# Fundamentals Of Electronic Circuits

An 1

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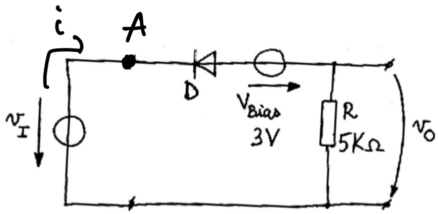
# Seminar 2

**1**. Consider for D - constant voltage drop model, $v_D$=0.7V.
a) Derive and plot the VTC $v_O(v_I)$ of the circuit, for $v_I \in [-20V;20V]$.
b) What is the maximum value for $v_I$ to have a non-zero output value $v_O$?
c) Plot $v_O(t)$ for $v_I(t) = 5\sin\omega t$ [V]. What is the application of the circuit?
d) **$V_{Bias}$=0.** A capacitor C is connected in parallel to R. Assume $v_I(t) = 5\sin\omega t$ [V] Replot, qualitatively, $v_O(t)$.




a) $V_I \in [-20V, 20V]$

$$\xrightarrow{KVL} \begin{cases} -V_I - V_D + V_{BIAS} + V_R = 0 \\ V_O = -V_R = -i_D \cdot R \end{cases}$$

$$V_R = V_O = V_I + V_D - V_{BIAS}$$

$$V_O = V_I + 0{,}7 - 3$$

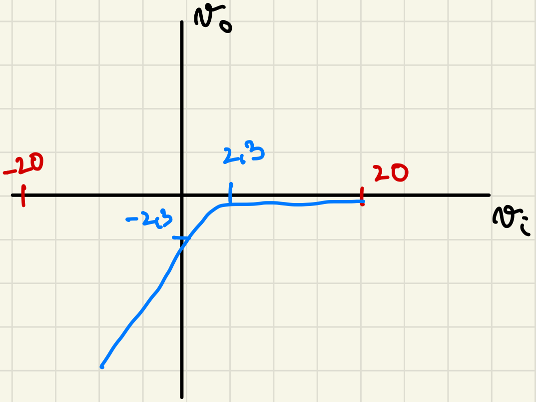
$$V_O = V_I - 2{,}3$$

$$D\text{-on} \Rightarrow \begin{cases} i_D > 0 \Rightarrow V_O > 0 \\ v_D = 0{,}7 \end{cases}$$

$$\Rightarrow -V_I - 0{,}7 + 3 + i_D \cdot R = 0$$

$$\Rightarrow V_I = i_D \cdot R + 2{,}3 \Leftrightarrow V_I - 2{,}3 = i_D \cdot R \Rightarrow i_D = \frac{V_I - 2{,}3}{R} > 0$$

$$D\text{-off} \Rightarrow i_D = 0 \Rightarrow v_O = 0$$

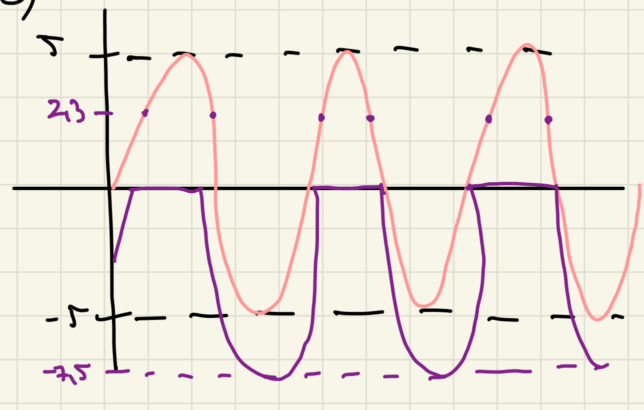



b) $\boxed{v_o = v_i - 2{,}3}$

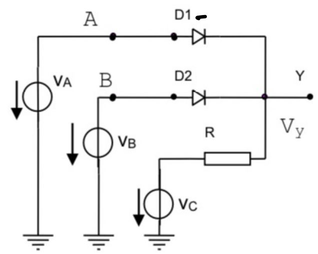
$v_o \neq 0 \rightarrow v_i \neq 2{,}3\,V$

max val of $v_i \in [-20\,V,\ 2{,}3\,V)$

c)



**2**. Consider for $D_1$ and $D_2$ - constant voltage drop model, $v_D$=0.7V.
a) Find the expression $v_Y(v_A,v_B,v_C)$.
b) Plot $v_Y(t)$ if $v_C(t)=0$; $v_A(t)=2V$; $v_B(t)=5\sin\omega t$ [V]. Mention the states (on, off) for $D_1$ and $D_2$
c) For $v_C$=0V; $v_A,v_B \in \{0v;10V\}$; assuming the logic convention: 0V-"0" logic, 10V-"1"logic, fill the truth table Y(A,B) and find the logic function of the circuit .




a) maximum multi-port network

$$V_y = \max(v_A - 0{,}7,\ v_B - 0{,}7,\ v_C)$$

b) plot $v_y(t)$ if $v_C(t) = 0$, $v_A(t) = 2V$, $v_B = 5\sin\omega t$

for $\begin{cases} D_1 \text{ off} \\ D_2 \text{ off} \end{cases}$, $v_y = v_C = 0$

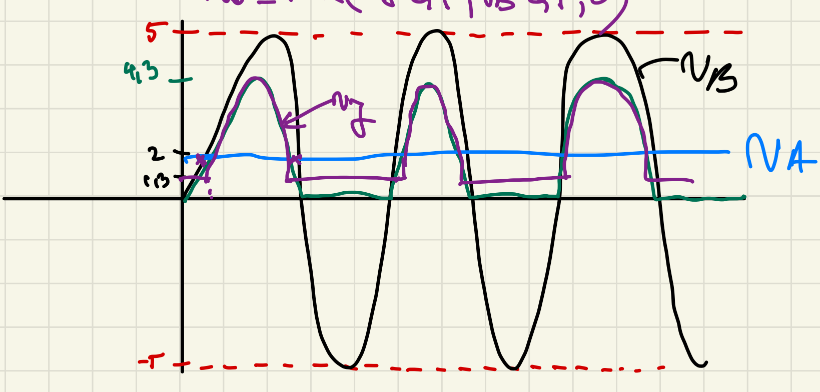
$$V_O = \max(v_A - 0{,}7;\ v_B - 0{,}7;\ v_C)$$

for $\begin{cases} D_1 \text{ on} \\ D_2 \text{ off} \end{cases}$, $v_y = v_A - 0{,}7 = 1{,}3\ V$

for $\begin{cases} D_1 \text{ off} \\ D_2 \text{ on} \end{cases}$, $v_y = v_B - 0{,}7 = 5\sin\omega t - 0{,}7 = 4{,}3\sin\omega t$

for $\begin{cases} D_1 \text{ on} \\ D_2 \text{ on} \end{cases}$, $v_y = \max(v_A - 0{,}7,\ v_B - 0{,}7) = \max(1{,}3V;\ 4{,}3\sin\omega t)$

$v_O = \max(v_A - 0{,}7;\ v_B - 0{,}7;\ 0)$



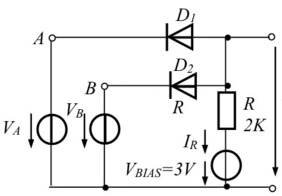
c)

| $V_A$ | $V_B$ | $V_C$ | $V_y$ |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 9,3 |
| 0 | 10 | 0 | 9,3 |
| 10 | 10 | 0 | 9,3 |

| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 1 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 1 | 1 |

OR

**3.** Assume for $D_1$, $D_2$ - constant voltage drop model, $v_D$=0.7V.
a) What is the expression of $v_O(v_A, v_B)$? Determine the value of $v_O$, the current $i_R$, the states of $D_1$ and $D_2$ and the voltages on $D_1$ and $D_2$ for $v_A$= - 2V and $v_B$ = 8V. Draw the circuit's model in this case.
b) Is it possible to use this circuit as a logic circuit with the inputs A and B, considering the following voltage levels: 0V – "0", 10V – "1"? Where should be the output Y of the logic circuit? Find the suitable value of $V_{Bias}$ to use the circuit as a logic circuit with these voltage levels and give the logic table of the circuit with inputs A, B and output Y.




a) • $v_o(v_A, v_B)$

• for $v_A = -2V$, $v_B = 8V$, det the value of $v_o$, $i_R$, states of $D_1$ & $D_2$, $v_{D_1}$, $v_{D_2}$

Minimum multiport network

$v_o = \min(v_A + 0{,}7;\ v_B + 0{,}7,\ V_{BIAS})$

KVL pt circuit interior => $V_{BIA} - V_B - v_{D_2} + V_R \Rightarrow V_{BIAS} + V_R = v_{D_2} + v_B$

dreapta => $v_o - v_R - v_{BIAS} = 0 \Rightarrow v_o = V_{BIAS} + V_R = v_{D_2} + v_B$

$v_o = 3V + 2 \cdot i_R$ (1)

KVL pt circuit exterior $\Rightarrow V_A - V_{BIAS} - v_R + v_{D_1} = 0$

$$\Rightarrow V_{BIAS} + v_R = v_A + v_{D_1}$$

$$v_0 - v_R - v_{BIAS} = 0$$

$$\Rightarrow v_0 = V_{BIAS} + v_R = v_A + v_{D_1} \quad (2)$$

$$v_0 = v_A + v_{D_1}$$

$$v_0 = v_B + v_{D_2}$$

$$\oplus$$

$$2v_0 = v_A + v_B + v_{D_1} + v_{D_2}$$

$$v_0 = \frac{v_A + v_B + v_{D_1} + v_{D_2}}{2}$$

for $v_A = -2V$, $v_B = 8V \Rightarrow D_1$ ON

$D_2$ OFF

$$V_0 = V_{BIAS} + i_R \cdot R \Rightarrow i_R = \frac{V_{BIAS} - v_0}{R} = 2{,}15 \text{ mA}$$

b)

| $V_A$ | $V_B$ | $V_y$ |
|---|---|---|
| 0 | 0 | 0,7 |
| 0 | 10 | 0,7 |
| 10 | 0 | 0,7 |
| 10 | 10 | 10 |

$v_y = \min(v_A + 0{,}7, v_B + 0{,}7, V_{BIAS})$

| A | B | y |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

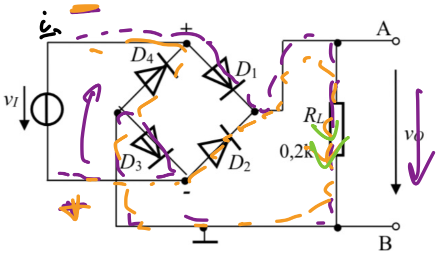
AND

**5.** Consider $v_I(t)$ a sine wave, 30V amplitude and 50Hz frequency.

a) How does $v_I(t)$, $v_O(t)$, and the current through $D_1$ look like?

b) What is the maximum value of the current through $D_1$?

c) Consider that a capacitor $C$ is connected at the output (between A and B points). What should be the value of the capacitor so that the output ripple $\Delta v_O < 2V$?




a) for $v_I > 0\,V \Rightarrow D_1, D_3$ ON
$D_2, D_4$ OFF

for $v_I < 0\,V \Rightarrow D_1, D_3$ OFF
$D_2, D_4$ ON

KVL $\Rightarrow$ for $v_I > 0\,V$

$$\left.\begin{aligned} v_I - v_{D_1} + v_{R_L} - v_{D_3} &= 0 \\ v_{O\,max} &= -v_{R_L} \end{aligned}\right\} \Rightarrow \begin{aligned} v_{O\,max} &= v_I - v_{D_1} - v_{D_3} \\ v_{O\,max} &= 30V - 1{,}4V = 28{,}6V \end{aligned}$$

for $v_I < 0\,V$

KVL $\Rightarrow$

$$\left.\begin{aligned} v_I + v_{D_2} + v_{R_L} + v_{D_4} &= 0 \\ v_{O\,max} &= v_{R_L} \end{aligned}\right\} \Rightarrow v_{O\,max} = -\left(v_I + v_{D_2} + v_{D_4}\right)$$

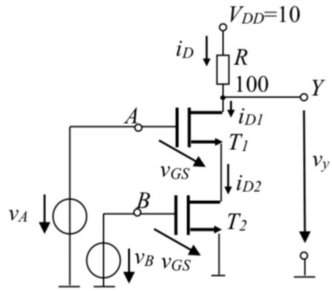
$\cancel{V_{O\,max} = -28{,}6}$

$v_i > 1{,}4V$ $\quad v_O = v_i - 1{,}4 \Rightarrow V_{O\,max} = 28{,}6V$

$v_i < -1{,}4$ $\quad v_O = -(v_i + 1{,}4)$ $\quad / D_2 + D_4$

# Seminar 3
# TRANSISTORS

**1.**
For both n-type transistors, $V_{Thn}$=3V. The transistors operate as ideal switches; $v_A$, $v_B \in \{0V; 10V\}$. Assume the logic convention: 0V-"0"; 10V-"1".




**a)** Draw the electrical operating table of the circuit. Specify for each line in the table the state of both transistors (*on* or *off*).
**b)** Draw the logic operating table of the circuit, considering the output Y. What is the logic function of this circuit?
**c)** Compute the maximum output current. For what combinations of values of $v_A$ and $v_B$ does this current appear?

a)

| $V_A$ | $V_B$ | $T_1$ | $T_2$ | $V_y$ |
|---|---|---|---|---|
| 0 | 0 | off | off | 10 |
| 0 | 10 | of | on | 10 |
| 10 | 0 | on | of | 10 |
| 10 | 10 | on | on | 0 |

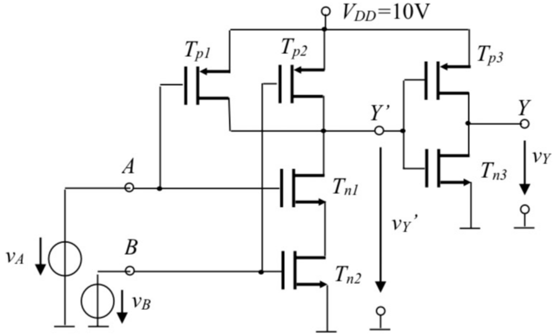
b)

| A | B | Y |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

c) $I_{omax} = \frac{V}{R} = \frac{10V}{100\Omega} = 100\,mA$

**2.**
For all n-type transistors $T_{ni}$, $V_{Thn}$=3V and for all p-type transistors $T_{pi}$, $V_{Thp}$=-3V. The transistors operate as ideal switches; $v_A$, $v_B$∈{0V; 10V}. Assume the logic convention: 0V-“0”; 10V-“1”.

**a)** Draw the electrical operating table of the circuit, for both outputs $v_{Y'}$, respectively $v_Y$. Specify for each line in the table the state of all six transistors (*on* or *off*).
**b)** Draw the logic operating table of the circuit, considering the output Y. What is the logic function of this circuit?



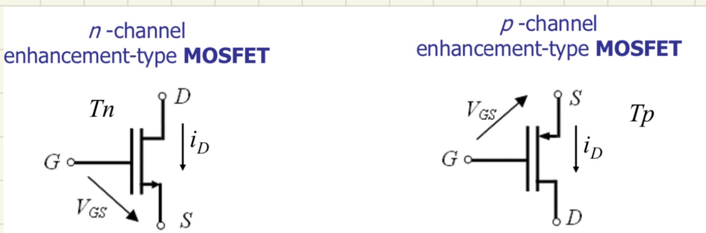

a)

| $V_A$ | $V_B$ | $T_{n_1}$ | $T_{n_2}$ | $T_{p_1}$ | $T_{p_2}$ | $V_{y'}$ | $T_{n_3}$ | $T_{p_3}$ | $V_y$ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | off | off | on | on | 10V | on | off | 0V |
| 0 | 10 | off | on | on | off | 10V | on | off | 0V |
| 10 | 0 | on | off | off | on | 10V | on | off | 0V |
| 10 | 10 | on | on | off | off | 0V | off | on | 10V |

b)

| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

AND

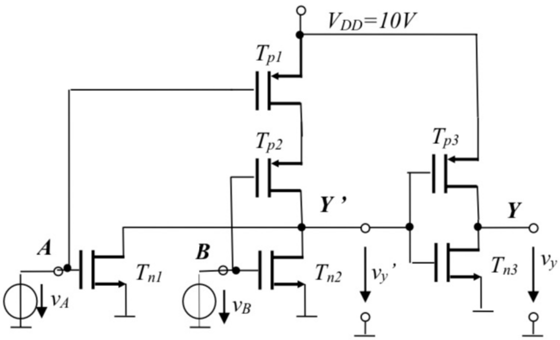



$V_{GS} > V_{th} \Rightarrow$ ON
$V_{GS} < V_{th} \Rightarrow$ off

$V_{GS} < V_{Th} \Rightarrow$ ON
$V_{GS} > V_{Th} \Rightarrow$ off

**3.**

For all n-type transistors $T_{ni}$, $V_{Thn}$=3V and for all p-type transistors $T_{pi}$, $V_{Thp}$= -3V. The transistors operate as ideal switches; $v_A$, $v_B \in \{0V; 10V\}$. Assume the logic convention: 0V-“0”; 10V-“1”.




**a)** Draw the electrical operating table of the circuit, for both outputs $v_{Y'}$, respectively $v_Y$. Specify for each line in the table the state of all six transistors (*on* or *off*).

**b)** Draw the logic operating table of the circuit, considering the output Y. What is the logic function of this circuit?

**c)** Change the circuit to obtain the logic function OUT= AND(A,B).

a)

| $v_A$ | $v_B$ | $T_{n1}$ | $T_{n2}$ | $T_{p1}$ | $T_{p2}$ | $v_y'$ | $T_{n3}$ | $T_{p3}$ | $v_y$ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | off | off | on | on | 10V | on | off | 0V |
| 0 | 10 | off | on | on | off | 0V | off | on | 10V |
| 10 | 0 | on | off | off | on | 0V | off | on | 10V |
| 10 | 10 | on | on | off | off | 0V | off | on | 10V |

b)

| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

OR

c) ?

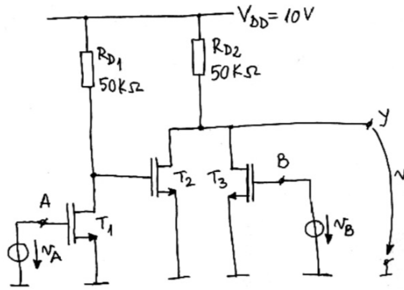
**5.**

For $T_1$, $T_2$, $T_3$, $V_{Th}$=3V. $T_1$, $T_2$, $T_3$ operate as ideal switches. $v_A$, $v_B \in$ {0V; 10V}. Assume the logic convention: 0V-"0"; 10V-"1".

**a)** Draw the electrical operating table of the circuit for all the possible voltage combinations of $v_A$, $v_B$. Specify for each line in the table the state (on or off) of $T_1$, $T_2$ and $T_3$.

**b)** Draw the logic operating table of the circuit. What is the logic function of the circuit?

**c)** Compute the maximum power consumption of the circuit from $V_{DD}$. For what combinations of values of $v_A$ and $v_B$ does this maximum power consumption appear?




a)

| $V_A$ | $V_B$ | $T_1$ | $T_2$ | $T_3$ | $V_y$ |
|---|---|---|---|---|---|
| 0 | 0 | off | on | off | 0V |
| 0 | 10 | off | on | on | 0V |
| 10 | 0 | on | off | off | 0V |
| 10 | 10 | on | on | on | 10V |

b)

| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

AND

c) $P = V \cdot I$

caz : $v_A = 10V$, $v_B = 10V$

KVL ⇒ $-v_A + R_1 \cdot I - v_{DD} = 0$

$R_1 \cdot I = v_A + v_{DD}$

$R_1 \cdot I = 20$

$I = \frac{20}{50} = \frac{2}{5} mA$

$-v_B + R_2 I_2 - v_{DD} = 0$

$R_2 I = v_{DD} + v_B$

$R_2 I = 20$

$I = \frac{2}{5} mA$

$P = V \cdot I = V_{DD} \cdot I$

$= 10 \cdot 0,4 = 4W$

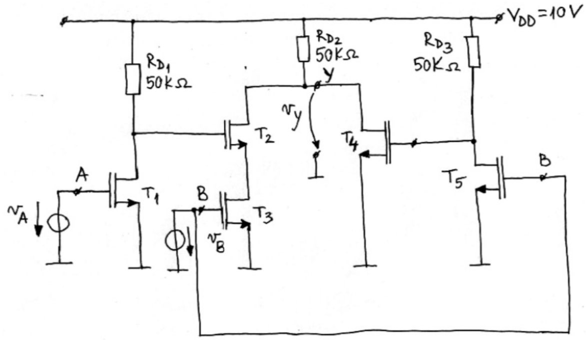
**6.**

For $T_1$, $T_2$, $T_3$, $T_4$, $T_5$, $V_{Th}$=3V. $T_1$, $T_2$, $T_3$, $T_4$, $T_5$ operate as ideal switches. $v_A$, $v_B \in \{0V;\ 10V\}$. Assume the logic convention: 0V-“0”; 10V-“1”.

**a)** Draw the electrical operating table of the circuit considering the output $v_Y$. Specify for each line in the table the state (on or off) of all five transitors.

**b)** Draw the logic operating table of the circuit. What is the logic function of the circuit?

**c)** Compute the maximum currents through $T_1$, $T_2$, $T_3$, $T_4$ and $T_5$ and the maximum power consumption of the circuit from $V_{DD}$.




a)

| $V_A$ | $V_B$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $V_y$ |
|---|---|---|---|---|---|---|---|
| 0 | 0 | off | on | off | on | off | 0 V |
| 0 | 10 | off | on | on | off | on | 0V |
| 10 | 0 | on | off | off | on | off | 0V |
| 10 | 10 | on | off | on | off | on | 10V |

b)

| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

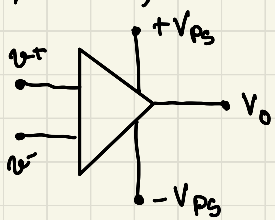
AND

# Seminar 4
# Op Amp Comparators

## Op Amp Identification:

**Simple comparator:**

- No feedback
- Output only takes two values



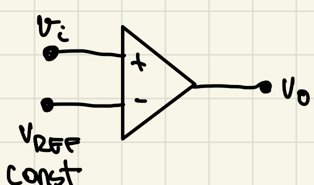

$v_o = +V_{PS}$ when $v^+ > v^-$

$v_o = -V_{PS}$ when $v^+ < v^-$

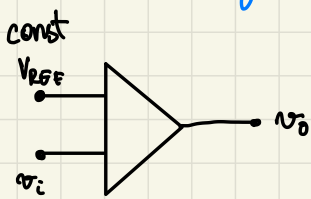
$V_{th}$ = the value of the input at which $v_o$ switches, that is when $v^+ = v^-$

"The input" is either specified by the problem or is the only adjustable element in the circuit

Input connected to $v^+$ ⇒ non inverting
Input connected to $v^-$ ⇒ inverting

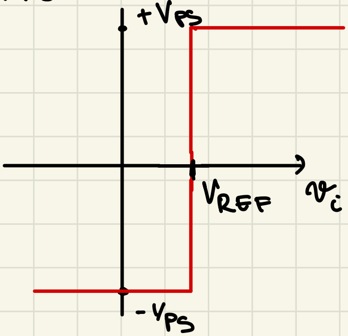



non-inverting simple comparator

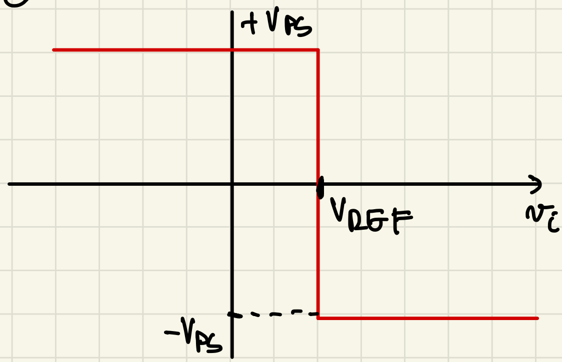



inverting simple comparator

VTC:




VTC:

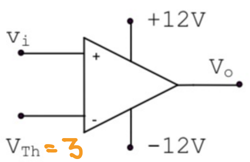



# Probleme seminar 4
## Op Amp Comparators:

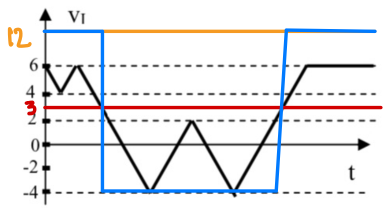
**1.**

a) Plot VTC $v_o(v_I)$ for $v_I \in [-12V;12V]$ considering $V_{Th}=3V$.

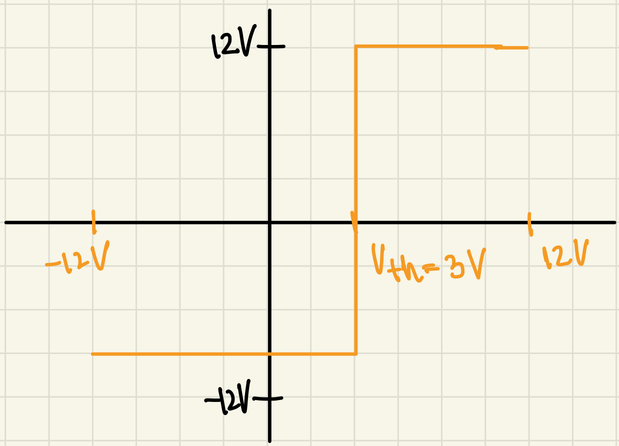
b) Plot vo(t) for $v_I(t)$ in the figure.




b)




a)




$v_i < 3V \Rightarrow v_0 = -12V$

$v_i > 3V \Rightarrow v_0 = 12V$

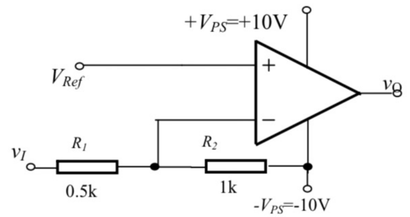
**2.**

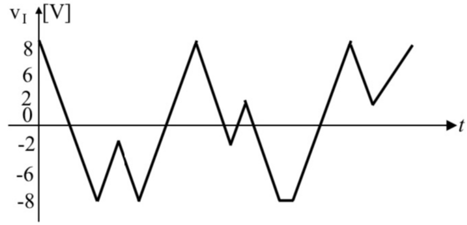
Considering $V_{Ref}$=1V:

a) What is the application of the circuit? Justify the answer.

b) For what value of $v_I$, vo switches?

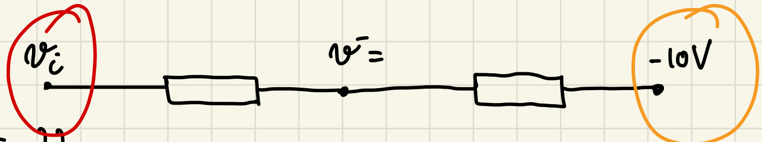
c) Plot $v_O(t)$ for $v_I(t)$ in the figure.



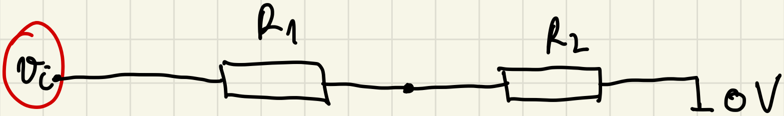




a) comparator

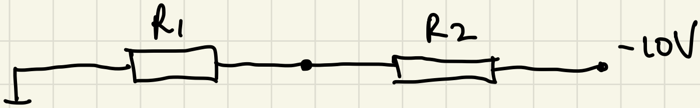
b)




$v^- = !!$




$$v_1^- = \frac{R_2}{R_1+R_2} \cdot v_i$$




$$v_2^- = \frac{R_1}{R_1+R_2} \cdot (-10V)$$

the supperposition theorem

$$v^- = \frac{R_2}{R_1+R_2} v_i + \frac{R_1}{R_1+R_2} \cdot (-10V) =$$

$$v^- = \frac{1}{1.5} v_i + \frac{0{,}5}{1{,}5} (-10V)$$

$$v^- = \frac{2}{3} v_i - 3{,}33\,V$$

$v^+ > v^-$

$\Leftrightarrow \quad v_{REF} > \frac{2}{3} v_i - 3{,}33$

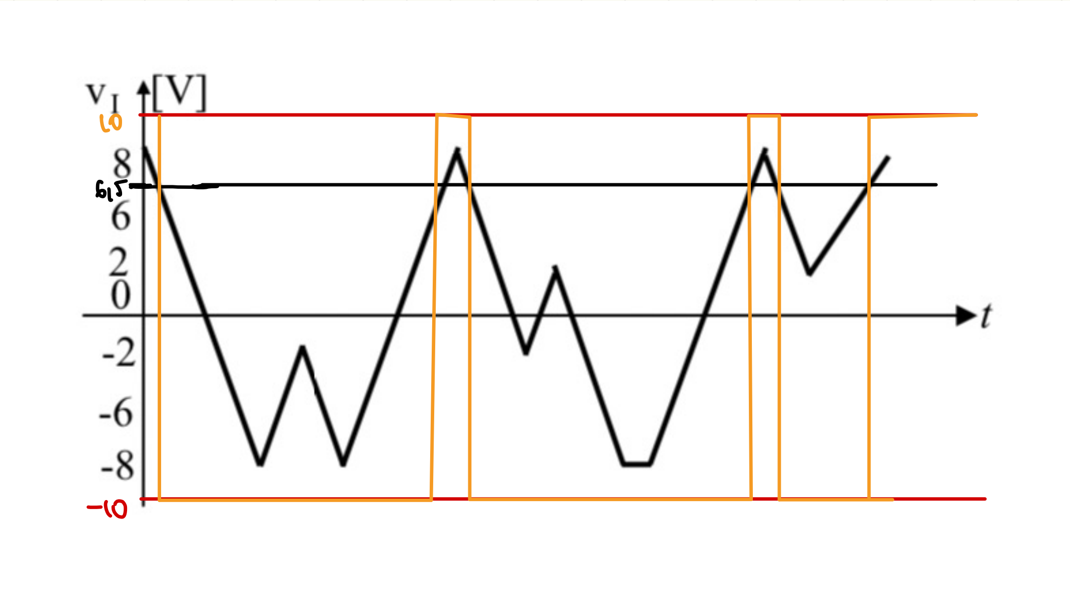
$\Rightarrow \quad 1 > \frac{2}{3} v_i - 3{,}33$

$4{,}33 > \frac{2}{3} v_i$

$v_i > 4{,}33 \cdot \frac{3}{2} \quad \Rightarrow v_i > 6{,}5\,V$

$$v_0 \in \begin{cases} +10V, & v_i > 6{,}5\ V \\ -10V, & v_i < 6{,}5\ V \end{cases}$$

c)



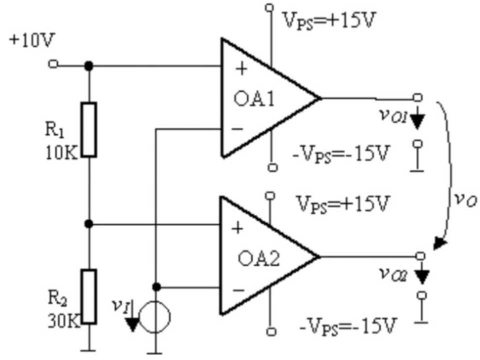
**3.**
Assume $OA_1$, $OA_2$ ideal.

**a)** For $v_I \in [-12V;12V]$, find the expression of $v_{O1}(v_I)$ and plot the VTC $v_{O1}(v_I)$. What is the application of the circuit assuming $v_{O1}$ as output?

**b)** For $v_I \in [-12V;12V]$, find the expression of $v_{O2}(v_I)$ and plot the VTC $v_{O2}(v_I)$. What is the application of the circuit assuming $v_{O2}$ as output?

**c)** Plot the VTC $v_O(v_I)$ for $v_I \in [-12V;12V]$.

**d)** Assuming $v_I(t) = 11\sin\omega t [V]$, plot $v_I(t)$ and $v_O(t)$. What is the application of the circuit?




On parts

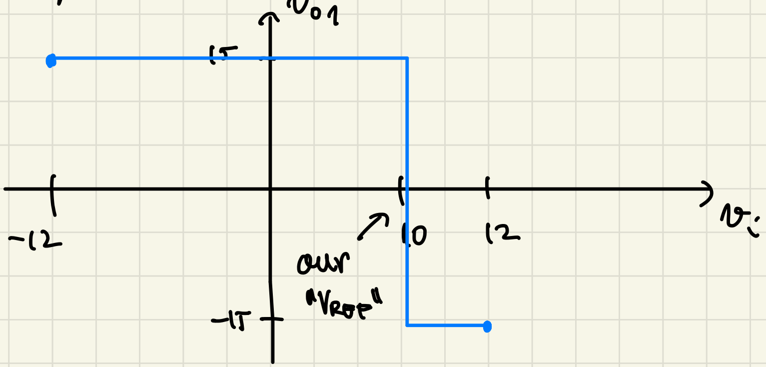
$OA_1$ : $v_1^+ = 10V$
$v_1^- = v_i$

$OA_2$ : $v_2^+ = \frac{R_2}{R_1+R_2} \cdot 10V = 7{,}5V$
$v_2^- = v_i$

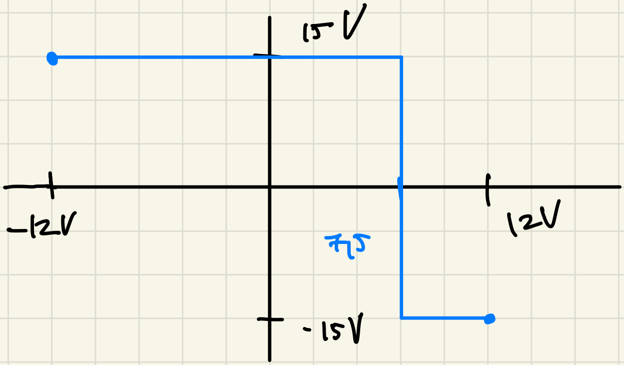
$OA_1$ and $OA_2$ inverting ($v_i$ legat la $v^-$)

$$v_{01} = \begin{cases} +15V, & v_i < 10V \\ -15V, & v_i > 10V \end{cases} \qquad v_{02} = \begin{cases} +15V, & v_i < 7{,}5V \\ -15V, & v_i > 7{,}5V \end{cases}$$

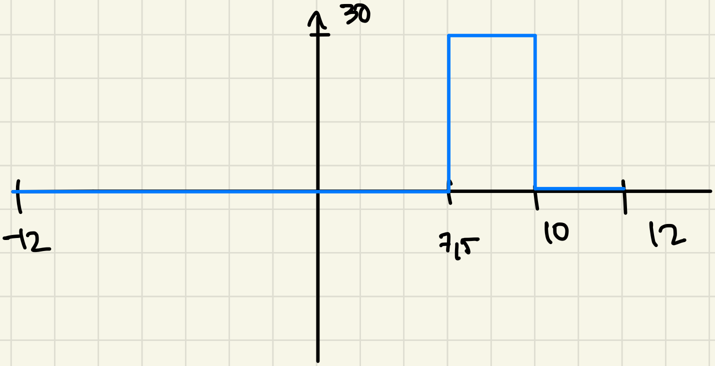
a) application: simple inverting comparator



b) application : simple inverting comparator




c) $v_0(v_i)$ (combinam $v_{01}$ cu $v_{02}$)




$$v_0 = v_{01} - v_{02}$$

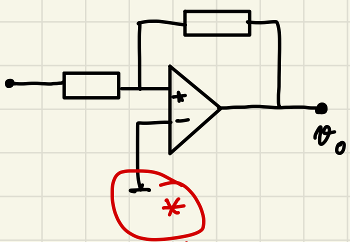
$$v_0 = \begin{cases} 15-15=0 & , v_i < 7{,}5\,V \\ 15-(-15)=30 & , 7{,}5\,V < v_i < 10\,V \\ (-15)-(-15)=0 & , 10\,V < v_i \end{cases}$$

Tot Seminar 4

doar că Op Amps Hysteresis Comparators (pos feedback)

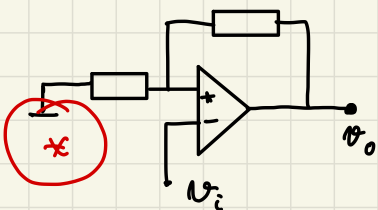
- positive feedback
- Output only takes 2 values: $+V_{PS}$, $-V_{PS}$
- Output changes at 2 different points ($V_{th,L}$, $V_{th,H}$) depending on what the current output is
- To find threshold voltages, ask:

"At what of $v_i$ does $v^+ = v^-$ in the case when $v_o$ is $+V_{PS}$, and the case when $v_o$ is $-V_{PS}$



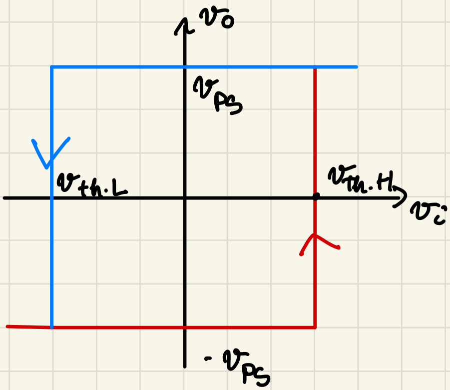

non-inverting

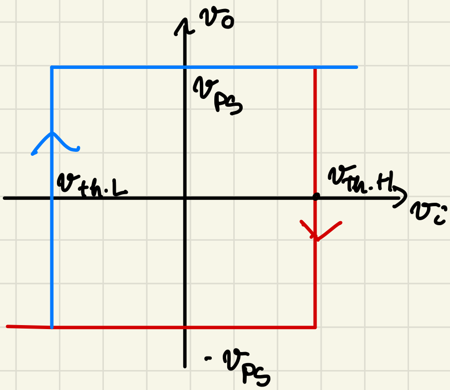
$v_i \to v^+$




inverting

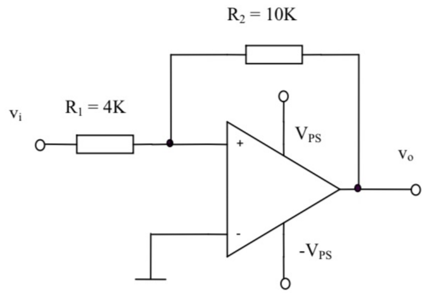
$v_i \to v^-$



# Probleme Seminar 4 cu Op Amps Hysterisis

**5.**
The supply voltages for this voltage comparator are $V^+ = +15V$ and $V^- = -15V$.
a) What are the values of the threshold voltages?
b) How does the voltage transfer characteristic $v_O(v_I)$ look like? Show numerical values on the axes.
c) Show the waveforms of $v_O(t)$ and $v_I(t)$ for $v_I(t)$ sine wave with 10V amplitude.
d) Show the waveforms of $v_O(t)$ and $v_I(t)$ for $v_I(t)$ sine wave with 5V amplitude.




a) $v^- = 0V$

$$v^+ = \frac{R_2}{R_1+R_2}\cdot v_i + \frac{R_1}{R_1+R_2}\cdot v_o = \frac{10}{14}v_i + \frac{4}{14}v_o$$

$v_D = v^+ - v^-$

$v_o = a\cdot v_D$

$$\begin{cases} v^+ > v^- \Rightarrow v_o = +v_{PS} \\ v^+ < v^- \Rightarrow v_o = -v_{PS} \end{cases}$$

(1) $v_o = 15V$

$$v^+ = \frac{10}{14}v_i + \frac{4}{14}\cdot 15 = \frac{10}{14}v_i + 4{,}28V$$

To change $v_o$

$v^+ = v^-$

$\frac{10}{14}\cdot v_i + 4{,}28\,V = 0V$

$v_i = -6V$

(2) $v_o = -15$

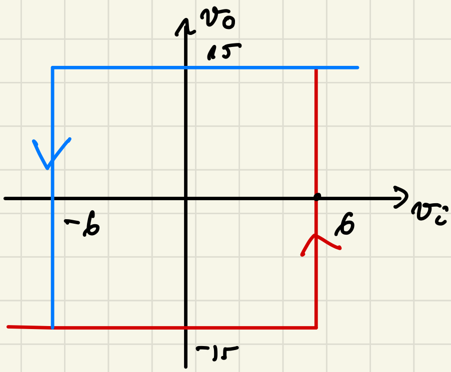
$$v^+ = \frac{10}{14}v_i - 4{,}28\,V$$

To change $v_o$

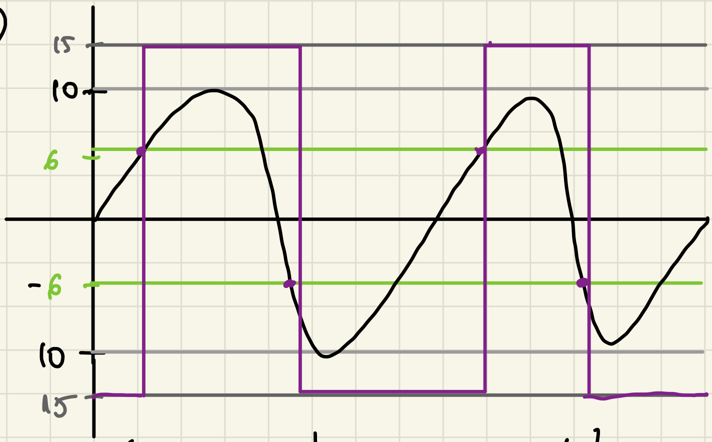
$v^+ = v^-$

$v_i = 6V$

b)




c)



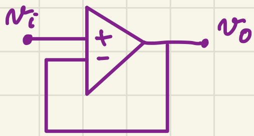

(in 6 creste, in -6 scade)

# Seminar 5

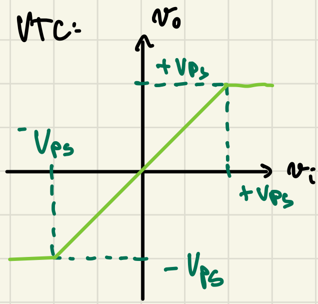
## OA Voltage Amplifiers (neg. feedback)

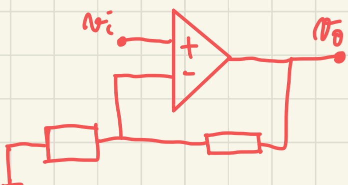
- negative feedback
- output takes any value between $+V_{PS}$, $-V_{PS}$
- Tries it best to keep $v^+ = v^-$
- To solve, keep in mind $v^+ = v^-$ to find a relationship of the form: $V_o = a \cdot v_i$

Special case: Voltage follower
Keeps $v_o = v_i$

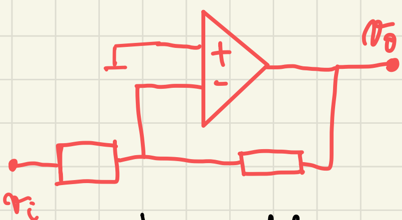



VTC:



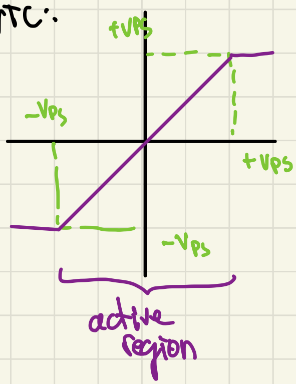




Non-inverting amplifier




inverting amplifier

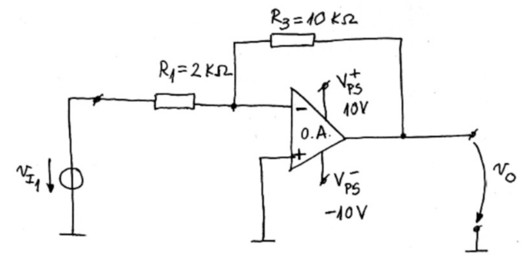
VTC:




VTC:

# Seminar 5
## OA Amplifiers – Problems

**1.** OA – ideal
**a)** Find the expression $v_O(v_{I1})$ assuming the range of $v_{I1}$ small enough to keep OA in the active region. What is the application of the circuit?
**b)** Plot $v_O(t)$ for $v_{I1}(t)=3\sin\omega_0 t$ [V]
**c)** What are the values of : the input resistance $R_{i1}$ seen by $v_{I1}$ and the output resistance $R_o$ of the amplifier?




a) $v^+ = v^-$ $\quad (v_D = 0)$

$v^+ = 0$

$$v^- = \frac{R_3}{R_1+R_3} \cdot v_I + \frac{R_1}{R_3+R_1} v_O = \frac{5}{6} v_I + \frac{1}{6} v_O$$

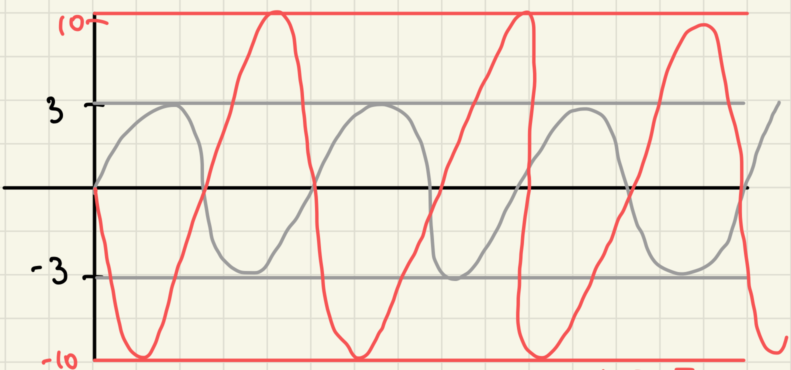
$$\Rightarrow \frac{5}{6} v_I = -\frac{1}{6} v_O$$

$$\frac{v_O}{v_I} = -5 \;, \; -A_v = -5$$

$A_v = \dfrac{v_o}{v_i}$ (gain) $\quad v_O \in [-10, 10] \Rightarrow v_I \in [-2, 2]$
in the active region

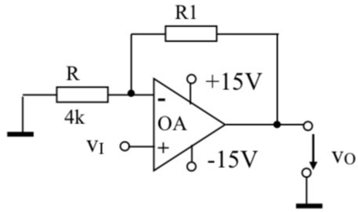
application: Inverting amplifier

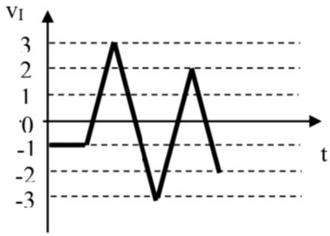
b)




$v_O = A_v \cdot v_I \Rightarrow v_I = 3\sin\omega t$ [V]

**2.**



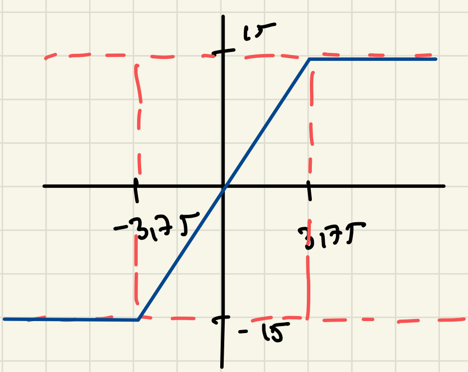

**a)** For $R_1$=12K find the values of the voltage gain, the input resistance and plot VTC $v_O(v_I)$.
**b)** How does the $v_O(t)$ look like for $v_I(t)$ in the above figure?
**c)** Redesign the circuit to obtain the adjustable voltage gain $A_v \in [5;10]$.

a) $A_v = \frac{v_O}{v_i}$ (gain)

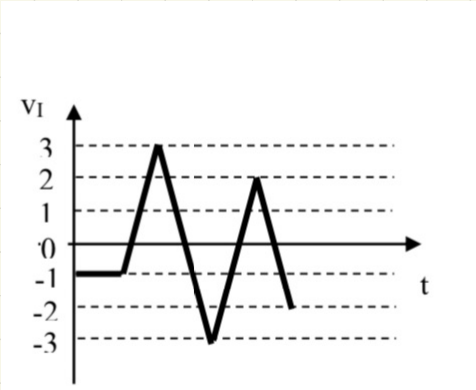
$$\left.\begin{aligned} v^+ &= v_i \\ v^- &= \frac{R}{R+R_1}\cdot v_0 \\ v^+ &= v^- \end{aligned}\right\} \Rightarrow v_i = \frac{R}{R+R_1}\cdot v_0 = \frac{4}{16}\cdot v_0 = v_i$$

$$\Rightarrow v_0 = 4 v_i$$

$v_0 \in [-15V, 15V]$ $\qquad$ $v_i \in [-3{,}75 ; 3{,}75]$



b)



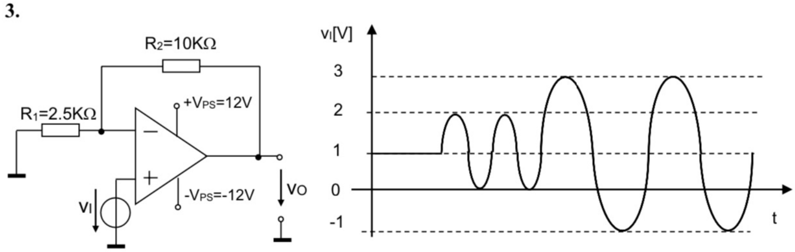

??

c) $A_v = \frac{v_o}{v_i} = \frac{\frac{4+R_1}{4}\cdot v_i}{v_i} = \frac{4+R_1}{4}$

$A_{vmin} = 5 \Rightarrow R_{1min} = 16\ k\Omega$

$A_{vmax} = 10 \Rightarrow R_{1max} = 36\ k\Omega$

**3.**




Assume a rail-to-rail op amp.

a) What is the expression and the value of the gain and how does the VTC, $v_O(v_I)$ look like considering $v_I \in [-5V;5V]$? What is the $v_I$ range for that the amplifier remains in its active region?

b) What are the values of the input and output resistances. What is the application of the circuit?

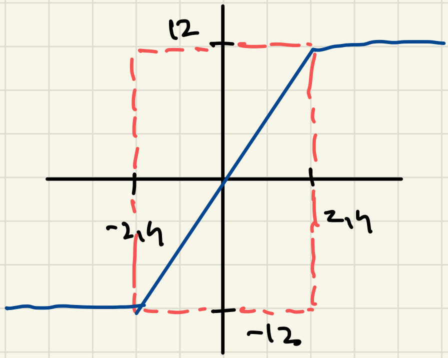
c) How does the $v_O(t)$ look like for $v_I(t)$ in the above figure?

d) Where another source $v_{I1}$ should be connected to obtain $v_O=5v_I-4v_{I1}$?

a) $A_v = \frac{v_o}{v_i}$

$$\left.\begin{aligned} v^+ &= v_i \\ v^- &= \frac{R_1}{R_1+R_2}\cdot v_o = \frac{2.5}{12.5}\cdot v_o \\ v^+ &= v^- \end{aligned}\right\} \Rightarrow v_i = \frac{1}{5} v_o \Rightarrow A_v = 5$$

$v_0 = [-12V, 12V] \Rightarrow v_i \in [-2{,}4V; 2{,}4V]$




d)

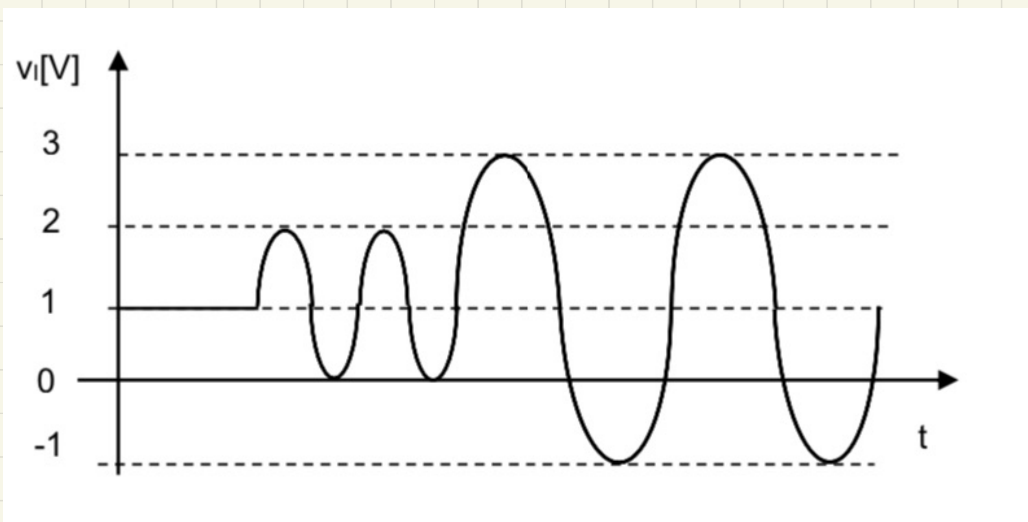
$$\left.\begin{aligned} v_0 &= 5v_i - 4v_i \\ v^- &= \frac{R_1}{R_1+R_2}\cdot v_0 + v_{i1}\cdot\frac{R_2}{R_1+R_2} \\ v^- &= \frac{1}{5}v_0 + \frac{4}{5}v_{i1} \\ v^- &= v^+ \end{aligned}\right\} \Rightarrow$$

$$v_i = \frac{1}{5}v_0 + \frac{4}{5}v_{i1}$$

$$5v_i = v_0 + 4v_{i1}$$

$$\Rightarrow v_0 = 5v_i - 4v_{i1}$$

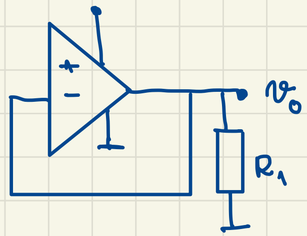
c)



# Seminar 6
## Voltage Regulators

$v_o = v_{REF}$

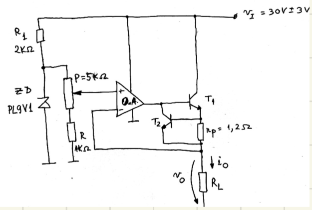
$I_{o,max}$ given by max OpAmp output



# Seminar 7

**4.**
For $T_1$ and $T_2$, $V_{BE,on} = 0.6V$

**b)** Find the expression and the possible range of values of $v_O$ depending on the position of the tap of the potentiometer P.
**c)** Plot the $v_O(i_O)$ output characteristic of this voltage regulator for the position of the tap of the potentiometer in the lower end, for $R_L$ from $\infty$ to 0.
**d)** What components form the short-circuit protection for this voltage regulator? Explain the short-circuit protection mechanism.
**e)** For $R_L$=50Ω, compute the maximum power dissipation on $T_1$.




a) $v_D = v^+ + v^-$

$$v^+ = \frac{R+(1-K)P}{R+P} v_Z$$

$v^- = v_O$

$$v_D = 0 \Rightarrow v_O = \frac{R+(1-K)P}{R+P} \cdot v_Z \Rightarrow v_Z = 9.1V$$

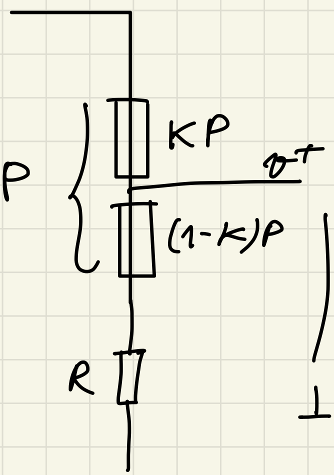
For $K=1$

$$\Rightarrow v_O = \frac{R}{R+P} \cdot v_Z = \frac{1}{6} \cdot 9,1 = 1,5V$$

For $K=0$

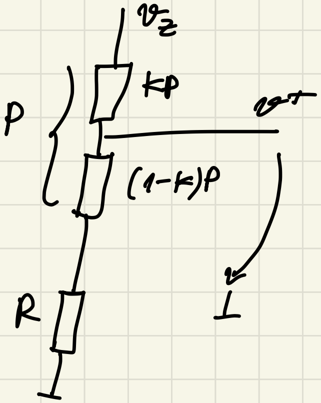
$$\Rightarrow v_{O_{max}} = v_Z = 9,1$$

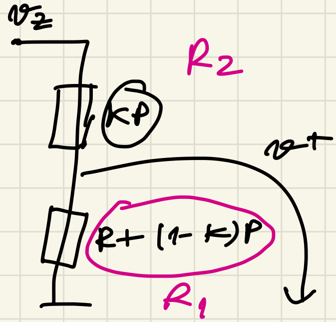
$$v_O = [1.5, 9.1][V]$$




$$= \frac{R+(1-K)P}{R+(1-K)P+KP} v_Z$$

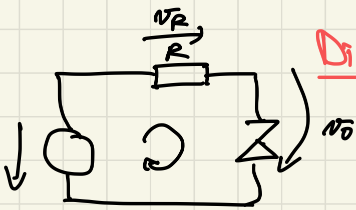
din nou:



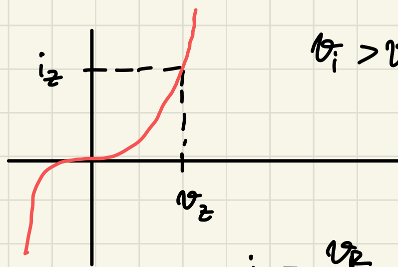

$$v^+ = \frac{R+(1-k)P}{R+(1-k)P+kP}\cdot v_z$$

De ce nu depinde de $v_i$???




Diodă Zener

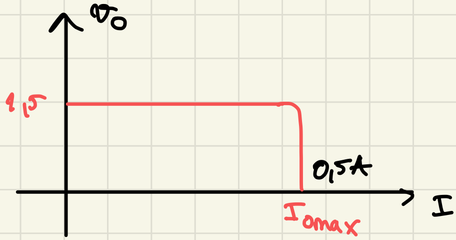
$$v_o = v_i - v_R$$




$$v_i > v_Z \Rightarrow v_o = v_Z$$

$$i = \frac{v_R}{R} = \frac{v_i - v_Z}{R}$$

b) Lower end $\Rightarrow k=1 \Rightarrow v_o = 1{,}5\,V$




$$R_L = 0 \Rightarrow v_o = 0$$

$$I_{omax} = \frac{v_{R_p}}{R_p} = \frac{v_{BE\,on}}{r_p} = \frac{0{,}6}{1{,}2}$$

$$I_{omax} = 0{,}5\ (A)$$

c) $I_0$ small $\quad I_0 \cdot r_p < 0{,}6\,V \Rightarrow T_2$ off

$I_0 \cdot r_p = 0{,}6\,V \Rightarrow T_2$ on $\Rightarrow I_0 = I_{0max} = \frac{0{,}6}{r_p}$

d) $I = \frac{v_0}{R_L} = \frac{9.1}{50\Omega} = 0{,}182A < I_{0max}$

$R_L = 50\Omega$)

$$P_T = V_{CE} \cdot I_0 = \left(V_{Imax} - v_{Rp} - v_0\right) \cdot I_0$$

$$= \left(33 - I_0 \cdot r_p - v_0\right) \cdot I_0$$

$$= \left(33 - 0{,}182 \cdot 1{,}2 - 9{,}1\right) \cdot 0{,}182$$

$$= \left(33 - 9{,}3\right) \cdot 0{,}182$$

$$= 4{,}3134\,W$$

$R_L = 5\Omega$)

$I = \frac{v_0}{R_L} = \frac{9{,}1}{5\Omega} = 1{,}82\,A > I_{0max}$

$I = I_{0max}$

$v_0 = I_{0max} \cdot R_L = 0{,}5 \cdot 5 = 2{,}5\,V$

$$P = V_{CE} \cdot I_{0max} = \left(v_I - v_{Rp} - v_0\right) \cdot 0{,}5$$

$$= \left(33V - 0{,}6V - 2{,}5V\right) \cdot 0{,}5$$

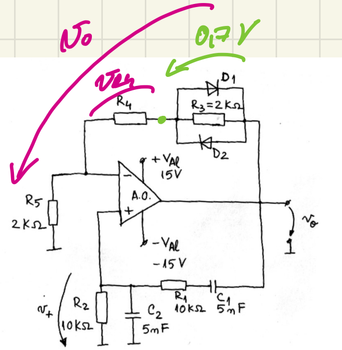
$$= 29{,}9 \cdot 0{,}5 = 14{,}95\,W$$

**1.**

**a)** How do the $v_o(t)$ and $v_+(t)$ signals look like, qualitative, in permanent regime? Compute the frequency of the $v_o(t)$ output signal.

**b)** Size $R_4$ such that the circuit will sustain the oscillations in steady-state regime. Consider that in conduction, the equivalent resistances of $D_1$ and $D_2$ diodes are $r_{D1}=r_{D2}=0{,}5K\Omega$. Verify the chosen value for the condition of starting-up the oscillation in transient regime.

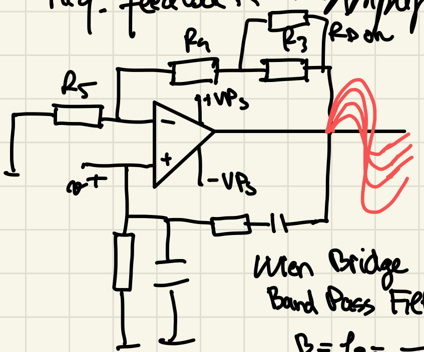
**c)** How does the $v_o(t)$ signal shape modifies in permanent regime if the $D_2$ diode connection is omitted in the circuit?




no $v_i$

has both negative & possitive feedback

neg. feedback — Amplifier




$D_1, D_2$ off

$$a = 1 + \frac{R_4+R_3}{R_5} > 3$$

$D_1$ on or $D_2$ on

$$a_0 = 1 + \frac{R_4 + R_3 \| R_{D\,on}}{R_5}$$

Wien Bridge
Band Pass Filter

$$B = f_0 = \frac{1}{2\pi\sqrt{R_s R_p C_s C_p}}$$

s - serial    p- parallel

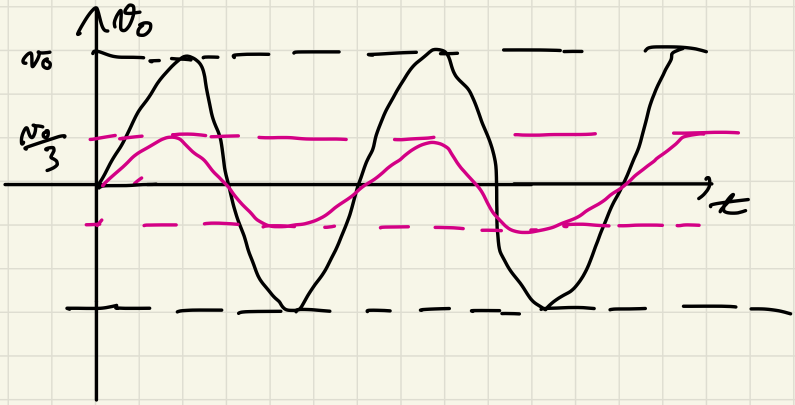
$$f_0 = \frac{1}{2\pi \cdot 10 \cdot 10^3 \cdot 5 \cdot 10^{-9}} = \frac{10^4}{\pi} = \frac{10}{3{,}14} \cdot 10^3 = 3{,}18\ KHz$$

oscillation Not 0

$$r = \frac{1}{1 + \frac{R_s}{R_p} + \frac{C_p}{C_s}} = \frac{1}{3}$$

Start up osc. $ar > 1$, $a > 3$

Maintain osc. $ar = 1$; $a = 3$

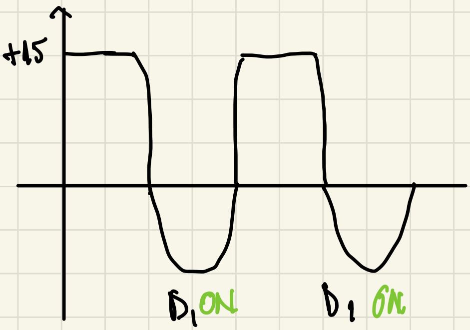



$\Rightarrow a_0 = 3 \Rightarrow 1 + \frac{R_4 + R_3 \| r_D}{R_5} = 3 \Rightarrow R_4 + R_3 \| r_D = 2R_5$

$\Leftrightarrow R_4 = \underbrace{2R_5}_{4k\Omega} - \underbrace{R_3 \| r_D}_{0,4\,k\Omega} \Rightarrow R_4 = 3,6\ k\Omega$

$a = 3,8 > 3$ W

$D_1$ ON $\Rightarrow v_0 < -0,7 \Rightarrow a_0 = 3$




$I = \frac{v_{DON}}{R_3 \| r_{DON}} = 1,75\ mA$

$v_0 = V_{R_3} + V_{R_4} + V_{R_5}$ or $V^- = V^+ = \frac{v_0}{3} = V_{R_5} = R_3 I$

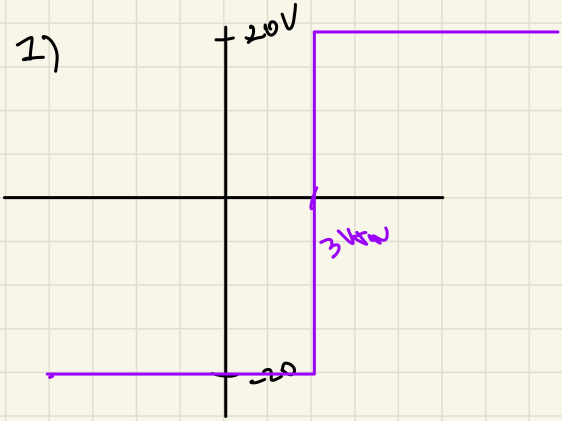
$v_0 = I\left(R_3 \| r_{DON} + R_4 + R_5\right)$

$\frac{V_{R_3}}{3} = 2 \cdot 1,75 = 3,5 \Rightarrow v_0 = 10,5\ V$

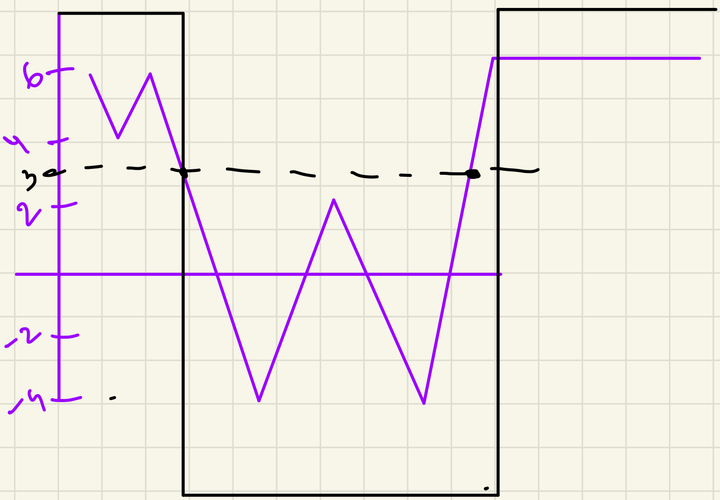
$v_0 = 1,75 \cdot \left(0,4 + 3,6 + 2\right) = 10,5\ V$

Restanță :D

1)




b)



b) $v_{ref} = v^+ = 1$

$$v_i^- = \frac{R_2}{R_1+R_2} \cdot v_i + \frac{R_1}{R_1+R_2} \cdot V_{AS}^- = \frac{1}{1{,}5} \cdot v_i + \frac{0{,}5}{1{,}5}(-10)$$

$$= \frac{2}{3} v_i - 3{,}33$$

$$v^+ = v^-$$

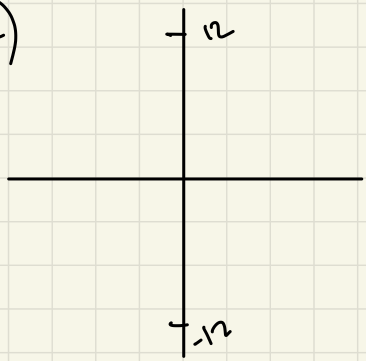
$$1 = \frac{2}{3} v_i - 3{,}33$$

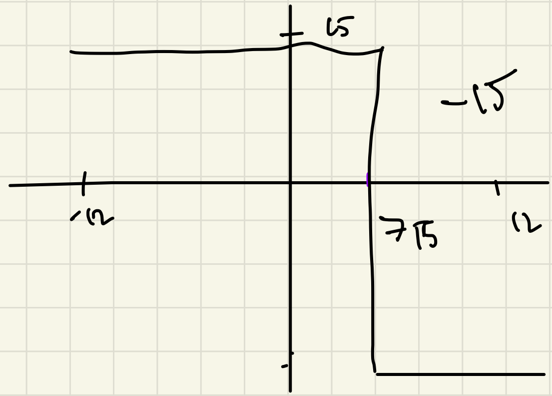
$$4{,}33 = \frac{2}{3} v_i$$

$$6{,}5 \square v_i$$

$$\boxed{v_0 = \begin{cases} -10, & v_i < 6{,}5 \\ 10, & v_i > 6{,}5 \end{cases}}$$

3 a)




comparator inv

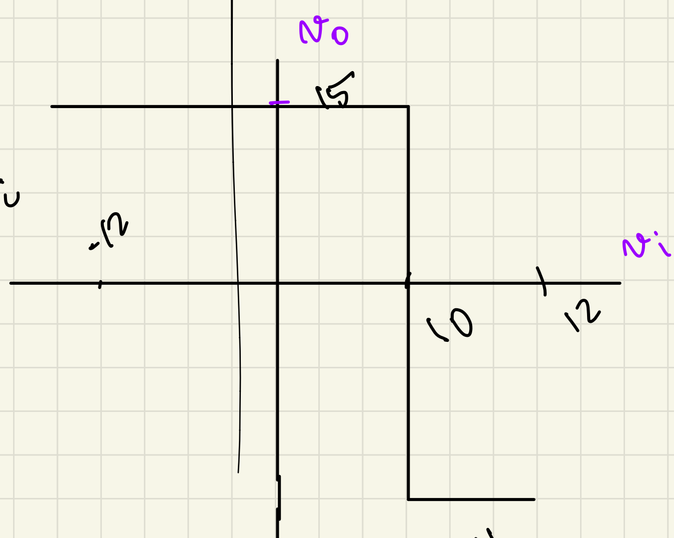
$v_1^- = v_i = v_2^-$

$v_1^+ = 10$

$v_2^+ = \frac{R_2}{R_1+R_2} \cdot 10 = \frac{30}{40} \cdot 10 = \frac{30}{4} = 7.5$

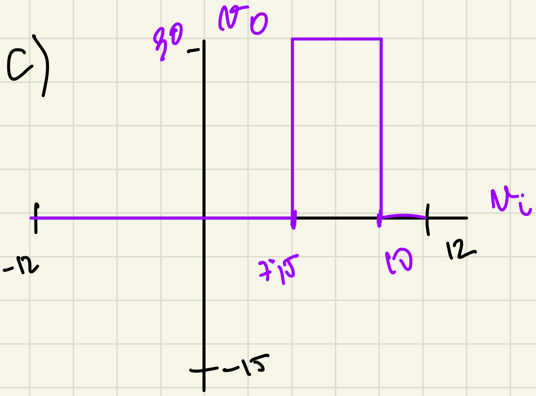
$v^+ = v^-$

$10 = v_i$




comp inv

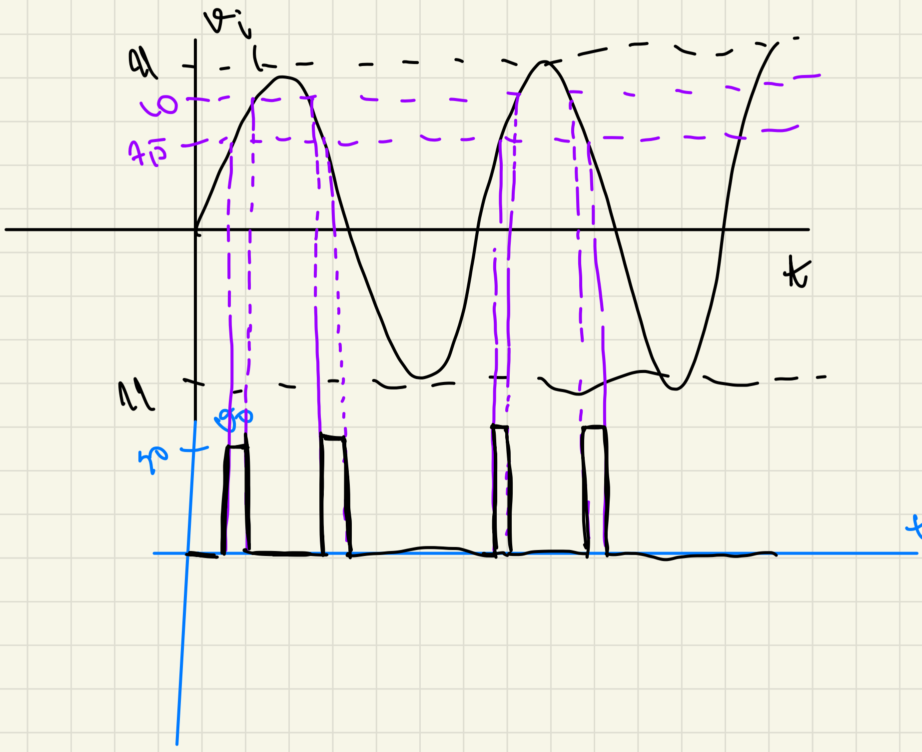
c)




$$v_0 = \begin{cases} 0, & v_i < 7{,}5 \\ 30, & 7{,}5 < v_i < 10 \\ 0, & v_i > 10 \end{cases}$$

$$v_0 = v_{01} - v_{02}$$

d)



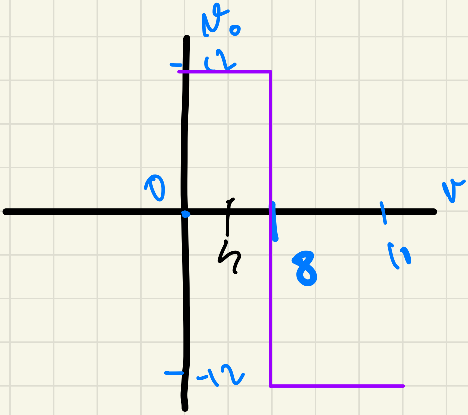
4) inverting comp - applic

$v_1^- = v_i = v_2^-$

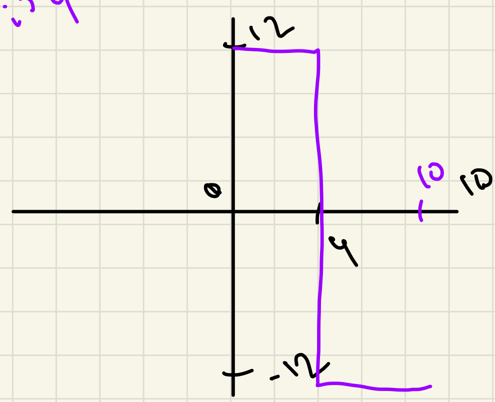
$v_1^+ = v_{PS}^+ \cdot \frac{R_2 + R_3}{R_1 + R_2 + R_3} = 12 \cdot \frac{10+10}{30} = \frac{24}{3} = 8$

$v_2^+ = \frac{R_3}{R_1 + R_2 + R_3} \cdot v_{PS} = \frac{12}{3} = 4$

$v_{o1} \begin{cases} 12, & v_i < 8 \\ -12, & v_i > 8 \end{cases}$




$v_{o2} \begin{cases} 12, & v_i < 4 \\ -12, & v_i > 4 \end{cases}$



c)

| $v_i$ | Led1 | Led2 |
|---|---|---|
| [0, 4) | OFF | ON |
| [4, 8] | ON | OFF |
| (8, 12] | OFF | OFF |

5)

a) noninverting voltage comp.

$v^+ = v^-$ , $v^- = 0$

$$v^+ = \frac{R_2}{R_1+R_2} \cdot v_i + \frac{R_1}{R_1+R_2} \cdot v_0 = \frac{5}{7} v_i + \frac{2}{7} v_0$$

$\frac{5}{7} v_i + \frac{2}{7} v_0 = 0 \mid \cdot 7$

$5v_i + 2v_0 = 0$

$\boxed{5v_i = -2v_0}$

$v_D = v^+ - v^-$

$$\boxed{\begin{cases} v^+ > v^-, & v_0 = +V_{PS} \\ v^+ < v^-, & v_0 = -V_{PS} \end{cases}}$$

$v^+ = v^- \Rightarrow$ threshold

I $v^+ > v^-$

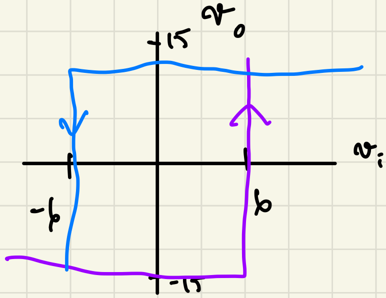
$5v_i = -30$

$v_i = -6$

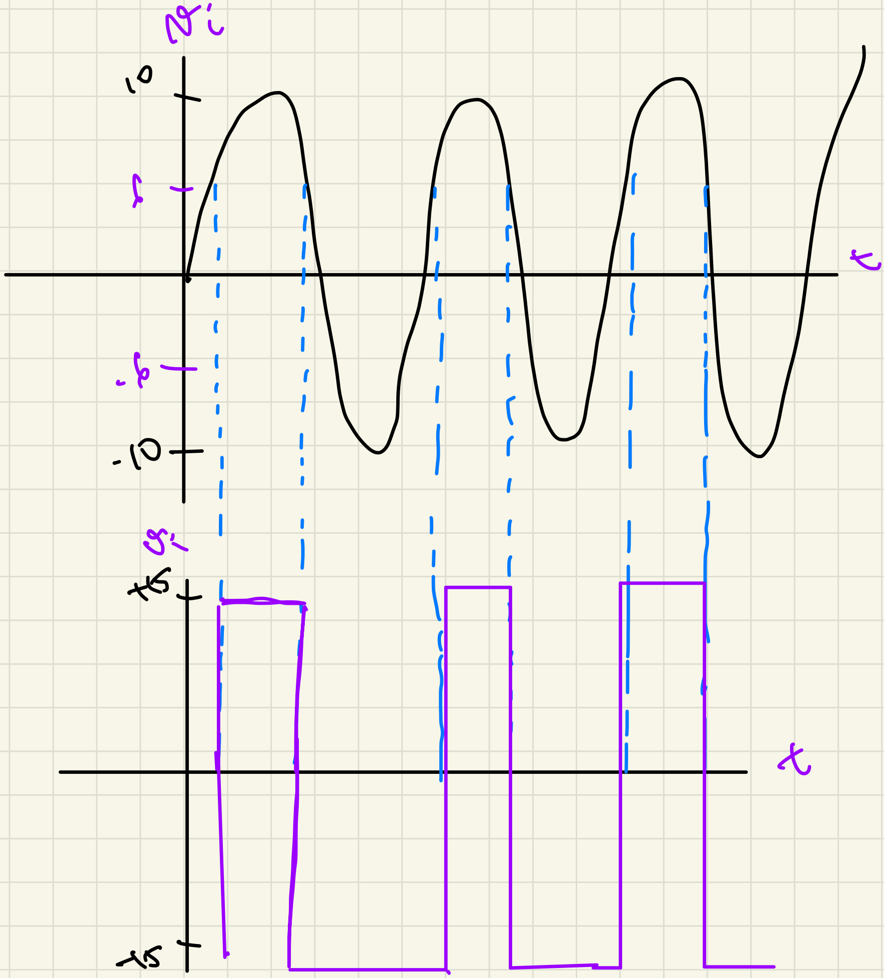
II $v_i = 6$

the values 6 and -6

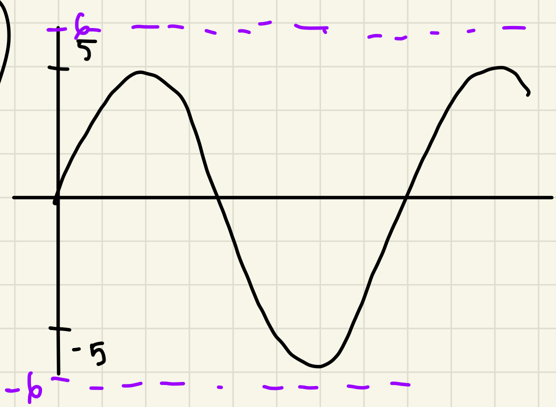
b)

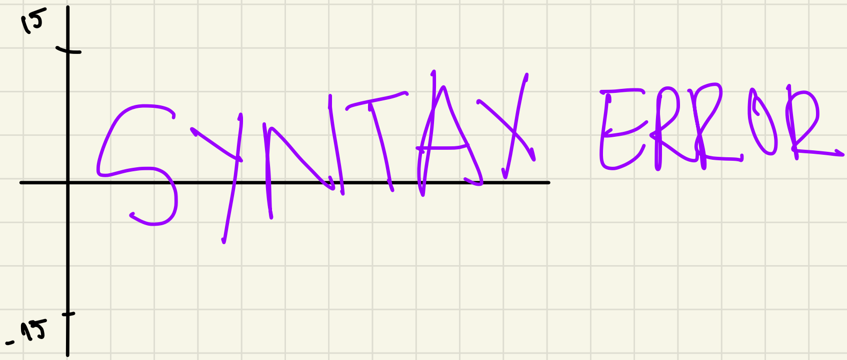



c)



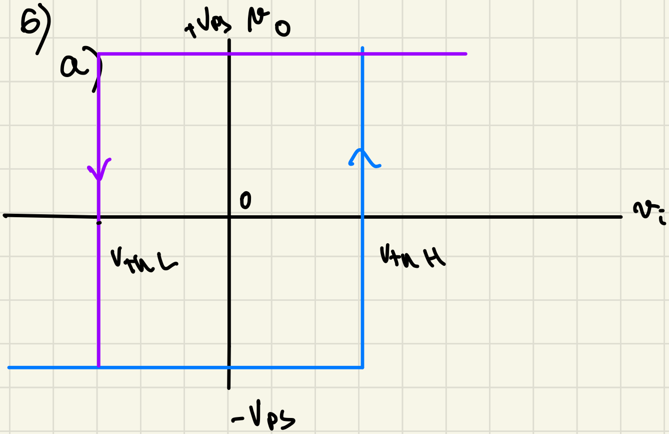
d)




6)

a)




Hysteresis noninverting
comp.

b) $\begin{cases} v^+ > v^- \ , v_0 = V_{PS}^+ \\ v^+ < v^- \ , v_0 = V_{PS}^- \end{cases}$

$$v^- = \frac{R_4}{R_3+R_4} \cdot v_{PS}^+ = \frac{2}{12} \cdot 9 = \frac{18}{12} = \frac{9}{6} = \frac{3}{2} = v^-$$

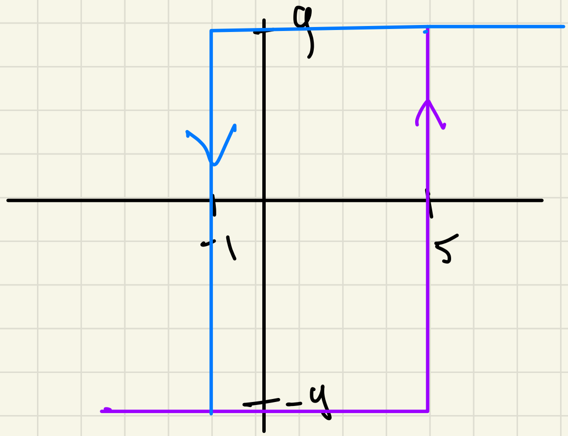
$$v^+ = \frac{R_2}{R_1+R_2} \cdot v_i + \frac{R_1}{R_1+R_2} \cdot v_0 = \frac{9}{12} \cdot v_i + \frac{3}{12} \cdot v_0 = \frac{3}{4} v_i + \frac{1}{4} v_0$$

$$v^+ = v^-$$

$$\frac{3}{4} v_i + \frac{1}{4} v = \frac{3}{2} \Big/ \, 4$$

$$3v_i + v_0 = 6$$

$$3v_i - 6 = -v_0$$




$v^+ > v^-$ , $v_0 = V_{PS}^+$

$$3v_i - 6 = -9$$

$$3v_i = -3$$

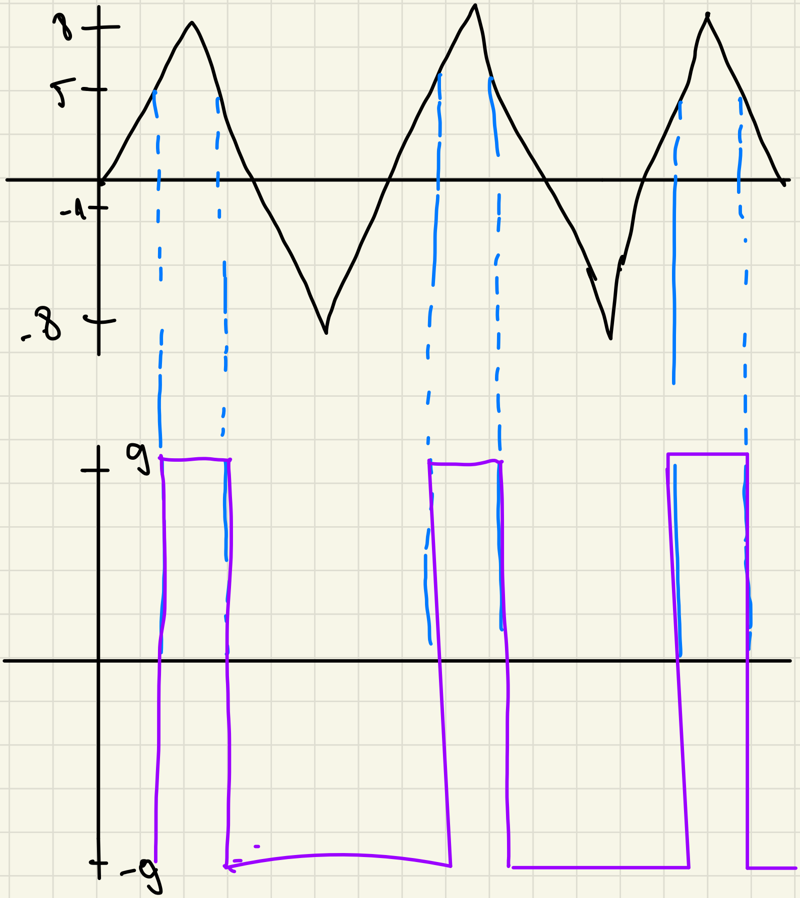
$$v_i = -1$$

$v^+ < v^-$ , $v_0 = v_{PS}^-$

$$3v_i - 6 = 9$$

$$v_i = 5$$

c)



# Seminar 5

1) inverting amplifier (neg. feedback)

$v_o = v^+ + v^-$

$v^+ = v^-$

$v^+ = 0$

$v^- = \frac{R_3}{R_1+R_3} v_i + \frac{R_1}{R_1+R_3} v_o$

$= \frac{10}{12} v_i + \frac{2}{12} v_o$

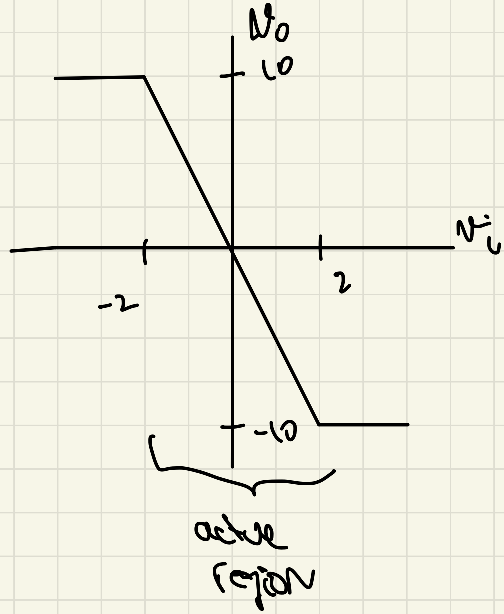
$\frac{5}{6} v_i + \frac{1}{6} v_o = 0 \;|\cdot 6$

$5v_i + v_o = 0$

$v_o = -5v_i$

$A_v = \frac{v_o}{v_i} = \frac{-5\cancel{v_i}}{\cancel{v_i}} = -5$

$\underline{v_o = [-10, 10]} \Rightarrow \underline{v_i \in [-2, 2]}$




c) $R_{i2} = R_1 = 2k\Omega$

$R_0 = 0$

2) a) $v^+ = v_i$

$$v^- = \frac{R}{R_1+R} \cdot v_o = \frac{4}{16} v_o = \frac{1}{4} v_o$$

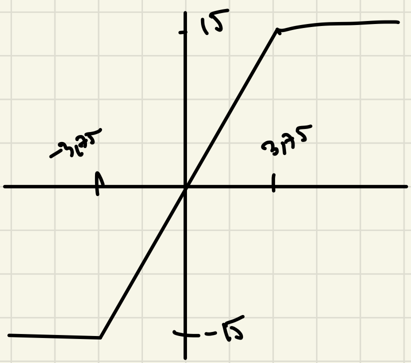
$v_D = v^+ - v^-$ non-inv amp

$v^+ = v^-$

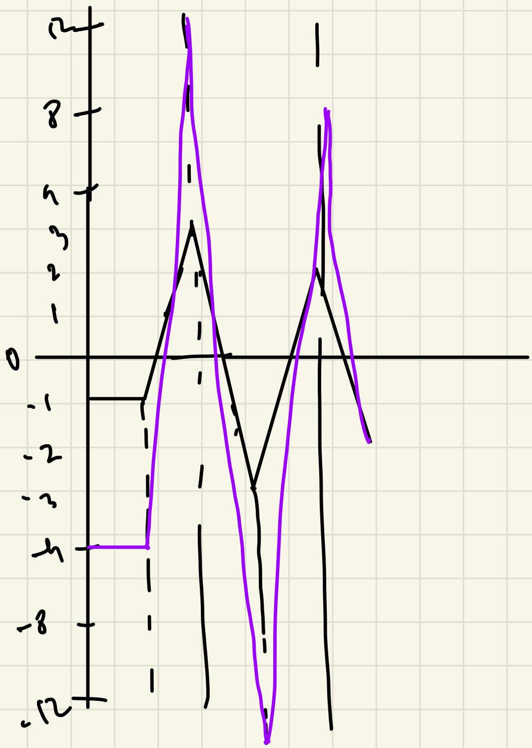
$$v_i = \frac{1}{4} v_o \Rightarrow 4 v_i = v_o$$

$$A_v = \frac{v_o}{v_i} = \frac{v_o}{\frac{v_o}{4}} = v_o \cdot \frac{4}{v_o} = 4$$

$v_o = [-15, 15]$ ; $v_i = [-3{,}75, 3{,}75]$




b)


12
8
4
3
2
1
0
-1
-2
-3
-4
-8
-12

c) $A_V \in [5,10]$

$$A_V = \frac{v_o}{v_i}$$

$$A_V v_i = v_o$$

$$v_i = \frac{v_o}{A_V} \left\{ \begin{array}{l} \frac{45}{5} \\ \frac{45}{10} \end{array} \right.$$

$$A_V = \frac{v_o}{v_i}$$

$v^- = v^+$ $\Rightarrow v_+ = v_i$

$$v^- = v_o \cdot \frac{4}{R_1+4} = v_i$$

$$A_V = \frac{v_o}{v_i} = \frac{\cancel{v_o}}{\cancel{v_o} \cdot \frac{4}{R_1+4}} = \frac{1}{\frac{4}{R_1+4}} = \boxed{\frac{R_1+4}{4}}$$

$$A_V = \frac{4}{R_1+4}$$

$$R_{min}\ 5 = \frac{4}{R_1+4} = 16$$

$$R_{max} = \frac{4}{R+4} = 10 \Rightarrow 36$$

a) $v^+ = v^-$

$v^+ = v_i$

$v^- = \frac{R_1}{R_1+R_2} \cdot v_o = \frac{2{,}5}{12{,}5} \cdot v_o$

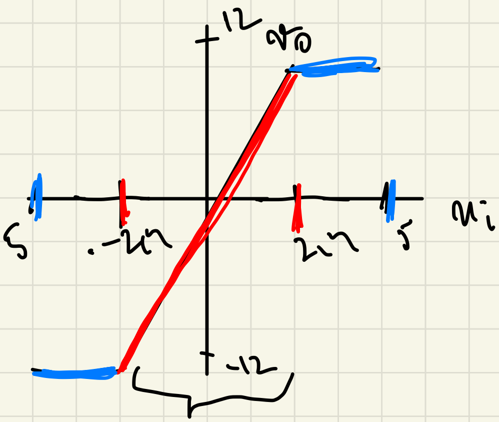
$v_i = \frac{2{,}5}{12{,}5} \cdot v_o$

$v_i = 0{,}2\, v_o = \frac{2}{10} v_o = \frac{1}{5} v_o \Rightarrow 5 v_i = v_o$

$A_v = \frac{v_o}{v_i} = \frac{v_o}{0{,}2 v_o} = \frac{1}{0{,}2} = \frac{1}{\frac{2}{10}} = 5$

$v_o = [-12, 12]$

$v_i = (-2{,}4; 2{,}4)$




b) non-inverting amp (neg feedback)

$R_o = 0$

$R_i = \infty$

c) $v_i = 0{,}2\, v_o$

~~$v_i = \frac{2}{10} \cdot v_o \mid \cdot \frac{10}{2}$~~

$5 v_i = v_o$     ~~fat~~ $\times 5$

d) $v_0 = 5v_i - 4v_{i1}$

$\boxed{v_0 = 5v_i}$

$v^+ = v_i$

$$v^- = \frac{R_1}{R_1+R_2} v_0 + \frac{R_2}{R_1+R_2} v_{i1}$$

$$= \frac{2{,}5}{12{,}5} v_0 + \frac{10}{12{,}5} v_{i1} = \frac{1}{5} v_0 + \frac{4}{5} v_{i1} = v_i$$

$$A_v = \frac{v_0}{v_i} = \frac{v_0}{\frac{1}{5}v_0 + \frac{8}{10} v_{i1}} = 5$$

$$\boxed{v_0 = 5v_i + 4v_{i1}}$$

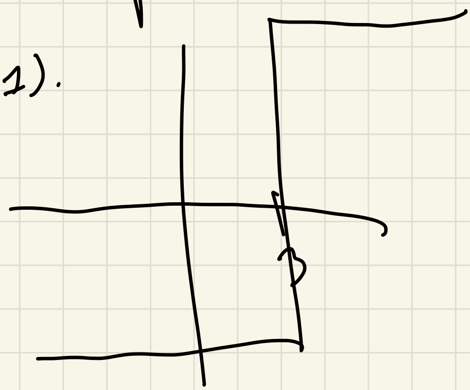
4) a) $v_0$ is connected to $v_0$ → neg feedback

b) app - differential amp (neg feedback)

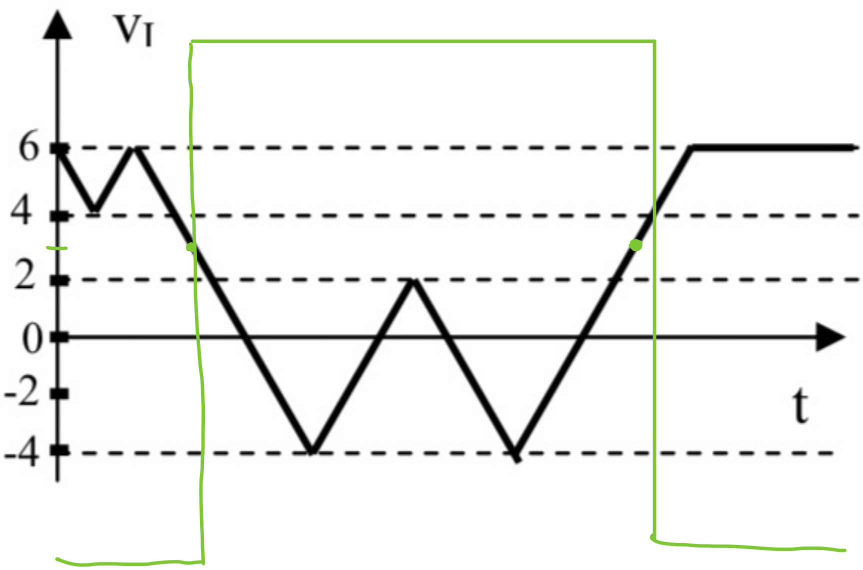
$v^+ = v^-$

Recup.

1).



2)



2) comparator inv (no feedback)

$$\frac{-10}{5}$$

$v^+ = v^-$

$v^+ = 1$

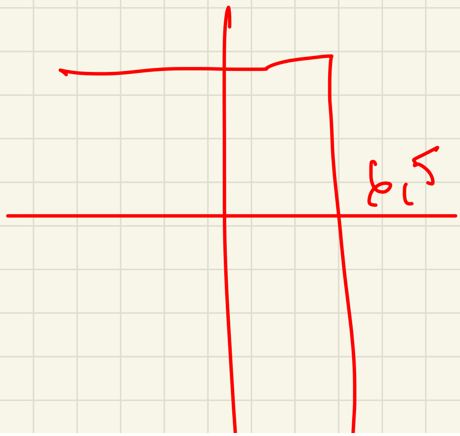
$v^- = v_i \frac{R_2}{R_1+R_2} + V_{ps}^- \cdot \frac{R_1}{R_1+R_2}$

$= v_i \frac{1}{1{,}5} + \frac{-10 \cdot 0{,}5}{1{,}5}$

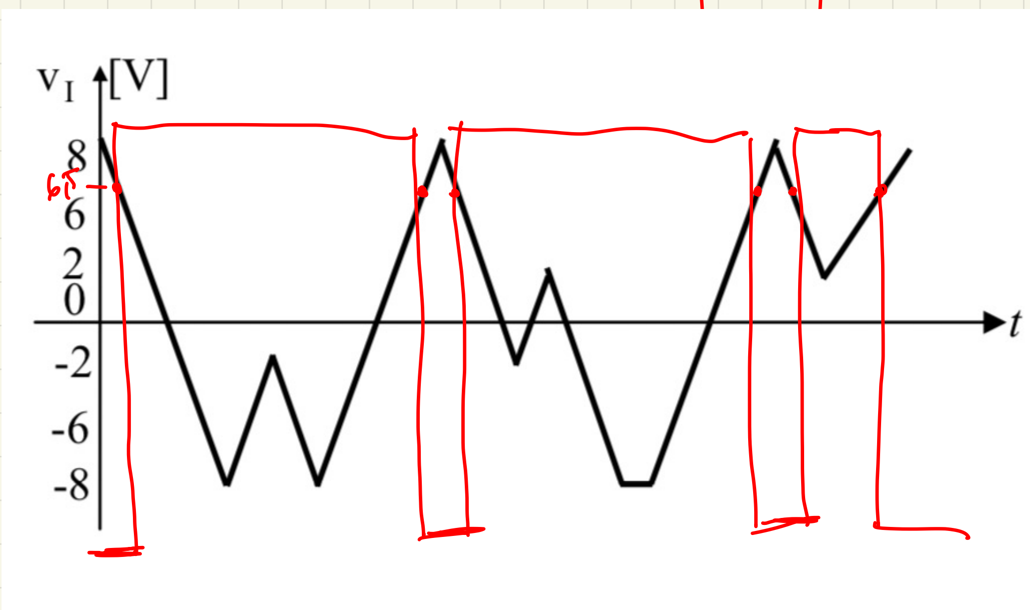
$= \frac{2}{3} v_i + 3{,}33 \square 1$

$v_i \square 6{,}5$

$$v_o \begin{cases} +10, & v_i < 6{,}5 \\ -10, & v_i > 6{,}5 \end{cases}$$




c)



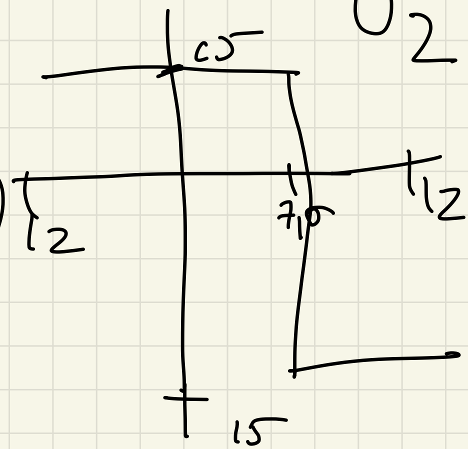
3) b) $v_1^- = v_i = v_2^-$

$v_1^+ = 10$

$$v_2^+ = \frac{R_2}{R_1+R_2} \cdot 10 = \frac{30}{40} 10 = \frac{30}{4} = 7{,}5$$

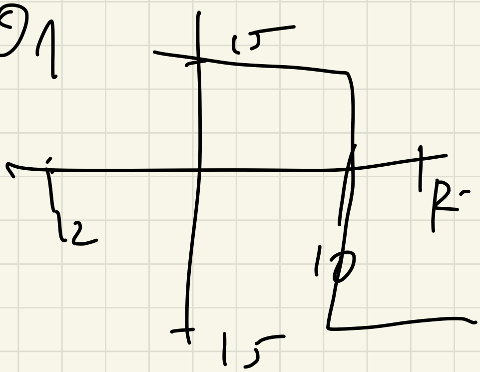
$$v_0 \begin{cases} 15, & v_i < 7{,}5 \\ -15, & v_i > 7{,}5 \end{cases}$$

$O_2$




inv. comparator (no feedback)

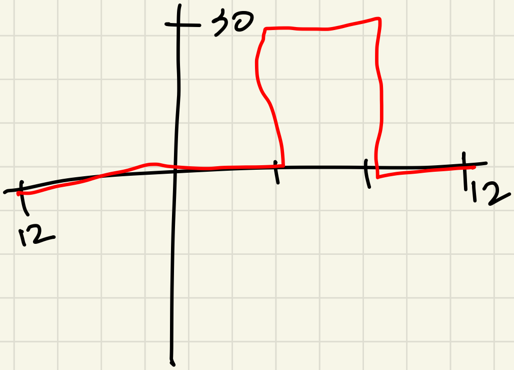
a) $O_1$




inv. comp.

$v_0 = v_{o1} - v_{o2}$

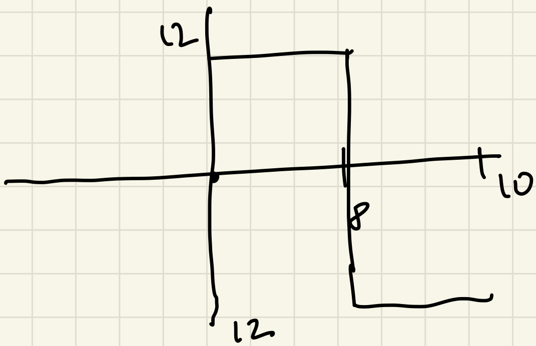
c) $$v_0 \begin{cases} 0, & v_i < 7{,}5 \\ 30 & 7{,}5 < v < 10 \\ 0 & v > 10 \end{cases}$$




4) inv comp

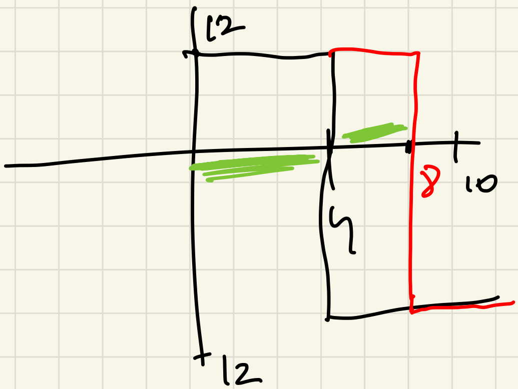
$$v^- = v_i$$

$$v^+ = \frac{R_2 + R_3}{R_1 + R_2 + R_3} \cdot V_{ps}^+ = \frac{2}{3} \cdot 12 = 8$$



b) $v_2^- = v_i$

$$v_2^+ = \frac{R_3}{R_1+R_2+R_3} = \frac{10}{30} \cdot 12 = 4$$




c)

| $v_i$ | $L_1$ | $L_2$ |
|---|---|---|
| $(0,4)$ | OFF | ON |
| $(4,8]$ | ON | OF |
| $(8,10]$ | OFF | OFF |

a) $v^+ = v^-$

$v^- = 0$

$$v^+ = \frac{R_2}{R_1+R_2} \cdot v_i + \frac{R_1}{R_1+R_2} \cdot v_0$$

$\boxed{v^+ = v^-}$

$$\frac{10}{14} v_i + \frac{4}{14} v_0 = 0$$

$$\frac{5}{7} v_i + \frac{2}{7} v_0 = 0$$

$\boxed{5v_i + 2v_0 = 0}$ $\Rightarrow$ $v_0 = 15$

$5v_i = -2 \cdot 15 = -30$

$v_i = -6$

$v_i = 6$

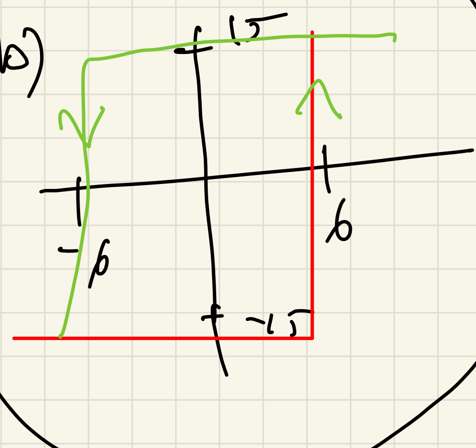
$$\boxed{\begin{cases} \text{I} \ v^+ > v^- \ , \ v_0 = V_{PS}^+ \\ \text{II} \ v^+ < v^- \ , \ v_0 = v_{PS}^- \end{cases}}$$

I $5v_i = -30$

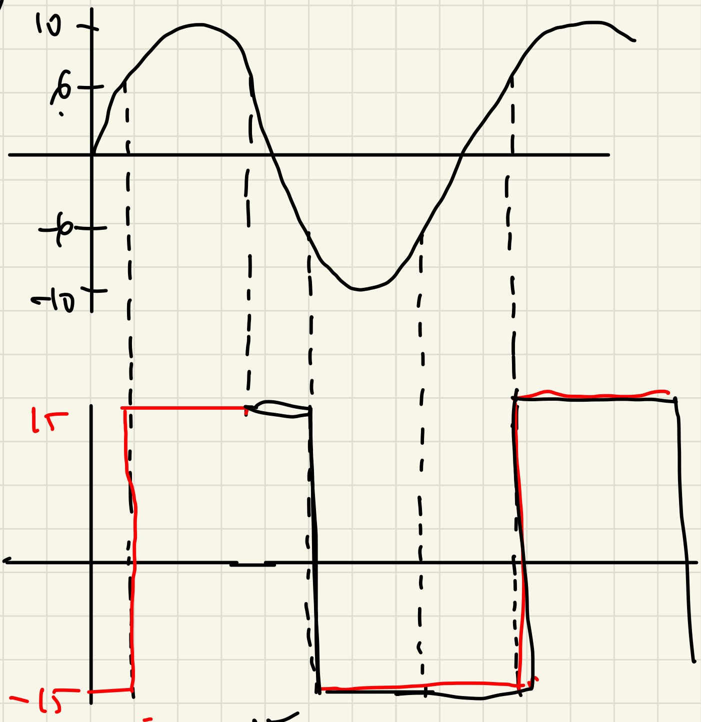
$v_i = -6$

II $v_i = 6$

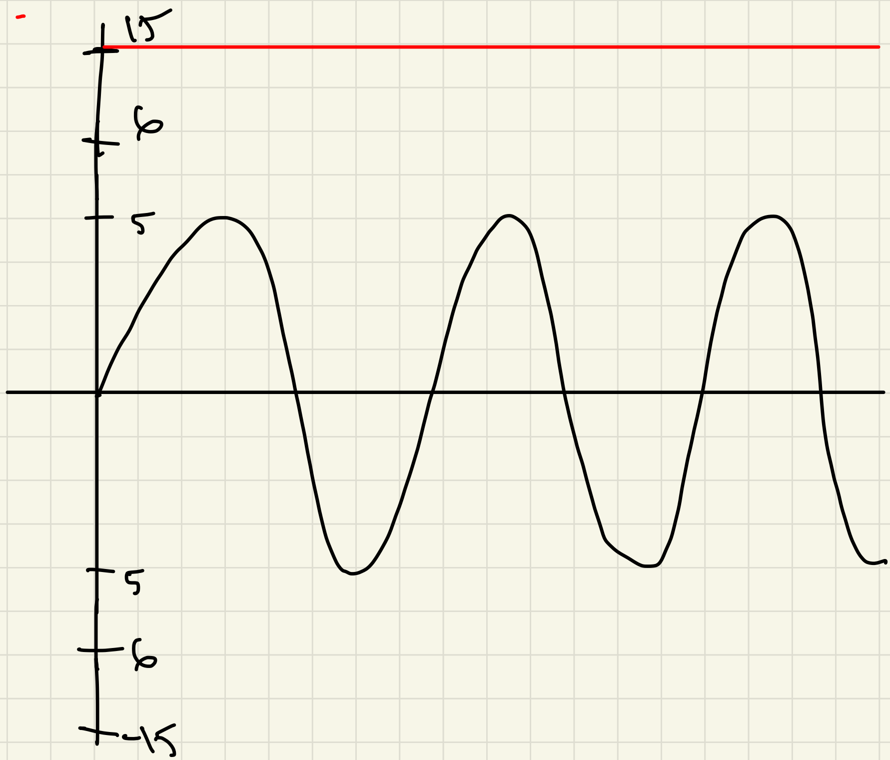
b)



c)

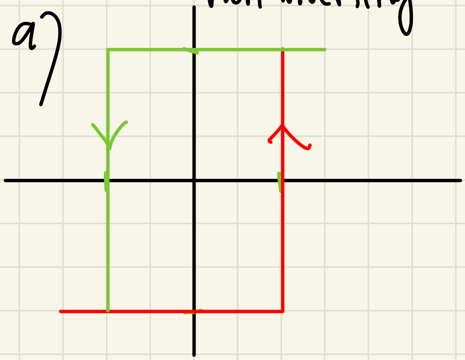



d)



6) Hysteresis comparator (positive feedback)
non inverting

a)



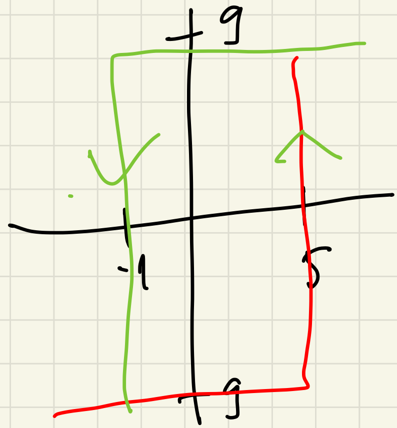
b) $V_{OH} = 9$ $\quad V_{OL} = -9$

$$v^+ = \frac{R_2}{R_1+R_2} v_i + \frac{R_1}{R_1+R_2} v_o$$

$$= \frac{9}{12} v_i + \frac{3}{12} v_o$$

$$= \frac{3}{4} v_i + \frac{1}{4} v_o$$

$$v^- = \frac{R_4}{R_3+R_4} V_{PS}^+ = \frac{2}{12} \cdot 9 = \frac{9}{6} = \frac{3}{2}$$




$v^+ = v^-$

$$\frac{3}{4} v_i + \frac{1}{4} v_o = \frac{3}{2} \quad \Big| \cdot 4$$

$$3v_i + v_o = 6$$

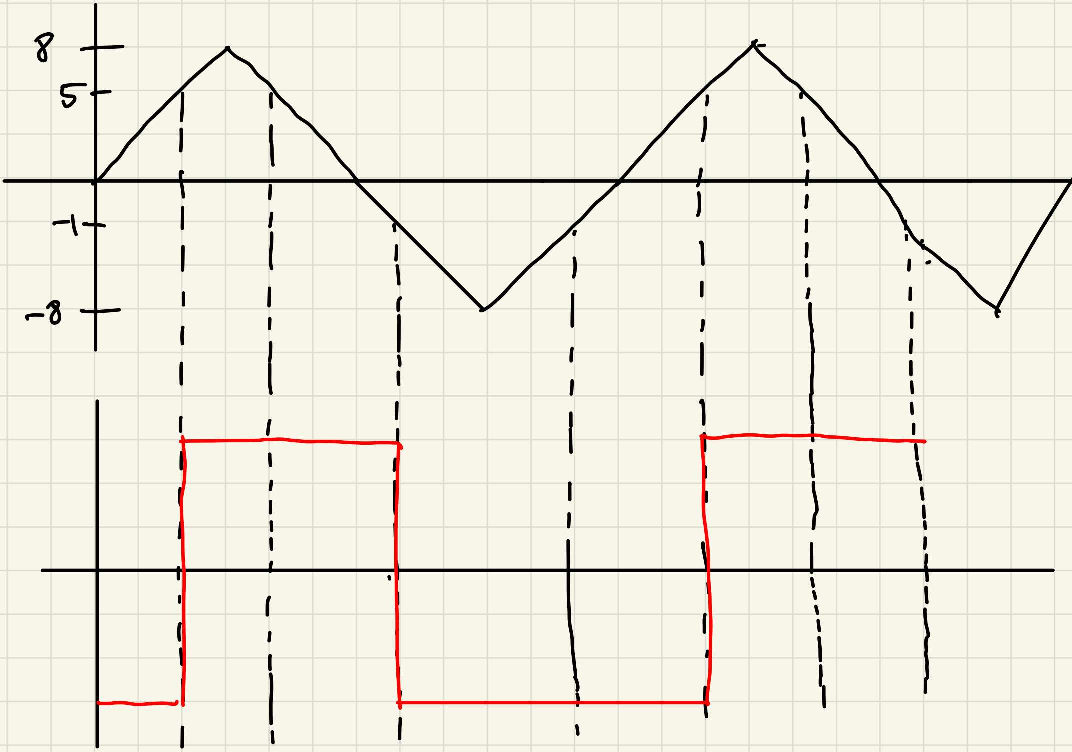
$v^+ > v^-$, $\quad v_o = v_{PS}^+$

$3v_i = -3 \Rightarrow v_i = -1$

$v^+ < v^-$, $\quad v_o = V_{PS}^-$

$v_i = 5$

c)



# Seminar 5

1)

a) inverting amplifier (neg feedback)

$$v^+ = 0$$

$$v^- = \frac{R_3}{R_1+R_3} v_i + \frac{R_1}{R_1+R_3} v_0 = \frac{10}{12} v_i + \frac{2}{12} v_0$$

$$= \frac{5}{6} v_i + \frac{1}{6} v_0$$

$$v^+ = v^-$$

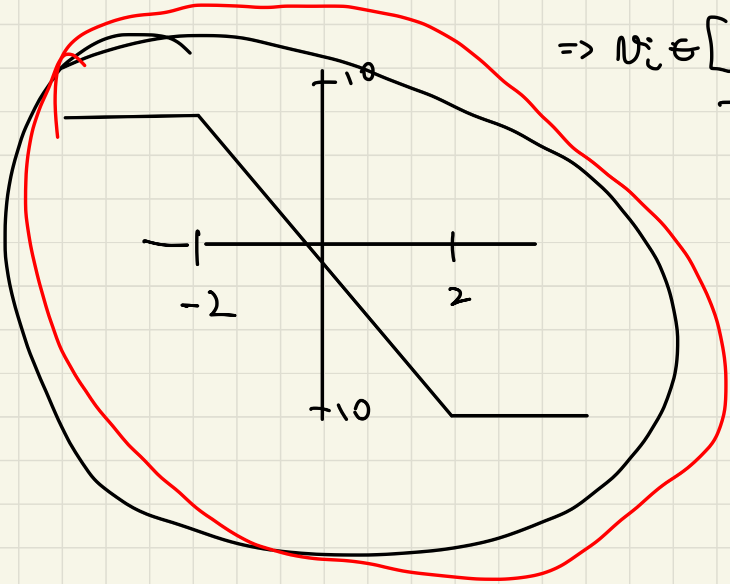
$$\frac{5}{6} v_i + \frac{1}{6} v_0 = 0 \quad \Big| \cdot 6$$

$$5 v_i + v_0 = 0$$

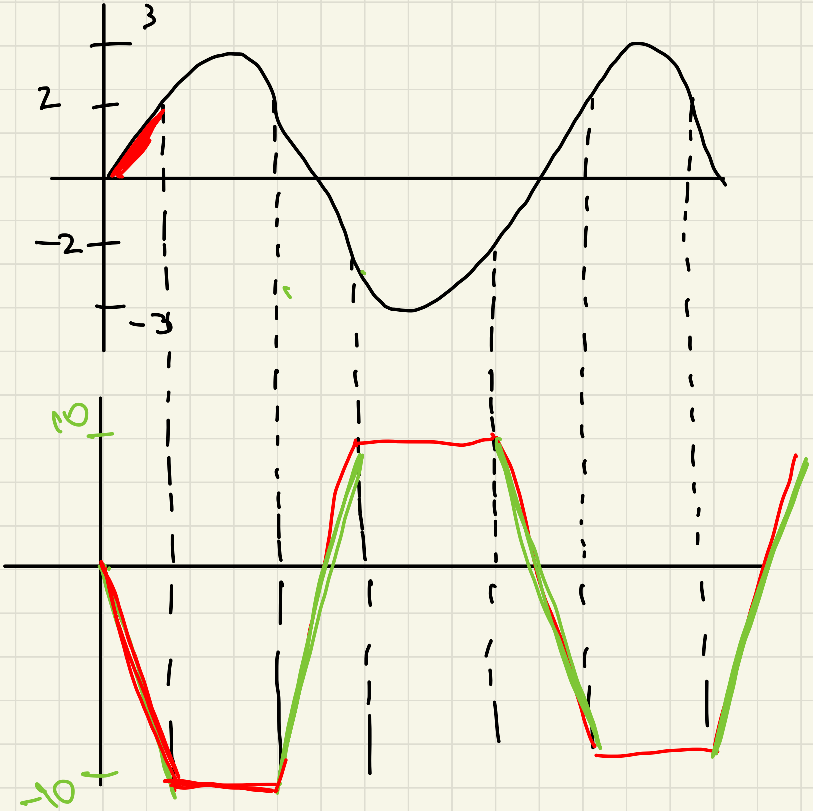
$$A_V = \frac{v_0}{v_i} = \frac{-5 \cancel{v_i}}{\cancel{v_i}} = -5$$

$v_0 \in [-10, 10]$ $\qquad v_0 = -5 v_i$

$\Rightarrow v_i \in [-2, 2]$



b)




c) $R_o = 0$

inv $R_i = R_{ez1}$

noninv $R_i = \infty$

$$\boxed{\begin{array}{l} R_1 = 2\ k\Omega \\ R_o = 0 \end{array}}$$

2)

$v^+ = v^-$

$v^+ = v_i$

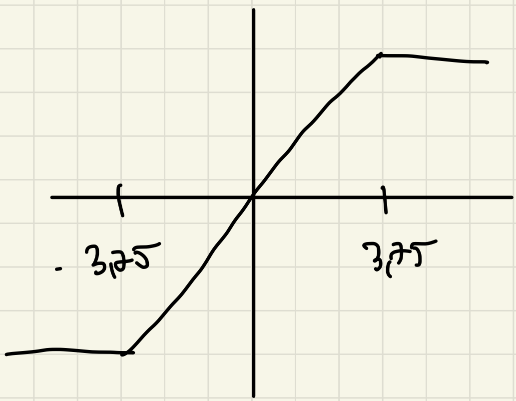
$v^- = \frac{R}{R_1+R} \cdot v_o = \frac{4}{16} v_o$ $\qquad v^- = \frac{4}{R_1+4} v_o$

$v_i = \frac{1}{4} v_o$

$\boxed{4v_i = v_o}$

$A_v = \frac{v_o}{v_i} = \frac{4v_i}{v_i} = 4$

$v_o \in [-15, 15] \qquad v_i \in [-3{,}75, 3{,}75]$




$\frac{4+R_1}{4} = 5$

$\cancel{4+}R_1 = 16$

$R_1 = 36$

b) grafic x 4

$A_v \in [5, 10]$

$A_v = \frac{v_o}{v_i} = \frac{v_o}{\cancel{v_o} \cdot \frac{4}{4+R_1}} = \frac{4+R_1}{4}$

4) $v^+ = v^-$

$v^+ = v_i$

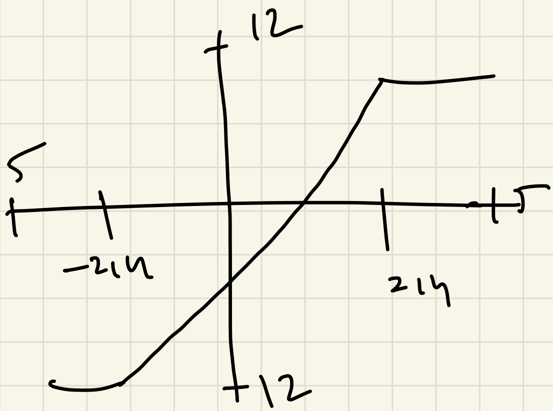
$v^- = \frac{R_1}{R_1+R_2} v_o = \frac{2,5}{12,5} v_o = \frac{1}{5} v_o$

$v_i = \frac{1}{5} v_o$

$5v_i = v_o$

$v_o = [-12, 12]$ , $v_i \in [-2,4 ; 2,4]$ active region

$A_v = \frac{v_o}{v_i} \Rightarrow A_v = 5$



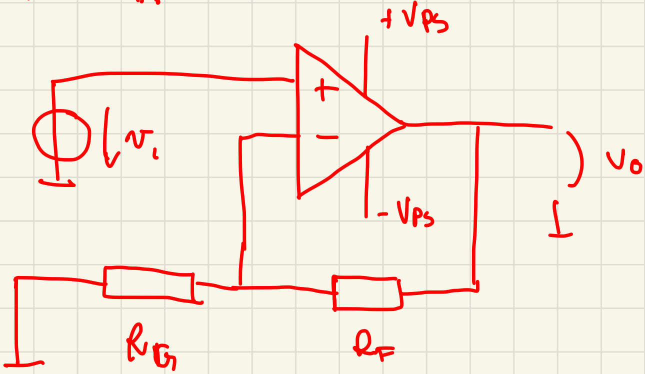
4) a) $v_o$ is connected to $v^-$

b) $v_{i1}$, $v_{i2}$ values to be in active region

$v_o(v_{i1}, v_{i2})$, app. of circ. $\quad v_{i1} = 3\sin\omega t$

$v_{i2} = -3\sin\omega t$

Teorie!!



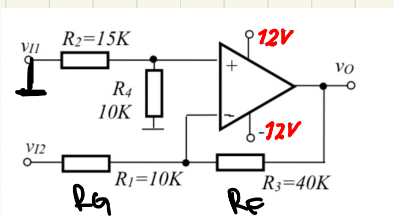

Non-inv

$A = 1 + \frac{R_F}{R_G}$

inv

$A = -\frac{R_F}{R_G}$

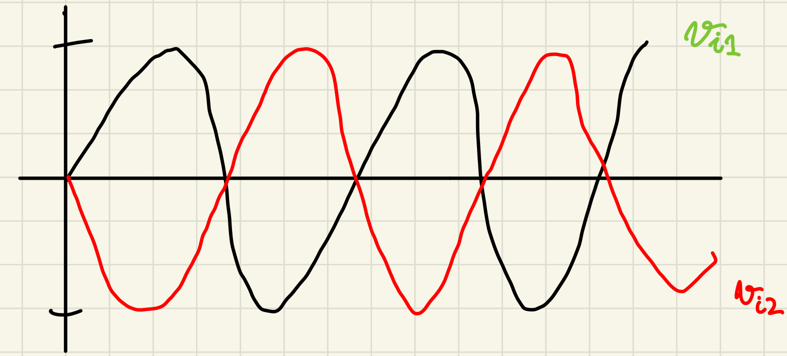
$$v^+ = \frac{R_4}{R_2+R_4} v_{i1} = \frac{10}{25} v_{i1}$$

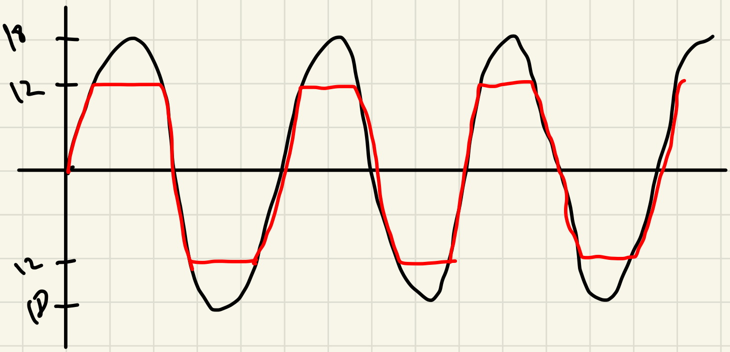



$$v^- = \frac{R_1}{R_1+R_3} v_0 + \frac{R_3}{R_1+R_3} v_{i2} = \frac{1}{5} v_0 + \frac{4}{5} v_{i2}$$

$$v^+ = v^- \Rightarrow \frac{1}{5} v_0 + \frac{4}{5} v_{i2} = \frac{2}{5} v_{i1} \quad | \cdot 5$$

$$v_0 = 2v_{i1} - 4v_{i2}$$




$$v_0 = 2(v_{i1} - 2v_{i2}) = 2(3+6) = 18$$

c) $v_0 = 5(v_{i1} - v_{i2})$

$$-\frac{R_3}{R_1} = -5 \Rightarrow R_3 = 5R_1 \Rightarrow \begin{cases} R_3 = 5 \\ R_1 = 1 \end{cases}$$

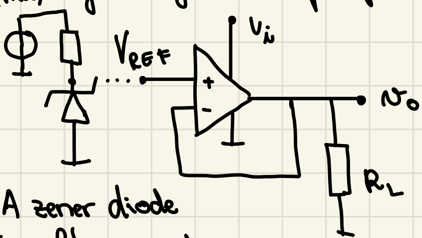
$$\left(\frac{R_4}{R_2+R_4}\right)(1+5) = 5 \Leftrightarrow \frac{R_4}{R_2+R_4} = \frac{5}{6} \Rightarrow \begin{cases} R_4 = 5 \\ R_2 = 1 \end{cases}$$

$$6R_4 = 5(R_2+R_4)$$
$$6R_4 = 5R_2 + 5R_4$$
$$R_4 = 5R_2$$

# Voltage regulator

$v_0 = V_{REF}$

$I_{o,max}$ given by max OpAmp output

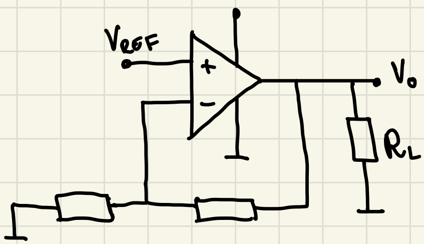



A zener diode
is often used as
a voltage reference

## Voltage regulator 1 (+ adjustable output range)

$V_o = V_{REF} \cdot (R_1 + R_2) / R_1$

$I_{o,max}$ given by max OpAmp output

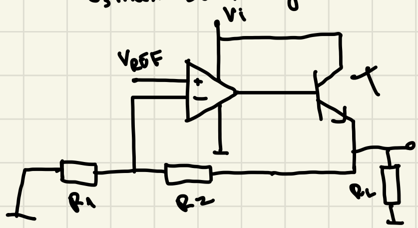



## Voltage regulator 2 (+ NPN transistor for more output current)

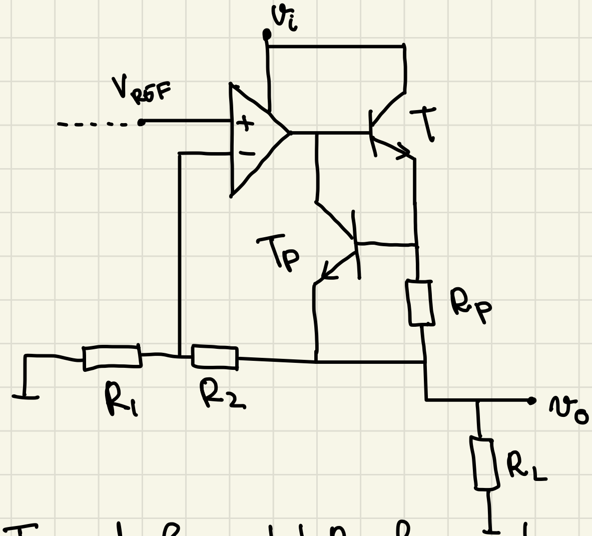
$v_0 = V_{REF} \cdot (R_1 + R_2) / R_1$

$I_{o,max}$ basically unlimited*

*limited to $\beta$*
$I_{o,OpAmp,max}$, which is a lot
$(\beta = 100)$



# Voltage regulators 3 (+ Max current protection)




$T_P$ and $R_P$ protect $R_L$ from too much current

$I_{o,max} = 0{,}7 / R_P$

If $R_L$ demands an $I_o > I_{o,max}$, then $T_P$ is on and the voltage drops to limit the current

$v_o = V_{REF} \cdot (R_2 + R_1) / R_1$ when $I_o < I_{o,max}$

$v_o = I_{o,max} \cdot R_L$

# SEMINAR 6

1)

a) Voltage regulator

6) I $v_{i1}$ ON

$v_{i2}$ OFF

$$A_v = -\frac{R_3}{R_1} = -5$$

II $v_{i1}$ OFF

$v_{i2}$ ON

$$A_v = \frac{-R_3}{R_2} = -2 \qquad A_v = \frac{v_o}{v_i}\Big|_{v_i}$$

$$v_i A_v = v_o$$

$$\boxed{v_o = -5 \cdot v_{i1} + (-2) v_{i2}}$$


$3\sin\omega t$

$v_{i1} = 3\sin\omega t$

$v_{i2} = 3 - 2\sin\omega t$

$v_o = -15\sin\omega t - 6 + 4\sin\omega t$

$v_o = -11\sin\omega t - 6$

c) $R_o = 0$

$v_{i1}$ ON $R_i = 2\,k\Omega$

$v_{i2}$ ON $R_i = 5\,k\Omega$

d) $v_0 = -(v_{i1} + v_{i2})$

$$A_v = \frac{-R_3}{R_1} = -1$$

$$-R_3 = -R_1$$

$$R_3 = R_1$$

$\Rightarrow R_1 = R_2 = R_3$

$$A_v = \frac{-R_3}{R_2} = -1 \Rightarrow R_3 = R_2$$

4) b) I $v_{i1}$ ON
$v_{i2}$ OFF

$$A_v = 1 + \frac{R_F}{R_G} = 1 + \frac{R_3}{R_1}$$

$$A_v = \boxed{1 + \frac{R_3}{R_1}} = 1 + \frac{4}{1} = 5$$

II $v_{i1}$ OFF
$v_{i2}$ ON

$$\boxed{A_v} = -\frac{R_F}{R_G} = -\frac{R_3}{R_1}$$

$$A_v = -\frac{R_3}{R_1} = -4$$

$$\boxed{A_v} = \frac{v_o}{v_i} \Rightarrow v_o = A_v v_i$$

$$\boxed{v_o = \boxed{5v^+} - 4v_{i2}}$$

$$A_v\, v^+ - 4 v_{i2}$$

$$v^+ = \left(\frac{R_4}{R_2+R_4} \cdot v_{i1}\right) = \frac{10}{25} v_{i1} =$$

$$v_o = \underbrace{2v_{i1}}_{A_v} \underbrace{-4v_{i2}}_{A_v}$$

$$6R_4 = 5R_2 + 5R_4$$

$$\boxed{R_4 = 5R_2}$$

c) $v_o = 5(v_{i1} - v_{i2}) = 5v_1 - 5v_{i2}$

$$A_v = -\frac{R_3}{R_1} = -5$$

$$\Rightarrow -R_3 = -5R_1 \Rightarrow \boxed{R_3 = 5R_1}$$

$$\frac{R_4}{R_2+R_4}\left(1 + \frac{R_3}{R_1}\right) = 5 \Rightarrow \frac{R_4}{R_2+R_4} = \frac{5}{6}$$

$R_4 = 5 \Rightarrow R_2 = 1$

$$\boxed{v_0 = \boxed{5(v_1 - v_2)} - \boxed{\underbrace{5}_{A_v} v_1 - \underbrace{5}_{A_v} v_2}}$$

$$\boxed{v_0 = \underbrace{5}_{A_v} v^+ - \underbrace{4}_{A_v} v_2}$$

I $v_2$

$$A_v = -\frac{R_3}{R_1} = -5 \Rightarrow R_3 = 5R_1$$

II $v_1$

$$v^+ = \frac{R_4}{R_2+R_4}\underbrace{\left(1 + \frac{R_3}{R_1}\right)}_{v_{i1}} = 5$$

$$\frac{R_4}{R_2+R_4} \cdot 6 = 5$$

$$\frac{R_4}{R_2+R_4} = \frac{5}{6} \Rightarrow R_4 = 5R_2$$

d) I $v_{i1}$ ON
$v_{i2}$ OFF
$R_i = \infty$

else $R_i = 10K$

d) $R_i = \infty$

$v_2$ OFF

5) $v_o(v_{i1}, v_{i2}, v_{i3})$

$v^- = v_o \frac{1}{2} + v_i \cdot \frac{1}{2}$

$v^+ = v_{i3} \cdot \frac{1}{2} + v_{i2} \cdot \frac{1}{2}$

$v_D = v^+ - v^-$

$v_D = 0$

$v^+ = v^-$

$\frac{1}{2} v_0 + \frac{1}{2} v_{i1} = \frac{1}{2} v_{i3} + \frac{1}{2} v_{i2} \quad \Big| \cdot 2$

$v_0 = v_{i2} + v_{i3} - v_{i1}$

b) I

$v_{i1}$ ON

$v_{i2}$ OFF

$A_V = \boxed{-\frac{R_2}{R_1}} = -1$

II $v_{i1}$ OFF

$v_{i2}$ ON

$A_V = 1 + \frac{R_2}{R_1} = 2$

$v_0 = -1 v_{i1} + 2 \boxed{v^+}$

$v^+ = \frac{R_3}{R_3 + R_4} v_{i2} = \frac{1}{2} v_{i2}$

$v_0 = -v_{i1} + v_{i2}$

$-\frac{R_2}{R_1} = -3$

$R_2 = 3R_1$

$$\frac{R_3}{R_4+R_3}\left(1+\frac{R_2}{R_1}\right) = 3$$

$$\frac{R_3}{R_4+R_3} = \frac{3}{4} \Rightarrow 4R_3 = 3R_4 + 3R_3$$

$$R_3 = 3R_4$$

$$R_3 = -3R_4$$

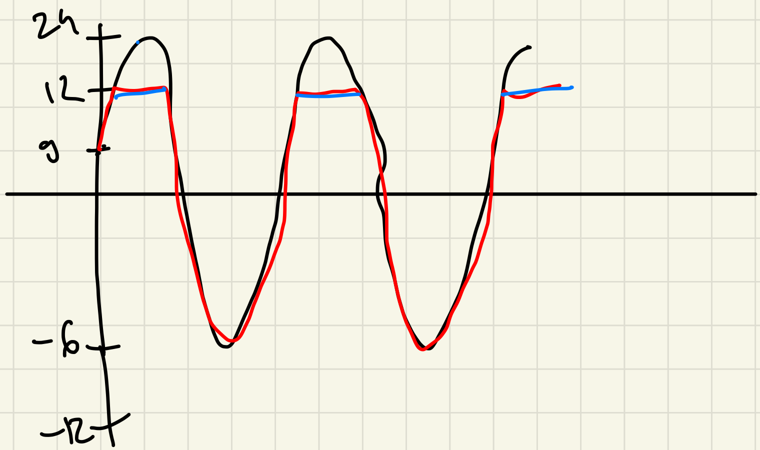
$$3(v_{i1} - v_{i2}) \in [-12, 12]$$

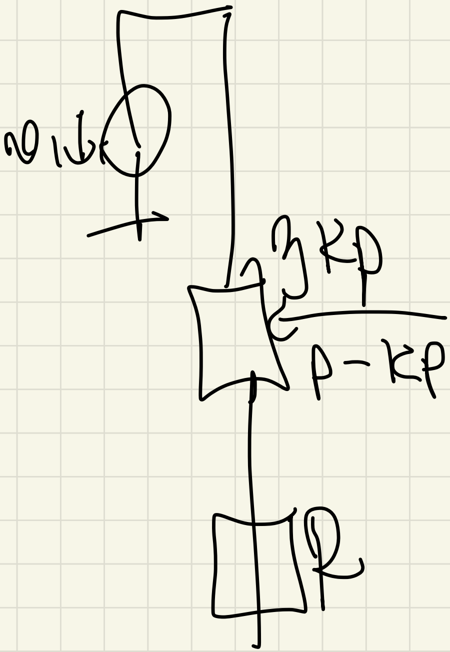
$$-4 \leq v_{i1} - v_{i2} \leq 4$$

c) $v_{i3}$ OFF

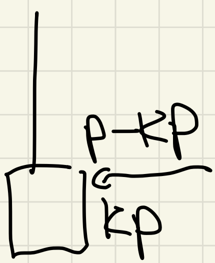
$$v_0 = 3(-3\sin\omega t + 4 - 2\sin\omega t - 1)$$

$$= -15\sin\omega t + 9$$






$K \in [0, 1]$




$K = 0 \Rightarrow$ wiperul e într-un capăt

$K = 1$ . . . . .

**P1. 2.5p = 0.5p * 5**

Consider for D the constant voltage drop model, with $v_D = 0.7V$, $v_I(t) = 7.7\sin\omega t$ [V], $V_{BIAS}=-2V$ and $R=10K\Omega$.

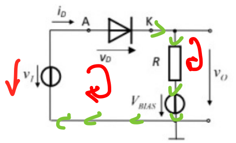
**a)** What is the application of the circuit? Justify.

**b)** Deduce and plot VTC $v_O(v_I)$. Specify the states of the diode (on/off) on the plot.

**c)** Plot $v_O(t)$, $v_D(t)$ and $i_D(t)$.

**d)** Size R so that the maximum current through the diode is $I_{D,\,max}=300mA$.

**e)** Consider another voltage source $v_{I2} = -3\sin\omega t$ [V], and another diode $D_2$ added to the circuit in the same way as $v_I$ and D are connected (between ground and K point). Draw the new circuit, find the expression of the output voltage and plot vo(t).




a) Aplicația circuitului este redresor de imp.

b) VTC $v_O(v_i)$

$-v_i + v_D + v_O = 0$

D off $\begin{cases} v_D < 0{,}7 \\ i_D = 0 \end{cases}$

$v_O - V_{BIAS} - V_R = 0$

$v_O = v_{BIAS} + V_R$

$v_D = v_i - v_O$, $v_O = 0$

$-v_i + v_D + v_{BIAS} + v_R = 0$

$v_D < 0{,}7$

$v_i < 0{,}7$

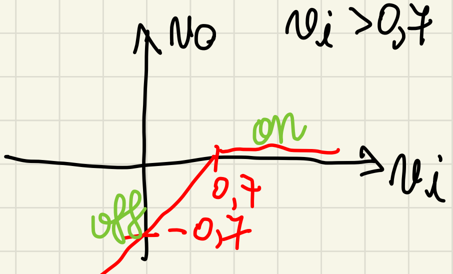
D on $\begin{cases} v_D = 0{,}7 \\ i_D > 0 \Rightarrow v_O > 0 \end{cases}$

$v_O = v_i - v_D$

$v_i - 0{,}7 > 0$

$v_i > 0{,}7$

$v_O = \begin{cases} 0, & v_i < 0{,}7 \\ v_i - 0{,}7 & v_i > 0{,}7 \end{cases}$



**P1. 2.5p = 0.5p * 5**

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**a)** What is the application of the circuit? Justify.

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**c)** Plot $v_O(t)$, $v_D(t)$ and $i_D(t)$.

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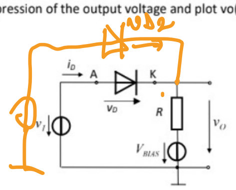



$v_o = \max(v_{i2} - 0,7,$
$v_{12} - 0,7, V_{BIAS})$

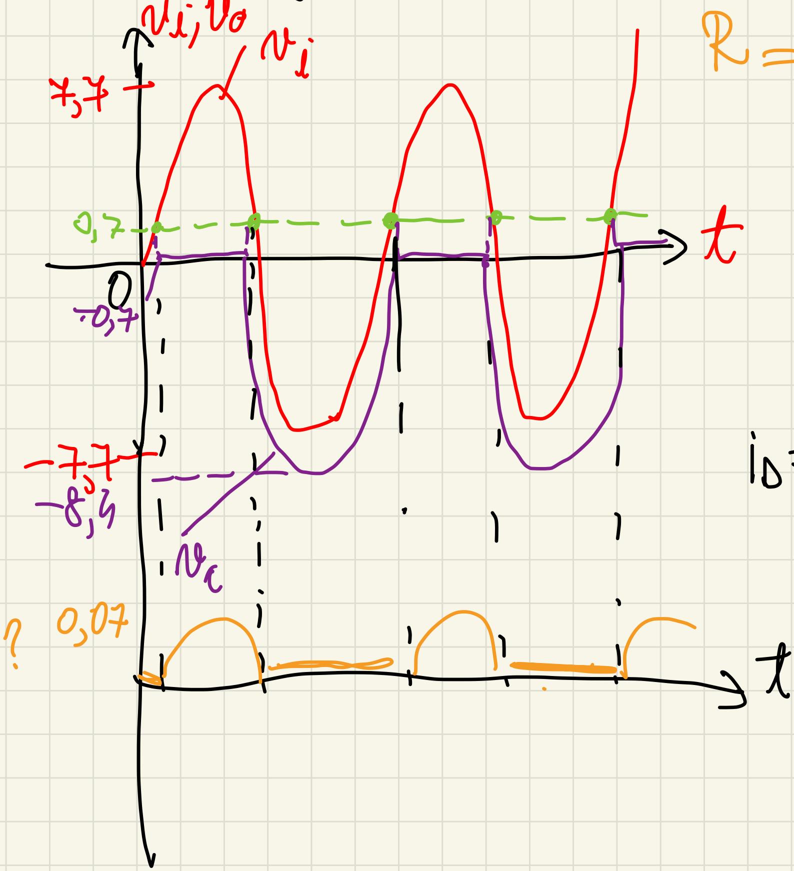
d) $I_{D max} = \frac{v_R}{R}$

$R = \frac{v_R}{I_{D max}} = \frac{v_i - v_{BIAS} - v_1}{300mA}$

$= \frac{7,7-5-0,7}{300}$

$R = \dots \Omega$

$$v_o = \begin{cases} 0, & v_i > 0,7 \\ v_i - 0,7 & v_i < 0,7 \end{cases}$$




$i_D = \{ 0 \quad v_i < 0,7$

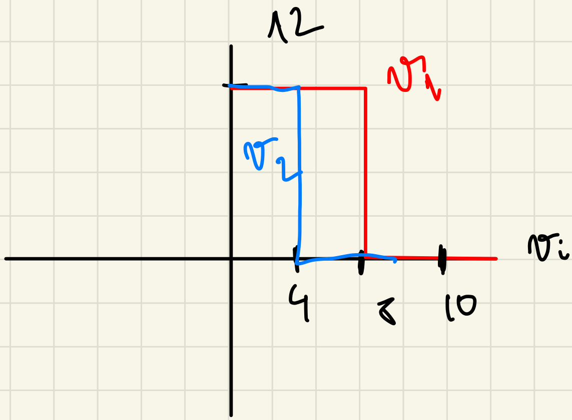
4)

a) $v_1^- = v_i$

$$v_1^+ = \frac{R_2+R_3}{R_1+R_2+R_3} \cdot V_{PS}^+ = \frac{2}{3} \cdot 12 = 8\,V$$

app. inverting comp.

$$v_0 \begin{cases} 12, & v_i < 8 \\ 0, & v_i > 8 \end{cases}$$



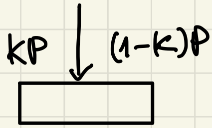

$v_2^- = v_i$

$v_2^+ = 4$

c)

| $v_i$ | L1 | L2 |
|---|---|---|
| 0, 4 | ~~off~~ on | ~~on~~ |
| 4, 8 | on | off |
| 8, 10 | ~~off~~ | ~~off~~ |

# Seminar 6




a) Voltage regulator

b) $v_D = v^+ - v^-$
$= 3{,}3 - v^-$

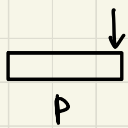
$$v^- = \frac{R_1 + kP}{R_1 + kP + (1-k)P} \cdot v_o = \frac{R_1 + kP}{R_1 + P} \cdot v_o = \frac{1 + kP}{6} \cdot v_o$$

$$v_D = 3{,}3 - \frac{1+kP}{6} \cdot v_o = 0 \Rightarrow 3{,}3 = \frac{1+kP}{6} v_o$$

$$\Rightarrow \frac{6 \cdot 3{,}3}{1+kP} = v_o$$

$$v_o = \frac{(3{,}3)6}{1+kP} = \frac{19{,}8}{1+kP}$$

min $V_0 \Rightarrow k = 1 \longrightarrow$

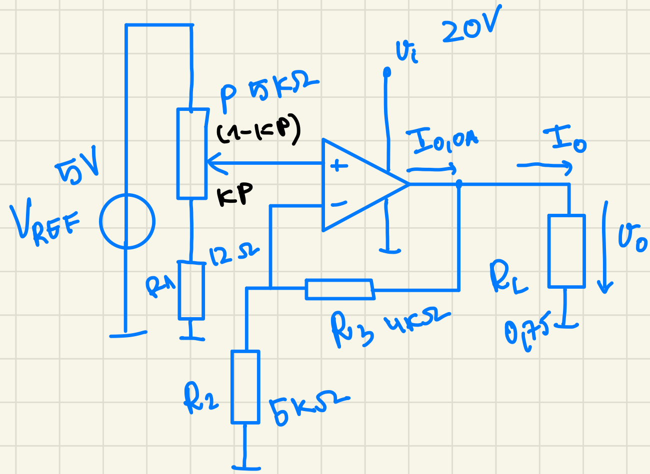



c) $v_{o,max} = 19{,}8$

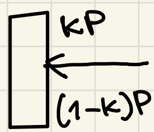
$$v_{o,min} = \frac{19{,}8}{1+5} = \frac{19{,}8}{6} = 3{,}3V$$

$$v_o \in [3{,}3V ; 19{,}8V]$$

2




a) $v_D = v^+ - v^-$




$$v^- = \frac{R_2}{R_2+R_3} \cdot v_o = \frac{5}{9} v_o$$

$$v^+ = \frac{R_1 + KP}{R_1 + KP + (1-K)P} \cdot v_{REF} = \frac{12 + KP}{17} \cdot 5 = \frac{60 + 5KP}{17}$$

$$v_D = \frac{60 + 5KP}{17} - \frac{5}{9} v_o = 0$$

$$\frac{60 + 5KP}{17} = \frac{5}{9} v_o$$

$$v_o = \frac{\cancel{5}(12 + KP)}{17} \cdot \frac{9}{\cancel{5}} = \frac{9(12 + KP)}{17}$$

$K=1 \Rightarrow \max\ v_o = 9\ V$

$K=0 \Rightarrow \min\ v_o = 6{,}35\ V$

$v_o \in [6{,}35V,\ 9V]$

b) $v^- = v_0$

$v_D = v^+ - v^- = v^+ - v_0$

$v_D = \frac{(12+kP)5}{17} - v_0 = 0$

$v_0 = \frac{5(12+KP)}{17}$

$\min v_0 = \frac{5(12+0)}{17} = 3{,}52V$

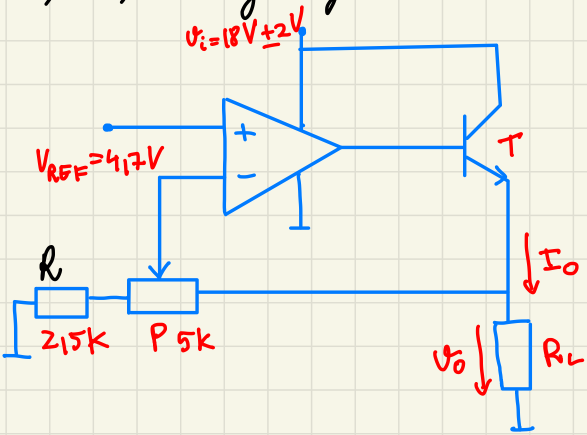
$\max v_0 = \frac{5(12+5)}{17} = 5V$

$v_0 \in [3{,}52V, 5V]$

c) $R_L = \frac{v_{R_L}}{i} = \frac{v_0}{i}$

$R_{L_{min}} = \frac{v_{0\,min}}{i} = \frac{3{,}52}{25} = 0{,}14$

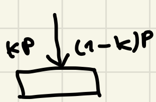
3) a) voltage regulator




$v_D = v^+ - v^-$

$v^+ = V_{REF} = 4{,}7V$

$v^- = \frac{R + kP}{R + KP + (1-k)P} \cdot v_0 = \frac{2{,}5 + KP}{7{,}5} \cdot v_0$




$v_0 \cdot \frac{2{,}5 + kP}{7{,}5} = 4{,}7$

$v_0 = \frac{4{,}7 \cdot 7{,}5}{2{,}5 + KP}$

$v_0 = \frac{35{,}25}{2{,}5 + kP}$

$K = 1 \Rightarrow \frac{35{,}25}{7{,}5} = 4{,}7$

$K = 0 \Rightarrow \frac{35{,}25}{2{,}5} = 14{,}1$

$v_0 \in [4{,}7; 14{,}1]$

b) $I_{0,max} = 750\, mA$

$$I_0 = \frac{V_0}{R_L} \Rightarrow 750 = \frac{V_0}{R_L}$$

$$\left.\begin{aligned} I_C &= \beta I_B \\ I_B + I_C &= I_E \end{aligned}\right\} \Rightarrow \begin{aligned} I_E &= I_0 \\ (1+\beta) I_B &= I_E \end{aligned}$$

$$750\, mA = (1+\beta) I_0\, OA \qquad I_0\, OA = \frac{750}{1+\beta}$$

Suppose $I_{0,OA} = 25\, mA$

$$25 = \frac{750}{1+\beta}$$

$$25 + 25\beta = 750$$

$$\beta = \frac{725}{25} = 29$$

c)

a) $v^+ = v^-$

$v^+ = V_{REF}$

$$v^- = \frac{R+KP}{R+KP+(1-K)P} \cdot v_0 = \frac{5+KP}{15} v_0$$

$$v_0 (5+KP) = 70,5$$

$$v_0 = \frac{70,5}{5+KP} =$$

Pt $K=0 \Rightarrow v_0 = 14,1$

Pt $K=1 \Rightarrow \frac{70,5}{15} = 4,7$

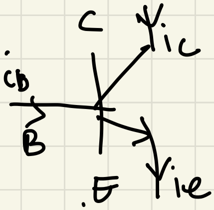
b) $v^+ = v^-$

$$\frac{R+KP}{R+KP+(1-K)P} v_0 = V_{REF}$$

We take $K=1$

c) $I_{o,max} =$

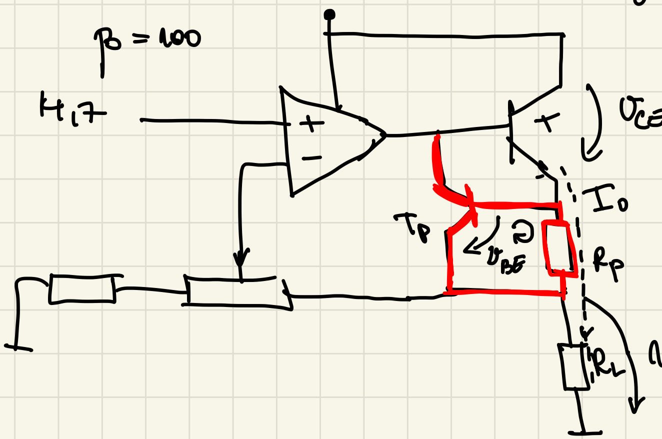
3) $I_{O,OA} \longrightarrow$ max 20 ≈ 25 mA




$$\left.\begin{aligned} i_b + i_c &= i_e \\ i_c &= \beta i_b \end{aligned}\right\} \quad i_e = (\beta+1) i_b$$

$$I_o = \frac{V_o}{R_L}$$

$\beta = 100$




$v_{rp} = r_p I_o$

$I_o \nearrow = v_{rp}$

$$I_o = \frac{v_{Rp}}{r_p} = \frac{v_{BE}}{r_p}$$

$v_{rp} = 0{,}7V = v_{BE} \Rightarrow T_p$ c

$v_{BE} \simeq ct \quad (0{,}7 \ldots 0{,}8)$

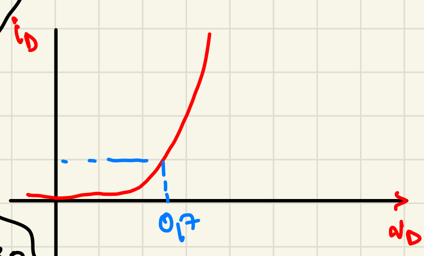
b) $I_o = 750\,mA$

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

$$r_p = \frac{v_{rp}}{I_o} = \frac{0{,}7}{750mA} = \frac{0{,}7}{0{,}75A} = \frac{70}{75}\Omega$$

$= 0{,}93$

$\frac{750\,mA}{25\,mA} = 30 \Rightarrow$ Tranzistor ales trebuie să aibe $\beta > 30$



c) $K = 0{,}5 \Rightarrow v_o = \frac{P+R}{0{,}5P+R} \cdot V_{REF}$ ; $v_o = \frac{7{,}5}{5} \cdot 4{,}7$ ; $v_o = 7{,}05V$

$R_L = 70\Omega \qquad P_T = ?$

$P_T = V_{CE} \cdot I_o$

$I_o = \frac{v_o}{R_L} \qquad I_o = \frac{7{,}05}{70\Omega} = 100\ mA < I_{o\,max}$
$T_p\,coff)$

$v_{CE} = v_i - v_{Rp} - v_o$

$v_{Rp} = R_p \cdot I_o \Rightarrow v_{Rp} = 0{,}93 \cdot 0{,}1 = 0{,}09V$

$v_o = 7{,}05$

$v_{i\,max} = 20V$

$v_{CE} = 20 - 7{,}14 = 12{,}86\ V$

$P_T = 12{,}86V \cdot 0{,}1A \Rightarrow P_{T\,max} = 1{,}28W$

worst case scenario

$I_o = I_{o,max}$ ; $v_o = 0\ V$

$V_{CE\,max} = v_{i\,max} - v_{Rp} = 20 - 0{,}7 = 19{,}3\ V$

$P_{T\,max} = 19{,}3 \cdot 0{,}75 \Rightarrow P_{T\,max} = 14{,}47W$

$(P_{T\,max} = V_{CE\,max} \cdot I_{o\,max})$

$R_L = 2\Omega \Rightarrow I_o = \frac{V_o}{R_L} = \frac{7{,}05}{2\Omega} = 3{,}525A$

$\Rightarrow I_o = I_{o\,max}$

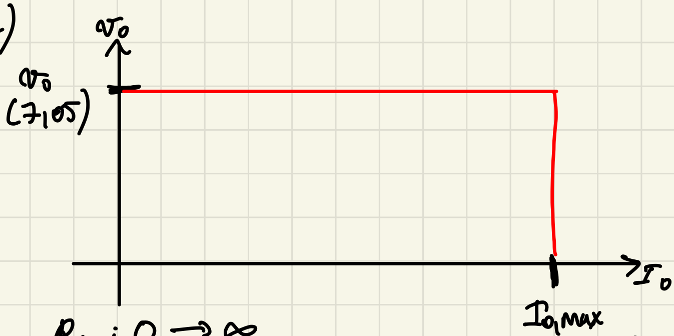
$V_{o\,real} = I_{o\,max} \cdot R_L = 2{,}075 = 1{,}5V$

$V_{CE} = 20 - V_{Rp} - 1{,}5 = 20 - 2{,}2 = 17{,}8$

$(I_{o\,max} \cdot R_p = 0{,}75 \cdot 0{,}93)$

$P_T = V_{CE} \cdot I_{o\,max} \Rightarrow P_T = 13{,}$

4) c)



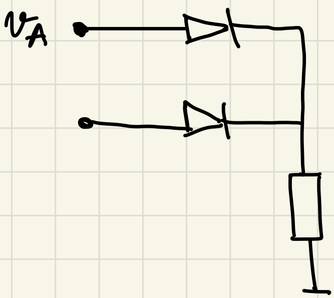

$$I_{o\,max} = \frac{v_{R_p}}{R_p} = \frac{v_{BE}}{R_p}$$

$R_L : 0 \to \infty$

$R_L \to \infty \Rightarrow I_o \to 0$ $\qquad I_o = \frac{v_o}{R_L}$

$R_L = 0 \Rightarrow$ short circuit $\qquad V_o = 0V$

## Diode




$D_1$ ON , $D_2$ OFF

$v_o = v_A - 0{,}7V$

$D_1$ OFF , $D_2$ ON

$v_o = v_B - 0{,}7V$

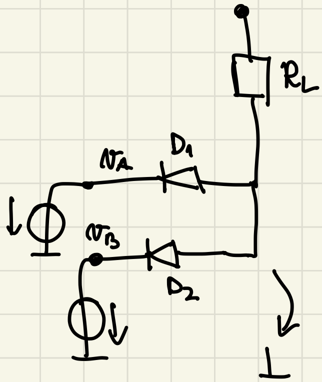
$D_1$ OFF , $D_2$ OFF

$v_o = 0$

$D_1$ ON , $D_2$ ON

$$\left.\begin{array}{l} v_o = v_A - 0{,}7 \\ v_o = v_B - 0{,}7 \end{array}\right\} \Rightarrow v_A = v_B$$

$v_o = \max(v_A - 0{,}7,\ v_B - 0{,}7,\ 0)$



R_L
D_1
v_A
v_B
D_2

Sem. 5

6) a) inverting summing amplifier

I $v_{i1}$ ON
$v_{i2}$ OFF

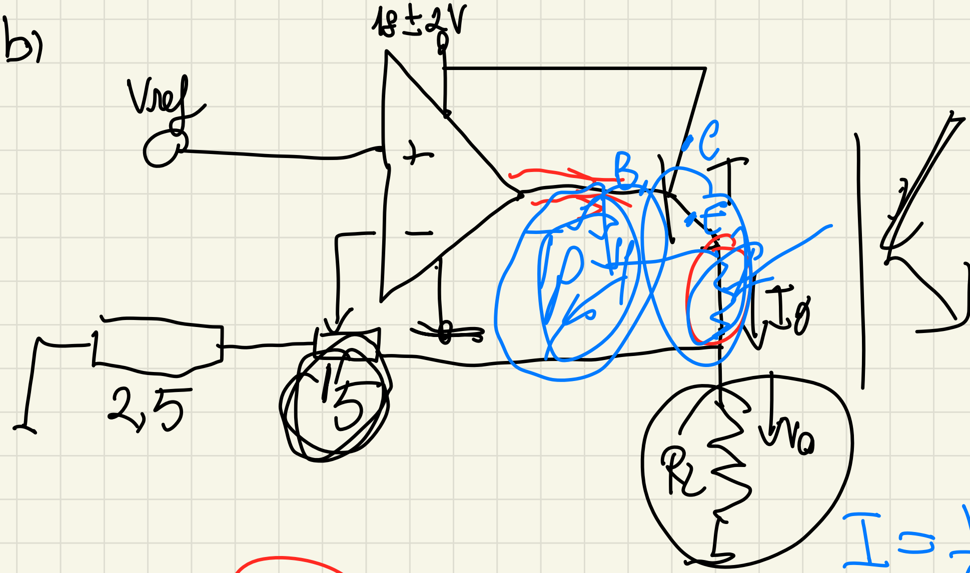
$$A_V = -\frac{R_3}{R_1} = -5$$

II $v_{i2}$ ON
$v_{i1}$ OFF

$$A_V = -\frac{R_3}{R_2} = -2$$

$$v_o = -5v_{i1} - 2v_{i2}$$

3) b)




$I = \frac{V}{R}$

$$R_p = \frac{V}{I} = \frac{V_{BE\,max}}{750mA} = \frac{0{,}7}{0{,}750\,A}$$

$$= \frac{7 \cdot 10^{-1}}{75 \cdot 10^{-3}} = \frac{70}{75} = \cancel{0{,}1}\ 0{,}9$$

c) $P = U \cdot I$

$R_L = 70$

$I_{Vo}$ / $I_O$, $R_L$

$v^- = \frac{5}{75} V_O$ $\qquad$ $V_O = \frac{75 \cdot 4{,}3}{5}$

$v^+ = 4{,}3$ $\qquad$ $I_O = \frac{V_O}{R_L} = 0{,}1A$

$v_i = v_t + v_{Rp} + v_o$

$v_t = v_i - v_{Rp} - v_o$

# BARKHAUSEN CRITERIA

① $a \cdot r = 1$ stable oscilator
$a \cdot r < 1$
$a > r > 1$

dacă zice satisface cond lui Barkhausen sau accomplish the oscil. criteria $a \cdot r = 1$

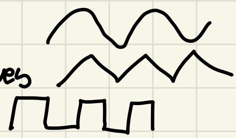
② $\varphi_a + \varphi_r = 2k\pi$
$\varphi_a \to 0$, $\varphi_r \to 0$ la Wien Bridge

$$a = \frac{v_0}{v_i}$$

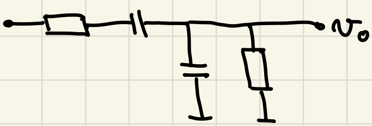
$$T = 2RC \ln \frac{1+r}{1-r}$$

$$f_0 = \frac{1}{T}$$

3 tipuri
- sine waves
- triangle waves
- square waves



$\boxed{\text{Wien Bridge}}$ → filtrează frecvența




$$f_0 = \frac{1}{2\pi\sqrt{R_s \cdot C_s \cdot R_p \cdot C_p}}$$

La ce folosim
① Selectează / filtrează doar frecvența $f_0$
② Amplifică cu factorul $r$

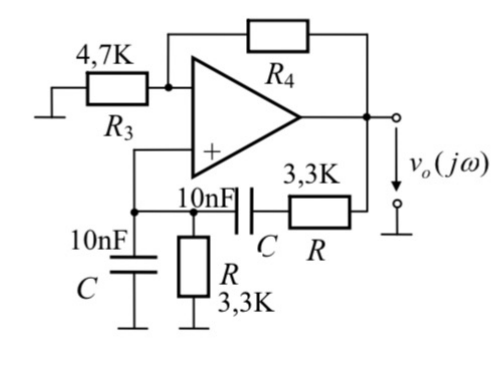
$$r = \frac{1}{1 + \frac{R_s}{R_p} + \frac{C_s}{C_p}}$$

$$a = \frac{1}{r}$$

$$a = 1 + \frac{R_3}{R_4}$$

$$a = 2 + \frac{R_2}{R_1}$$

Ex 2 Sem 7

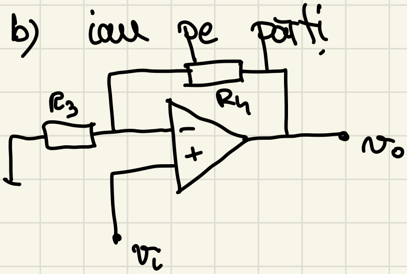



a) calculez $r$ și $f_0$

$$f_0 = \frac{1}{2\pi\sqrt{R_s R_p C_s C_p}} \qquad r = \frac{1}{1 + \frac{R_s}{R_p} + \frac{C_s}{C_p}}$$

$$r = \frac{1}{3}, \quad f_0 = \frac{1}{2\pi \cdot 33} = 0,004823 \text{ Hz}$$

b) iau pe părți




$v_0 = v^- \Rightarrow$ NF amplifier

$$\left.\begin{aligned} & v^+ = v_i \\ & v^- = v_0 \cdot \frac{R_3}{R_3 + R_4} = v_0 \cdot \frac{4{,}7}{4{,}7 \cdot R_4} \\ & v_D = 0 \Rightarrow v^+ = v^- \end{aligned}\right\} \Rightarrow v_0 \cdot \frac{4{,}7}{4{,}7 + R_4} = v_i$$

$$v_0 = \frac{(4{,}7 + R_4) v_i}{4{,}7}$$

$$a = \frac{\frac{(4{,}7 + R_4) \cdot v_i}{4{,}7}}{v_i} = \frac{4{,}7 + R_4}{4{,}7}$$

$a \cdot r = 1$

$\frac{1}{3}$

mai sus

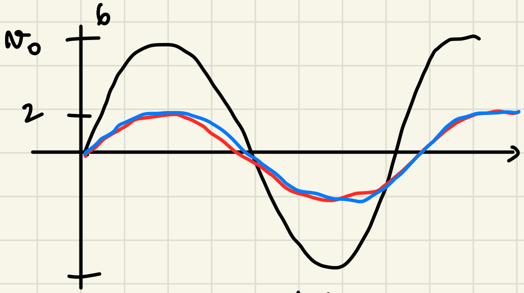
$$\frac{4,7+R_4}{4,7}\cdot\frac{1}{3}=1$$

$$\frac{4,7+R_4}{14,1}=1$$

$$4,7+R_4=14,1 = 9,4\ k\Omega$$

c) $v_0 = 6\sin(\omega t)$

ne cere $v^+$ și $v^-$



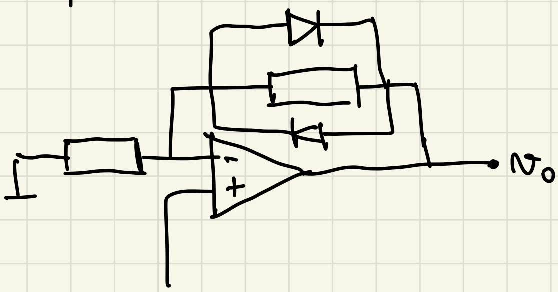

$v^- = \frac{1}{3}\cdot v_0$

$a=3 \quad v^- = v_0 \cdot \frac{1}{a}$

$v^+ = v^-$

$v^- = \frac{v_0}{3} = \frac{6}{3} = 2$

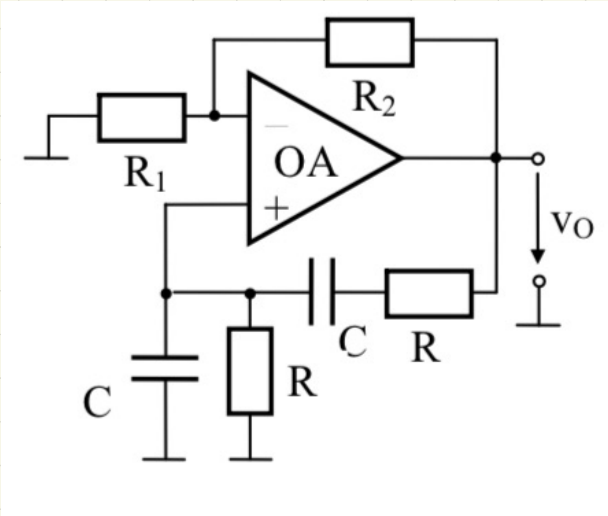
d)




diodele fac

$a \cdot r > 1$ "când e nevoie!

3)




a) $a \cdot \beta = 1$

$$\beta = \frac{1}{1 + \frac{R_S}{R_P} + \frac{C_S}{C_P}}$$

$$f_0 = \frac{1}{2\pi\sqrt{R^2C^2}} = \frac{1}{2\pi R \cdot 10^{-8}} = \frac{10^{8}}{2\pi R} = 3{,}18$$

$$2\pi R \cdot 3{,}18 = 10^{8}$$

$$R = \frac{10^{8}}{2\pi \cdot 3{,}18}$$

b) $a \cdot \beta = 1$

$$a = \frac{v_o}{\frac{R_1}{R_1+R_2} v_o}$$

$$a = \frac{v_o}{v_i}$$

$$\left.\begin{aligned} v^+ &= v_i \\ v^- &= \frac{R}{R_1+R_2} \cdot v_o \end{aligned}\right\} \Rightarrow v_i = \frac{R_1}{R_1+R_2} v_o$$

$$a = \frac{R_1+R_2}{R_1} = \frac{R_1+5{,}6}{R_1}$$

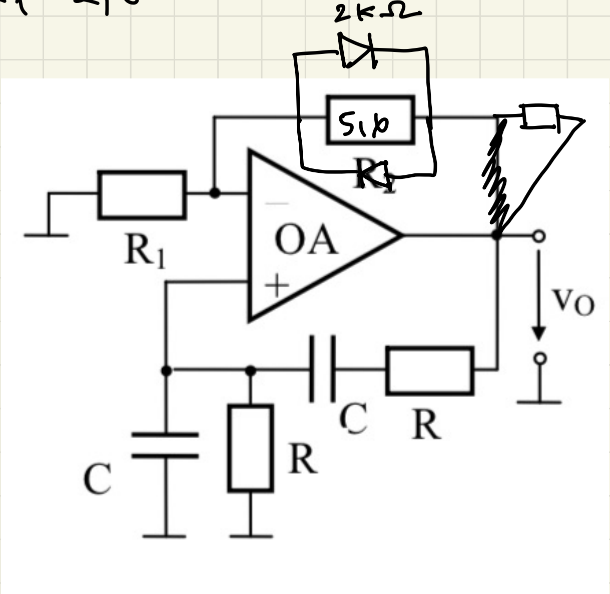
$$\frac{R_1+5{,}6}{3R_1}=1$$

$$R_1+5{,}6=3R_1$$

$$2R_1=5{,}6$$

$$R_1=2{,}8$$

c)




$a_{off}$

4) a) $f_0 = \frac{1}{2\pi\sqrt{R_s R_p C_s C_p}} = \frac{1}{2\pi\, 15\cdot 10^3 \cdot 10\cdot 10^{-9}} = \frac{10^5}{2\pi\, 15} = \frac{10^4}{3\pi} =$

b) $n = \frac{1}{3}$

$A_V = 1 + \frac{R_F}{R_G}$

$n \cdot a = 1$

$\frac{a}{3} = 1 \Rightarrow a = 3$

$v^+ = v^-$

$v^+ = v_i$

$v^- = 1 + \frac{R_3 \| D_1 + P}{R_4} = \frac{\frac{R_3 \cdot D_1}{R_3 + D_1} + P}{R_4}$

$= \frac{\frac{5 \cdot 0{,}5}{5{,}5} + 2{,}5}{R_4} = \frac{2{,}95}{R_4} + 1 = 3$

$\frac{2{,}95}{R_4} = 2$

$2R_4 = 2{,}95$

$R_4 = \frac{2{,}95}{2} = 1{,}47$

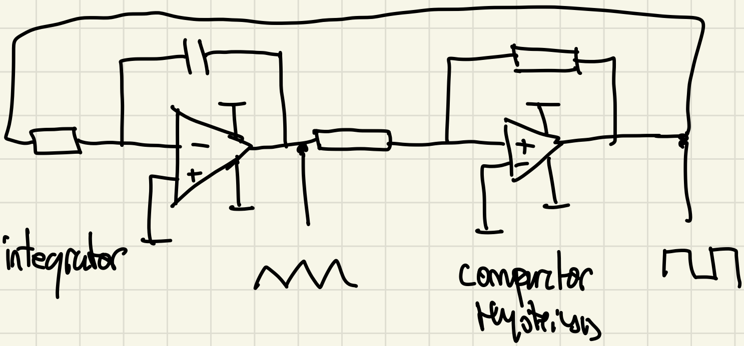
c) $a \cdot r > 1$

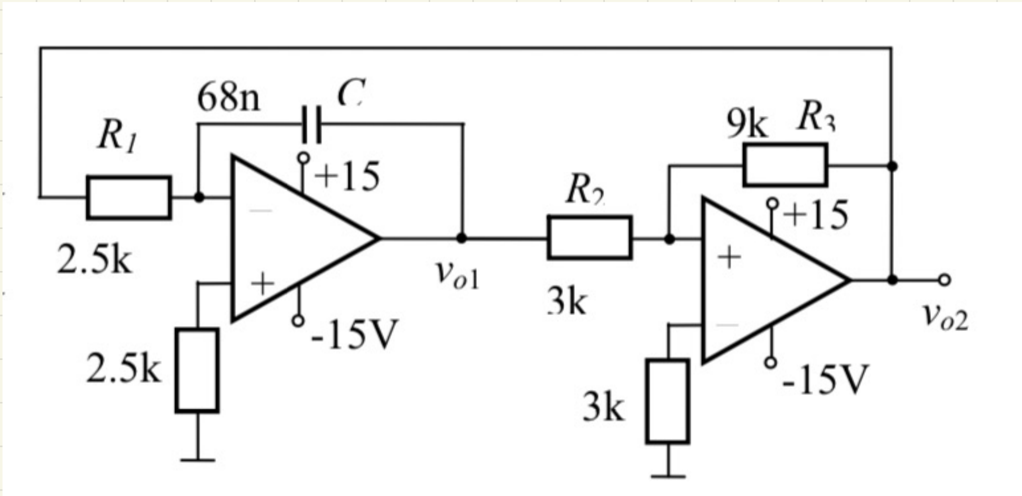
$a > 3$

$$\frac{5 \cdot 0{,}5 + 2{,}5}{1{,}47} > 2$$

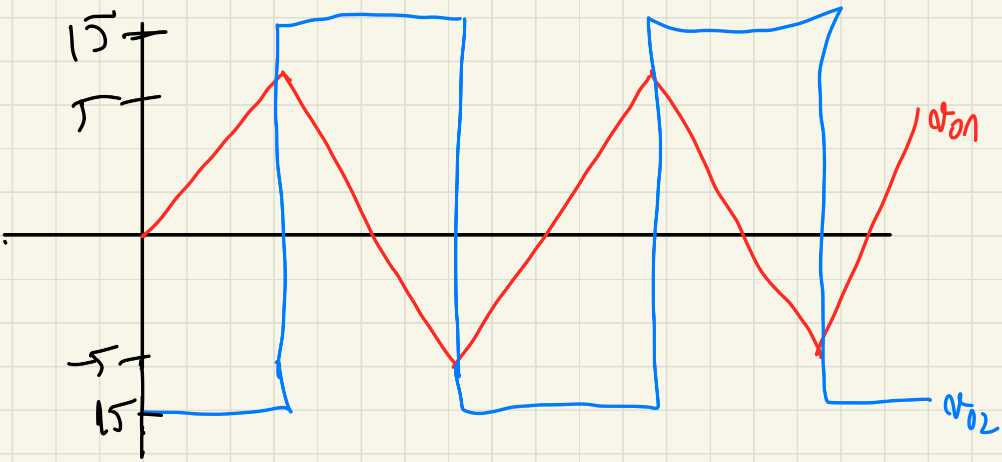
$$\frac{5}{1{,}47} > 2$$

$3{,}4 > 2$ "A"






a)




b) $v^- = 0$

$$v^+ = \frac{R_2}{R_3+R_2} \cdot v_{o2} + \frac{R_3}{R_2+R_3} \cdot v_{o1} = \frac{3}{12} v_{o2} + \frac{9}{12} v_{o1}$$

I $\quad v^+ > v^- \Rightarrow v_{o2} = 15$

$$\frac{15}{4} + \frac{3}{4} v_{o1} = 0 \Rightarrow \frac{3}{4} v_{o1} = \frac{15}{4} \Rightarrow v_{o1} = 5$$

II $v^+ < v^- \Rightarrow v_{O2} = -15$

$v_{O1} = -5$

$V_{thH} = 5 \quad V_{thL} = -5$

$V_{O1}\ max = 5V$ pt $V_{O2}\ max = 15$

$V_{O1}\ min = -5$ pt $V_{O2}\ min = -15$

c) $T = 4RC \rightsquigarrow f = \frac{1}{T}$, $f = \frac{1}{4RC}$

$T = 4 \cdot 2{,}5 \cdot 68\,nF = 0{,}68\,ms$

d) $f = \frac{1}{4RC}$