

# PROIECT

## SISTEME CU CIRCUITE INTEGRATE ANALOGICE

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**UNIVERSITATEA  
TEHNICĂ**  
DIN CLUJ-NAPOCA

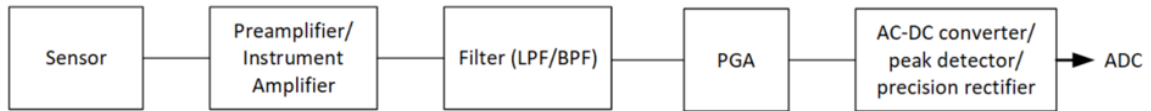
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# 1.TEMATICA PROIECTULUI

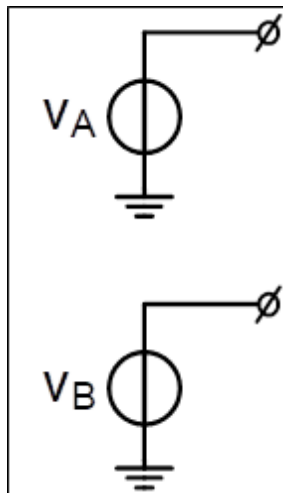
Proiectul consta in proiectarea unei interfete analogice formate din blocuri conectate in cascada, conform schemei bloc din Figura 1.



*Figura 1: Schema bloc*

## 1.1 Sursa de semnal

Sursa de semnal este o sursa diferentiala de tensiune.



*Figura 2: Sursa diferentiala de tensiune*

## 1.2 Etajul I: Amplificator de instrumentatie

Etajul I este reprezentat de un amplificator de instrumentatie cu 3 AO V-V, avand specificatiile din Tabelul 1.

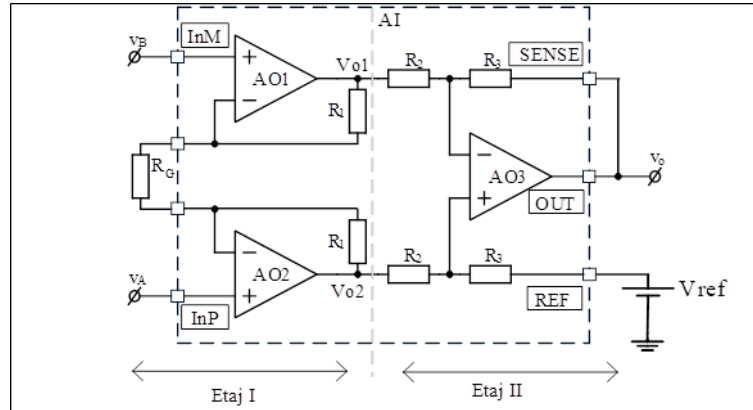


Figura 3: Amplificator de instrumentatie, 3 AO V-V

Amplitudine minima(castig maxim PGA)	Amplitudine maxima(castig minim PGA)	Castig liniar
1.56E-02	3.11E-02	16

Tabelul 1: Specificatii Etaj I

## 1.3 Etajul II: Filtru

Etajul II contine un filtru trece banda de tip Rauch, cu datele din Tabelul 2.

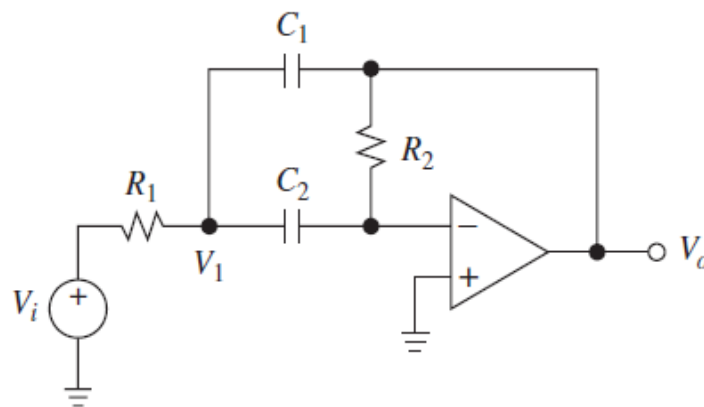


Figura 4: Filtru trece banda Rauch

Castig liniar in banda de trecere	Rintrare minim	Banda	Q
2.00E+00	1.00E+03	5000	1

Tabelul 2: Specificatii Etajul II

## 1.4 Etajul III: PGA

La etajul III, se foloseste un PGA RG serie.

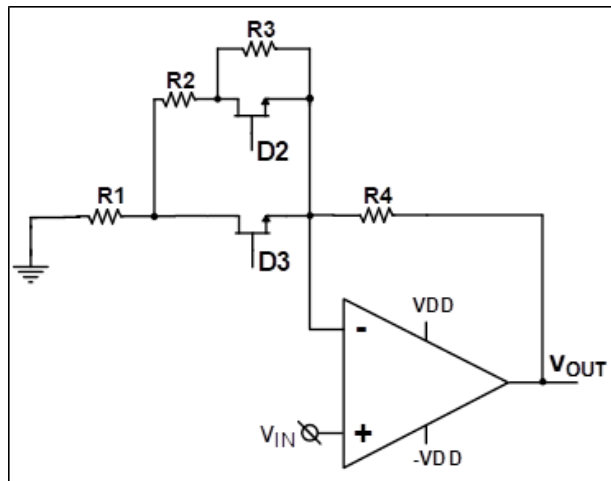


Figura 5: PGA RG serie

Specificatiile acestuia se regasesc in urmatorul tabel:

Castig minim[dB]	Castig maxim[dB]	Rezolutie(pas minim)	Numar pasi
8	14	2	4

Tabelul 3: Specificatii Etajul III

## 1.5 Etajul IV

Pentru etajul IV, se utilizeaza un redresor bialternanta in configuratie inversoare, implementat cu doua AO si doua diode, avand castigul liniar egal cu 1.

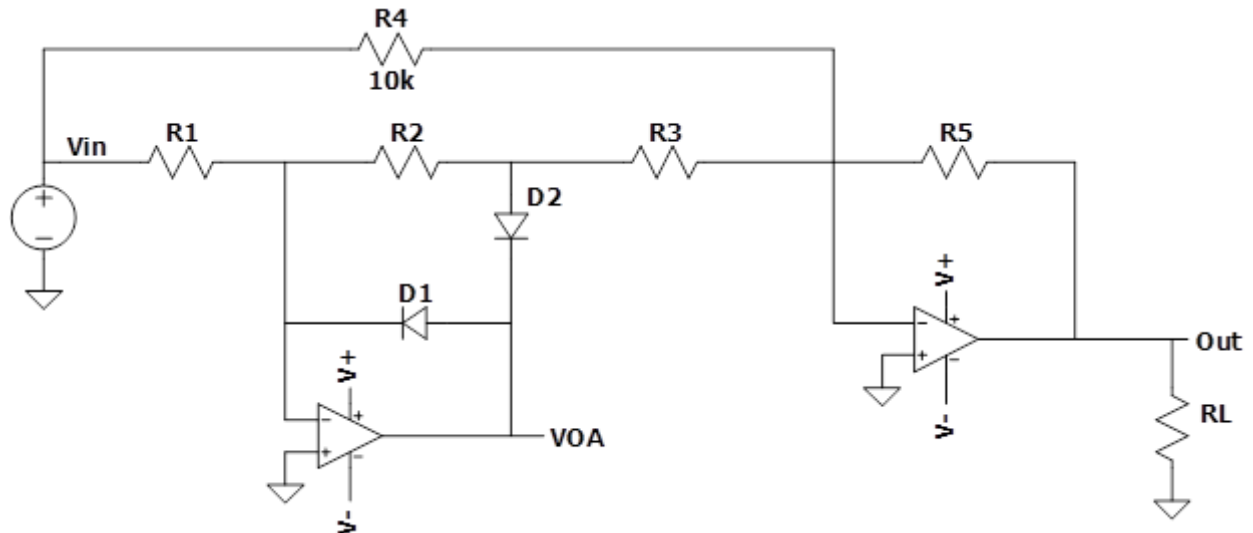


Figura 6: Redresor bialternanta

## 1.6 Tip AO

In proiectarea etajelor, voi folosi un AO de tip LT6234. Am alimentat amplificatoarele cu doua tensiuni  $V+$ ,  $V-$ , cu valori de +5, respectiv -5.

## 2 DIMENSIONARE

### 2.1 Dimensionarea etajului I

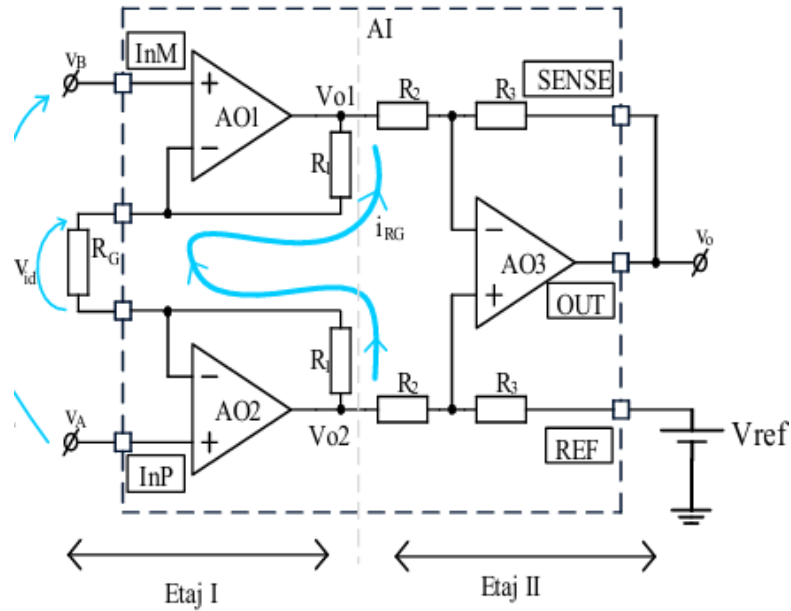


Figura 7: Etajul I

Pentru a obtine expresia castigului diferential al circuitului, dar si a tensiunii de iesire, am luat pe rand fiecare etaj al amplificatorului.

Etajul 1 reprezinta un amplificator cu intrare si iesire diferentiala,

$$V_{o2} - V_{o1} = (R_1 + R_G + R_1) \cdot i_{RG} = \frac{2R_1 + R_G}{R_G} (V_A - V_B)$$

$$AdI = \frac{V_{o2} - V_{o1}}{V_A - V_B} = \left(1 + \frac{2R_1}{R_G}\right)$$



Etajul 2 este un amplificator cu intrare diferentiala.

Astfel, ecuatia caracteristica si amplificarea diferentiala au urmatoarele expresii:

$$V_{out} = (V_A - V_B) \left(1 + \frac{2R_1}{R_G}\right) \frac{R_3}{R_2}$$

$$A_d = \left(1 + \frac{2R_1}{R_G}\right) \frac{R_3}{R_2}$$

Se stie din specificatii ca valoarea liniara a castigului este 16:

$$16 = \left(1 + \frac{2R_1}{R_G}\right) \frac{R_3}{R_2}$$

Am ales  $\frac{R_3}{R_2} = 10$ , de unde  $R_3 = 10\text{k}\Omega$  si  $R_2 = 1\text{k}\Omega$ . Astfel ajungem la urmatoarea

relatie:  $\frac{2R_1}{R_G} = 0.6$ , pentru care am ales  $R_G = 330\Omega$  si am obtinut  $R_1 = 100\Omega$ .

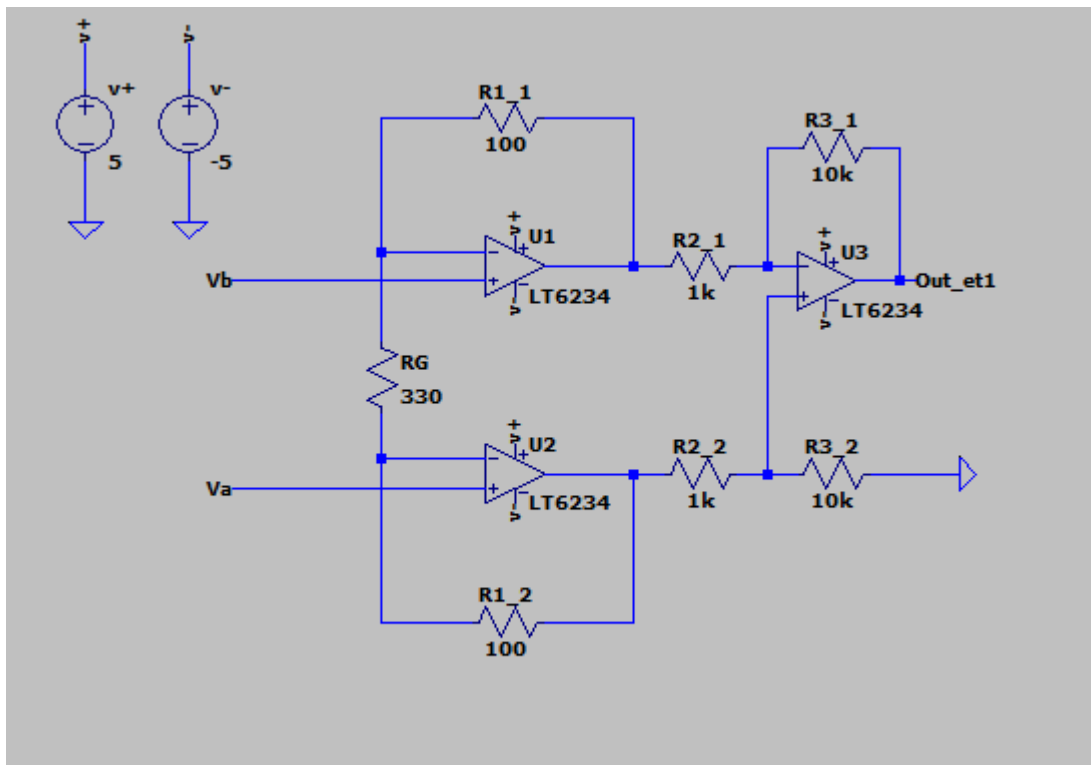


Figura 8: Dimensionarea etajului I

Am alimentat circuitul cu o sursa diferentiala de tensiune, avand amplitudinea maxima 31.1mV.

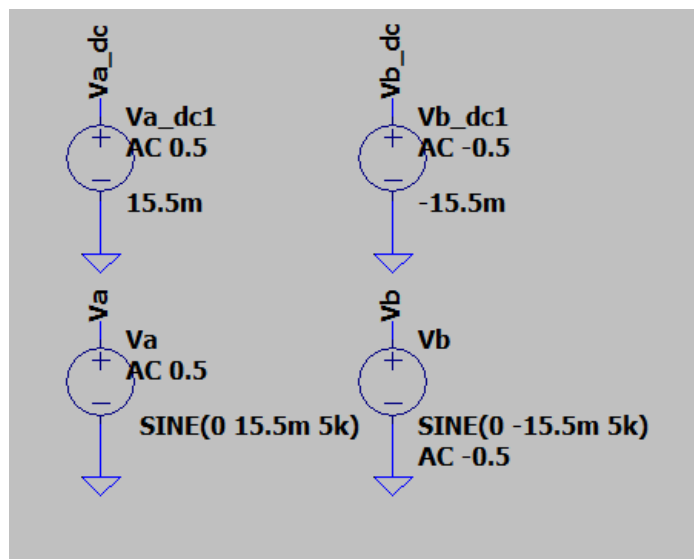


Figura 9: Alimentare etaj I

## 2.2 Dimensionarea etajului II

Pentru a dimensiona etajul II, filtrul Rauch trece banda, am folosit urmatoarele formule:

$$H0dB = \frac{-R2}{\frac{R1}{1+\frac{C1}{C2}}} \quad Q = \frac{\sqrt{R2/R1}}{\sqrt{\frac{C1}{C2}} + \sqrt{\frac{C2}{C1}}}$$

f0 [Hz]	w0 [rad/sec]	Q	H0  [V/V]	H0 [dB]
5.00E+03	3.14E+04	1.00E+00	2.00E+00	6.02E+00
	set C1=C2=C [F]	R1	R2	
	1.00E-09	1.59E+04	6.37E+04	

Am ales C1=C2=C si am folosit tabelul de dimensionare pentru a obtine urmatoarele valori:

Figura 10: Tabel de dimensionare pentru etajul II



Am ales  $R_{G1}=10k\Omega$ , din care am obtinut:  $R_F=40k\Omega$ ,  $R_{G2}=3.33k\Omega$ ,  $R_{G3}=5.18k\Omega$ ,  $R_{G4}=8.15k\Omega$ .

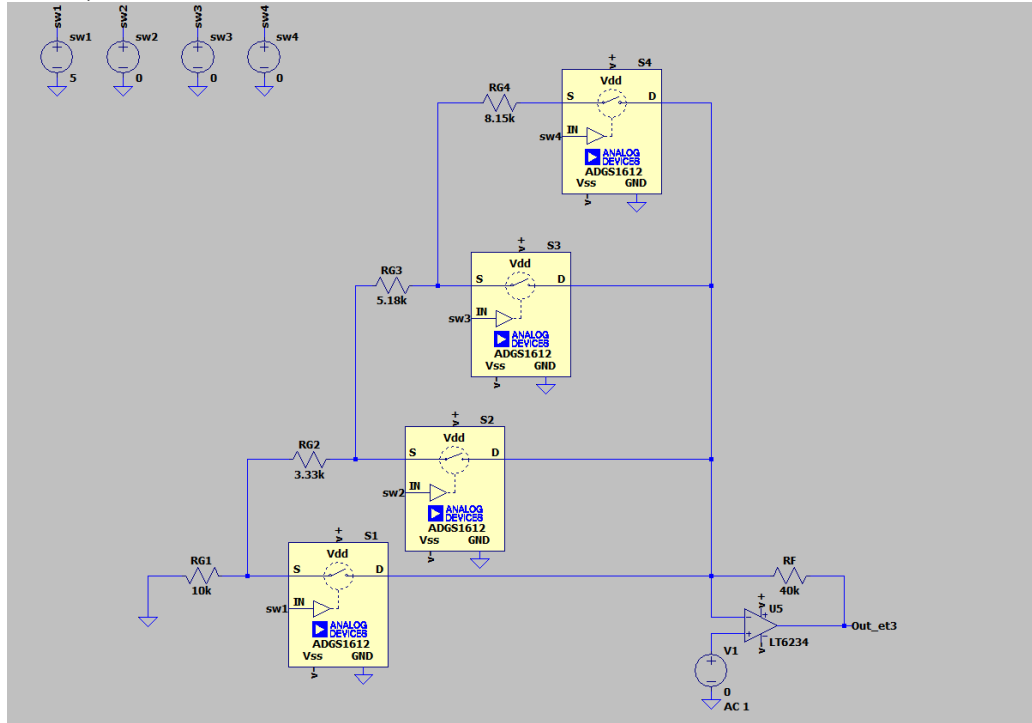


Figura 12: Dimensionarea etajului III

## 2.4 Dimensionarea etajului IV

Pentru o tensiune de intrare negativa, D1 este ON, astfel vom obtine  $V_{out1} = -\left(\frac{R_5}{R_4}\right) \cdot V_{in}$ . Pentru o tensiune de intrare pozitiva, D2 va fi ON, astfel va rezulta expresia  $V_{out2} = \frac{R_5}{R_4} \cdot V_{in}$ .

Avand in vedere ca tensiunea de intrare in cazul practic este pozitiva, iar castigul liniar este egal cu  $A=1$ , atunci  $\frac{R_5}{R_4} = 1$ .

Aleg  $R_5=10\text{k}\Omega$ .  $R_1$  va avea aceeași valoare cu  $R_2$ ,  $R_4$  și  $R_5$ , iar  $R_3 = \frac{R_5}{2}$ .

Atunci se obține:  $R_2=R_4=R_5=10\text{k}\Omega$  și  $R_3=5\text{k}\Omega$ .

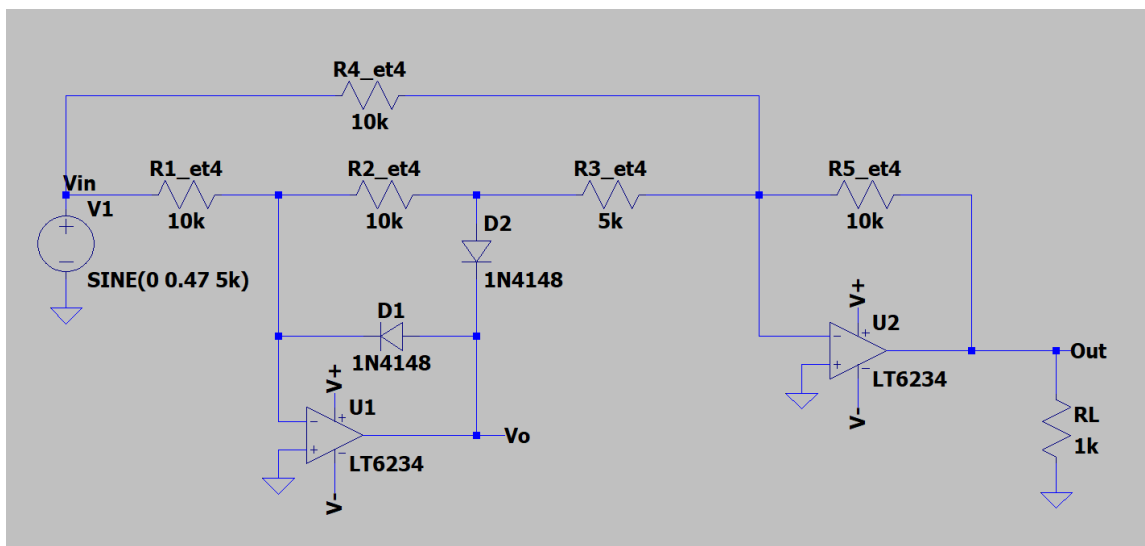


Figura 13: Dimensionarea etajului IV

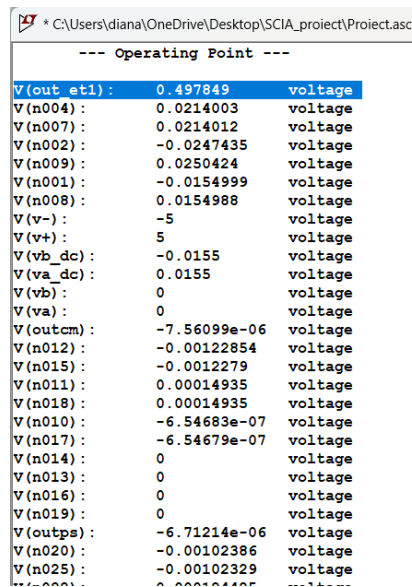
### 3 CARACTERIZARE

#### 3.1 Caracterizarea etajului I

##### 3.1.1 DCOP

##### 3.1.1.1 Punct static de functionare

Pentru a vedea punctul static de functionare, se ruleaza o analiza de tip .op.



--- Operating Point ---		
V(out_et1):	0.497849	voltage
V(n004):	0.0214003	voltage
V(n007):	0.0214012	voltage
V(n002):	-0.0247435	voltage
V(n009):	0.0250424	voltage
V(n001):	-0.0154999	voltage
V(n008):	0.0154988	voltage
V(v-):	-5	voltage
V(v+):	5	voltage
V(vb_dc):	-0.0155	voltage
V(va_dc):	0.0155	voltage
V(vb):	0	voltage
V(va):	0	voltage
V(outcm):	-7.56099e-06	voltage
V(n012):	-0.00122854	voltage
V(n015):	-0.0012279	voltage
V(n011):	0.00014935	voltage
V(n018):	0.00014935	voltage
V(n010):	-6.54683e-07	voltage
V(n017):	-6.54679e-07	voltage
V(n014):	0	voltage
V(n013):	0	voltage
V(n016):	0	voltage
V(n019):	0	voltage
V(outps):	-6.71214e-06	voltage
V(n020):	-0.00102386	voltage
V(n025):	-0.00102329	voltage

Figura 14: Punct static de functionare etaj I

Calculand  $V_{out}$  pentru etajul I, dupa formula  $V_{out} = (V_A - V_B)(1 + \frac{2R_1}{R_G}) \frac{R_3}{R_2}$ , se obtine  $V_{out}=0.497$ , ceea ce se regaseste si in simularea de mai sus.

##### 3.1.1.2 Compensarea nivelului DC la iesire

Am inceput prin a pasiviza ambele surse de tensiune si in acest fel am obtinut in simularea OP rezultatele din Figura 15.

\* C:\Users\diana\OneDrive\Desktop\SCIA\_proiect\Proiect.asc

--- Operating Point ---

V(out_et1):	-7.56099e-06	voltage
V(n004):	-0.00122854	voltage
V(n007):	-0.0012279	voltage
V(n002):	0.00014935	voltage
V(n009):	0.00014935	voltage
V(n001):	-6.54683e-07	voltage
V(n008):	-6.5468e-07	voltage
V(v-):	-5	voltage
V(v+):	5	voltage
V(vb):	0	voltage
V(vb_dc):	-0.0155	voltage
V(va):	0	voltage
V(va_dc):	0.0155	voltage
V(outcm):	-7.56099e-06	voltage
V(n012):	-0.00122854	voltage
V(n015):	-0.0012279	voltage
V(n011):	0.00014935	voltage
V(n018):	0.00014935	voltage
V(n010):	-6.54683e-07	voltage
V(n017):	-6.54679e-07	voltage
V(n014):	0	voltage
V(n013):	0	voltage
V(n016):	0	voltage
V(n019):	0	voltage
V(outps):	-6.71214e-06	voltage
V(n020):	-0.00102386	voltage
V(n025):	-0.00102329	voltage

Figura 15: Analiza dupa pasivizarea surselor

Pentru a compensa nivelul DC la iesire, am adaugat o sursa Vref, egala cu complementul tensiunii de iesire.

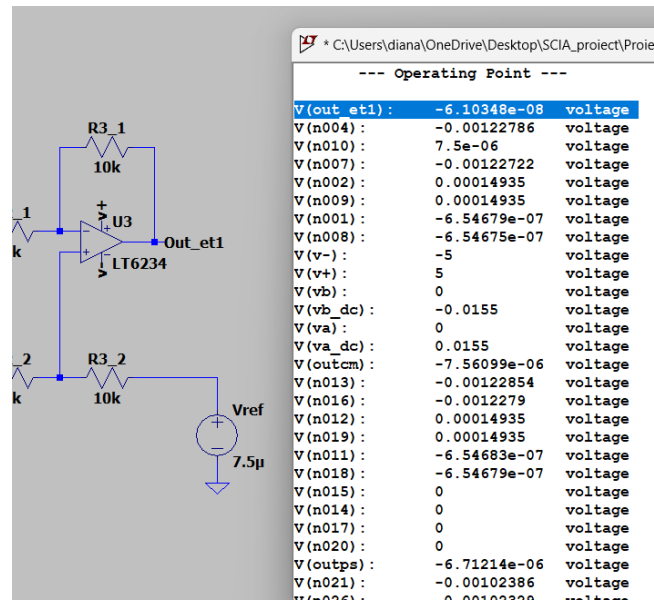


Figura 16: Compensarea nivelului DC la iesire

## 3.1.2 AC

### 3.1.2.1 Castig la joasa frecventa

Pentru a vedea castigul la joasa frecventa am utilizat o analiza .ac ca in Figura 17. Se pozitioneaza un cursor in partea stanga, la 1Hz, si se observa castigul care este aproximativ 16, conform specificatiilor.

**.ac dec 100 1 10Meg**

Figura 17: Analiza AC

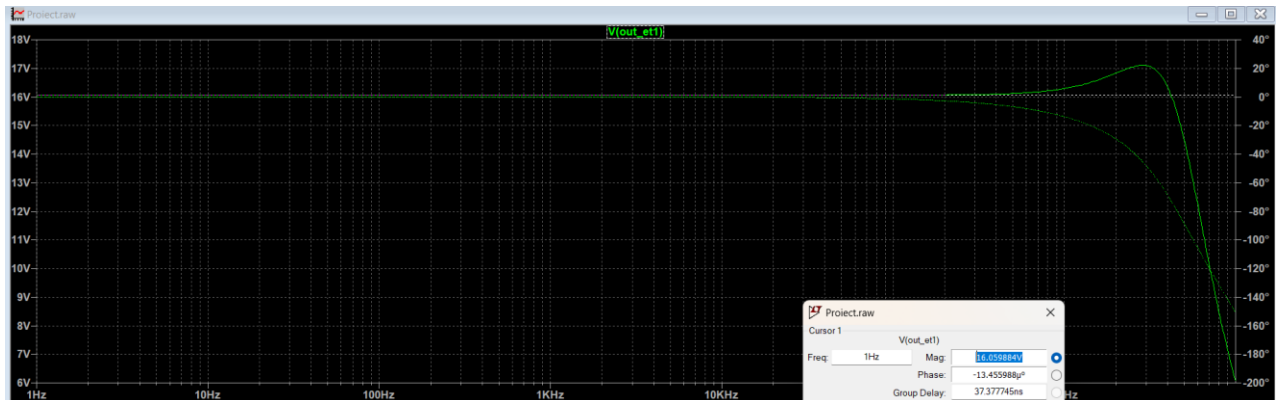


Figura 18: Castigul la joasa frecventa etaj I

### 3.1.2.2 Banda

Am pozitionat cursoarele astfel incat diferenta dintre ele sa fie de -3dB, masurand banda care este mult mai mare decat cea a a filtrului, 5kHz.

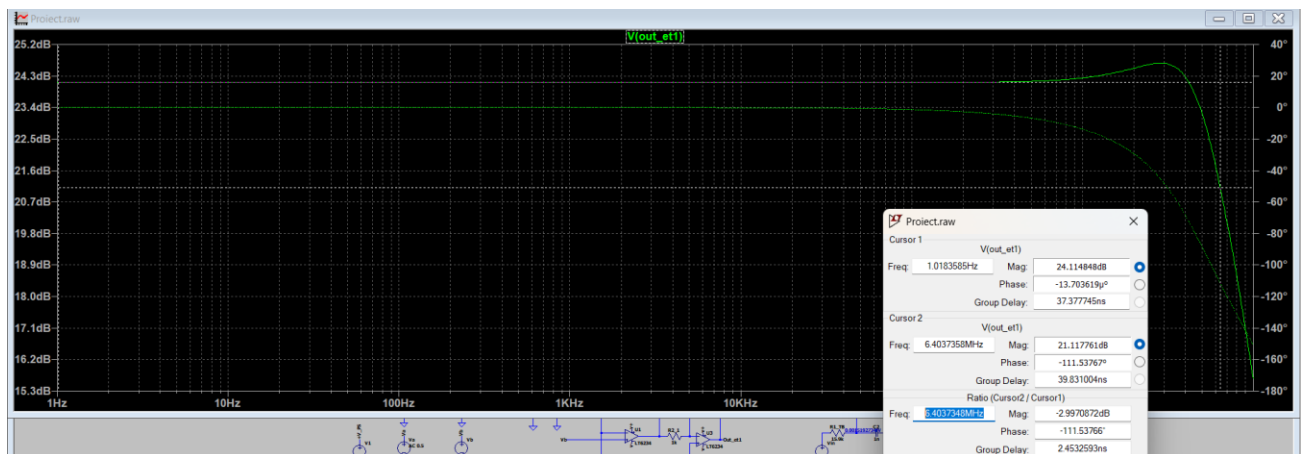


Figura 19: Banda etaj I > banda filtru



### 3.1.2.3 CMRR si PSRR

Am folosit circuitele proiectate in laborator pentru a vedea CMRR si PSRR, impreuna cu formulele din Figura 21.

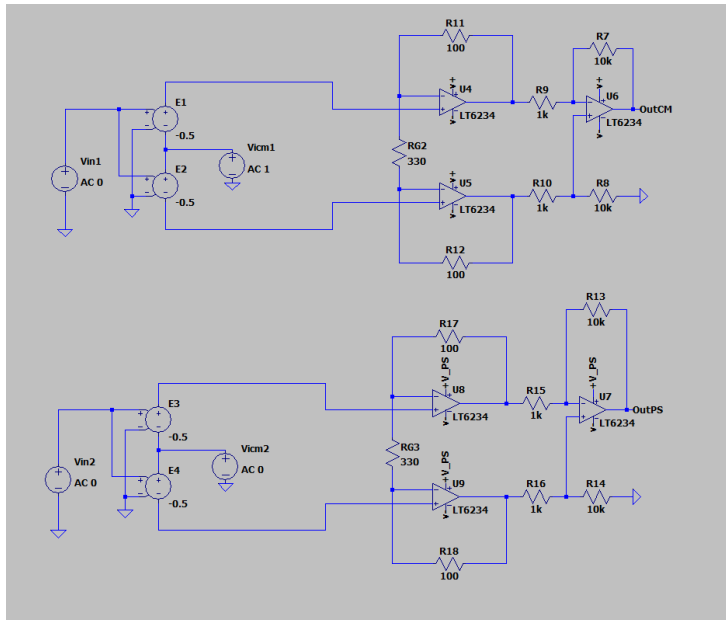


Figura 20: Circuite pentru CMRR si PSRR

```
.meas AC CMRR FIND (V(Out_et1)/V(outCM)) AT 1
.meas AC PSRR FIND (V(Out_et1)/V(outPS)) AT 1
```

Figura 21: Formule CMRR si PSRR

S-au obtinut urmatoarele simulari:

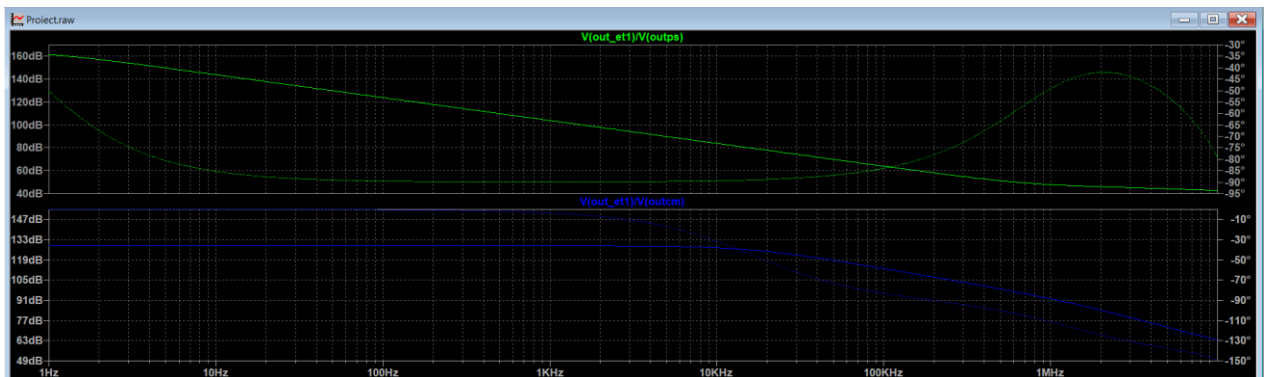


Figura 22: Plotare CMRR, PSRR

```
cmrr: (v(out_et1)/v(outcm))=(128.758dB,-0.00350268°) at 1
psrr: (v(out_et1)/v(outps))=(161.633dB,-50.3681°) at 1
aps: v(outps)=(-137.518dB,50.368°) at 1
```

Figura 23: CMRR si PSRR

### 3.1.3 TRANSIENT

#### 3.1.3.1 Slew Rate

Pentru Slew Rate am utilizat circuitul din laborator, la care a adaugat o sursa tip PULSE.

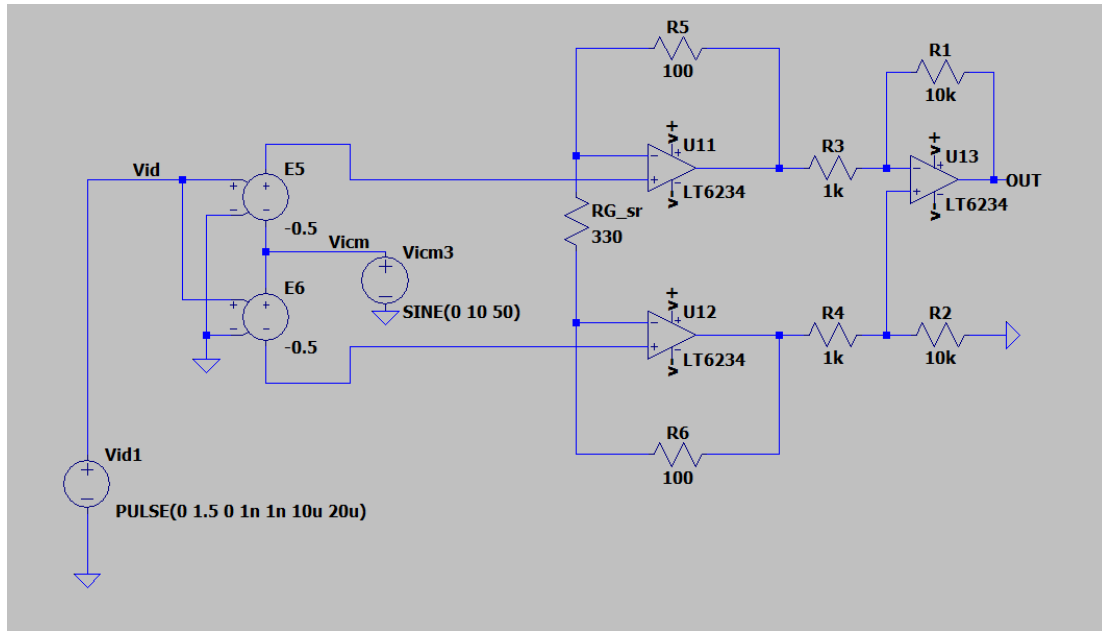


Figura 24: Circuitul pentru Slew-Rate

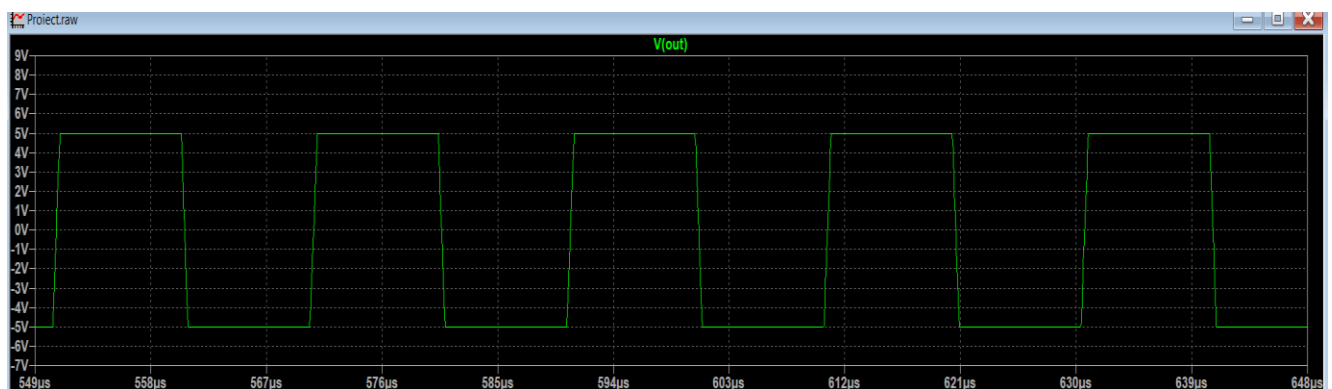


Figura 25: Plot Slew-Rate

### 3.1.3.2 Liniaritate

Pentru a vedea liniaritatea circuitului, am realizat o analiza Fourier de tipul:

**.FOUR 5k 10 V(Out\_et1)**

Figura 26: Analiza Fourier etaj I

Se pot observa in Spice Error Log rezultatele pentru THD<1%.

Harmonic Number	Frequency [Hz]	Fourier Component	Normalized Component	Phase [degree]	Normalized Phase [deg]
1	5.000e+3	4.977e-1	1.000e+0	90.07°	0.00°
2	1.000e+4	2.972e-5	5.970e-5	-46.61°	-136.68°
3	1.500e+4	2.161e-5	4.342e-5	-48.10°	-138.17°
4	2.000e+4	2.892e-5	5.809e-5	-19.65°	-109.71°
5	2.500e+4	4.314e-5	8.666e-5	61.21°	-28.86°
6	3.000e+4	4.254e-5	8.547e-5	150.38°	60.31°
7	3.500e+4	3.385e-5	6.801e-5	-121.44°	-211.51°
8	4.000e+4	2.368e-5	4.757e-5	22.74°	-67.32°
9	4.500e+4	1.186e-5	2.383e-5	115.73°	25.66°
10	5.000e+4	3.057e-5	6.143e-5	-111.18°	-201.25°
Partial Harmonic Distortion: 0.018674%					
Total Harmonic Distortion: 0.038025%					

Figura 27: Liniaritate etaj I

## 3.2 Caracterizarea etajului II

### 3.2.1 DCOP

#### 3.2.1.1 Punct static de functionare

La intrarea etajului II am adaugat o sursa de tensiune egala cu tensiunea de iesire a primului etaj. Pentru a vedea punctul static de functionare am rulat o analiza .op.

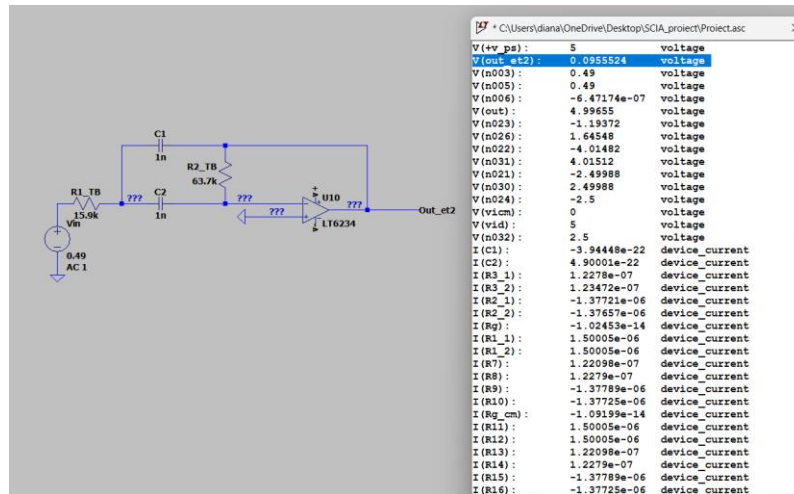


Figura 28: Punct static de functionare etaj II

### 3.2.2 AC

#### 3.2.2.1 Castig in banda de trecere

In specificatii, castigul linear al filtrului este egal cu 2, ceea ce se poate vedea si in analiza de tip AC.

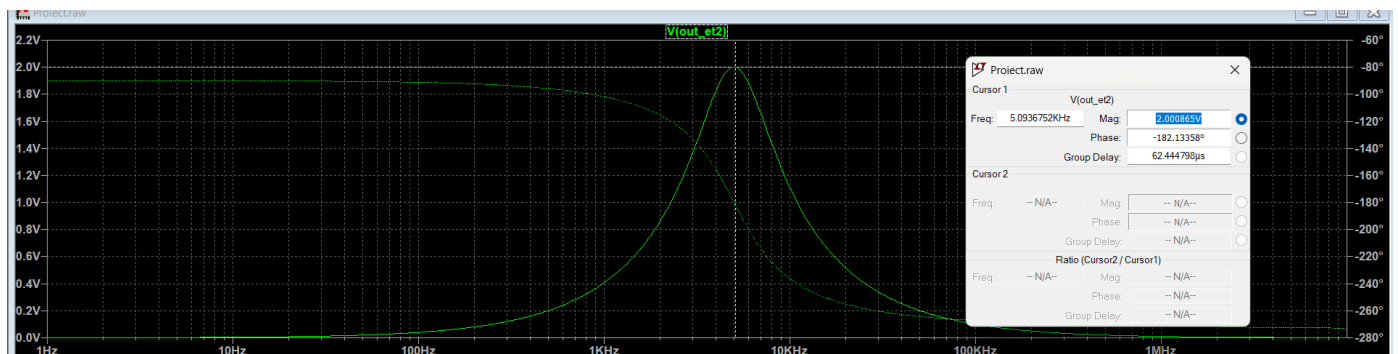


Figura 29: Castig in banda de trecere etaj II

### 3.2.2.2 Banda

Avand o frecventa  $f_0=5\text{kHz}$  si un factor de calitate  $Q=1$ , banda este egala, din calcule cu  $BW=5\text{kHz}$ .

$$f_0 = BW \cdot Q \Rightarrow BW = \frac{f_0}{Q} = \frac{5\text{kHz}}{1} = 5\text{kHz}$$

Pentru a o masura, am pozitionat cursoarele la o diferenta de -3dB fata de castig pe ambele parti.

Banda este aproximativ egala cu 5kHz:

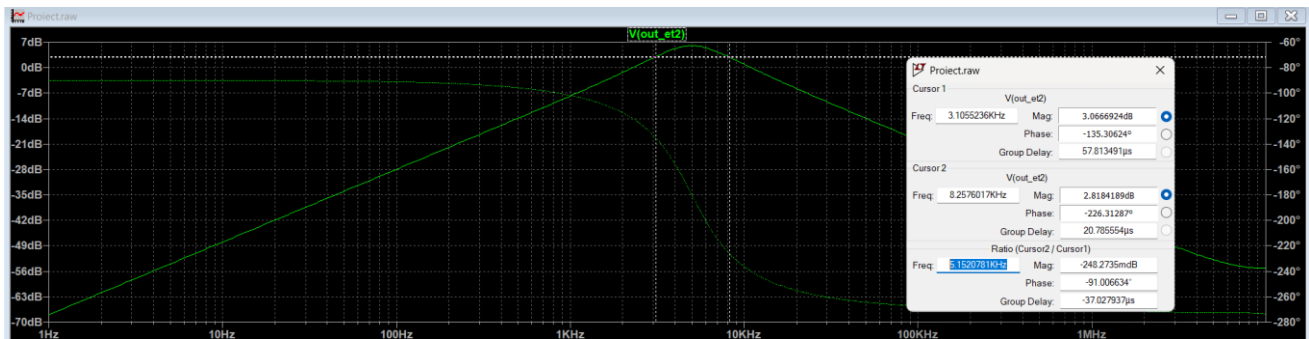


Figura 30: Banda etajului II

### 3.2.3 Transient

#### 3.2.3.1 Liniaritate

N-Period=1  
Fourier components of V(out\_et2)  
DC component:0.095609

Harmonic Number	Frequency [Hz]	Fourier Component	Normalized Component
1	5.000e+3	9.810e-1	1.000e+0
2	1.000e+4	9.560e-5	9.746e-5
3	1.500e+4	5.972e-5	6.087e-5
4	2.000e+4	6.232e-5	6.353e-5
5	2.500e+4	2.396e-5	2.442e-5
6	3.000e+4	2.588e-5	2.638e-5
7	3.500e+4	2.572e-5	2.621e-5
8	4.000e+4	4.085e-5	4.164e-5
9	4.500e+4	4.241e-5	4.323e-5
10	5.000e+4	1.474e-5	1.502e-5

Partial Harmonic Distortion: 0.015181%  
Total Harmonic Distortion: 0.036907%

Figura 31: Liniaritatea etajului II

### 3.3 Caracterizarea etajului III

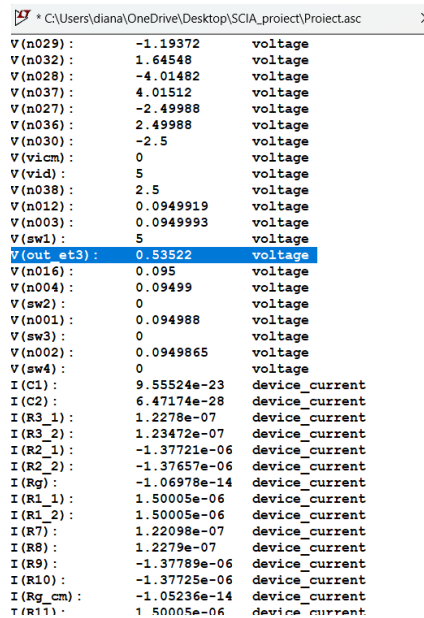
#### 3.3.1 DCOP

##### 3.3.1.1 Punct static de functionare

Am aplicat la intrarea PGA-ului tensiunea de iesire de la al doilea etaj, 95mV,

$$A = \frac{V_{out}}{V_{in}} \Rightarrow V_{out} = A \cdot V_{in}$$

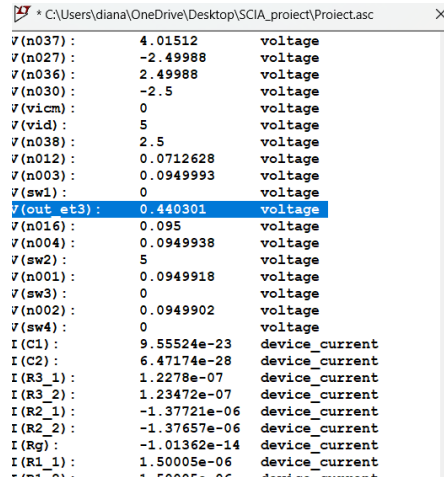
Pentru primul switch activ, tensiunea de iesire ar trebui sa fie egala cu  $V_{out1} = A1 \cdot 95m = 5 \cdot 95m = 0.475 V$ .



V(n029):	-1.19372	voltage
V(n032):	1.64548	voltage
V(n028):	-4.01482	voltage
V(n037):	4.01512	voltage
V(n027):	-2.49988	voltage
V(n036):	2.49988	voltage
V(n030):	-2.5	voltage
V(vicm):	0	voltage
V(vid):	5	voltage
V(n038):	2.5	voltage
V(n012):	0.0949919	voltage
V(n003):	0.0949993	voltage
V(sw1):	5	voltage
V(out_et3):	0.53522	voltage
V(n016):	0.095	voltage
V(n004):	0.09499	voltage
V(sw2):	0	voltage
V(n001):	0.094988	voltage
V(sw3):	0	voltage
V(n002):	0.0949865	voltage
V(sw4):	0	voltage
I(C1):	9.55524e-23	device_current
I(C2):	6.47174e-28	device_current
I(R3_1):	1.2278e-07	device_current
I(R3_2):	1.23472e-07	device_current
I(R2_1):	-1.37721e-06	device_current
I(R2_2):	-1.37657e-06	device_current
I(Rg):	-1.06978e-14	device_current
I(R1_1):	1.50005e-06	device_current
I(R1_2):	1.50005e-06	device_current
I(R7):	1.22098e-07	device_current
I(R8):	1.2279e-07	device_current
I(R9):	-1.37789e-06	device_current
I(R10):	-1.37725e-06	device_current
I(Rg_cm):	-1.05236e-14	device_current
I(R11):	1.50005e-06	device_current

Figura 32: Primul sw activ-dcop

Pentru al doilea switch,  $V_{out2} = A2 \cdot 95m = 4 \cdot 95m = 0.380 V$ .



V(n037):	4.01512	voltage
V(n027):	-2.49988	voltage
V(n036):	2.49988	voltage
V(n030):	-2.5	voltage
V(vicm):	0	voltage
V(vid):	5	voltage
V(n038):	2.5	voltage
V(n012):	0.0712628	voltage
V(n003):	0.0949993	voltage
V(sw1):	0	voltage
V(out_et3):	0.440301	voltage
V(n016):	0.095	voltage
V(n004):	0.0949938	voltage
V(sw2):	5	voltage
V(n001):	0.0949918	voltage
V(sw3):	0	voltage
V(n002):	0.0949902	voltage
V(sw4):	0	voltage
I(C1):	9.55524e-23	device_current
I(C2):	6.47174e-28	device_current
I(R3_1):	1.2278e-07	device_current
I(R3_2):	1.23472e-07	device_current
I(R2_1):	-1.37721e-06	device_current
I(R2_2):	-1.37657e-06	device_current
I(Rg):	-1.01362e-14	device_current
I(R1_1):	1.50005e-06	device_current
I(R1_2):	1.50005e-06	device_current

Figura 33: Al doilea sw activ-dcop

Activez switch-ul al treilea:  $V_{out3} = A3 \cdot 95m = 3.16 \cdot 95m = 0.3002 V$ .

```
* C:\Users\diana\OneDrive\Desktop\SCIA_project\Proiect.asc
V(n030):      -2.5      voltage
V(vicm):      0        voltage
V(vid):      5         voltage
V(n038):      2.5       voltage
V(n012):      0.0513202 voltage
V(n003):      0.0949993 voltage
V(sw1):      0         voltage
V(out_et3):   0.360527 voltage
V(n016):      0.095     voltage
V(n004):      0.0684102 voltage
V(sw2):      0         voltage
V(n001):      0.0949953 voltage
V(sw3):      5         voltage
V(n002):      0.0949938 voltage
V(sw4):      0         voltage
I(C1):      9.55524e-23 device_current
I(C2):      6.47174e-28 device_current
I(R3_1):     1.2278e-07  device_current
I(R3_2):     1.23472e-07 device_current
I(R2_1):     -1.37721e-06 device_current
I(R2_2):     -1.37657e-06 device_current
I(Rg):      -9.68154e-15 device_current
I(R1_1):     1.50005e-06 device_current
I(R1_2):     1.50005e-06 device_current
I(R7):      1.22098e-07  device_current
```

Figura 34: Al treilea sw acitiv-dcop

Pentru switch-ul 4,  $V_{out4} = A4 \cdot 95m = 2.5 \cdot 95m = 0.2375 V$ .

```
* C:\Users\diana\OneDrive\Desktop\SCIA_project\Proiect.asc
V(n029):      -1.19372  voltage
V(n032):      1.64548   voltage
V(n028):      -4.01482  voltage
V(n037):      4.01512   voltage
V(n027):      -2.49988  voltage
V(n036):      2.49988   voltage
V(n030):      -2.5      voltage
V(vicm):      0         voltage
V(vid):      5         voltage
V(n038):      2.5       voltage
V(n012):      0.0356313 voltage
V(n003):      0.0949993 voltage
V(sw1):      0         voltage
V(out_et3):   0.297766 voltage
V(n016):      0.095     voltage
V(n004):      0.0474968 voltage
V(sw2):      0         voltage
V(n001):      0.0659546 voltage
V(sw3):      0         voltage
V(n002):      0.0949966 voltage
V(sw4):      5         voltage
I(C1):      9.55524e-23 device_current
I(C2):      6.47174e-28 device_current
I(R3_1):     1.2278e-07  device_current
I(R3_2):     1.23472e-07 device_current
I(R2_1):     -1.37721e-06 device_current
I(R2_2):     -1.37657e-06 device_current
I(Rg):      -1.06176e-14 device_current
I(R1_1):     1.50005e-06 device_current
```

Figura 35: Al patrulea sw acitiv-dcop

### 3.3.2 AC

#### 3.3.2.1 Castigul

A1=14dB:

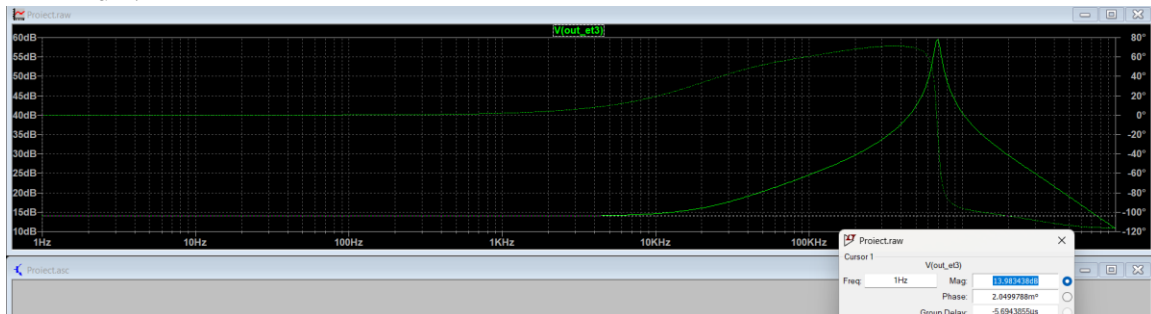


Figura 36: Castig etaj III-sw1 activ

A2=12dB:

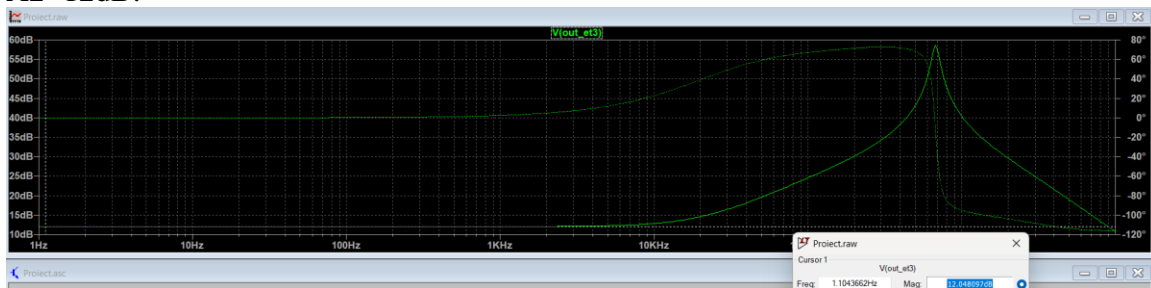


Figura 37: Castig etaj III-sw2 activ

A3=10dB:

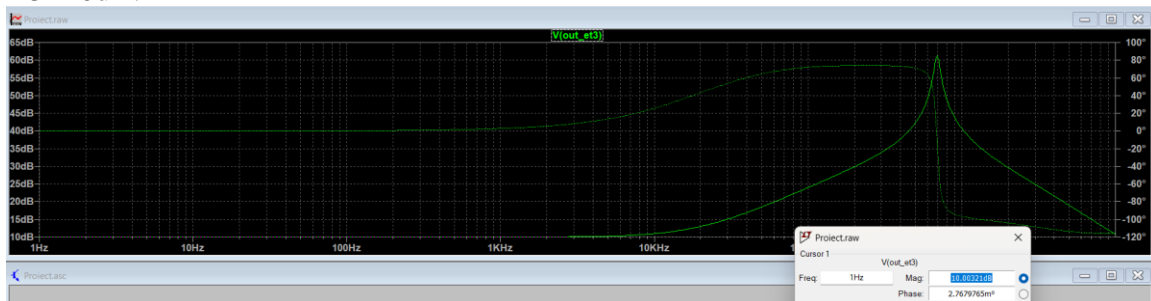


Figura 38: Castig etaj III-sw3 activ

A4=8dB

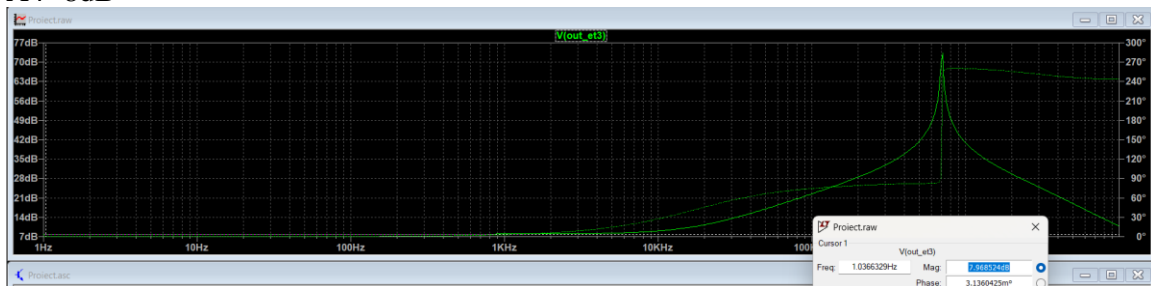


Figura 39: Castig etaj III-sw4 activ



### 3.3.2.2 Banda

Am masurat banda la diferenta dintre cursoare de  $-90^\circ$ .

Pentru primul switch activ:

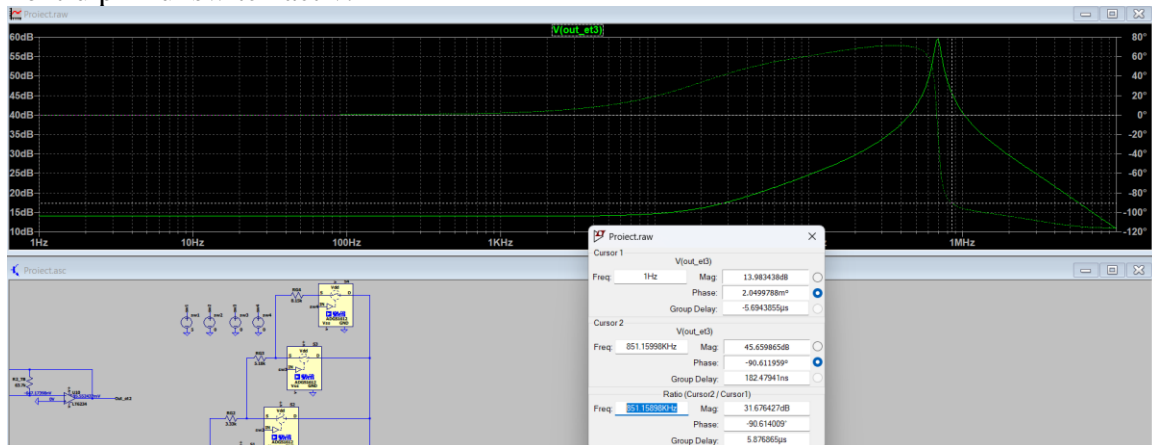


Figura 40: Banda PGA>banda filtru sw1 activ

Al doilea switch activ:

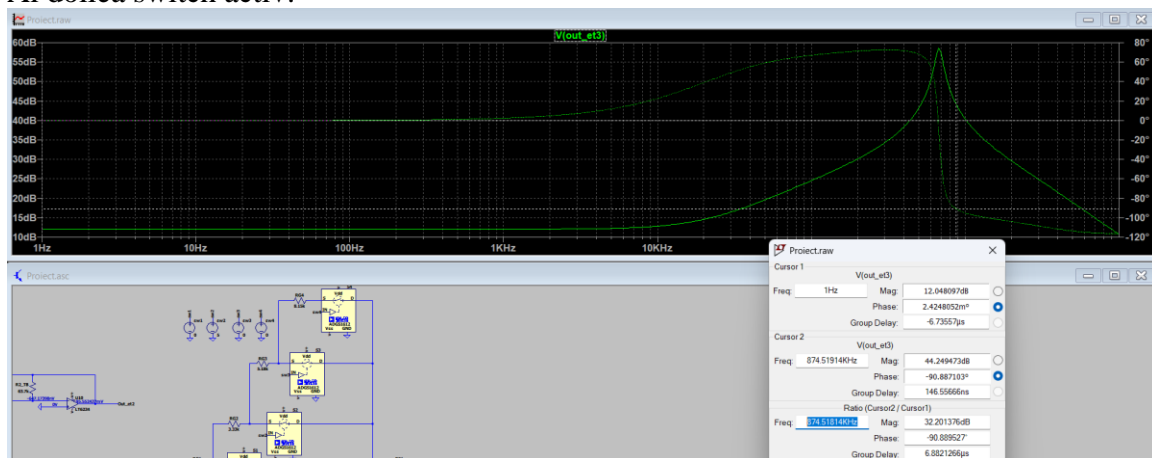


Figura 41: Banda PGA>Banda filtru sw2 activ

Al treilea switch activ:

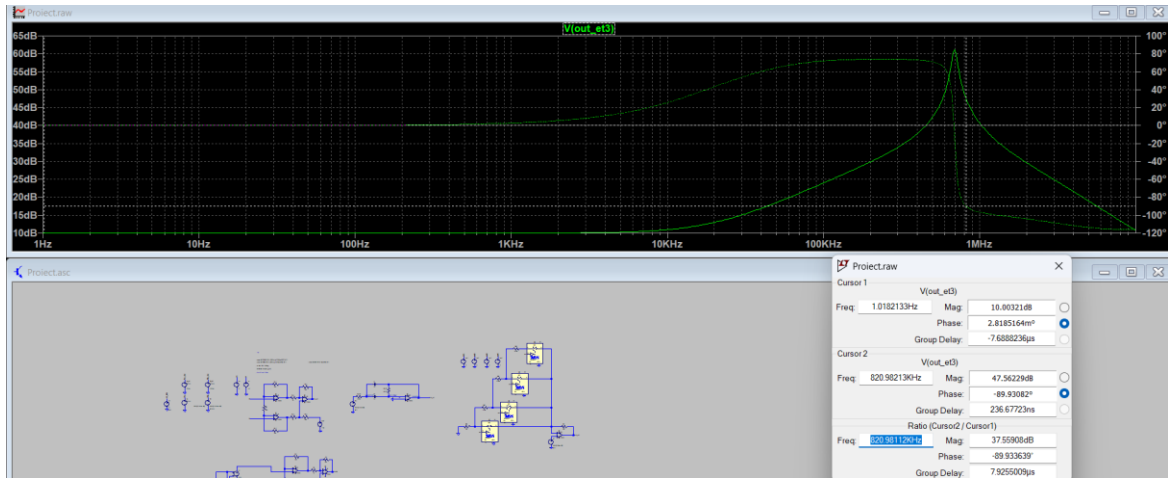


Figura 42: Banda PGA > Banda filtru sw3 activ

Pentru switch-ul 4 activ:

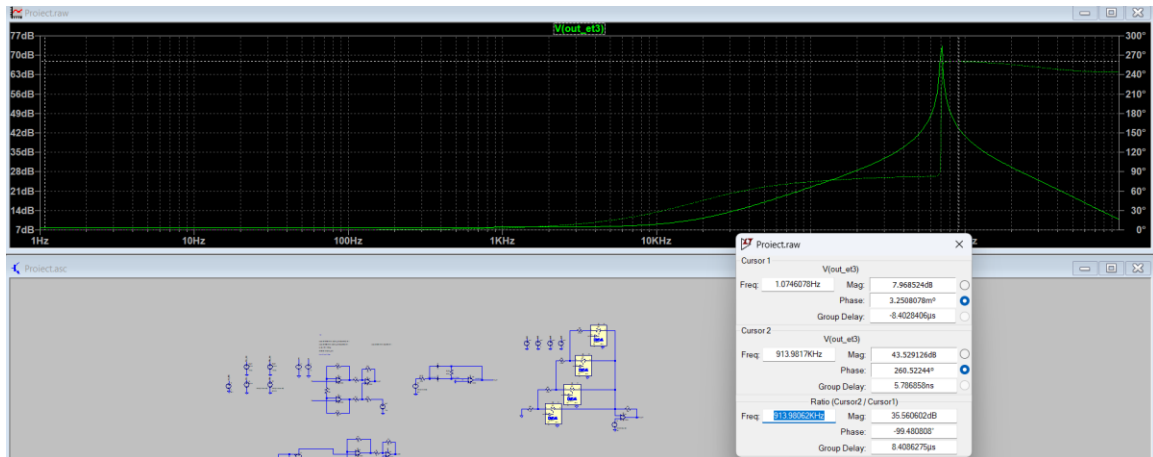


Figura 43: Banda PGA > Banda filtru sw4 activ

### 3.3.3 Transient

#### 3.3.3.1 Liniaritate

Pentru a vedea liniaritatea, am folosit PGA-ul proiectat cu switch uri ideale:

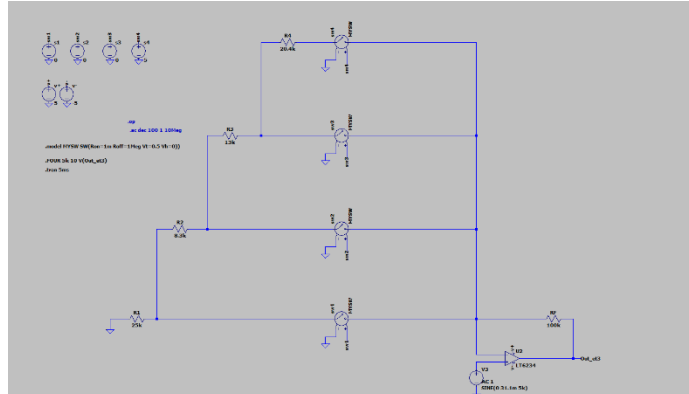


Figura 44: PGA cu switch uri ideale

Pentru castigul maxim:

N-Period=1  
Fourier components of V(out\_et3)  
DC component:0.150002

Harmonic Number	Frequency [Hz]	Fourier Component	Normalized Component	Phase [degree]	Normalized Phase [deg]
1	5.000e+3	3.575e-3	1.000e+0	89.91°	0.00°
2	1.000e+4	1.731e-6	4.842e-4	145.84°	55.93°
3	1.500e+4	3.406e-6	9.526e-4	-165.88°	-255.78°
4	2.000e+4	2.616e-6	7.318e-4	85.79°	-4.11°
5	2.500e+4	2.869e-6	8.024e-4	-122.37°	-212.28°
6	3.000e+4	1.747e-6	4.886e-4	75.11°	-14.80°
7	3.500e+4	2.205e-6	6.166e-4	-109.89°	-199.80°
8	4.000e+4	1.640e-6	4.586e-4	-3.53°	-93.44°
9	4.500e+4	2.812e-6	7.865e-4	-125.95°	-215.85°
10	5.000e+4	1.741e-6	4.871e-4	9.18°	-80.73°

Partial Harmonic Distortion: 0.200162%  
Total Harmonic Distortion: 0.355930%

Figura 45: THD<1% castig maxim

Pentru castig minim:

N-Period=1  
Fourier components of V(out\_et3)  
DC component:0.150003

Harmonic Number	Frequency [Hz]	Fourier Component	Normalized Component	Phase [degree]	Normalized Phase [deg]
1	5.000e+3	3.585e-3	1.000e+0	90.14°	0.00°
2	1.000e+4	1.050e-5	2.930e-3	-130.25°	-220.39°
3	1.500e+4	8.116e-6	2.264e-3	19.80°	-70.33°
4	2.000e+4	1.549e-5	4.321e-3	136.59°	46.45°
5	2.500e+4	2.112e-5	5.892e-3	-41.11°	-131.24°
6	3.000e+4	9.360e-6	2.611e-3	75.81°	-14.33°
7	3.500e+4	1.191e-5	3.322e-3	-7.03°	-97.17°
8	4.000e+4	5.238e-6	1.461e-3	29.11°	-61.03°
9	4.500e+4	1.393e-6	3.885e-4	46.81°	-43.33°
10	5.000e+4	1.261e-6	3.517e-4	60.22°	-29.92°

Partial Harmonic Distortion: 0.934658%  
Total Harmonic Distortion: 0.954886%

Figura 46: THD<1% castig minim

### 3.4 Carcaterizarea etajului IV

#### 3.4.1 DCOP

##### 3.4.1.1 Punct static de functionare

Am realizat o analiza de tip .op:

```
C:\Users\diana\OneDrive\Desktop\SCIA_proiect\Proiect.asc
V(sw3): 0 voltage
V(n002): -6.47085e-07 voltage
V(sw4): 0 voltage
V(vin): 0 voltage
V(out_et4): 0.0149822 voltage
V(n017): -6.47194e-07 voltage
V(n013): -7.28856e-07 voltage
V(n018): 7.68523e-06 voltage
V(vo): 0.289569 voltage
I(C1): 9.55524e-23 device_current
I(C2): 6.47174e-28 device_current
I(D1): -2.51606e-09 device_current
I(D2): 1.49915e-06 device_current
I(R3_1): 1.2278e-07 device_current
I(R3_2): 1.23472e-07 device_current
I(R2_1): -1.37721e-06 device_current
I(R2_2): -1.37657e-06 device_current
I(Rg): -1.09488e-14 device_current
I(R1_1): 1.50005e-06 device_current
I(R1_2): 1.50005e-06 device_current
I(R7): 1.22098e-07 device_current
I(R8): 1.2279e-07 device_current
I(R9): -1.37789e-06 device_current
I(R10): -1.37725e-06 device_current
I(Rg_cm): -1.0885e-14 device_current
I(R11): 1.50005e-06 device_current
I(R12): 1.50005e-06 device_current
I(R13): 1.22098e-07 device_current
I(R14): 1.2279e-07 device_current
I(R15): 1.2279e-07 device_current
```

Figura 47: analiza OP etajul 4

#### 3.4.2 DC SWEEP

##### 3.4.2.1 Castig

Pentru a vedea castigul liniar al etajului 4, am folosit o analiza de tip DC SWEEP cu urmatoorii parametri:

```
.dc V3 -5 5 0.1
```

Figura 48: Parametrii DC SWEEP

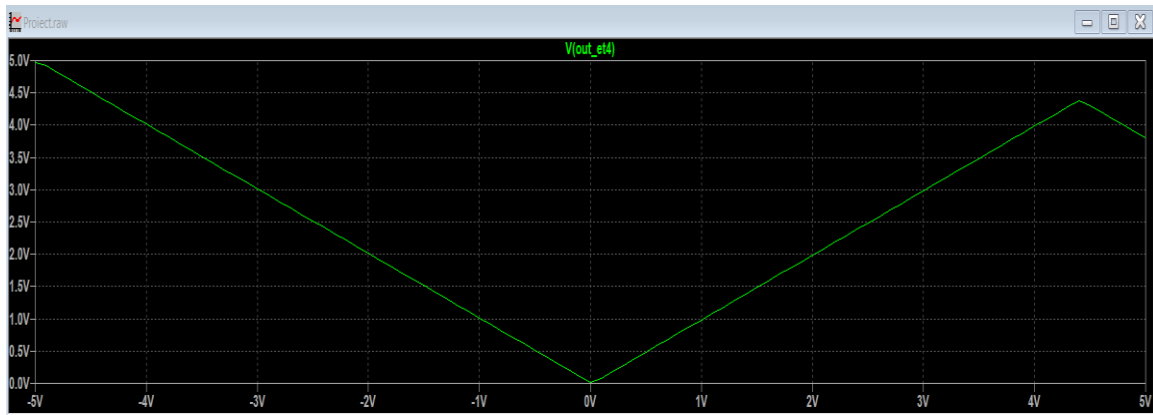


Figura 49: DC SWEEP etajul 4

Caracteristica din simulare respecta expresia tensiunii de iesire:

$$V_{out} = \begin{cases} -A \cdot V_{in}, & V_{in} < 0 \\ A \cdot V_{in}, & V_{in} > 0 \end{cases}$$

Castigul, pe ambele parti, este aproximativ egal cu 1, precum in specificatii:

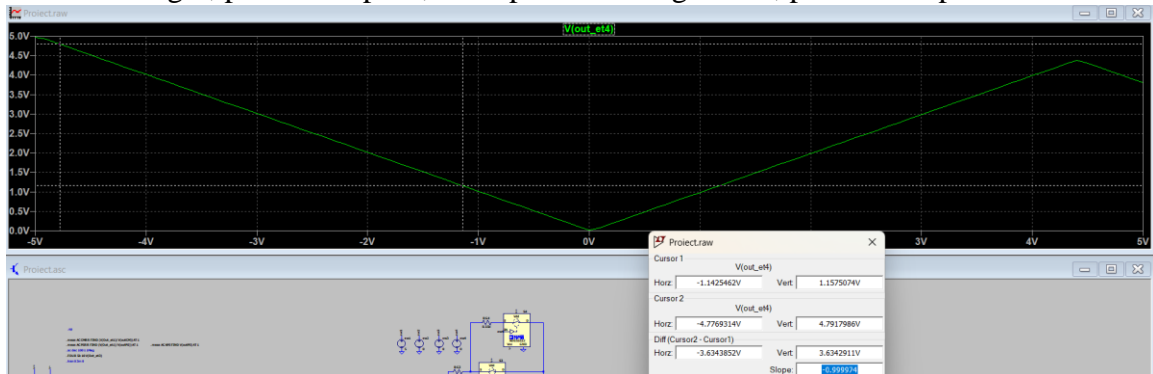


Figura 50: Castig=1

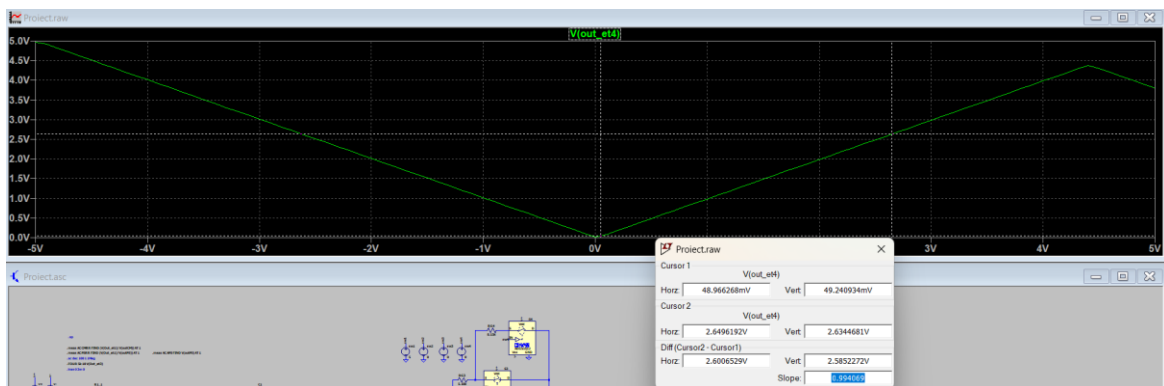


Figura 51: Castig=1

### 3.4.3 Transient

#### 3.4.3.1 Implementare functie de circuit

Graficul din poza respecta, de asemenea, expresia tensiunii de iesire. Pentru o intrare pozitiva, tensiunea de iesire este egala cu tensiunea de intrare, castigul fiind 1, iar pentru o tensiune de intrare negative, iesirea este egala cu  $-V_{in}$ .

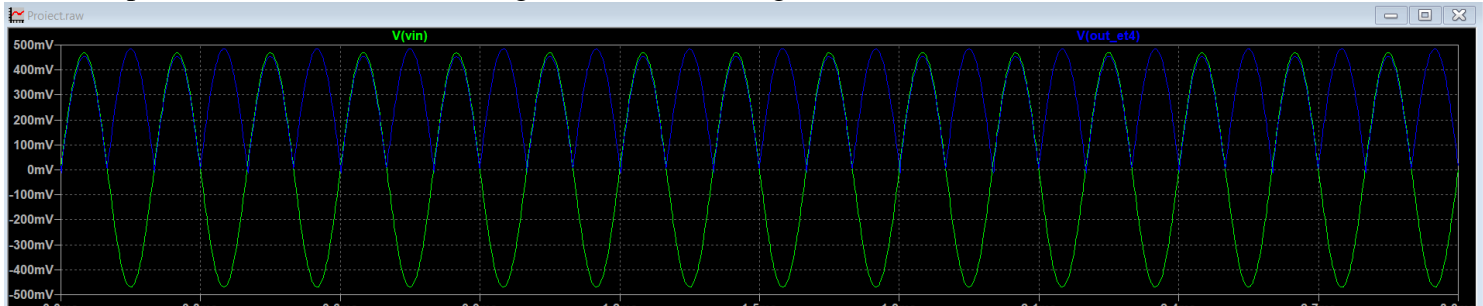


Figura 52: Implementare functie de circuit etajul 4

#### 3.4.4 Domeniu de liniaritate

Pentru alternanta pozitiva,  $V_{in}$  maxim:

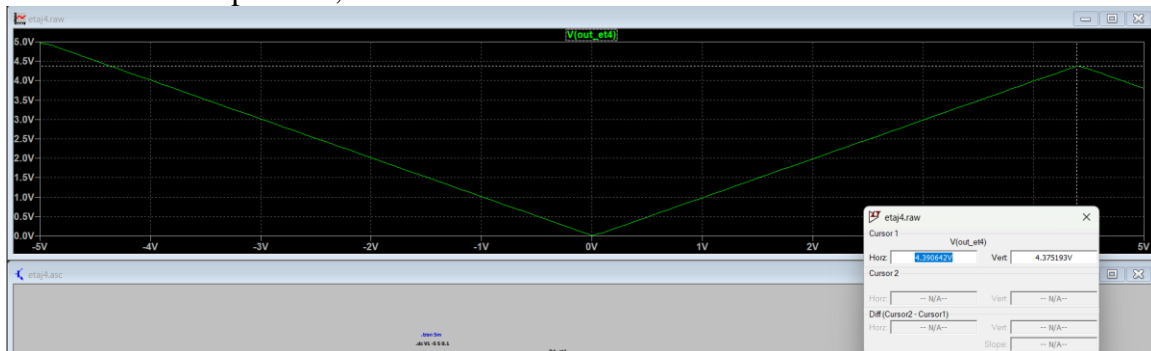


Figura 53: Alternanta pozitiva,  $v_{in}$  maxim

Pentru alternanta negativa:

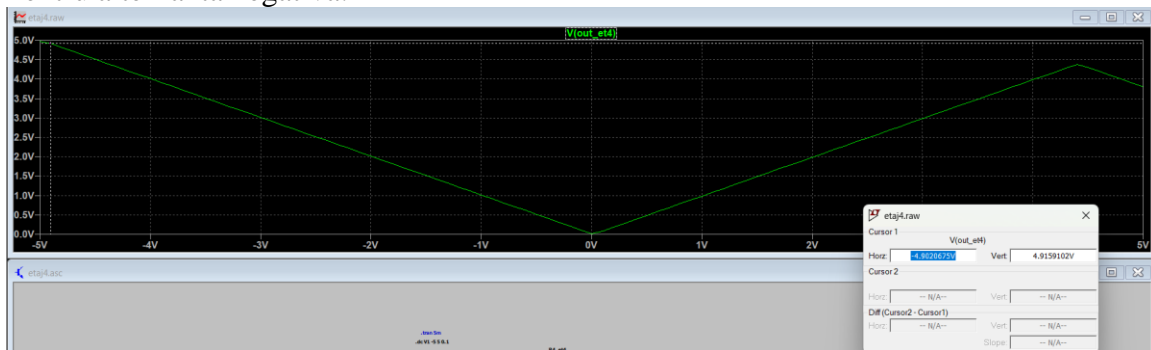


Figura 54: Alternanta negativa

## 4 CONCLUZIE

	<b>SPECIFICATII</b>		<b>SIMULARI</b>	
<b>ETAJ 1</b>	Castig liniar		Castig liniar	
	16		16.059	
<b>ETAJ 2</b>	Castig liniar	Banda	Castig liniar	Banda
	2	5k	2.00086	5.1520k
<b>ETAJ 3</b>	Castig minim(dB)	Castig maxim(dB)	Castig minim(dB)	Castig maxim(dB)
	8 dB	14 dB	7.96 dB	13.98 dB
<b>ETAJ 4</b>	Castig liniar		Castig liniar	
	1		0.99	

*Tabelul 4: Concluzie*

