \| r_{b_1})} \Rightarrow \frac{v_{o_1}}{v_{in}} = \frac{2r_{d_1}}{2r_{d_1} + R_1}$$

r_{bn} negligeabile față de $2r_{d_1}$; $\gg 2r_{d_1}$

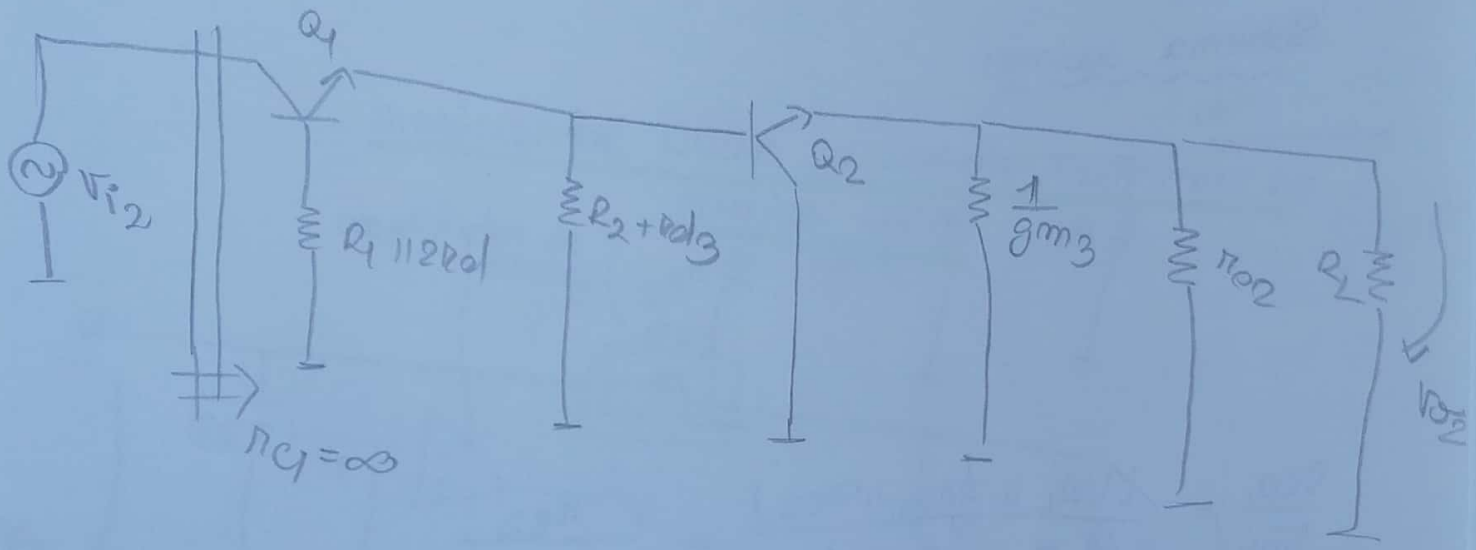
$\frac{v_{o2}}{v_{i2}} = 0$ (Amplificatorul este atacat în colector și nu răsp
în colector.

Seminar 11

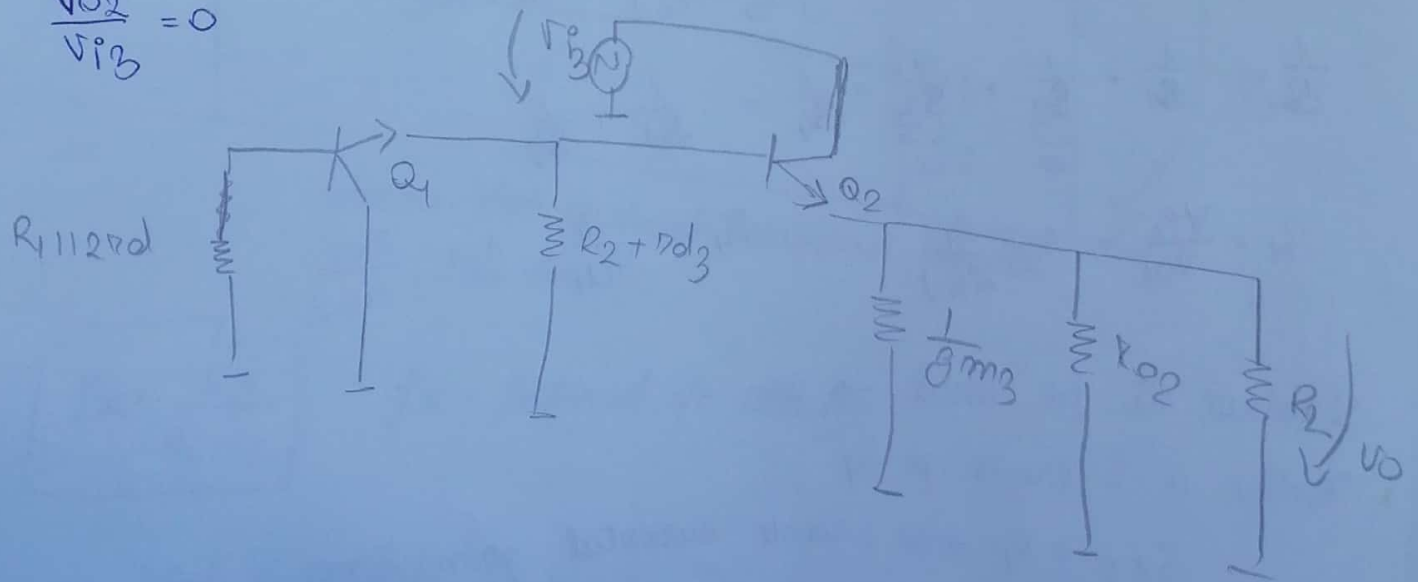
Problema anterioară

$$\frac{v_{o2}}{v_{i2}}\Big|_{v_{i2}\neq 0} = 0$$

$$v_{i1} = v_{i3} = v_{i4} = 0$$



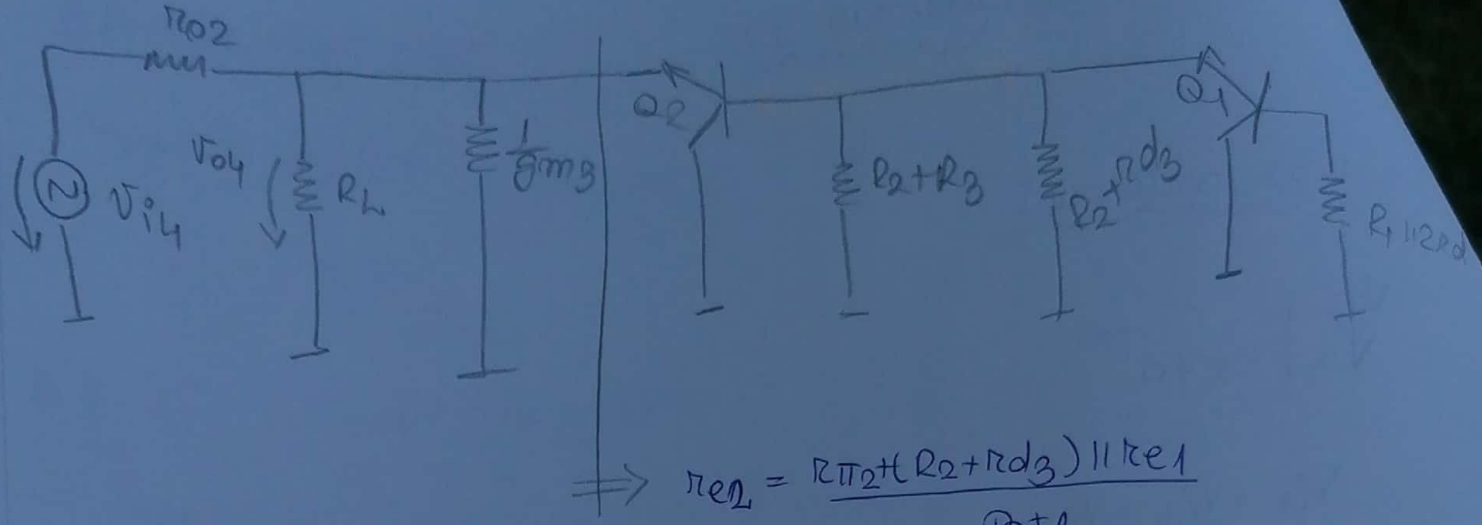
$$\frac{v_{o2}}{v_{i3}} = 0$$



$$\frac{v_{o2}}{v_{i4}}\Big|_{v_{i4}\neq 0}$$

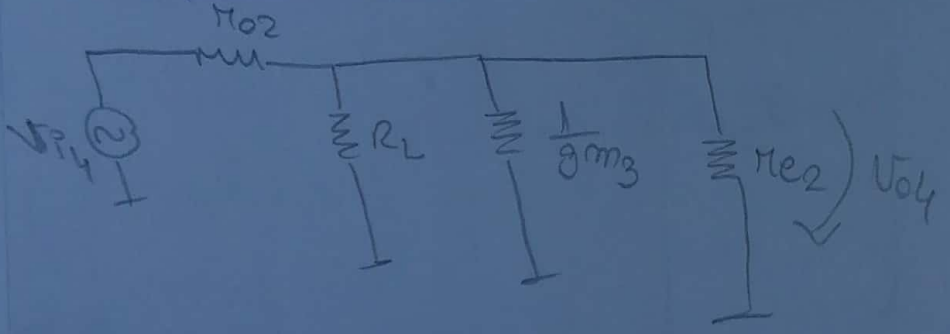
$$v_{i4-3} = 0$$

$$r_{eq} = \frac{r_{\pi 1} + R_1 \| 2r_d}{\beta + 1}$$



$$\Rightarrow r_{e2} = \frac{R \| r_2 + (R_2 + r_{d3}) \| r_{e1}}{\beta + 1}$$

Schema devine:



$$\frac{v_{o2}}{v_{o4}} = \frac{i(R_L \| \frac{1}{g_{m3}} \| r_{e2})}{i(r_{o2} + R_L \| \frac{1}{g_{m3}} \| r_{e2})} = \frac{r_{e2}}{r_{o2} + r_{e2}}$$

Pe $\frac{1}{S} = \frac{1}{S_1} + \underbrace{\frac{1}{S_2}}_{0} + \underbrace{\frac{1}{S_3}}_{0} + \frac{1}{S_4} = \frac{1}{S_1} + \frac{1}{S_4}$

$$S_1 = \frac{v_{i1}}{v_{o1}} = 1 + \frac{R_1}{2R_d} \qquad S_4 = \frac{v_{i4}}{v_{o4}} = 1 + \frac{r_{o2}}{r_{e2}}$$

Stabilitatea să fie ideal $\to \infty$

Pentru a-l crește pe S_1

S_1 → $R_1 \to \infty$ (scade curentul prin Zener ⇒ pere din stabilizare ⇒ nu putem crește R_1)

↓ $r_d \to 0$ (dioda să funcționeze la curent mare ⇒ nu se justifică)

pentru S_2:

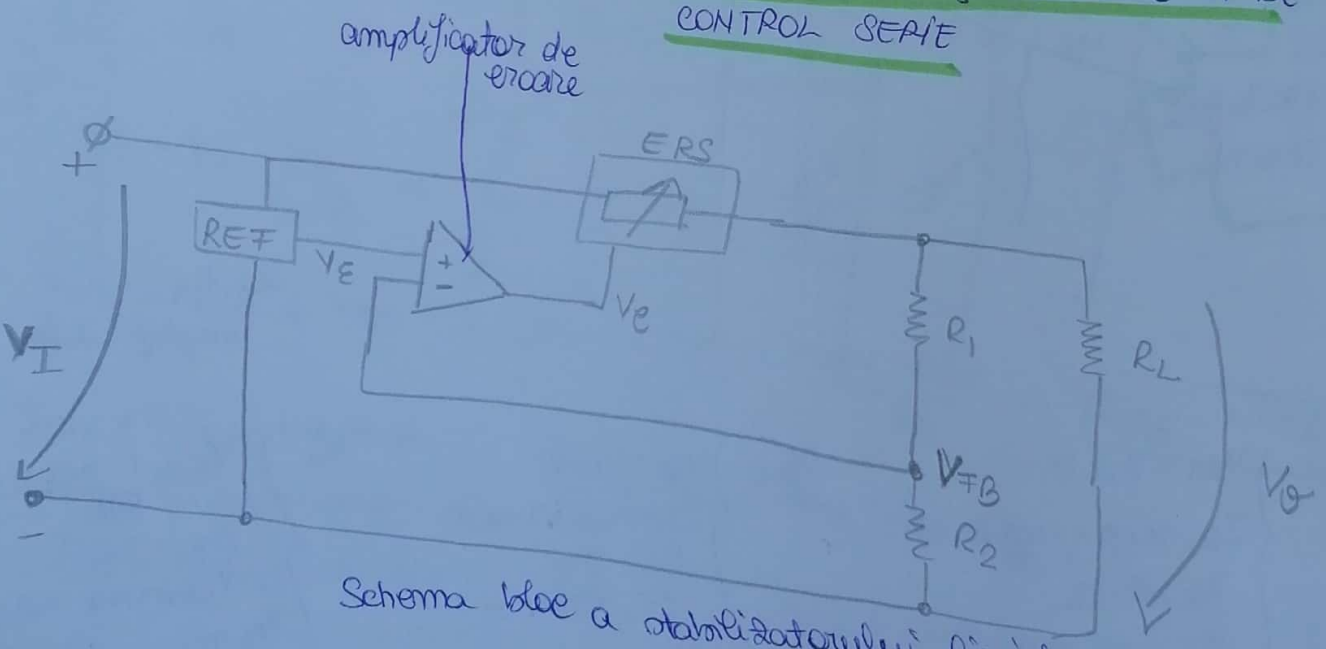
S_2 → $r_{O2} \to 0$ (V_A cât mai mare ⇒ putem alege tranz cu V_A mare)

$r_{e2} \to 0$ ($g_{m3} \uparrow$ ⇒ curent mare prin Q_3 ⇒ randament scăzut.

Soluții:

1) R_1 cu generator de curent constant
2) $V_A \uparrow$

STABILIZATOR LINIAR CU REACȚIE, ELEMENT DE CONTROL SERIE



Schema bloc a stabilizatorului liniar cu reacție

$$f_{vu} = \frac{R_2}{R_1 + R_2}$$

f_{vu} = factorul de reacție

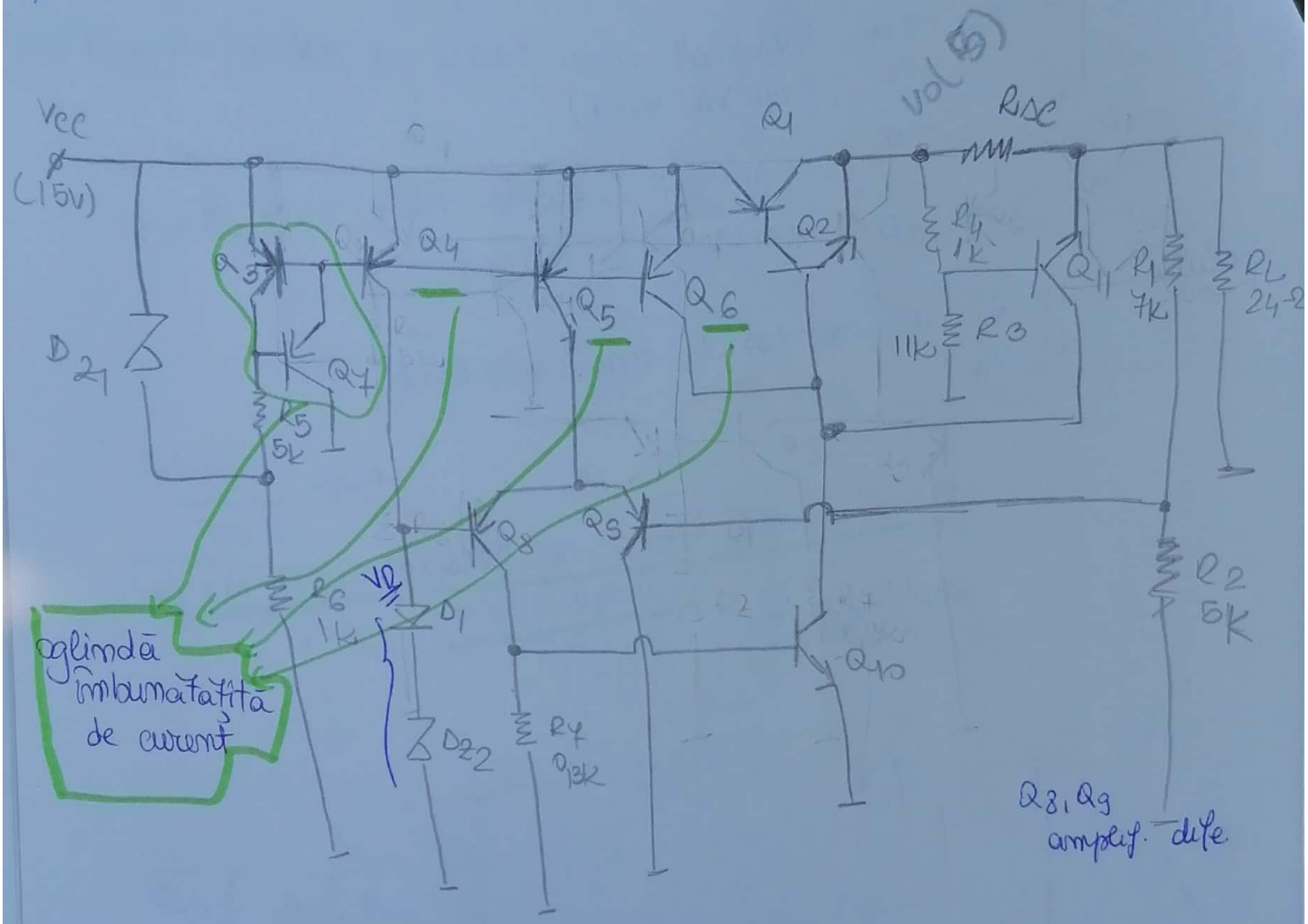
$$V_E = V_R - f_{vu} V_O$$

$$V_e = a_u (V_R - f_{vu} V_O) = a (V_+ - V_-)$$

↓ tensiunea de la ieșirea amplificatorului

$V_R = V_+$

$\int u V_0 = V_-$



D1: $V_{Z1} = 6,2V$; $I_{Z,min} = 1mA$; $R_Z = 0\Omega$; $\alpha_T = 0^\circ mV/^\circ C$

D22: $V_Z = 4,4V$; $I_{Z,min} = 1mA$; $R_Z = 0\Omega$; α_T 2mV/°C

Q4: $V_{EB\,RAN} = 0,6V$; $\beta_T = 50$; $V_{CE,MAX} = 25V$; $P_{D,max} = 1,6W$

Q2: $V_{BE\,RAN} = 0,6V$; $\beta_T = 100$; $V_{CE,max} = 25V$; $P_{D,MAX} = 0,5W$

Q3-11: $V_{BE\,RAN} = 0,6V$; $\beta_T = 200$

D1: $V_{D1,ON} = 0,6V$; $\frac{\Delta V_D}{\Delta T} = -2mV/°C$; $\frac{V_0}{\alpha_T} = -2mV/°C$

$I_{03} = \frac{1}{2} I_{04} = \frac{1}{4} I_{05} = \frac{1}{10} \cdot I_{06} \Rightarrow$ I_S-urile nu sunt egale

Se cer: 1) β_T ($V_{cc} = 15V$, $R_2 = 24\Omega$) $\frac{dV_0}{dT}$

2) $I_{o\,max}$, pt $V_o = ct$

3) $V_{EE,max}$, $V_{CE,max} = 25V$

4) $V_{EE,min}$

5) I_E, $R_L = 0$, $V_{EE} = 13V$

$$I_C = I_S \exp\left(\frac{V_{BE}}{V_{th}}\right)$$

$$I_{S3} = \frac{1}{2} I_{S4}$$

Referința e mereu formată din diode și diode Zener

$$V_O - V_{FB} = I_1 R_1$$

$$I_1 = \frac{V_O}{R_1 + R_2}$$

$$\Rightarrow V_O - V_{FB} = \frac{R_1 V_O}{R_1 + R_2} \Rightarrow V_{FB} = \frac{V_O(-R_1)}{R_1 + R_2} + 1$$

$$= V_O \frac{R_2}{R_1 + R_2} = f$$

$$V_{D2} + V_{D1} + V_{BE} = V_{BE} + V_{FB} \Rightarrow V_{FB} = 5V$$

$V_{D2} \Downarrow 4{,}4$ $\quad V_{D1} \Downarrow 0{,}6$

$$5 = V_O \cdot \frac{R_2}{R_2 + R_1} \Rightarrow V_O = \frac{60}{5} \Rightarrow V_O = 12V$$

$$V_{DZ1} = V_{BE} + V_{BE} + I_{C3} R_5 \Rightarrow I_{C3} = \frac{V_{DZ1} - 2V_{BE}}{R_5} \Rightarrow I_{C3} = 1mA$$

$$I_{C4} = 2 I_{C3} = 2mA$$

$$I_{C5} = 4 I_{C3} = 4mA$$

$$I_{C6} = 10 I_{C3} = 10mA$$

$$\Rightarrow I_{C7} = I_{B3} + I_{B4} + I_{B5} + I_{B6}$$

$$\Rightarrow I_{C7} = \frac{I_{C3}}{\beta}(1 + 2 + \tfrac{1}{2} + 10) = \frac{17}{\beta} \ll I_{C3}$$

$$I_{C8} \cdot R_7 = V_{BE} \Rightarrow I_{C8} = 2mA$$

$$I_{C9} = I_{C5} - I_{C8} = 2mA$$

$Q_1, Q_2 \rightarrow$ ERS

REF $\rightarrow D_1, D_{Z2}$

$R_{SC}, R_4, R_9, Q_4 \rightarrow$ protecție la supracurent

$I_{B2} << I_{C10} \Rightarrow I_{C10} \cong I_{C6} = \underline{10\,mA}$

$I_{C1} + I_{C2} = \frac{V_0}{R_1+R_2} + \frac{V_0}{R_L} + \frac{V_0}{R_3+R_4} \cong \frac{V_0}{R_L} = \frac{12}{24} = \frac{1}{2}\,A = \underline{500\,mA}$

$I_{C2} = \frac{I_{C1}}{\beta}$

$I_{C1} + \frac{I_{C1}}{\beta} = 0{,}5 \Rightarrow \boxed{I_{C1} \cong 0{,}5A} \Rightarrow I_{C2} = \frac{I_{C1}}{\beta} = \frac{0{,}5}{\beta} = \underline{5 \cdot 10^{-3}\,A}$

Verific căderea de tensiune pe R_{sc} (să vedem dacă chiar a fost neglijabilă).

$I_0 \cdot R_{sc} = 0{,}5 \cdot 0{,}5 = 0{,}25$ (negligabil $\Rightarrow$ aprox. ok)
(psf.. aceasă)

$\frac{\Delta V_0}{\Delta T} = \left(1 + \frac{R_4}{R_2}\right) \cdot \left(\frac{\Delta V_2}{\Delta T} + \frac{\Delta V_D}{\Delta T}\right)$
$\cong$ 0mV/°C

$\frac{\Delta V_2}{\Delta T} = 2\,mV/°C$ $\quad \alpha_T$ = coef de variație cu temperatura

$\frac{\Delta V_D}{\Delta T} = -2\,mV/°C$

$\frac{\Delta V_0}{\Delta T} = 0$

2) $I_{0\,max}$, $V_0 = ct$

$V_{RSC} + V_{EB} - V_{R4} = 0 \Rightarrow I_{0max} \cdot R_{SC} + 0{,}8 - \frac{V_0 \cdot R_4}{R_4+R_3} = 0$

$i_0 \cdot R_{SC} + V_{EB} - \frac{V_0 R_4}{R_4+R_3}$

$V_{RSC} = \cancel{V_0 R_4 / R_4}\ i_0 \cdot R_{SC}$

$V_{R4} = \frac{-V_0 \cdot R_4}{R_4+R_3}$

$I_{0,max} = \frac{V_{BE} - \frac{V_0}{R_4+R_3} \cdot R_4}{R_{SC}} = 3\,A$

$R_{L,min} = \frac{V_0}{I_{0max}} = \frac{12}{3} = 4\,\Omega$

$V_{CC,max}$

$V_{CC} - V_O = V_{CE1\,max}$

$V_{CC} - V_O \leq V_{CE1\,max}$

$V_{CC\,MAX_1} \simeq 37\,V$

$= (V_{CC} - V_O) \cdot \frac{V_O}{R_L} < P_{D,MAX}$

$V_{CC,MAX2} \simeq 17\,V$ → cel mai bun caz

$V_{CC} - V_O = -V_{BE1} + V_{CE2,MAX} \Rightarrow V_{CC,MAX_3} = 37{,}6\,V$

$(V_{CC} - V_O) \cdot \frac{V_O}{R_{L\,MIN}} \cdot \beta < P_{DMAX}$

$\simeq 21\,V$

- min $\{V_{CC\,MAX_1}, V_{CC\,MAX_3}\}$

4) $V_{CC,min}$

$V_{CE1\,min} \simeq 0{,}6\,V$

COND pt min. trans să rămână în SAT / RAN

- $V_{CC,min_1} = \underbrace{V_{CE1,min}}_{V_{EB1} = 9{,}6\,V} + V_O$ → $V_{CC,min_1} = 12{,}6\,V$

- $V_{CC,min_2} = V_{EB1} + V_{CE2,min} + V_O$

- $V_{CC,min_2} = 12{,}6 + 0{,}6 = 13{,}2\,V$

- $V_{CC,min_3} = V_{EB3} + i_{B3}(R_5 + R_6)$

$V_{CC,min_3} = 0{,}6 + 1 \cdot 6$ ⇒ $V_{CC,min} = 6{,}6\,V$

- $V_{CC,min_4} = V_{EC4,min} + V_D + V_{D2} = 0{,}6 + 0{,}6 + 3{,}4 = 6{,}6\,V$

~~Cel mai rau caz~~

$V_{ieemin} = \max\{V_{ieemin1}, V_{eemin2}, V_{eemin3}, \dots\} =$

$= 13{,}2\,V$

5) $i_o = ?$ $R_L = 0$; $V_{ee} = 13\,V$

$V_{ee} = V_{CE1}$

$R_L = 0 \Rightarrow V_o = 0$

$V_{BE11} = 0{,}6 \Rightarrow i_o \cdot R_{se} = i_4 R_4 + V_{BE11} \Rightarrow$

$i_4 = \frac{V_o}{R_4 + R_3} = \frac{0}{R_4 + R_3} = 0$ $\qquad i_o \cdot R_{se} = V_{BE11} \Rightarrow$

$i_o = \frac{V_{BE11}}{R_{se}} \Rightarrow$

$\Rightarrow i_o = \frac{0{,}6}{0{,}5} = 1{,}2\,mA$

$V_{EC_1} = V_{ee} = 13\,V$; deoarece $i_o \cdot R_{se}$ se consideră neglijabil

$P_{disipată\ de\ Q_4\ în\ se} = 13 - 1{,}2 = 16\,W$ $\Rightarrow$ când suntem în se Q_4 nu se distruge

$P_D = V_{CE} \cdot i_C$ (puterea disipată max de tranzistor.)