

PROIECT SCIA

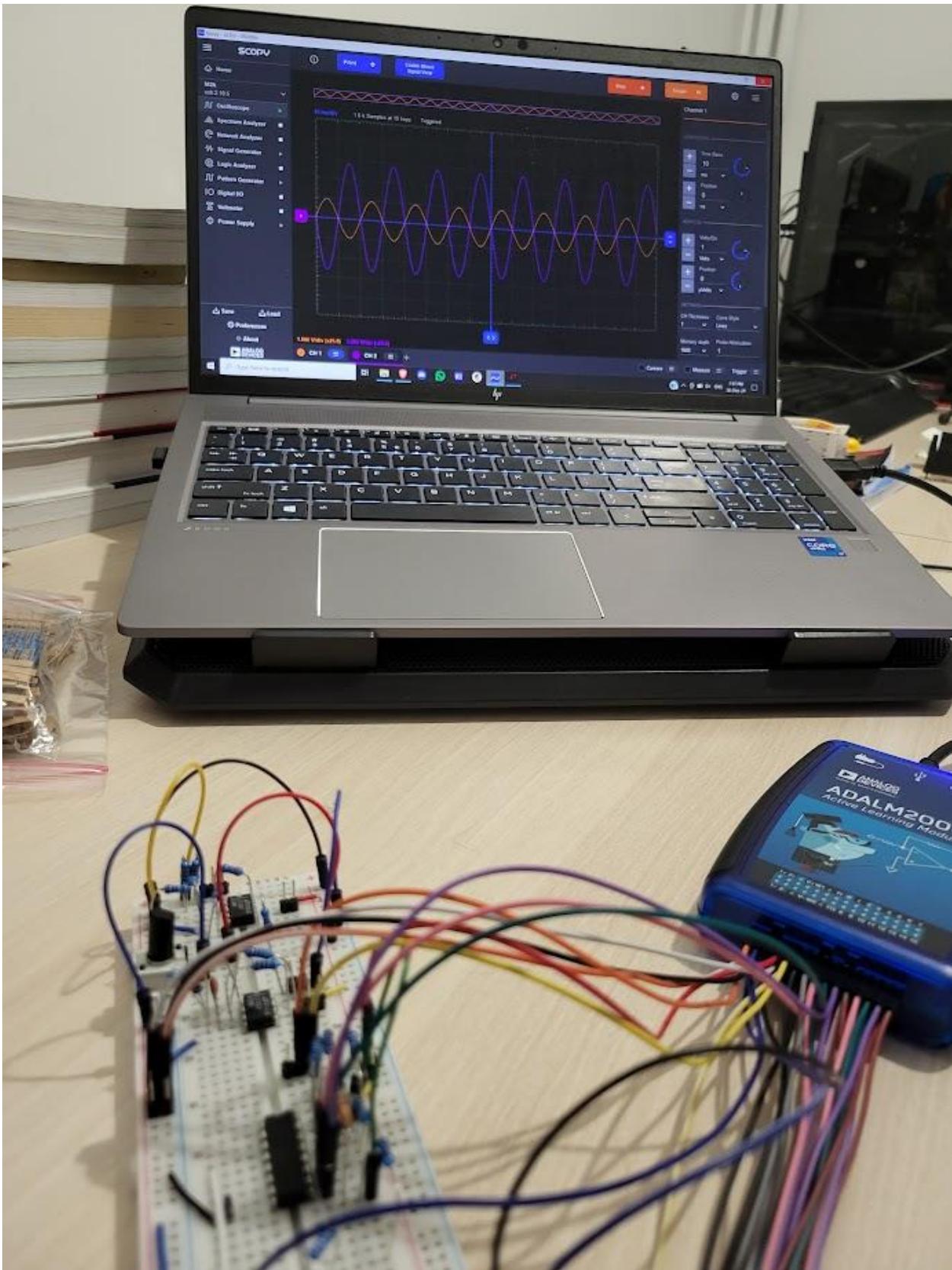
Proiectarea unei interfete analogice

Andrei Gabriel Zaulet

UNIVERSITATEA TEHNICA DIN CLUJ-NAPOCA, GRUPA 2132

Contents

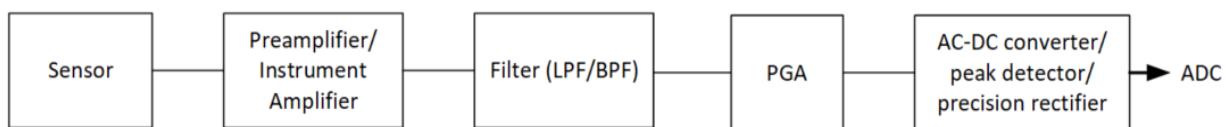
1.	Tematica proiectului	3
Specificatii generale:.....		3
Etajul 1:.....		3
Etajul 2:.....		4
Etajul 3:.....		4
Etajul 4:.....		5
2.	Dimensionarea etajelor.....	6
2.1.	Etajul 1 – Amplificator neinversor cu compensare DC	6
Dimensionarea retelei de compensare		6
Dimensionarea rezistentelor		7
2.2.	Etajul 2 – Filtru TB Sallen-Key	8
2.3.	Etajul 3 – Amplificator cu castig programabil (PGA)	9
2.4.	Etajul 4 – Redresor de precizie.....	11
3.	Caracterizarea etajelor.....	13
3.1.	Etajul 1	13
3.1.1.	Rezultate simulari	13
3.1.2.	Rezultate masuratori	18
3.2.	Etajul 2	19
3.2.1.	Rezultate simulari	19
3.2.2.	Rezultate masuratori	22
3.3.	Etaj 3.....	23
3.3.1.	Rezultate simulari	23
3.3.2.	Rezultate masuratori	29
3.4.	Etaj 4.....	34
3.4.1.	Rezultate simulari	34
3.4.2.	Rezultate masuratori	36
4.	Caracterizarea interfetei	37
5.	Concluzii	38
6.	Calcule manuale	39



1. Tematica proiectului

Acest proiect constă în proiectarea unei interfete analogice formată din urmatoarele blocuri în cascadă:

1. Amplificator neiverson cu intrare single ended și compensare DC
2. Filtru Trece-Banda de tip Sallen-Key
3. Amplificator cu castig programabil cu intrerupatoare în afara caii de semnal, invensor
4. Redresor de precizie



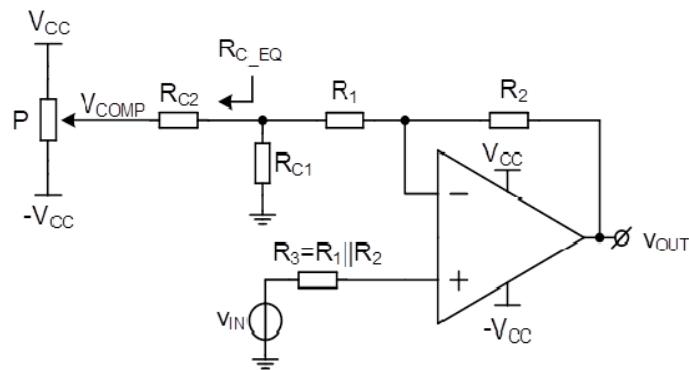
Specificatii generale:

Se cere utilizarea amplificatorului operational LT6234. Acesta este utilizat în simulații, însă, pentru circuitele reale se vor utiliza amplificatoarele LT1357 și OP482.

Tensiunea de alimentare pentru toate circuitele este furnizată de un ADALM2000 și este de $\pm 5\text{VDC}$.

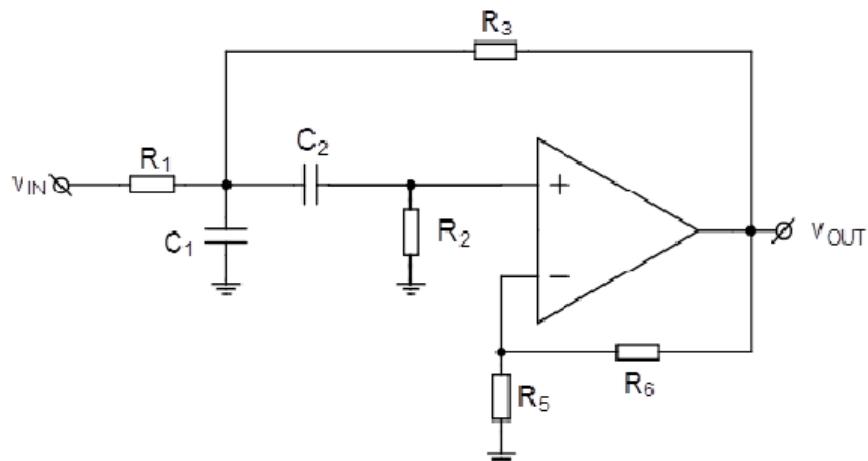
Etajul 1:

- Amplificator neiverson
- Reglaj DC al tensiunii de ieșire
- Banda > frecvența de intrare maxima
- Fără distorsiuni la frecvența de intrare maxima ($\text{THD} < 1\%$)
- Castig liniar = $10 \frac{\text{[V]}}{\text{[V]}}$
- Amplitudinea minima de intrare = 41.9 [mV]
- Amplitudinea maxima de intrare = 118 [mV]



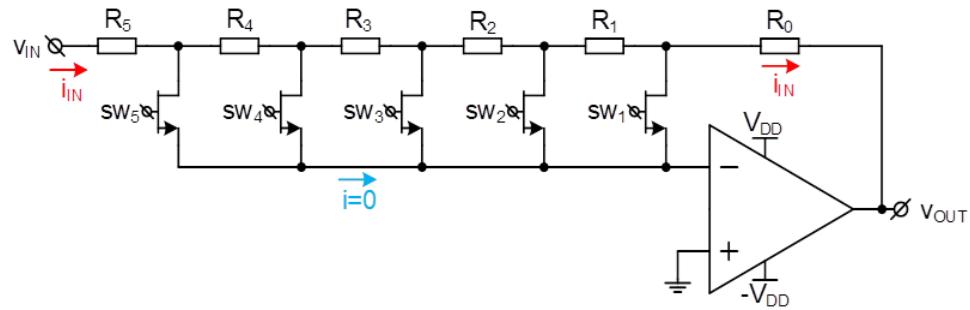
Etajul 2:

- Filtru de tip trece-banda Sallen-Key
- Rezistenta minima de intrare de $1 \text{ [k}\Omega\text{]}$
- Banda de trecere de 1 [kHz]
- Castig liniar in banda de trecere $= 1 \text{ [V/V]}$
- Factor de calitate $Q=0.707$
- Fara distorsiuni la frecventa de intrare maxima (THD<1%)



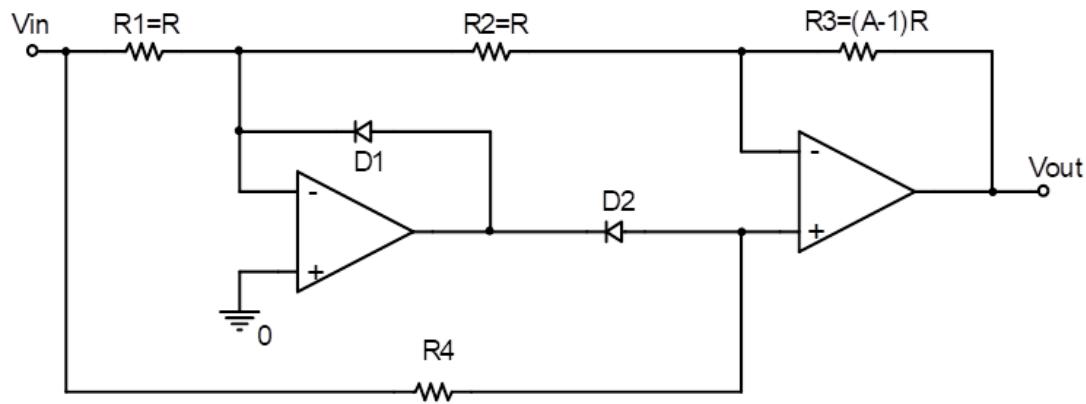
Etajul 3:

- Amplificator cu castig variabil cu intrerupatoare in afara caii de semnal – inversor
- Castig minim 3 [dB]
- Castig maxim 12 [dB]
- Numar pasi = 4
- Rezolutie pas = 3 [dB]



Etajul 4:

- Redresor de precizie
- Castig liniar = 1.5 [V]/[V]

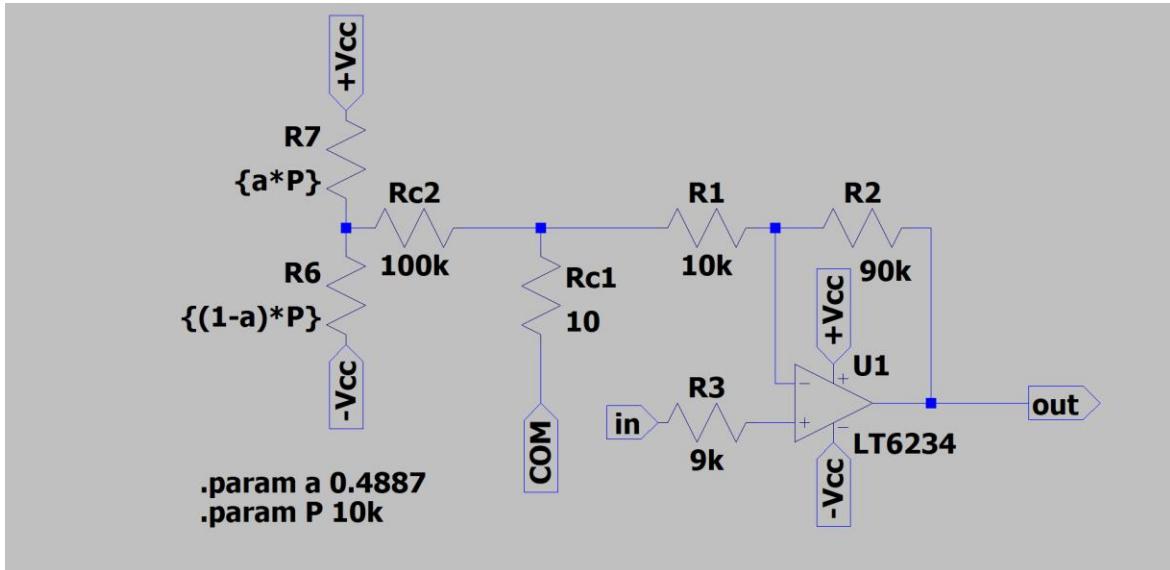


2. Dimensionarea etajelor

Calculele de mana le-am atasat la finalul acestui document.

2.1. Etajul 1 – Amplificator neinvorsor cu compensare DC

- Banda > frecventa de intrare maxima = 1,060.5 [Hz] (frecventa maxima de intrare, vezi dimensionare etaj 2)
- Castig liniar = 10 [V]/[V]
- Amplitudinea minima de intrare = 41.9 [mV]



- Amplitudinea maxima de intrare = 118 [mV]

Dimensionarea retelei de compensare

Relatia pentru castigul unui amplificator neinvorsor ideal este urmatoarea:

$$Av = 1 + \frac{R_2}{R_1} = 10 \text{ [V]/[V]}$$

Dar pentru ca aceasta sa ramana adevarata trebuie indeplinita urmatoarea conditie:

$$\begin{aligned} Req &\ll R_1, \\ \text{unde } Req &= R_{c1} \parallel (R_{c2} + (a - a^2) * P) \end{aligned}$$

Daca R_{c1} este foarte mic atunci $Req \cong R_{c1}$.

In fisă tehnica a amplificatorului tensiunea de offset la intrare apartine intervalului (-0.5, 0.5) [mV]

Potentiometrul primit are o cursa de 270° si caderea maxima de tensiune pe acesta este de $10 [V]$. Daca ar fi impartit in 10 pasi de cate $1 [V]$ fiecare atunci fiecarui pas o sa ii corespunda o cursa de 27° .

Rezolutia este suficient de buna astfel incat utilizatorul sa poata ajusta tensiunea fara prea mari dificultati. Mai exact aceasta este:

$$\frac{1[V]}{27^\circ}$$

Pentru a trece de la volti la sute de microvolti raportul de divizare necesar este 10^4 . Tensiunea culeasa de la cursorul potentiometrului este divizata cu un divizor rezistiv cu raportul mentionat anterior. Tensiunea de compensare are urmatoarea relatie:

$$V_{comp} = V_{pot} * \frac{Rc1}{Rc1 + Rc2}$$

Deci:

$$\frac{Rc1}{Rc1 + Rc2} = \frac{1}{10000} \rightarrow Rc1 \cong \frac{Rc2}{10000}$$

Rezolutia tensiuni de compensare este:

$$\frac{0.1[mV]}{27^\circ}$$

Iar domeniul de variatie al tensiunii de compensare este $(-0.5, 0.5) [mV]$.

Dimensionarea rezistentelor

Pentru minimizarea erori cauzate de curentul de polarizare $R3 = R1||R2$

$$Av = 1 + \frac{R2}{R1} = 10 \rightarrow R2 = 9 * R1$$

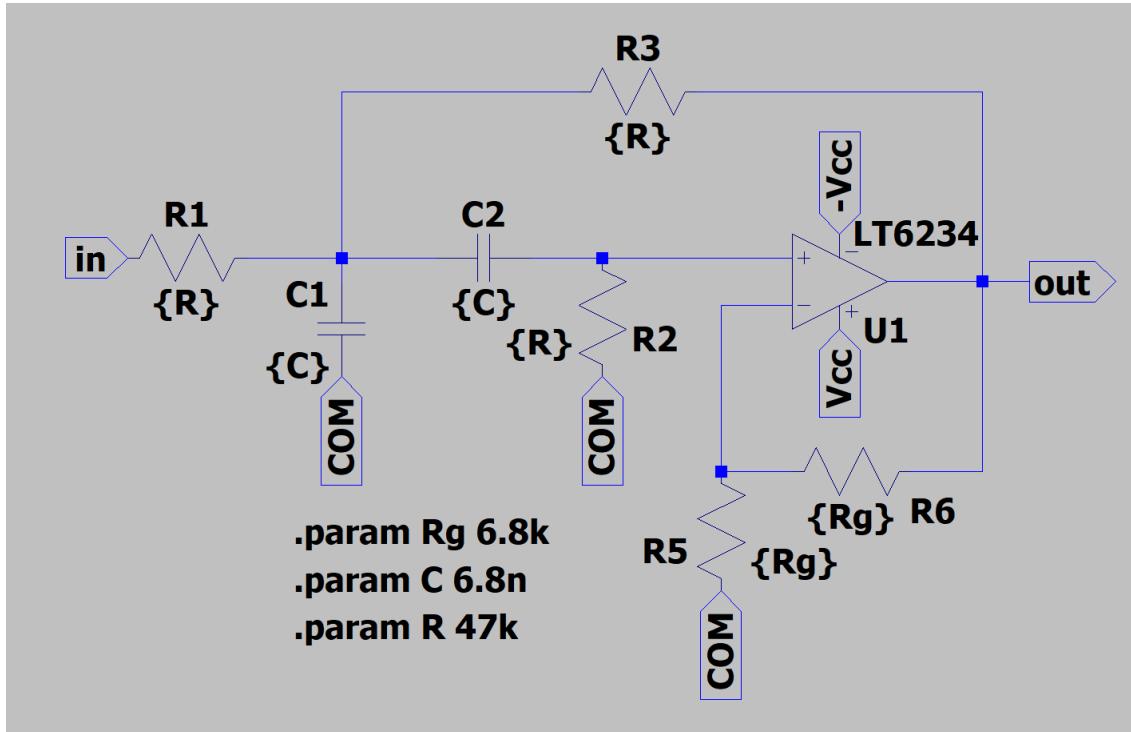
Aleg $R1 = 10[k\Omega] \rightarrow R2 = 90[k\Omega]$ si $R3 = 9[k\Omega]$

Aleg $Rc1 = 10[\Omega] \rightarrow Rc2 = 100[k\Omega]$

$P = 10[k\Omega]$ (din kit)

2.2. Etajul 2 – Filtru TB Sallen-Key

- Rezistenta minima de intrare de $1 [k\Omega]$
- Banda de trecere de $1 [\text{kHz}]$
- Castig liniar in banda de trecere = $1 [\text{V}]/[\text{V}]$
- Factor de calitate $Q=0.707$



Frecventa centrală se află cu relația următoare:

$$f_0 = BW * Q = 707 [\text{Hz}]$$

iar frecventa maxima de intrare este:

$$f_0 + \frac{f_0}{2} = 1060.5 [\text{Hz}]$$

Castigul de joasa frecventa este:

$$H_0 = 1 + \frac{R_6}{R_5} = 2$$

Dimensionarea acestui etaj a fost facuta cu ajutorul calculatorului primit pe MSTEams.

$$R1 = R2 = R3 = 47 [\text{k}\Omega]$$

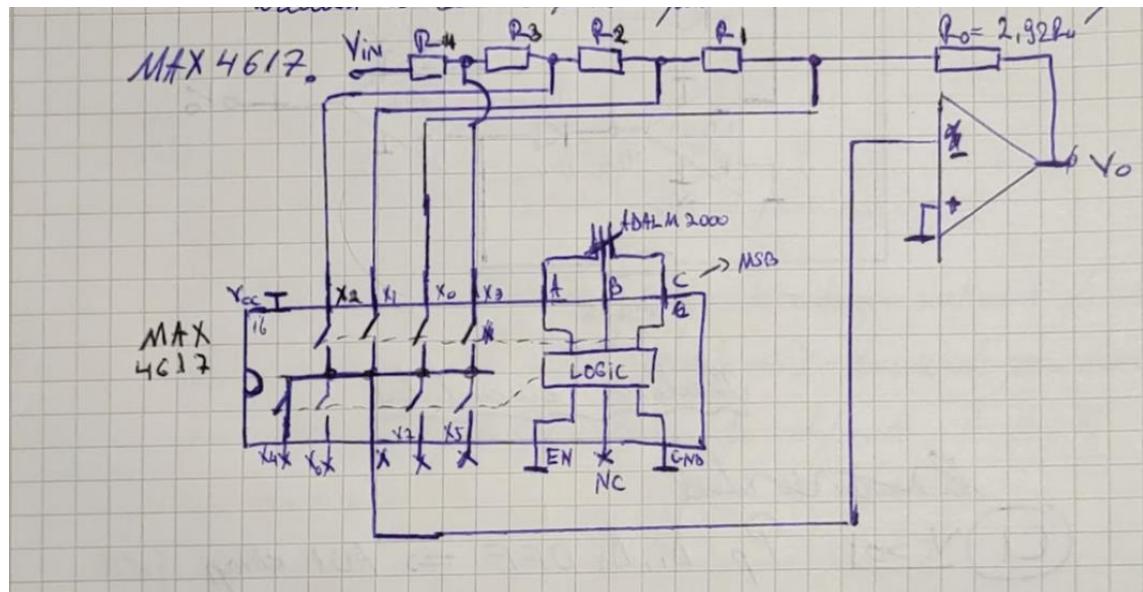
$$R6 = R5 = 6.8 [\text{k}\Omega]$$

$$C1 = C2 = 6.8 [\text{nF}]$$

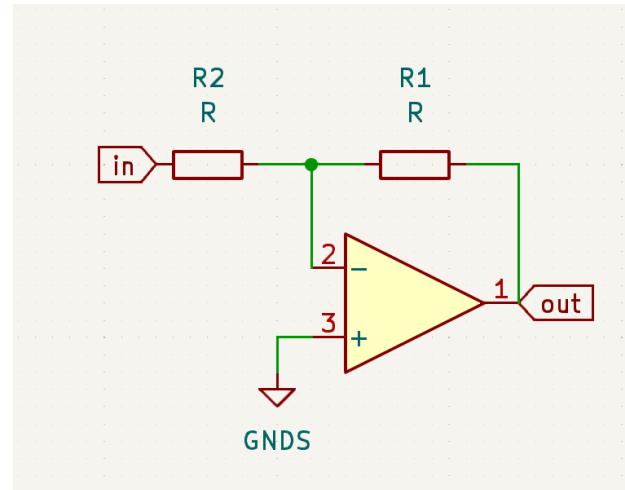
2.3. Etajul 3 – Amplificator cu castig programabil (PGA)

- Castig minim 3 [dB]
- Castig maxim 12 [dB]
- Rezolutie pas = 3 [dB]
- Numar pasi = 4

Pentru implementarea intrerupatoarelor a fost folosit multiplexorul integrat MAX4617.



$$H_0 \text{ [dB]} = [3, 6, 9, 12] \text{ [dB]} \rightarrow |H_0| = [1.41, 1.99, 2.81, 3.98] \frac{[V]}{[V]}$$



Pentru un amplificator inversor, ca in figura de mai sus, relatia castigului la joasa frecventa este :

$$H_0 = -\frac{R_1}{R_2}$$

Daca scriem relatia castigului pentru fiecare intrerupator si egalam cu valoarea amplificarii obtinem sistemul de mai jos:

$$S4 \text{ ON} \rightarrow R_0 + R_1 + R_2 + R_3 = 3.98 * R_4$$

$$S3 \text{ ON} \rightarrow R_0 + R_1 + R_2 = 2.81 * (R_3 + R_4)$$

$$S2 \text{ ON} \rightarrow R_0 + R_1 = 1.99 * (R_2 + R_3 + R_4)$$

$$S1 \text{ ON} \rightarrow R_0 = 1.41 * (R_1 + R_2 + R_3 + R_4)$$

Scazand pe rand din prima ecuatie obtinem valorile rezistentelor in functie de R4.

$$R_3 = 0.29 * R_4$$

$$R_2 = 0.37 * R_4$$

$$R_1 = 0.41 * R_4$$

Iar pe R0 il obtinem inlocuind in ultima ecuatie rezultatele precedente.

$$R_0 = 2.92 * R_4$$

Am ales R4 = 1 [kΩ]

$$R_3 = 290[\Omega]$$

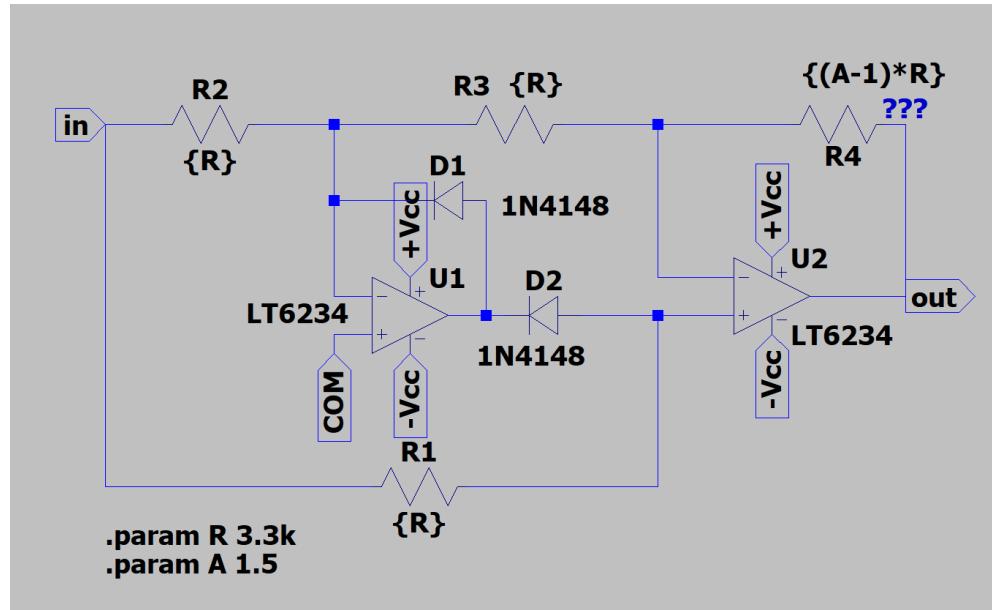
$$R_2 = 370[\Omega]$$

$$R_1 = 410[\Omega]$$

$$R_0 = 2.92[k\Omega]$$

2.4. Etajul 4 – Redresor de precizie

- Castig liniar = $1.5 \frac{[V]}{[V]}$



Calculul pentru acest circuit este destul de lung si poate fi gasit la sfarsitul acestui document la pagina 43. O sa trec numai peste ce este important aici.

$$\text{Pentru } Av = 1.5 \frac{[V]}{[V]} \rightarrow R4 = 0.5 * R$$

Pe alternata pozitiva dioda D2 este deschisa, iar D1 inchisa, si caderea de tensiune pe R1 este $2 * Vin$.

Pe alternanta negativa dioda D1 este deschisa, iar D2 inchisa.

Pentru a echilibra curentii prin diode pe ambele alternate ale semnalului de intrare se alege:

$$R1 = R2 = R3 = R$$

Domeniul de intrare pentru care circuitul functioneaza adevarat este:

$$Vin = (-3.33, 3.33)[V]$$

Daca aleg un curent maxim prin dioda = 2 mA atunci:

$$\begin{cases} \frac{2 * Vin}{R1} = 2 \text{ mA}, & Vin > 0 \\ \frac{|Vin|}{R2||R3} = 2 \text{ mA}, & Vin < 0 \end{cases}$$

$$R1 = 2 * R2||R3 = R$$

Inlocuim V_{in} cu valoarea sa maxima in modul si obtinem:

$$R = 3.3[k\Omega] = R_1 = R_2 = R_3 = 2 * R_4$$

3. Caracterizarea etajelor

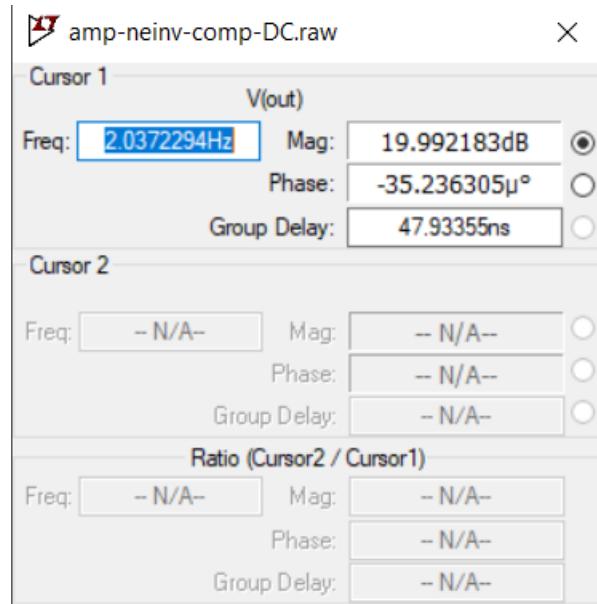
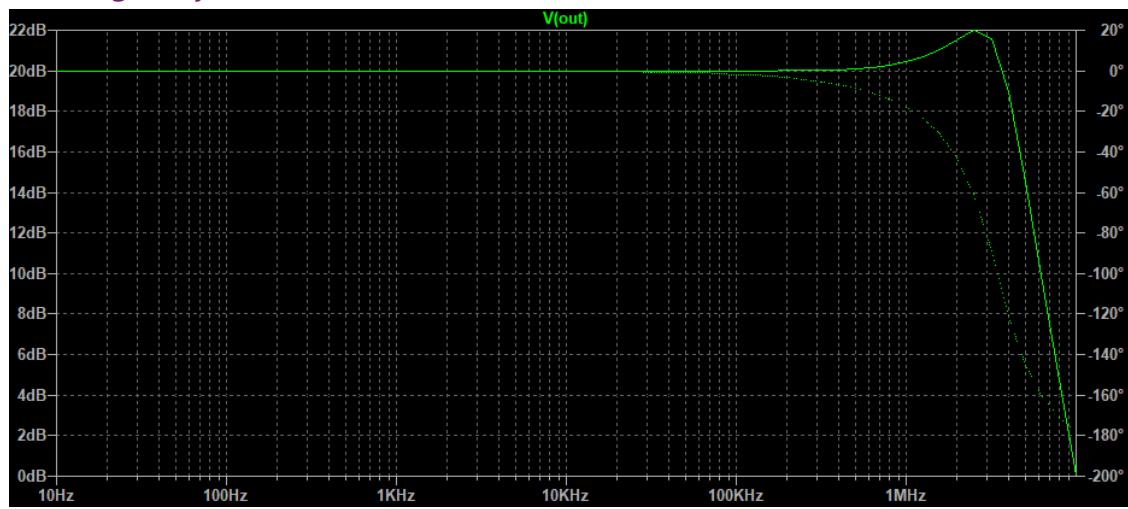
3.1. Etajul 1

3.1.1. Rezultate simulari

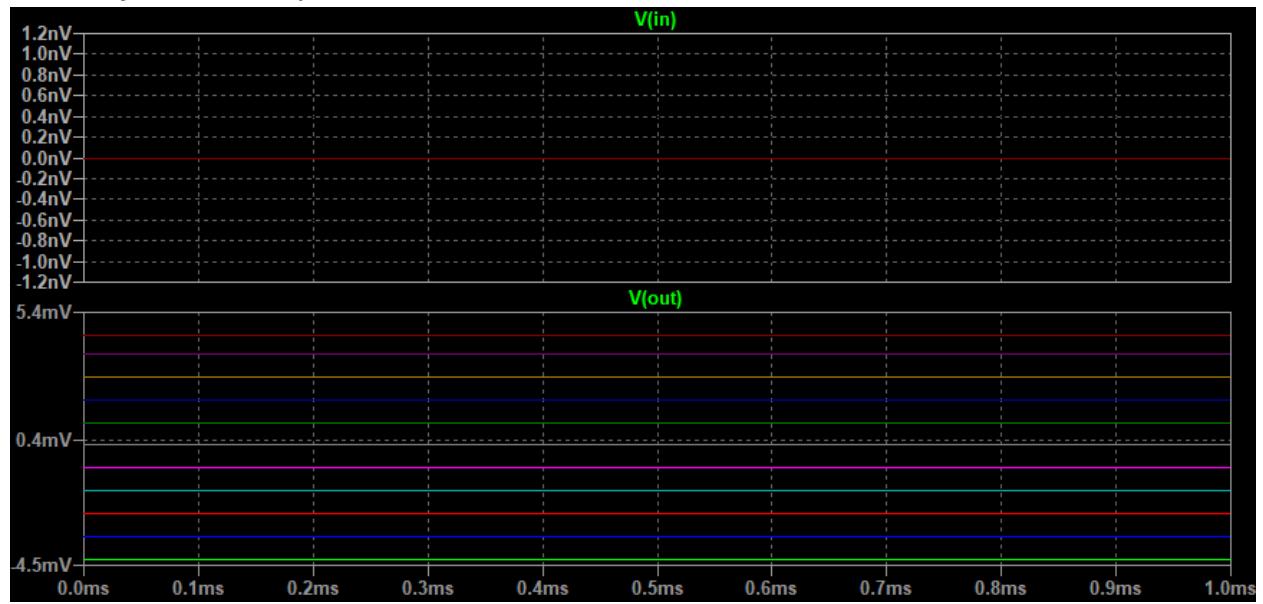
DC-OP

--- Operating Point ---		
V(out) :	2.24939e-05	voltage
V(-vcc) :	-5	voltage
V(+vcc) :	5	voltage
V(n003) :	-0.0134948	voltage
V(n002) :	-0.0134955	voltage
V(in) :	0	voltage
V(comp) :	-3.73519e-06	voltage
V(n001) :	0.0975618	voltage
I(R3) :	-1.49943e-06	device_current
I(R2) :	1.502e-07	device_current
I(R1) :	-1.34917e-06	device_current
I(Rc1) :	-3.73519e-07	device_current
I(Rc2) :	-9.75656e-07	device_current
I(R6) :	-0.000999522	device_current
I(R7) :	-0.0010005	device_current
I(V1) :	-0.00204092	device_current
I(V2) :	0.00204279	device_current
I(V3) :	-1.49943e-06	device_current
Ix(u1:1) :	1.49943e-06	subckt_current
Ix(u1:2) :	1.49937e-06	subckt_current
Ix(u1:3) :	-1.502e-07	subckt_current
Ix(u1:4) :	0.00104042	subckt_current
Ix(u1:5) :	-0.00104327	subckt_current

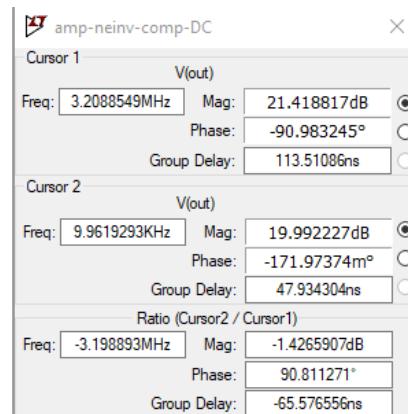
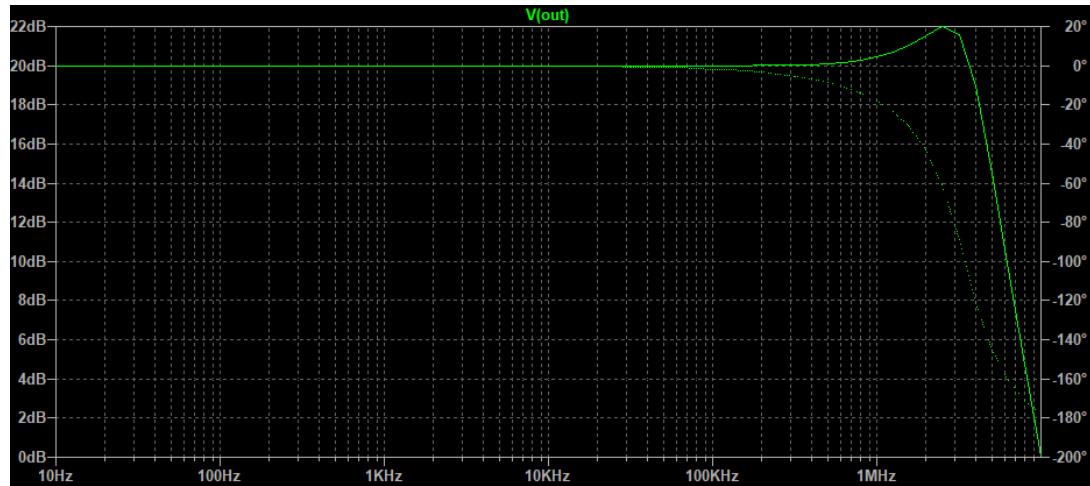
Castigul de joasa frecventa



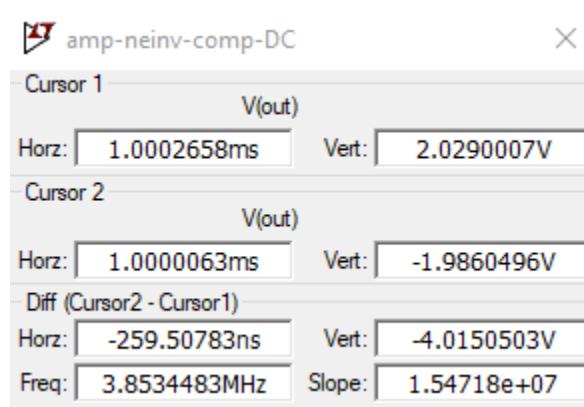
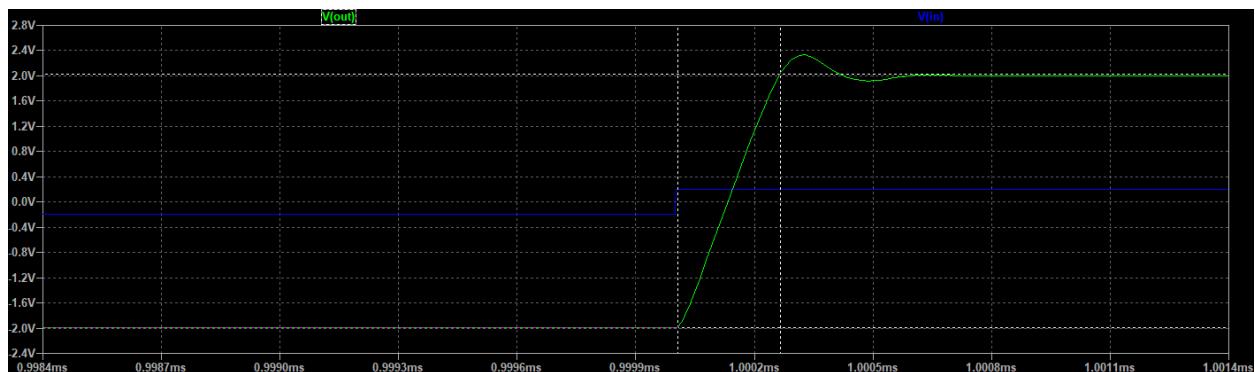
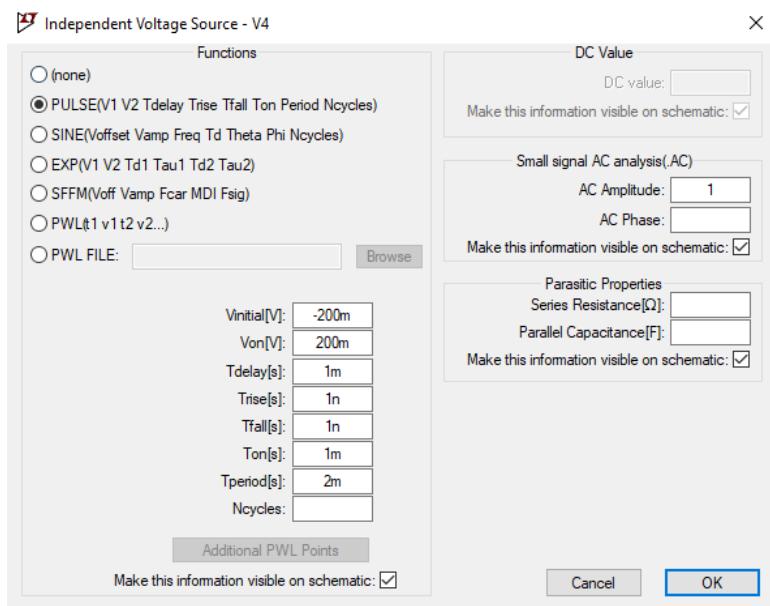
Ajustarea componentei DC



Banda amplificatorului

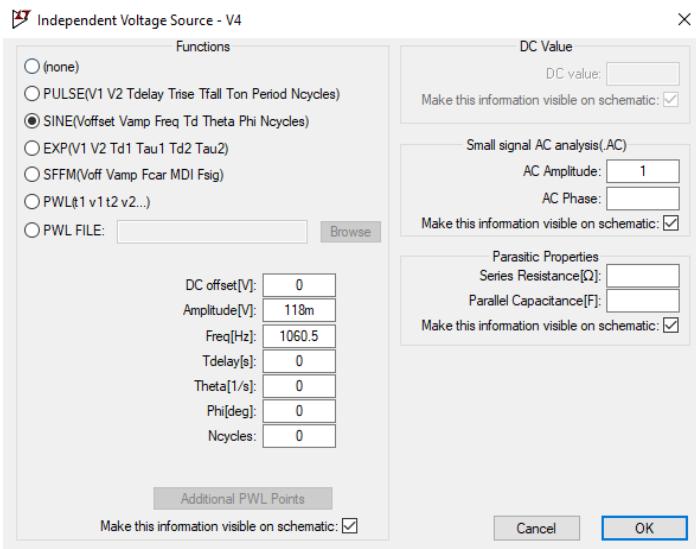
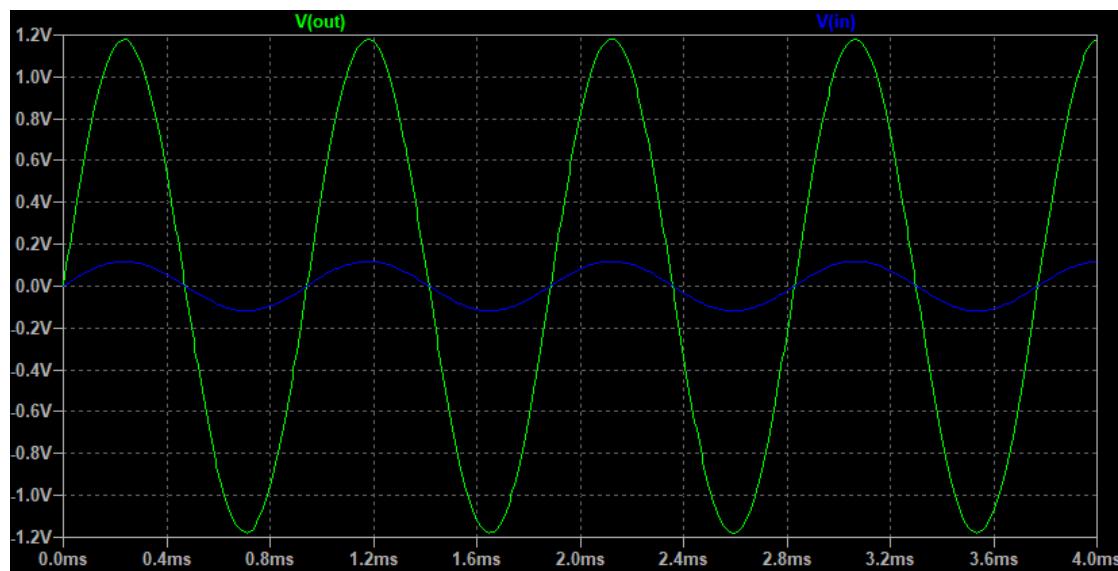


Limitare SR



Slew Rate-ul este de aproximativ $16[V]/\mu s$

Liniaritate



N-Period=1

Fourier components of V(out)

DC component: 9.1904e-06

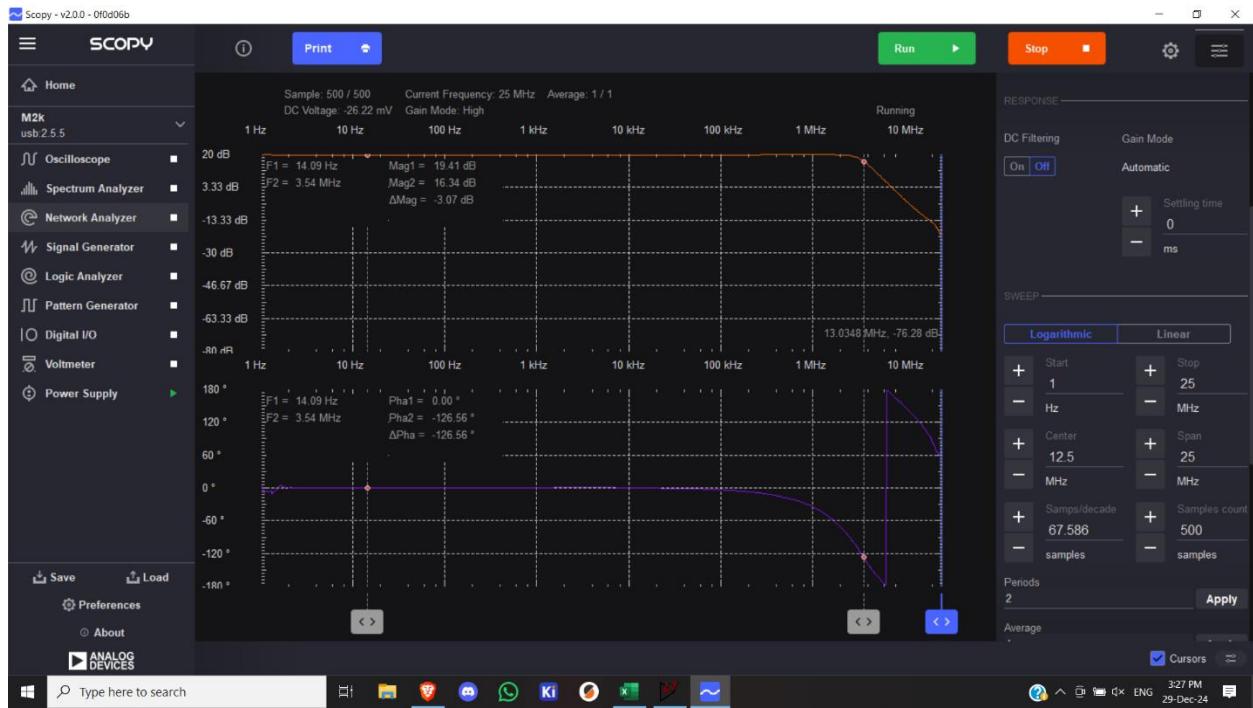
Harmonic Number	Frequency [Hz]	Fourier Component	Normalized Component
1	1.060e+3	1.179e+0	1.000e+0
2	2.121e+3	2.908e-4	2.467e-4
3	3.182e+3	5.610e-4	4.759e-4
4	4.242e+3	4.930e-4	4.182e-4
5	5.302e+3	4.634e-4	3.931e-4
6	6.363e+3	3.540e-4	3.003e-4
7	7.424e+3	3.002e-4	2.546e-4
8	8.484e+3	4.304e-4	3.651e-4
9	9.544e+3	1.234e-5	1.047e-5

Partial Harmonic Distortion: 0.095139%

Total Harmonic Distortion: 0.125731%

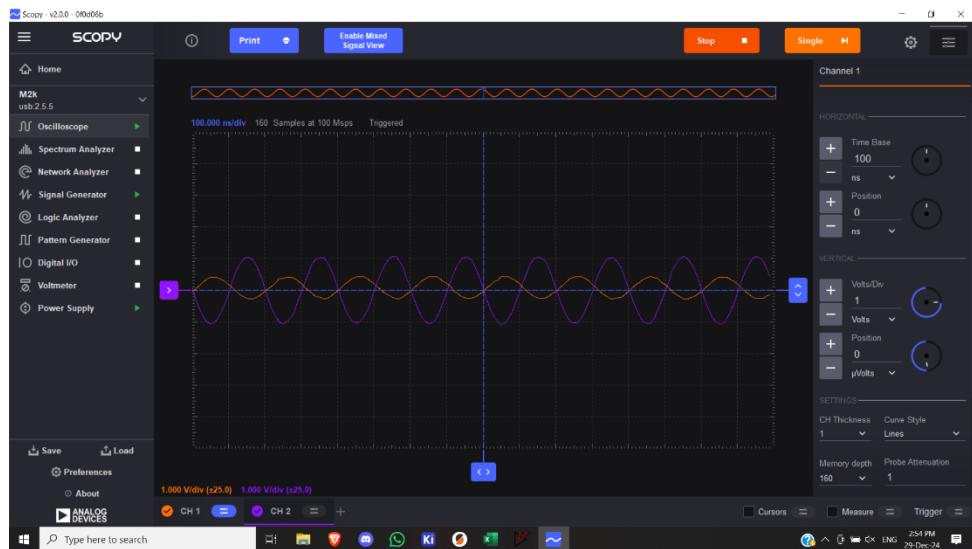
3.1.2. Rezultate masuratori

BW



Banda este de 3.54 [MHz], AO-ul folosit este LT1357.

SR



Acest AO are SR foarte mare, banda a fost limitata inainte de SR.

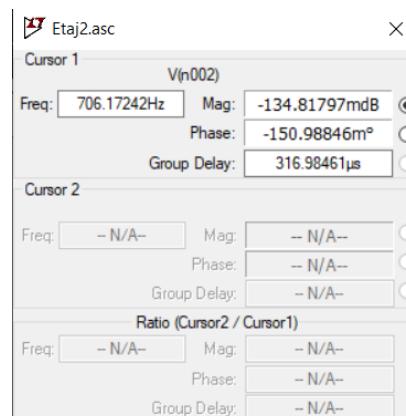
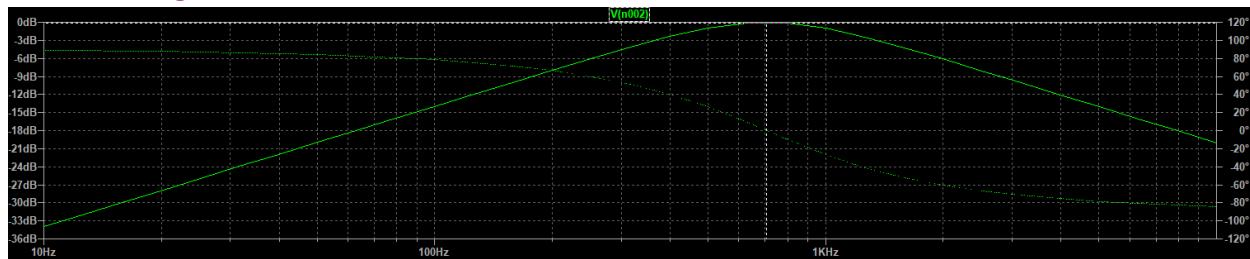
3.2. Etajul 2

3.2.1. Rezultate simulari

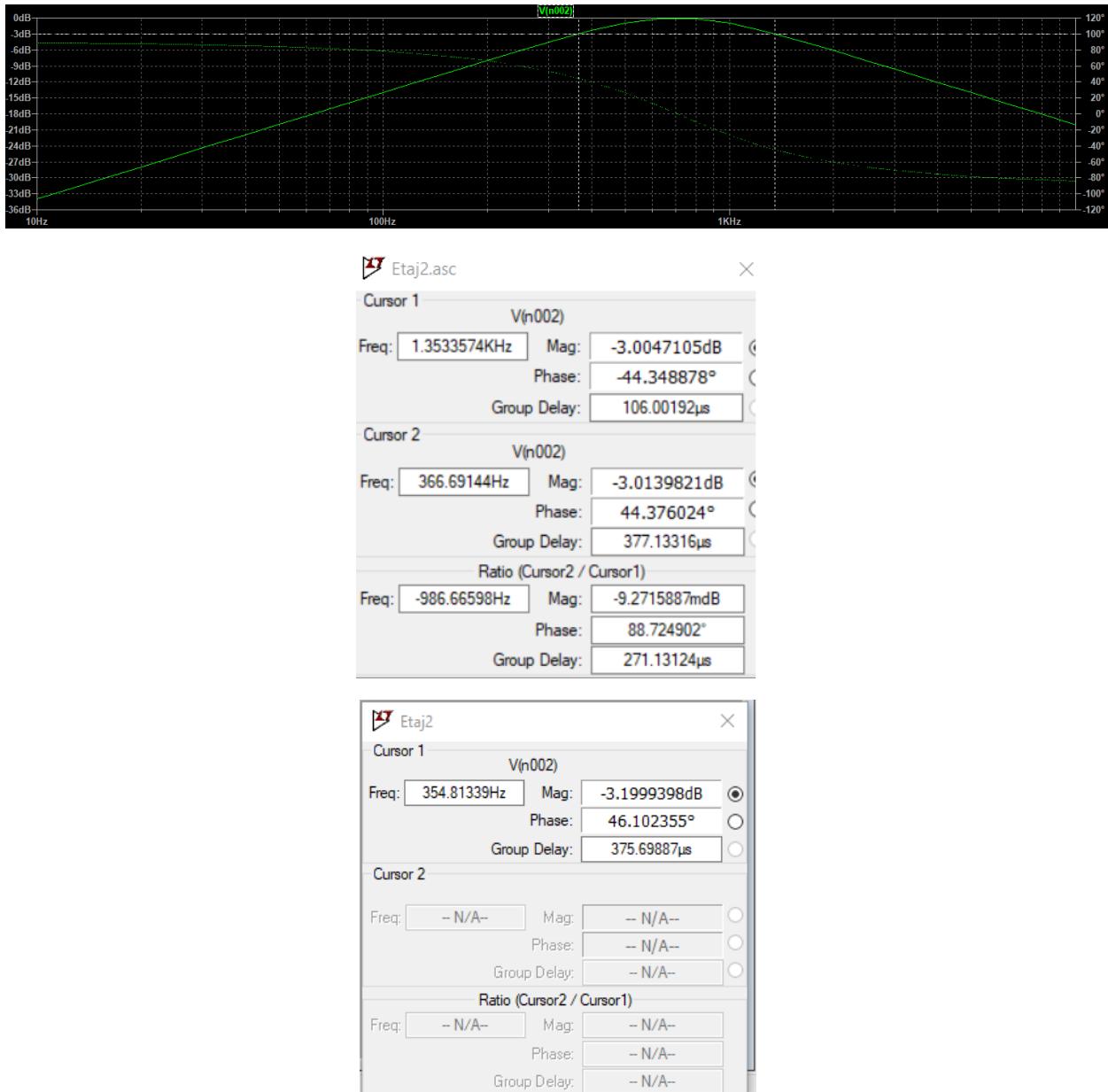
DC-OP

--- Operating Point ---		
V(n002) :	-0.0703394	voltage
V(in) :	0	voltage
V(n001) :	-0.0652517	voltage
V(out) :	-0.130503	voltage
V(-vcc) :	-5	voltage
V(vcc) :	5	voltage
V(n003) :	-0.0703399	voltage
I(C1) :	4.43712e-22	device_current
I(C2) :	3.45959e-23	device_current
I(R3) :	1.49658e-06	device_current
I(R4) :	1.38833e-06	device_current
I(R1) :	-1.03441e-05	device_current
I(R2) :	-8.84757e-06	device_current
I(R5) :	-1.38833e-06	device_current
I(V1) :	-0.00103523	device_current
I(V2) :	0.00104846	device_current
I(V3) :	-1.38833e-06	device_current
Ix(u1:1) :	1.49658e-06	subckt_current
Ix(u1:2) :	1.49653e-06	subckt_current
Ix(u1:3) :	1.02359e-05	subckt_current
Ix(u1:4) :	0.00103523	subckt_current
Ix(u1:5) :	-0.00104846	subckt_current

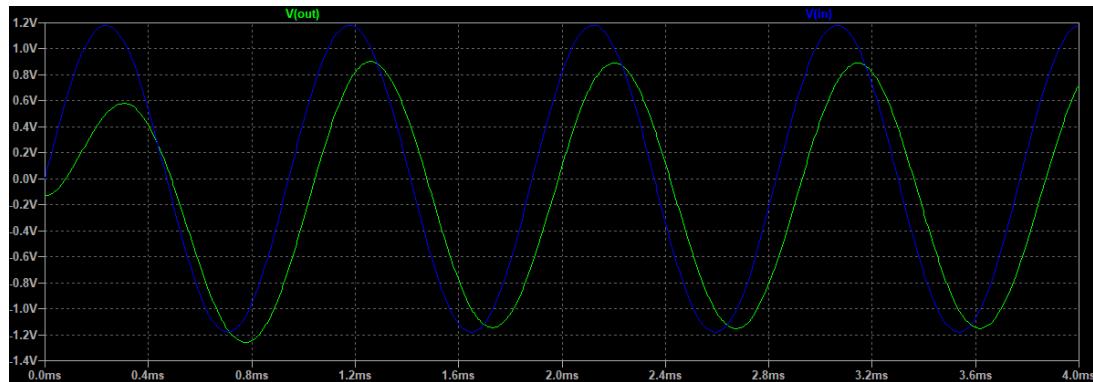
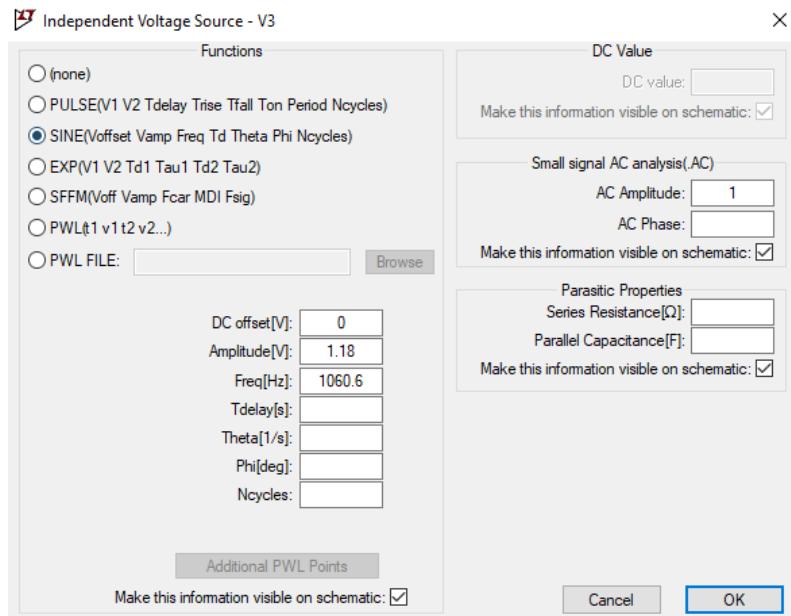
Castig in banda de trecere



Banda



Liniaritate



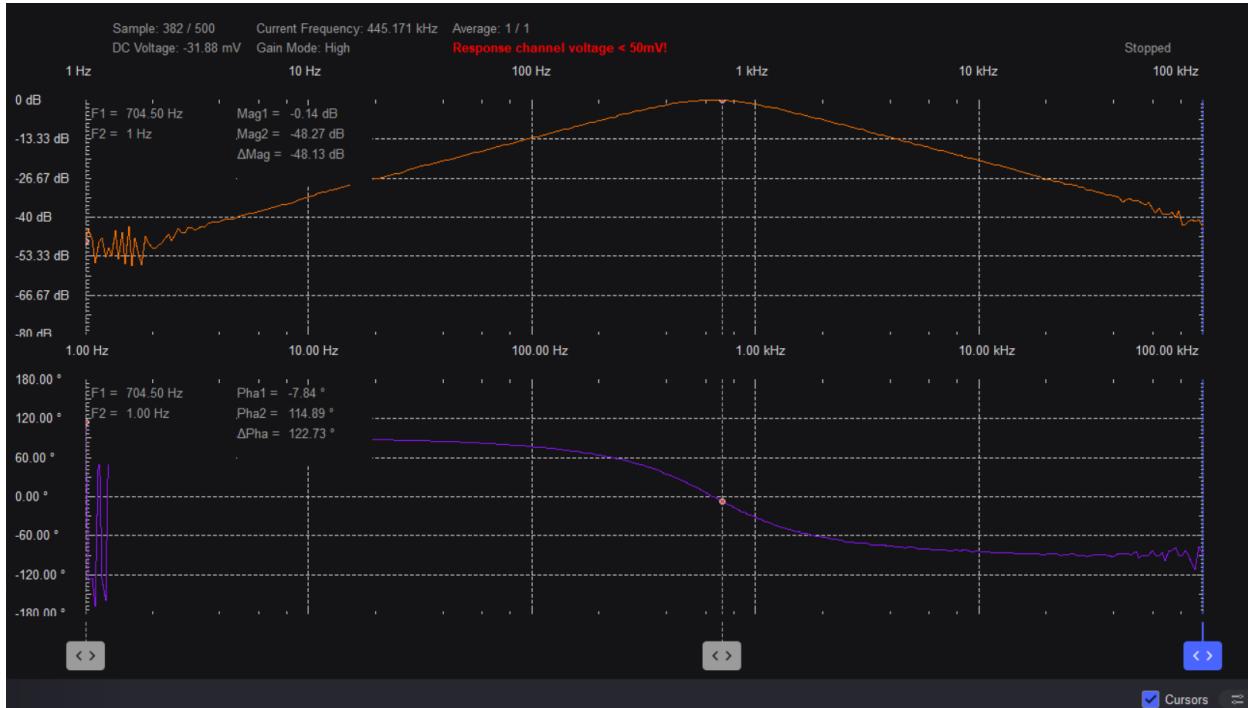
I-Period=1
Fourier components of V(out)
DC component:-0.13101

harmonic Number	Frequency [Hz]	Fourier Component	Normalized Component	Phase [degree]	Normalized Phase [deg]
1	1.060e+3	1.021e+0	1.000e+0	120.69°	0.00°
2	2.121e+3	7.892e-5	7.729e-5	46.40°	-74.29°
3	3.182e+3	9.064e-5	8.877e-5	174.73°	54.05°
4	4.242e+3	2.864e-5	2.805e-5	-58.92°	-179.61°
5	5.302e+3	5.733e-5	5.615e-5	12.49°	-108.20°
6	6.363e+3	6.833e-5	6.692e-5	162.14°	41.45°
7	7.424e+3	1.729e-5	1.693e-5	-149.93°	-270.62°
8	8.484e+3	7.873e-5	7.711e-5	-0.72°	-121.41°
9	9.544e+3	5.808e-5	5.688e-5	173.71°	53.02°

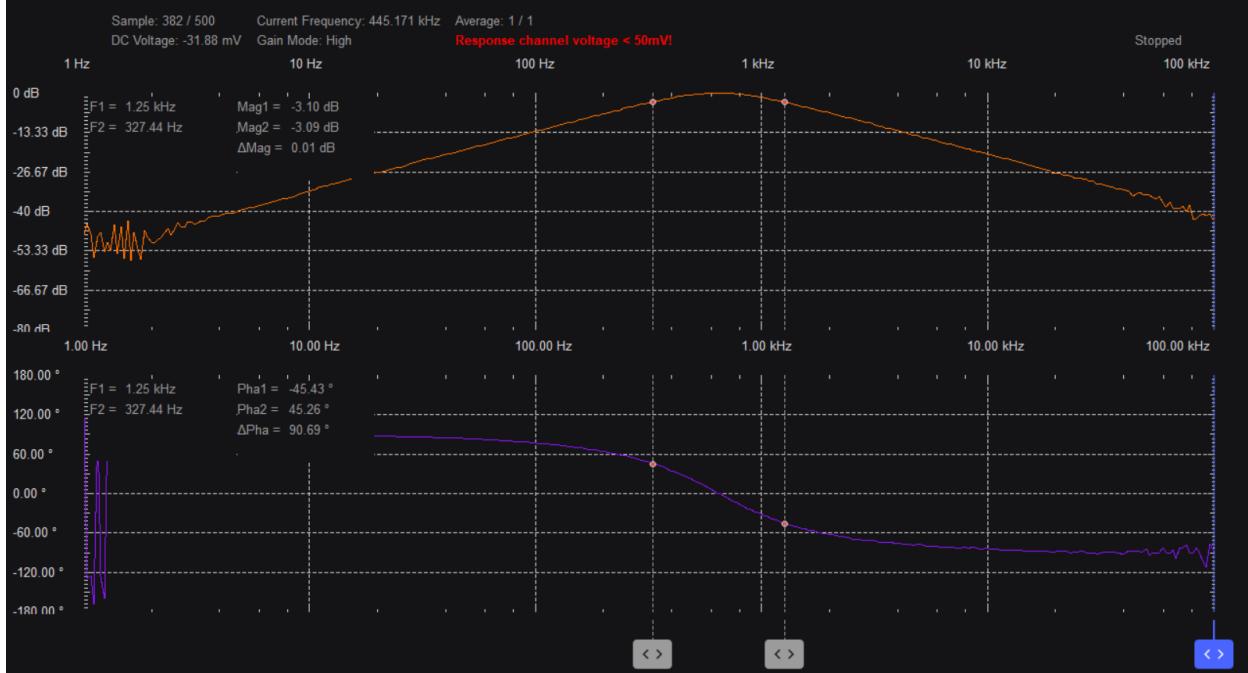
Partial Harmonic Distortion: 0.017816%
Total Harmonic Distortion: 0.023477%

3.2.2. Rezultate masuratori

Castig in banda de trecere



Banda



3.3. Etaj 3

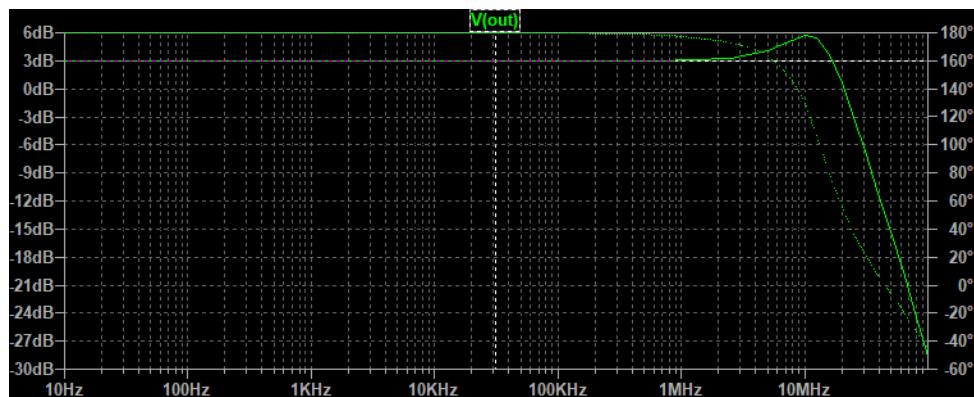
3.3.1. Rezultate simulari

DC-OP

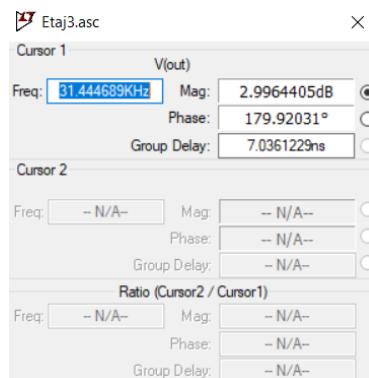
```
|| --- Operating Point ---  
V(n001) : 5.47661e-06 voltage  
V(p001) : 5.47656e-06 voltage  
V(n002) : 7.0666e-06 voltage  
V(p002) : 7.06654e-06 voltage  
V(n003) : 9.09807e-06 voltage  
V(p003) : 9.09799e-06 voltage  
V(n005) : -6.47199e-07 voltage  
V(s1) : 0 voltage  
V(s2) : 0 voltage  
V(s3) : 0 voltage  
V(p004) : -6.47049e-07 voltage  
V(s4) : 1 voltage  
V(out) : 0.00440749 voltage  
V(-vcc) : -5 voltage  
V(+vcc) : 5 voltage  
V(in) : 0 voltage  
V(n004) : 1.13531e-05 voltage
```

Treptele de castig si banda PGA

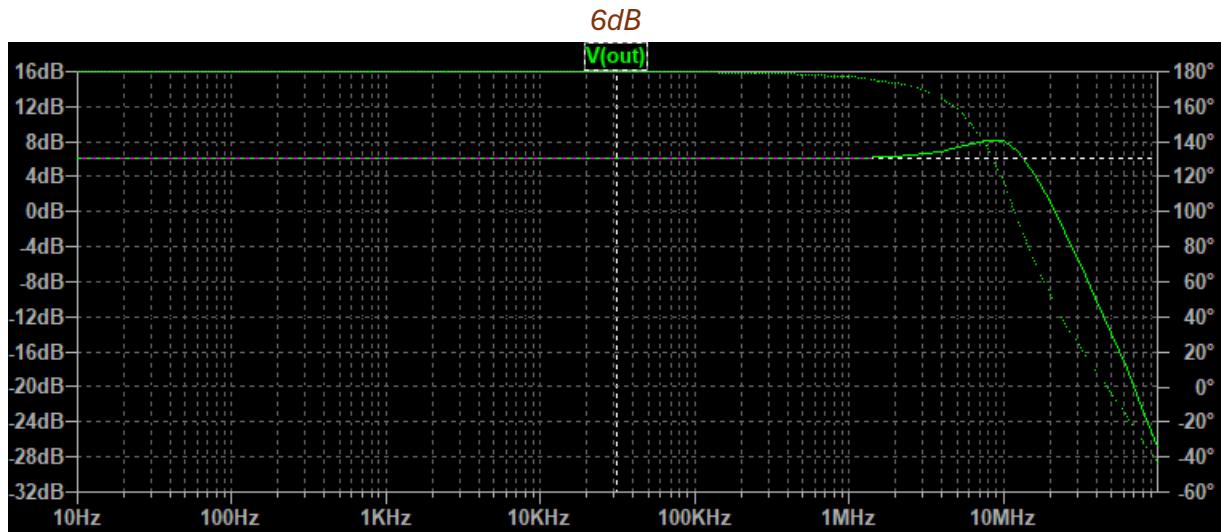
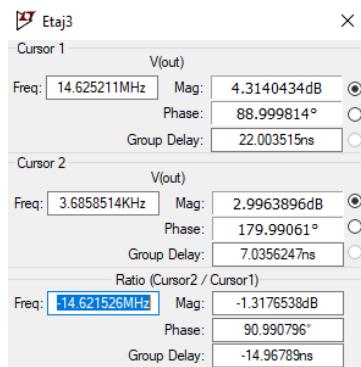
3dB



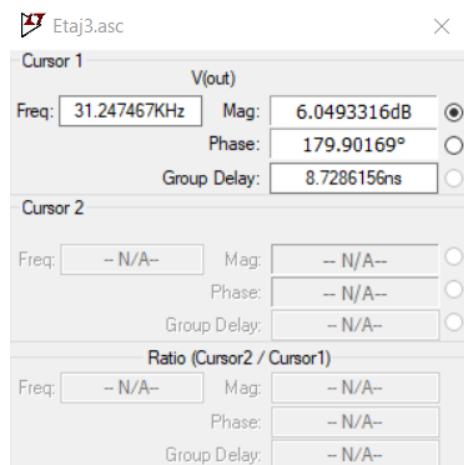
Castig



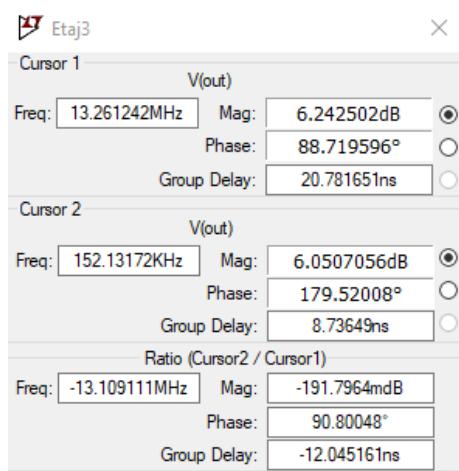
Banda



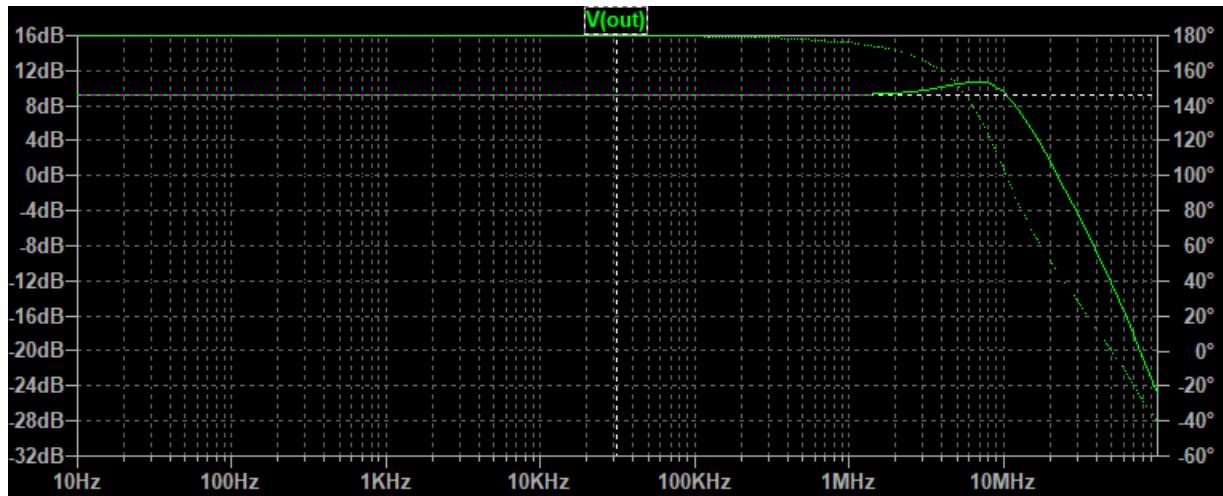
Castig



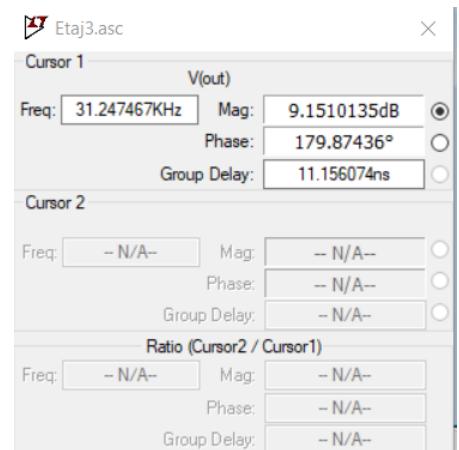
Banda



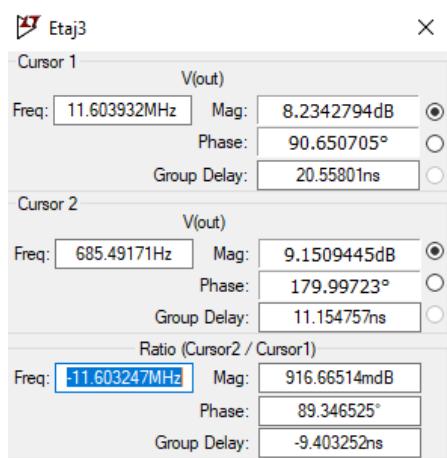
9dB



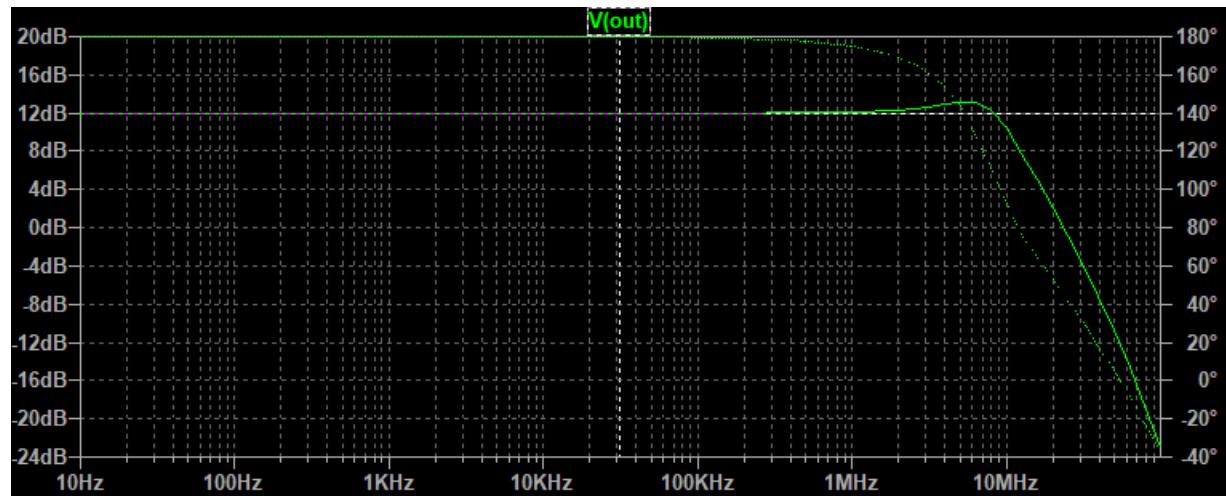
Castig



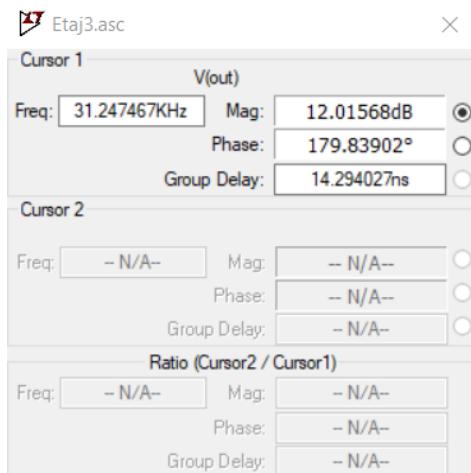
Banda



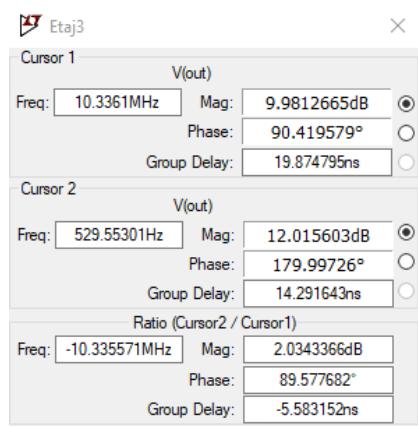
12dB



Castig

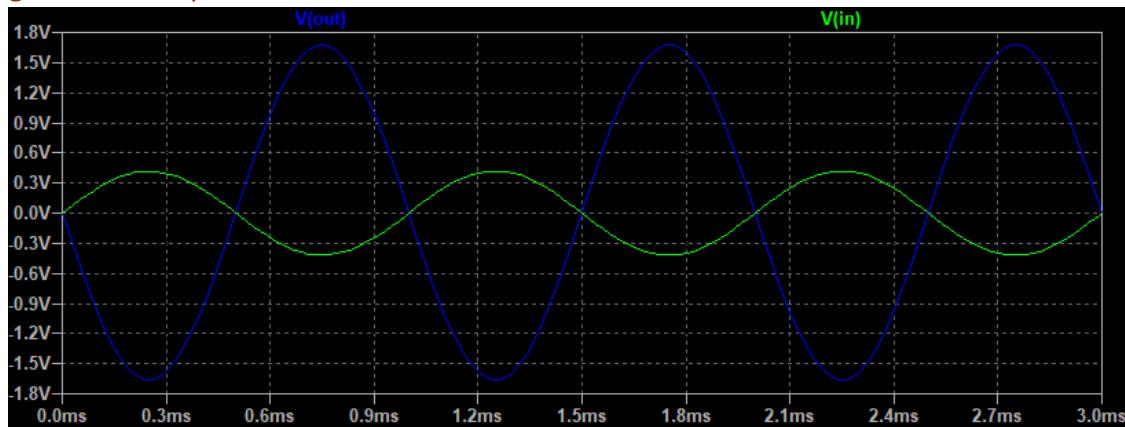


Banda



Liniaritate

Castig maxim si amplitudine minima de intrare



N-Period=1

Fourier components of V(out)

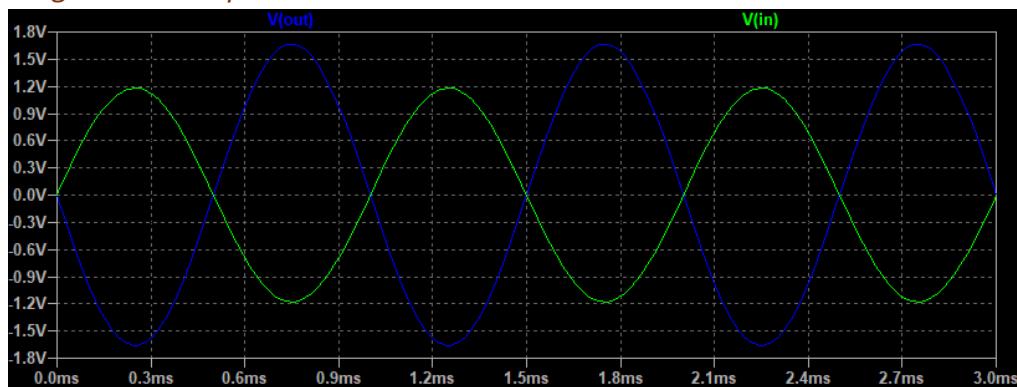
DC component: 0.00441897

Harmonic Number	Frequency [Hz]	Fourier Component	Normalized Component
1	1.060e+3	1.666e+0	1.000e+0
2	2.121e+3	5.344e-5	3.208e-5
3	3.182e+3	5.204e-4	3.124e-4
4	4.242e+3	1.291e-4	7.751e-5
5	5.302e+3	5.202e-5	3.123e-5
6	6.363e+3	6.493e-4	3.897e-4
7	7.424e+3	2.520e-4	1.513e-4
8	8.484e+3	4.804e-4	2.884e-4
9	9.544e+3	3.264e-4	1.959e-4

Partial Harmonic Distortion: 0.063396%

Total Harmonic Distortion: 0.091355%

Castig minim si amplitudine maxima de intrare



N_Period=1

Fourier components of V(out)

DC component: 0.00441897

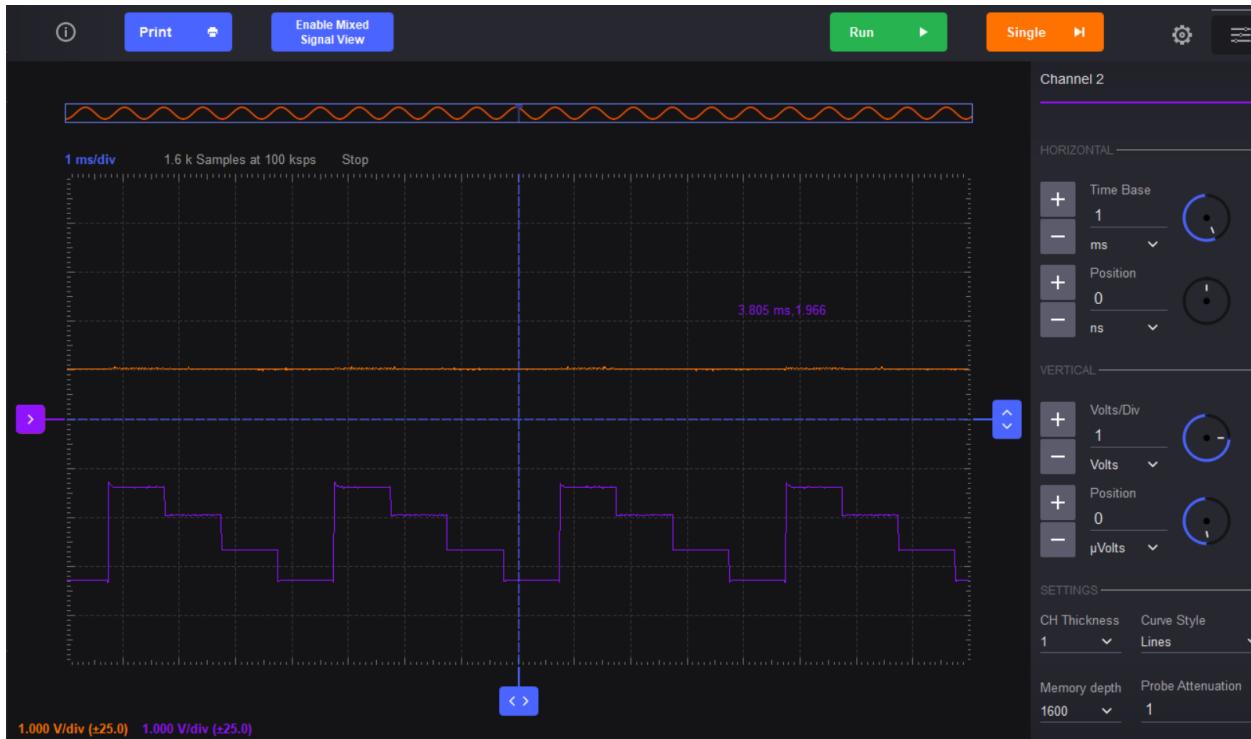
Harmonic Number	Frequency [Hz]	Fourier Component	Normalized Component
1	1.060e+3	1.666e+0	1.000e+0
2	2.121e+3	5.344e-5	3.208e-5
3	3.182e+3	5.204e-4	3.124e-4
4	4.242e+3	1.291e-4	7.751e-5
5	5.302e+3	5.202e-5	3.123e-5
6	6.363e+3	6.493e-4	3.897e-4
7	7.424e+3	2.520e-4	1.513e-4
8	8.484e+3	4.804e-4	2.884e-4
9	9.544e+3	3.264e-4	1.959e-4

Partial Harmonic Distortion: 0.063396%

Total Harmonic Distortion: 0.091355%

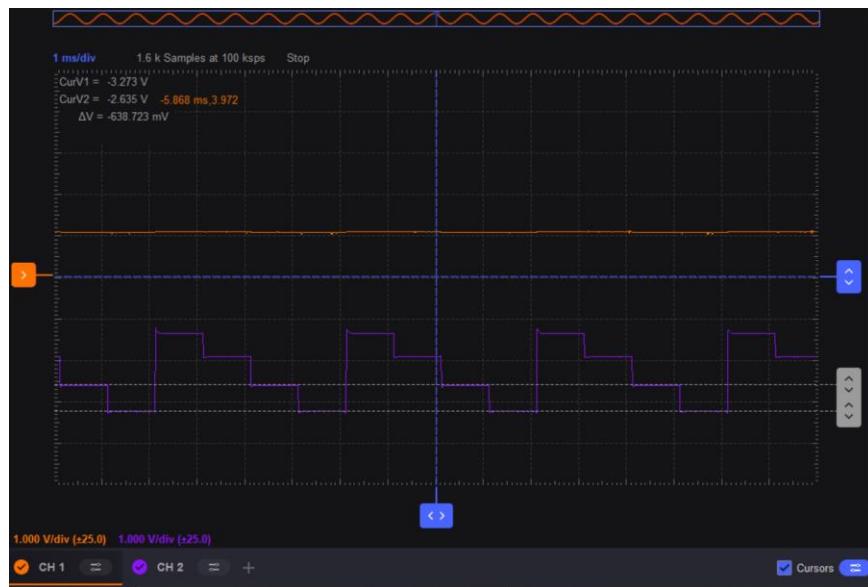
3.3.2. Rezultate masuratori

Trepte castig



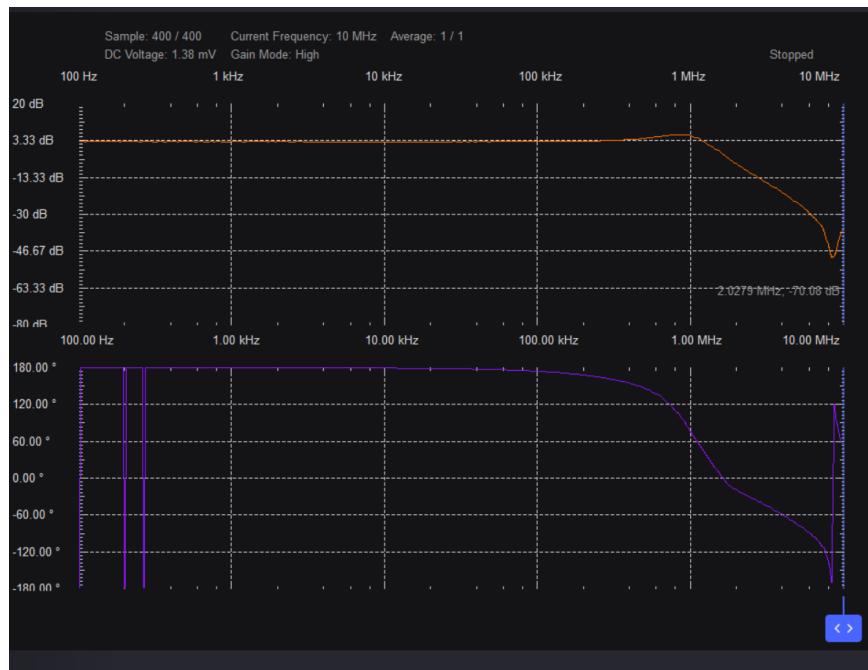
Pe intrarea circuitului a fost pusa o tensiune de 1VDC si apoi au fost selectate switch-urile cu un numarator binar. Fiecare treapta are valoarea castigului sau in volti \rightarrow 1.41, 1.99, 2.81, 3.98



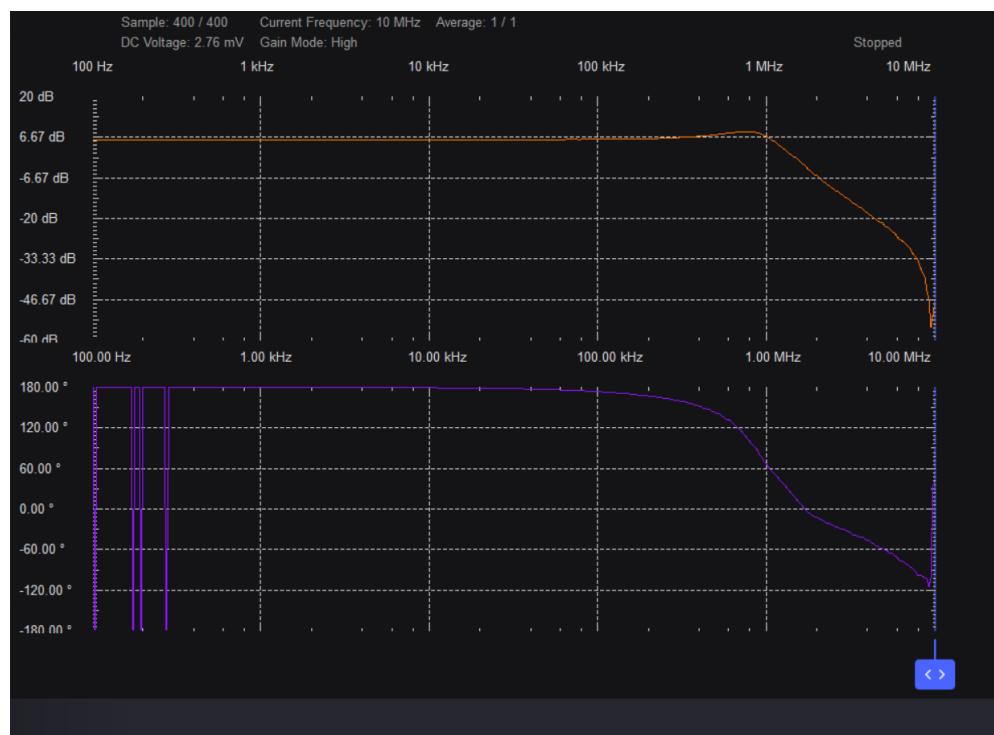


Banda

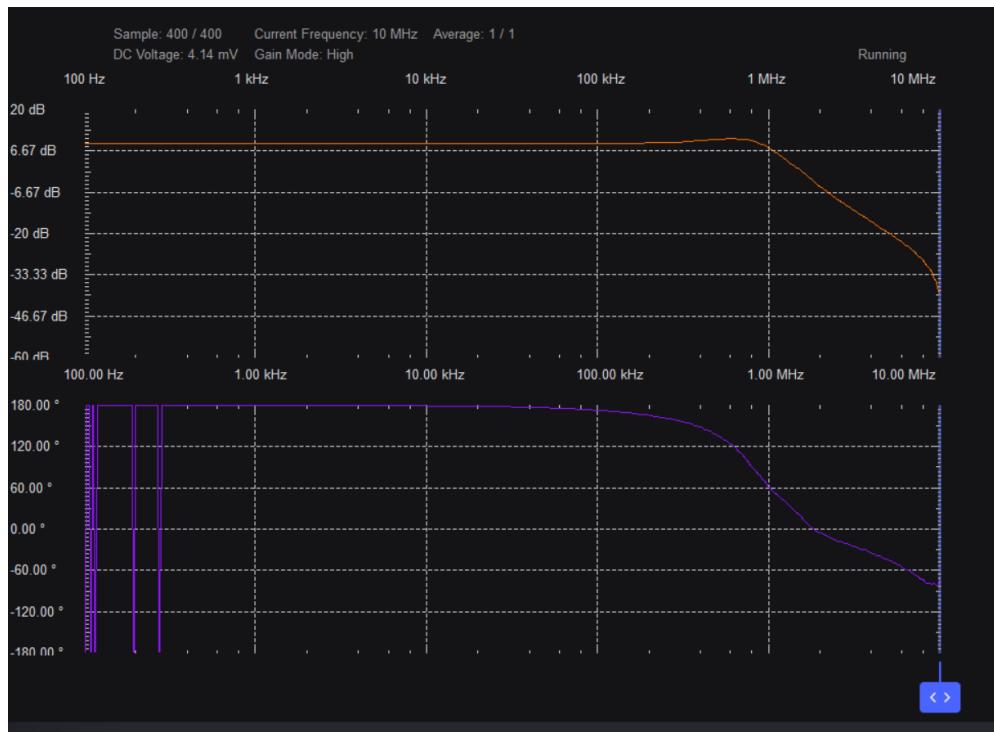
3dB



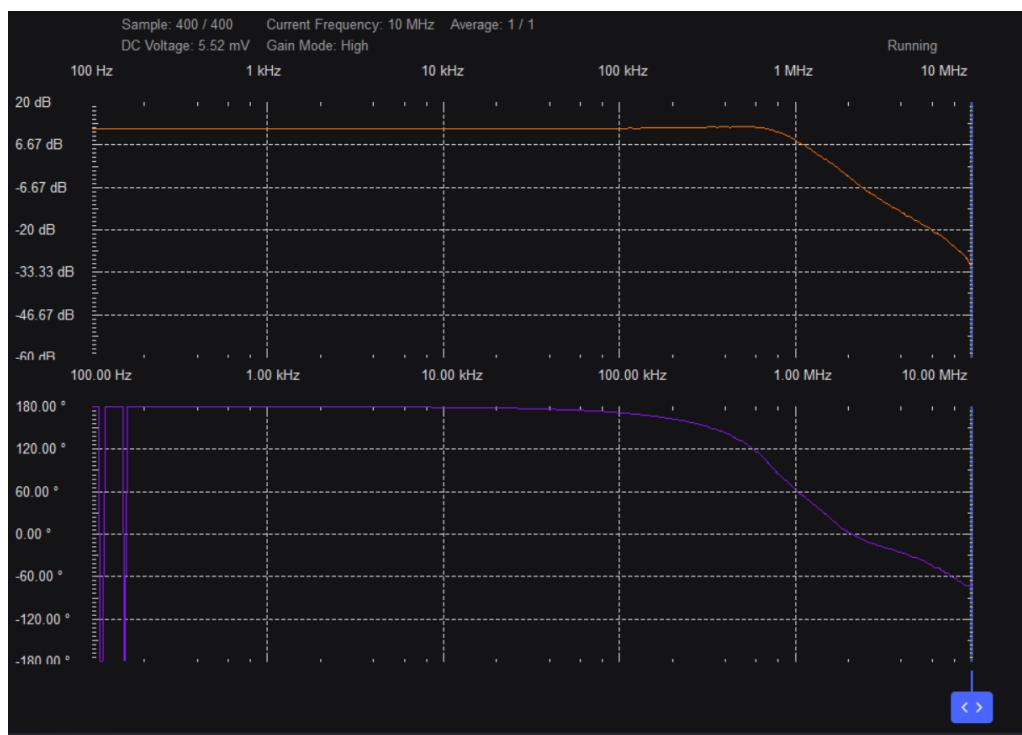
6dB



9dB



12dB



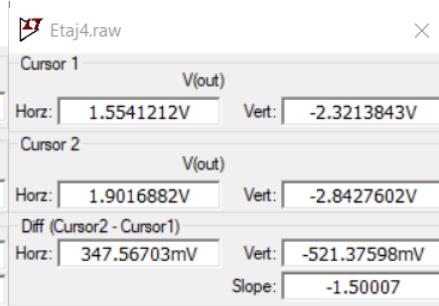
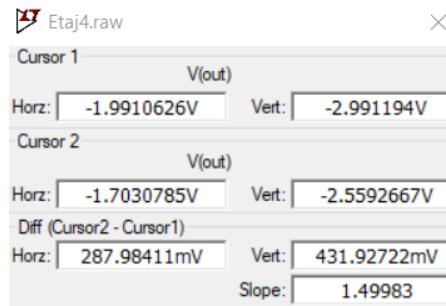
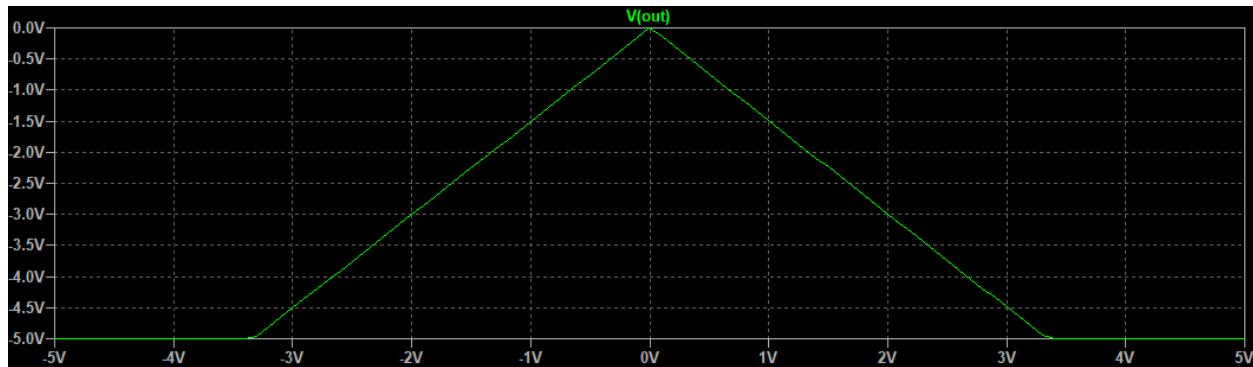
3.4. Etaj 4

3.4.1. Rezultate simulari

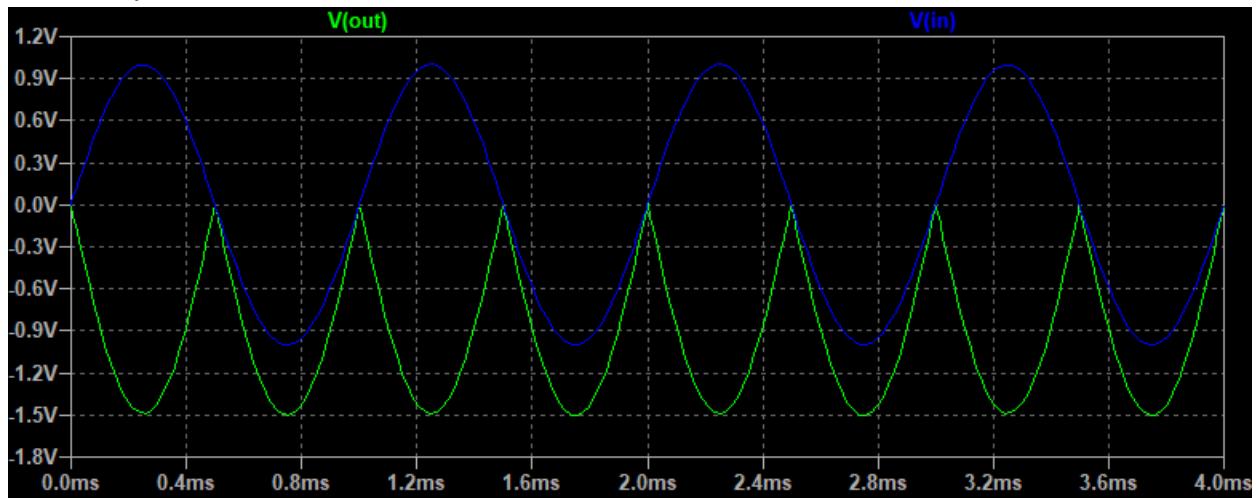
DC-OP

--- Operating Point ---		
V(n003) :	-0.00494121	voltage
V(in) :	0	voltage
V(n001) :	-6.55364e-07	voltage
V(n002) :	-0.00494185	voltage
V(out) :	-0.00493777	voltage
V(+vcc) :	5	voltage
V(-vcc) :	-5	voltage
V(out1) :	0.320925	voltage
I(D1) :	2.99718e-06	device_current
I(D2) :	-2.51843e-09	device_current
I(R1) :	-1.49734e-06	device_current
I(R2) :	-1.98595e-10	device_current
I(R3) :	-1.49733e-06	device_current
I(R4) :	2.47096e-09	device_current
I(V1) :	-0.00208219	device_current
I(V2) :	0.00208519	device_current
I(V3) :	-1.49753e-06	device_current
Ix(u1:1) :	1.5001e-06	subckt_current
Ix(u1:2) :	1.50005e-06	subckt_current
Ix(u1:3) :	-2.9997e-06	subckt_current
Ix(u1:4) :	0.00104185	subckt_current
Ix(u1:5) :	-0.00104185	subckt_current
Ix(u2:1) :	1.49985e-06	subckt_current
Ix(u2:2) :	1.4998e-06	subckt_current
Ix(u2:3) :	-2.47095e-09	subckt_current
Ix(u2:4) :	0.00104035	subckt_current
Ix(u2:5) :	-0.00104334	subckt_current

Caracteristica de transfer si castigul liniar

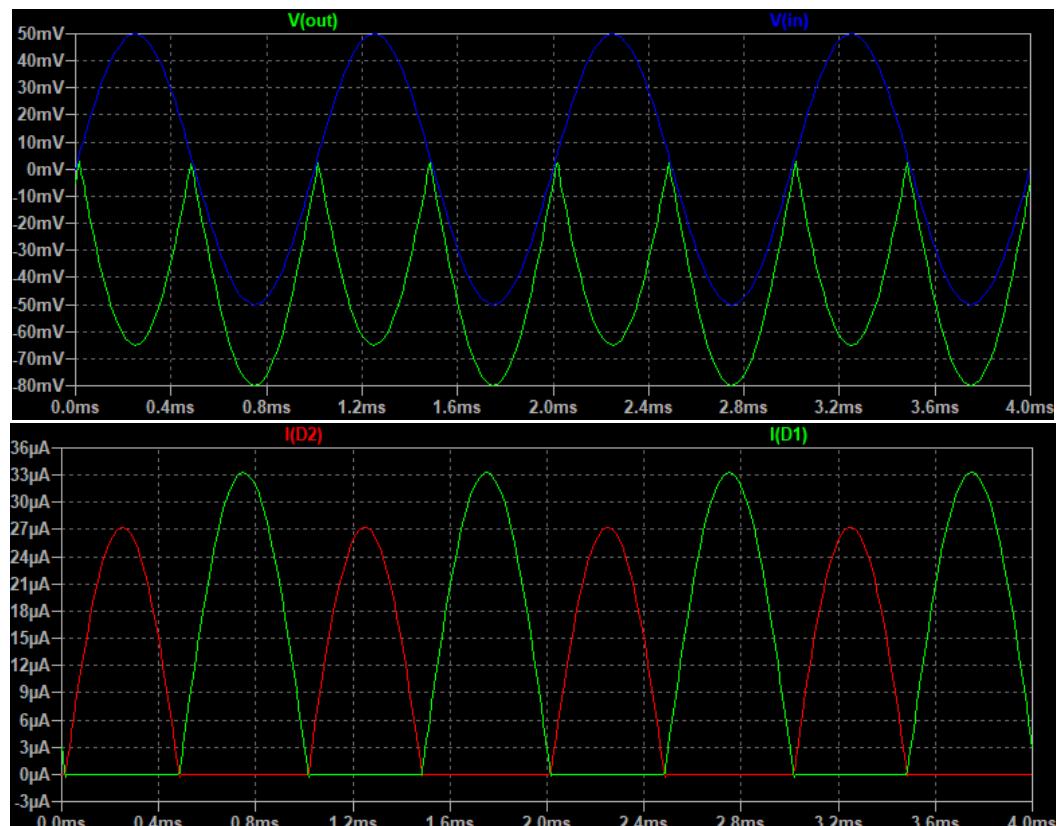


Implementarea functiei de circuit

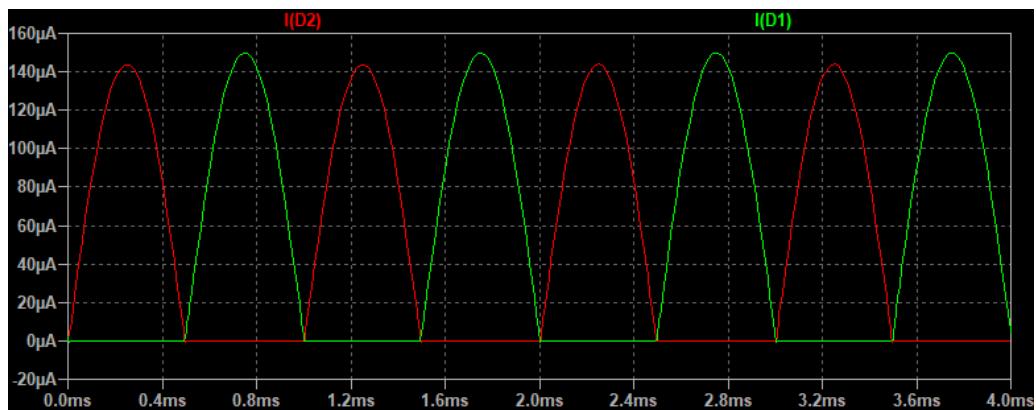


OBS:

Pentru rezistente mari circuitul nu mai functioneaza corespunzator



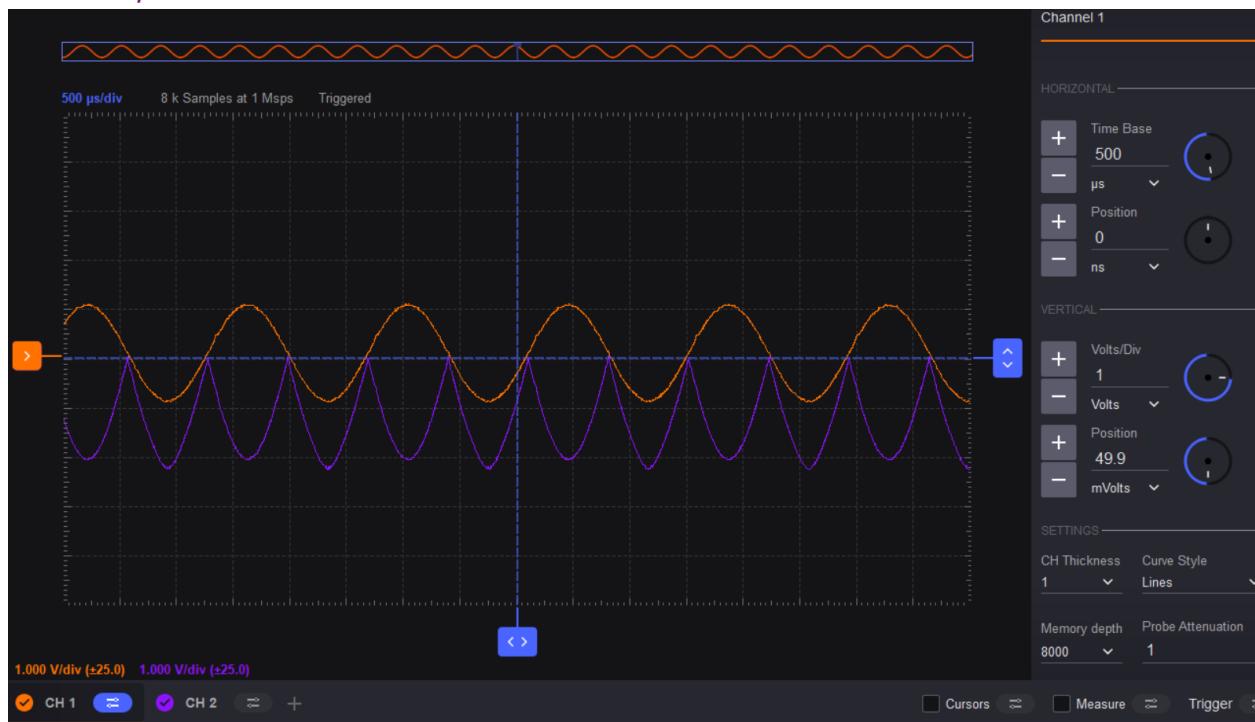
$$R=3.3[\text{k}\Omega]$$



$R=680[\text{k}\Omega]$

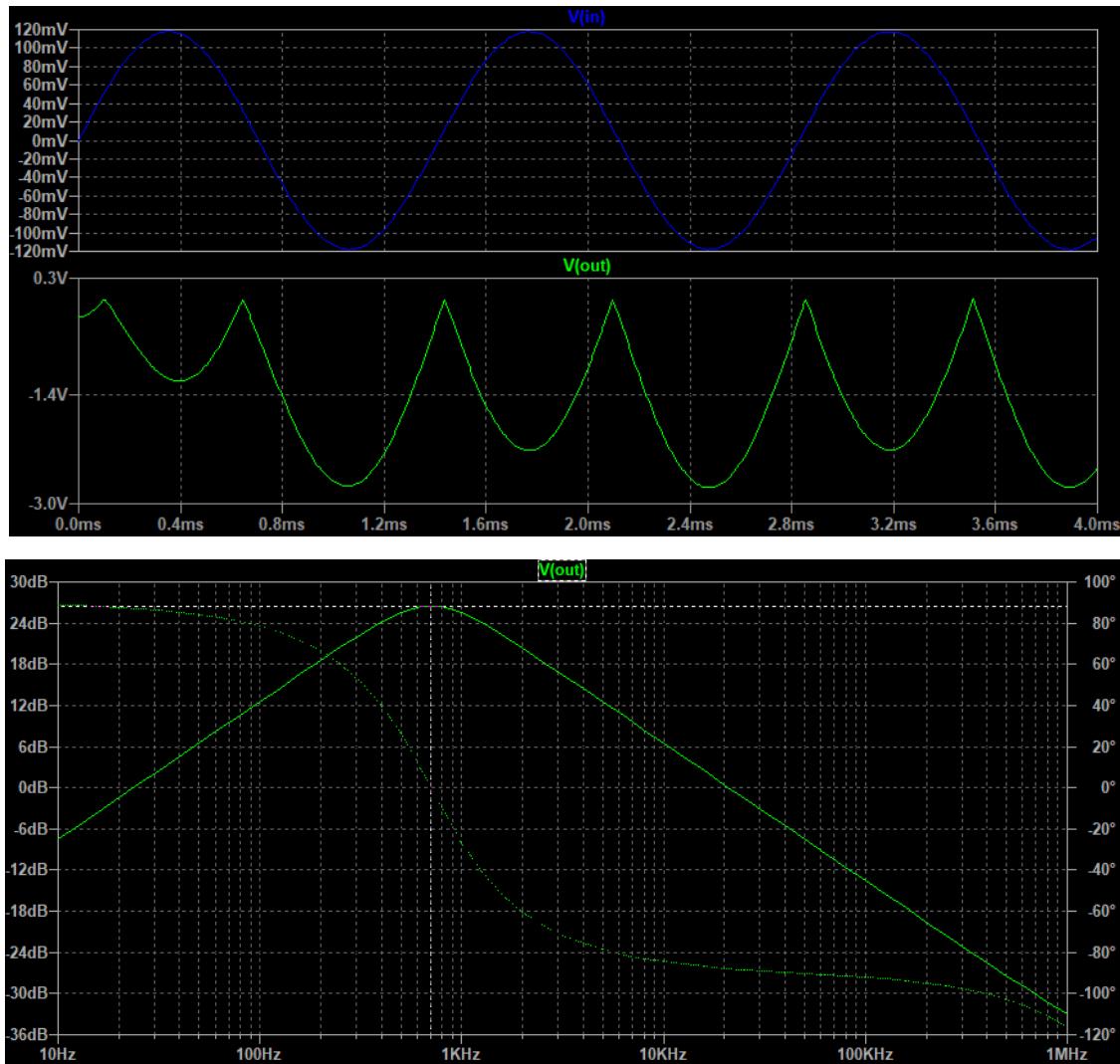
3.4.2. Rezultate masuratori

Implementarea functiei de circuit



4. Caracterizarea interfetei

Interfata preia un semnal analogic pe care il preamplifica, il filtreaza, il amplifica din nou si il redreseaza.



5. Concluzii



Amplificarea in banda de trecere a filtrului nu este unitara, din masuratori este mai aproape de 0.9. Frecventa centrala nu este 707 [Hz], ci 690[Hz]. Banda este aproximativ 960[Hz], atunci nici factorul de calitate nu este 0.707.

Nivelele de castig ale PGA-ului sunt foarte aproape de valoarea ceruta, banda pentru fiecare castig este mult mai mare decat banda filtrului. Aceasta poate functiona mult mai bine cu componente de tolerante mai mici.

Redresorul functioneaza corect doar pe o semialternanta dar nu si pe cealalta. Amplificatoarelor le este dificil sa furnizeze suficient curent din cauza valorilor mari ale rezistentelor, o posibila solutie este scaderea valorii rezistentelor dar din simulari sa observat ca nu este suficient cand etajele sunt conectate impreuna.

Circuitul functioneaza dar performanta acestuia nu este ideală, toleranțelor mari ale componentelor în anumite pozitii cheie și elementele parazite adăugate de breadboard contribuie la degradarea performantei.

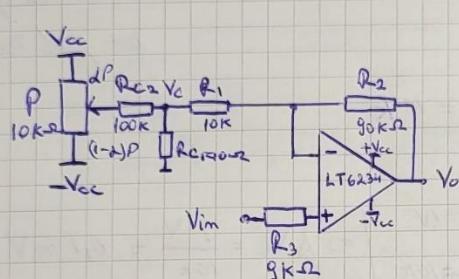
6. Calcule manuale

Etapă 1 - stmp. menire cu comp. DC

Specificatii:

- Urestă single pole.
- Stmp. min $\rightarrow G_{\max} \text{PGA} = 41,9 \text{ mV} \Rightarrow V_{in} \in (41,9, 118) \text{ mV}$
- Stmp. max $\rightarrow G_{\min} \text{PGA} = 118 \text{ mV} \Rightarrow V_o = (419, 1180) \text{ mV}$
- Eantig. $\text{deg} < 10 \Rightarrow V_o = (0,419, 118) \text{ V}$

Schimbul electrică:



$$V_{cc} = 5 \text{ V}$$

$$R_2 = \frac{E_G}{68 \text{ k}\Omega + 22 \text{ k}\Omega}$$

$$R_3 = \frac{E_G}{6,8 \text{ k}\Omega + 2,2 \text{ k}\Omega}$$

Relație de dimensiuni:

$$\begin{aligned} G = 10 \\ G = 1 + \frac{R_2}{R_1} \end{aligned} \Rightarrow 1 + \frac{R_2}{R_1} = 10 \Rightarrow R_2 = 9R_1, \text{ aleg } R_1 = 10 \text{ k}\Omega \Rightarrow R_2 = 90 \text{ k}\Omega$$

$$R_3 = R_1 / R_2 \Rightarrow R_3 = 9 \text{ k}\Omega \quad (\text{minimum. cf. curent polarizare})$$

$$P = 10 \text{ k}\Omega \quad (\text{asta este ce avem disponibil})$$

Pentru a nu robi la costigul $R_C \ll R_1$ ☺

Asum neraportare de la compunere de ordinul mV, deci
raportul de divizare al lui R_{C1}, R_{C2} este nevoie să fie mare.

$$V_o / V_c = - \frac{R_2}{R_1} \cdot V_c = -9 \cdot V_c$$

$$V_c = \frac{R_{C1}}{R_{C1} + R_{C2}} \cdot V_{pot} \approx \frac{R_{C1}}{R_{C1} + R_{C2}} \cdot 10V$$

$$V_{pot} \in (-5, 5) [V]$$

DS
 $LTC234 \rightarrow V_{op} \in (-500, 500) \mu V$

$$\boxed{|H_1 = 10|}$$

DS
 $LTC1357 \Rightarrow V_{op} \in (-0,6, 0,6) mV$

$\Delta V_{pot} = 10 V$
 $\Delta Pot = 27^\circ$
 10 peri

$$\Rightarrow \Delta Pot \sim 1V$$

27° sunt rezonabile
 din cauza de ajutat pe
 un pot real.

$$R_{distr} = \frac{\Delta V_{pot}}{\Delta V_{op}} = \frac{10V}{1mV} = 10k$$

1 pas $\rightarrow \Delta V_{pot} = 1V$
 $R_{distr} = 10k$

Unici pot de 27° în coresp. $0,1mV$
 de compensare. Dacă rezoluția este
 acceptabilă.

$$\frac{R_{C1}}{R_{C1} + R_{C2}} = \frac{1}{R_{distr}} \Leftrightarrow R_{C1} = \frac{10k(R_{C1} + R_{C2})}{10k}$$

~~DOBROGEE~~

$$\Leftrightarrow R_{C1} = \frac{R_{C1} + R_{C2}}{10k}, R_{C2} \gg R_{C1}$$

$$\Rightarrow R_{C1} = \frac{R_{C2}}{10k}, \text{ aleg } \underline{R_{C2} = 100k\Omega} \Rightarrow$$

$$\Rightarrow \boxed{R_{C1} = 10,5k}, \quad \text{OK}$$

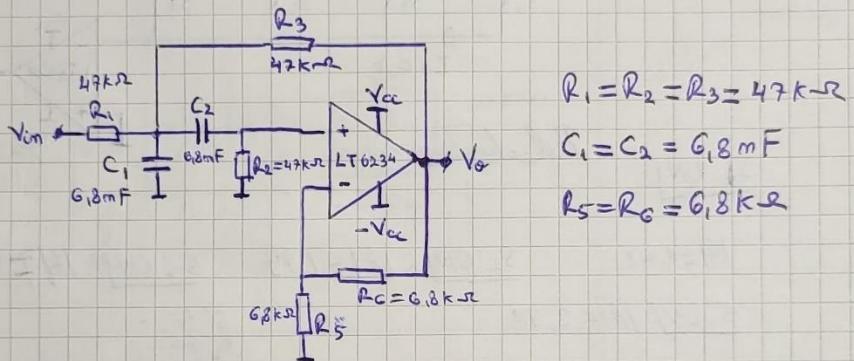
$\ll R_1$

Etapă 2 Filtru TB Lallen-Key

Specificații:

- $|H_0| = 1$
 - $R_{in_min} = 1\text{k}\Omega$
 - $BW = 1000\text{ Hz}$
 - $Q = 0,707$
- $$\Rightarrow f_0 = 707\text{ Hz} \Rightarrow \begin{cases} f_{in_min} = 707 + \frac{707}{2} \\ = 1060,5\text{ Hz} \end{cases}$$
- ETI

Schema electrică



Dimensionare

În ajutorul calculatorului atașat.

$$|H_0| = \frac{R_C}{R_C} = 1$$

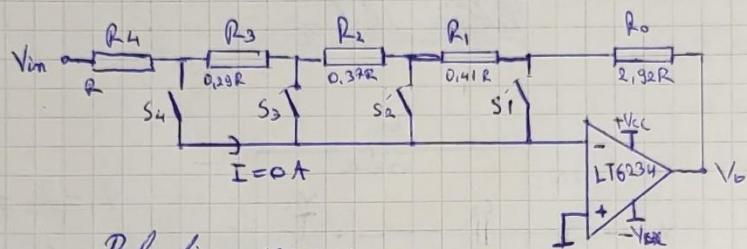
ITP

Etapă 3 PGA Încreșterea în afara răii de semnal

Specificări:

- $G_{min} = 3 \text{ dB}$, $G_{max} = 12 \text{ dB}$
- Rezoluție 3 dB
- 4 pasi $[3 \text{ } 6 \text{ } 9 \text{ } 12] \text{ dB}$

Schimbă electrică



S₁ ON Betă-măsurare:

$$|A| = 1,41 \quad S_2 \text{ ON} : |A| = 1,99 \quad S_3 \text{ ON} : |A| = 2,81$$

$$S_4 \text{ ON} : |A| = 3,98$$

$$\begin{matrix} S_1 \text{ ON} \\ S_2 \text{ ON} \\ S_3 \text{ ON} \end{matrix}$$

$$\left\{ \begin{array}{l} R_0 + R_1 + R_2 + R_3 = 3,98 R_4 \quad (1) \\ R_0 + R_1 + R_2 = 2,81 (R_3 + R_4) \quad (2) \\ R_0 + R_1 = 1,99 (R_2 + R_3 + R_4) \quad (3) \\ S_4 R_0 = 1,41 (R_1 + R_2 + R_3 + R_4) \quad (4) \end{array} \right.$$

$$S_1 : |A| = \frac{R_0}{R_0 + R_1 + R_2 + R_3} = 1,41$$

$$S_2 : \frac{R_0 + R_1}{R_2 + R_3 + R_4} = 1,99$$

$$S_3 : \frac{R_0 + R_1 + R_2}{R_3 + R_4} = 2,81$$

$$(1) - (2) \Rightarrow R_3 = 3,98 R_4 - 2,81 R_3 - 2,81 R_4$$

$$\Leftrightarrow 3,81 R_3 = 1,17 R_4$$

$$\Leftrightarrow R_3 = 0,29 R_4$$

$$(1) - (3) \Rightarrow R_2 + R_3 = 3,98 R_4 - 1,99 (R_2 + R_3 + R_4)$$

$$3,99 R_2 = 1,99 R_4 - 0,99 R_3$$

$$\Leftrightarrow R_2 = 0,38 R_4$$

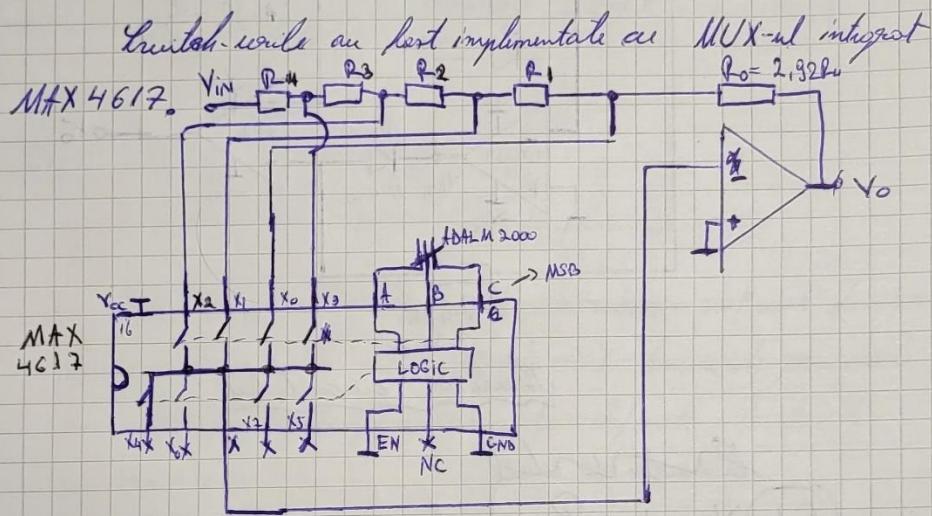
$$(1) - (4) \Rightarrow R_1 = \frac{2,92 R_4}{0,41}$$

$$\Leftrightarrow R_0 = 2,92 R_4$$

Schaltungsprinzip ($R_4 = 1\text{ k}\Omega$) =

$$\left. \begin{array}{l} R_3 = 290\Omega \stackrel{E_G}{\approx} 220 + 68\Omega \\ R_2 = 370\Omega \stackrel{E_G}{\approx} 220 + 150\Omega \\ R_1 = 410\Omega \stackrel{E_G}{\approx} 3,3\text{k} \parallel 470\Omega \\ R_0 = 2920\Omega \stackrel{E_G}{\approx} 2,2\text{k} + 680\Omega \end{array} \right\}$$

Implementare practica:



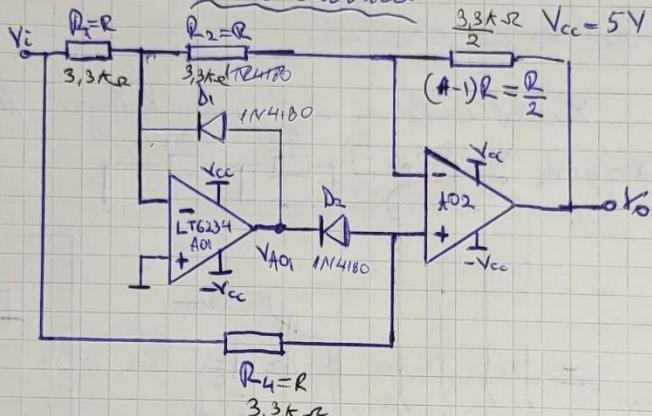
Adresa SW 2b \rightarrow A=0, BC \rightarrow 00 S₁ - X₀ - G_{min}
 01 S₂ - X₁
 10 S₃ - X₂
 11 S₄ - X₃ - G_{max}

Etapă 4. Redresor.

* Specificații

$$|A_0| = 1,5$$

Schemă electrică



Analiza circuitului

Condiții de lucru

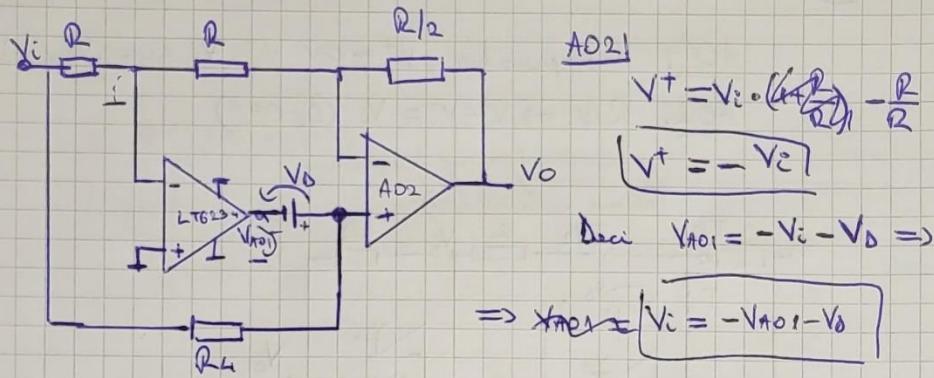
(c1) $V_i > 0$ P.p. D_1, D_2 OFF $\Rightarrow A01$ comp

$$\begin{aligned} A02 \text{ are } R.N. \Rightarrow V^+ = V^- \\ V^+ = V_C (I=0) \end{aligned} \quad \left. \begin{aligned} \Rightarrow V^- = V^+ \Rightarrow I_{\text{prin } R_1} \\ \text{și } R_2 = 0 \Rightarrow \end{aligned} \right.$$

$$\Rightarrow \begin{cases} A01 | V^- = V_i > 0 \\ V^+ = 0 \end{cases} \quad \Rightarrow V_{A01} = V_{OL} < 0 \Rightarrow \begin{cases} D_2 \sim ON \\ D_1 - OFF \end{cases}$$

Dacă D_2 - ON și $A02$ are RN ($V^+ = V^-$) \Rightarrow
 $\Rightarrow A01$ are RN. $\Rightarrow V^+ = V^- = 0V$ Deși, deși cind
 $A02$ are RN!!!

Redres. Schemă el. echiv.



A02

$$V^+ = V_i \cdot \left(1 + \frac{R}{R/2}\right) - \frac{R}{R/2}$$

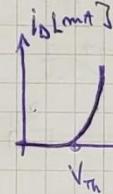
$$\boxed{V^+ = -V_i}$$

$$\text{Deci } V_{A01} = -V_i - V_D \Rightarrow$$

$$\Rightarrow \boxed{V_i = -V_{A01} - V_D}$$

Obs $V_{R4} = V_i - V_{A02}^+ = 2V_i$

$$|U_{R1}| = |U_{R2}| = V_i$$



Deci trebuie asigurat un curent suficient de mare prin diode, pt V_D mic (zeci de mV) tensiunile prin diode nu vor fi egale pe altorantele diverse ale lui V_i .

$$i_{D2} = i_{R4} = \frac{2V_i}{R_4}$$

A02 $V^+ = -V_i$

$$V_D = V^+ \cdot \left(1 + \frac{R_4}{\frac{R}{2}}\right) = -V_i - 1,5$$

$$\boxed{V_D = -1,5 V_i} \quad \text{Deci} \Rightarrow V_i = -\frac{V_D}{1,5}$$

Toate ale disutate mai sus sunt verificabile pt A02 cu R.N.. Deci V_D intră în satuație astăzi astăzi nu mai este aderent.

A02 $V_i = -\frac{V_{D2}}{1,5}$

$$V_i = -\frac{(-5)}{1,5} = +3,33 V$$

A01 $V_i = -V_{D2} - V_D$

$$V_i = -(-5) - 0,6 = 4,4 V$$

A0 este R2R

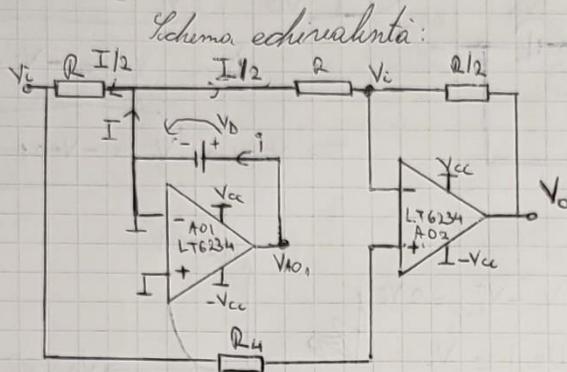
Deci A02 intră în satuație
mai târziu deci A02 $\Rightarrow V_i < 3,33 V$

$$\boxed{V_D = -1,5 V_i}$$

(C₂) $V_i < 0$ P.P. D_1, D_2 - OFF

A01: Comparator, $V^+ = 0V$ $V^- = V_i$ $\angle 0 \Rightarrow V_{AO1} = V_{OH} \Rightarrow I_A = \frac{V_{OH}}{R}$

A02: $R_A V_i \Rightarrow V^+ = V^- = V_i$ (D_2 -OFF)



$$I_{R_2} = 0A \Rightarrow V_{AO2}^+ = V_C \quad | \quad \Rightarrow V^- = V_i \\ V^+ = V^-$$

$$V_{AO1} = V_D$$

$$V_O = V^+ \cdot \left(1 + \frac{R_1/2}{R}\right) = V_C \cdot 1,5$$

$$V_O = 1,5V_i \quad | \quad \Rightarrow V_i = \frac{V_O}{1,5} = \frac{V_{OL}}{1,5} = -3,33V$$

$$\begin{cases} V_C = V_O \cdot 1,5 \\ V_O = -3,33V \end{cases}$$

$$\text{Obs} \quad \frac{i_D}{R} = \frac{0 - V_C}{R} = -\frac{2V_i}{R}, \quad V_i < 0$$

$$I_{D2} = \frac{2V_i}{R_4}$$

Dimensiunile

Pentru curent tensiuni mici de intrare se constată că impreună valoarea rezistorilor face o diferență mare.

$R_4 = R \Rightarrow$ curenti identici pe un diod și pe piezozonă alternativă. Dar și valoarea lui R este inversată.

Pt. R peia mare dischile nu functionază corect din cauza curentelor foarte mici și nici redresorul deține consecință.

$$V_i \in (-3,33, +3,33) V$$

$$\left| i_D \right| = \left| i_{D2} \right| = \frac{2V_i}{R} = \frac{6,66 V}{R}$$

Pt un $i_{D\max} = 2 \text{ mA}$

$$\Rightarrow R = \frac{6,66 V}{2 \text{ mA}}$$

$$R = 3,33 \text{ k}\Omega$$

$$R \approx 3,3 \text{ k}\Omega$$

B