Universitatea Tehnică din Cluj-Napoca
Facultatea de Electronică, Telecomunicații și Tehnologia Informației

Proiect SCIA

Student:Rad Amalia-Maria

Specializare: Electronică Aplicată, anul 3

Îndrumător proiect: PhD Student Vladu Eduard

Profesor curs: Conf.Dr.Ing. Neag Marius

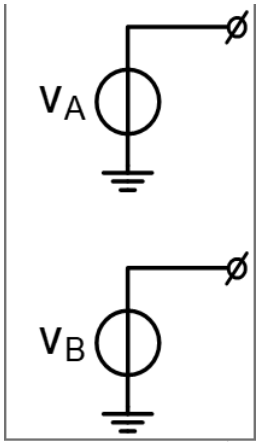
Cuprins

1.Specificații de proiectare

1.1 Etajul 1- AI reacție pasivă de curent

Sursă semnal

->tesniune diferențială



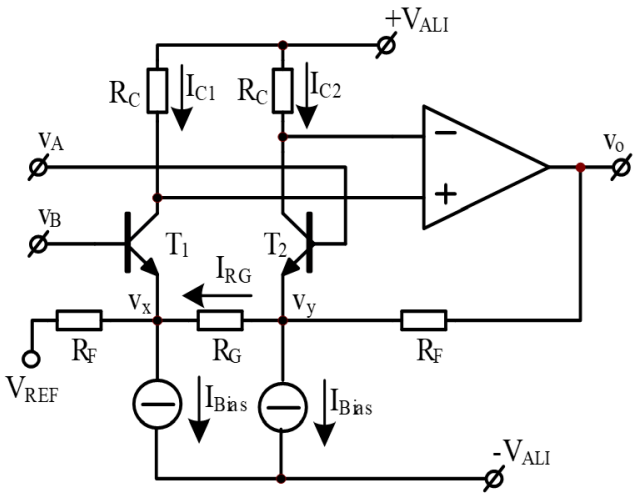
Amplitudine minimă(pentru câștig maxim PGA): 6.73E-02

Amplitudine maximă(pentru câștig minim PGA):2,68E-01

Unitate măsură:V-diferențial

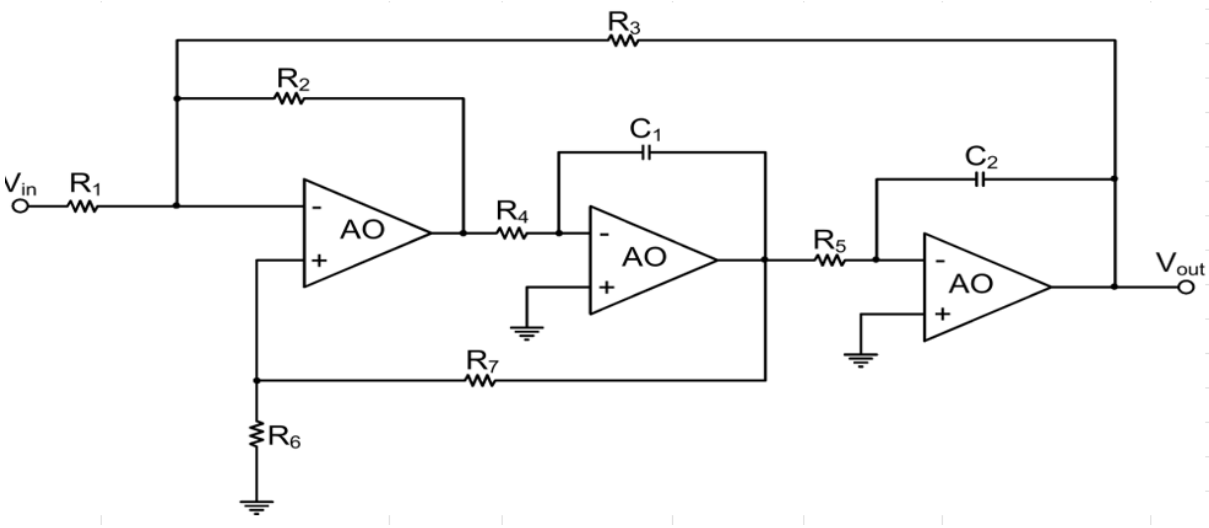
Câștig liniar: 10

Tip etaj 1-10



1.2 Etajul 2-Low Pass 3 AO V-V

KHN



|H0| câștig liniar în banda de trecere: 1

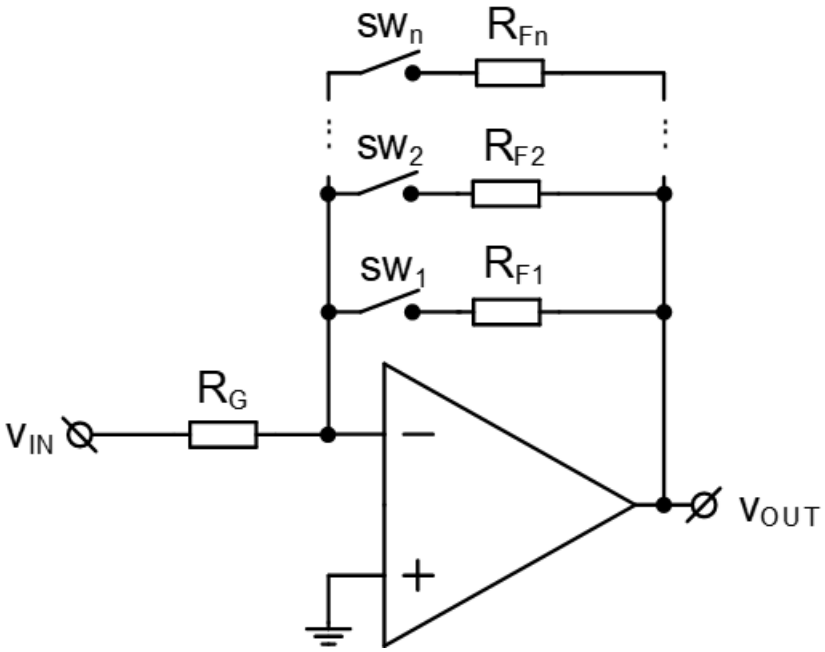
$Rin_{min} = 2E + 03$

$Banda = 2E + 03$

$Q = 1.73$

1.3 Etajul 3- AO inversor cu switch-uri in calea de semnal, conexiune in paralel

Tip etaj: 1



Câștig minim[dB]=7

Rezoluție(pas minim)[dB]=3

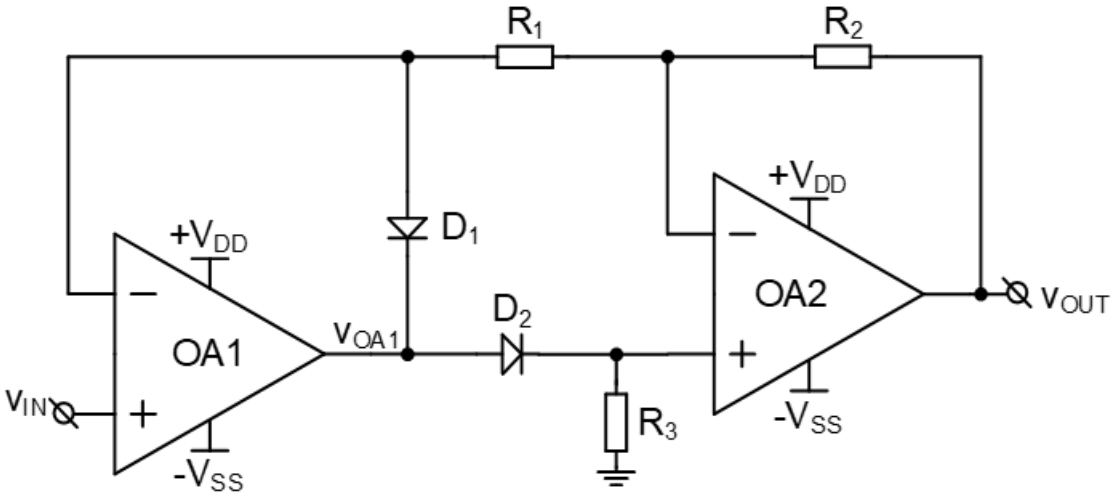
Număr pași:5

Câștig maxim[dB]=19

$Rin_{min} = 4E + 03$

1.4 Etajul 4- Redresor de precizie

Tip etaj-7

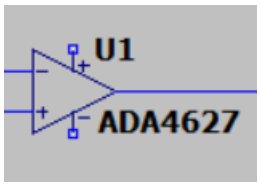


|Câștig| linear: 1

1.5 AO

Tip AO: ADA4627

Tensiuni de alimentare: $\pm 15V$



2.Dimensionarea circuitului

2.1. Dimensionare AI cu reacție pasivă de curent

$V^+ = V^-$ (1)

$\frac{VCC-V^-}{R_2} = I_{C1}$ (2)

$\frac{VCC-V^+}{R_1} = Ic2$ (3)

Din (1),(2) și (3)=> $I_{C1} = I_{C2} => V_{BE1} = V_{BE2}$

$V_{BE1} = V_B - V_X$ (1')

$V_{BE2} = V_A - V_Y$ (2')

$V_{BE1} = V_{BE2}$ (3')

Din (1'),(2') si (3') => $V_A - V_B = V_Y - V_X$

$I_{RG} = \frac{V_{OUT}-V_{REF}}{R_{Fa}+R_{Fb}+R_G}$ (1'')

$I_{RG} = \frac{V_Y-V_X}{R_G}$ (2'')

Din (1'') si (2'') =>$V_{OUT} = (V_A - V_B) * \left(1 + 2 * \frac{R_F}{R_G}\right) + V_{REF}$

$$A_V = \frac{V_{OUT}}{V_{ID}} = \frac{V_{OUT}}{V_A - V_B} = 1 + 2 * \frac{R_F}{R_G}$$

$$A_V = 10 => 9 = 2 * \frac{R_F}{R_G} => \frac{R_F}{R_G} = 4.5$$

$R_F = 20.25k(valoare\ standrdizata)$

$R_G = 4.5k\ (valoare\ standardizata)$

2.2 Dimensionare filtru KHN

$$Setam\ R_1 = R_2 = \cdots = R_7 = R => H_0 = 1; \omega_0 = \frac{1}{R\sqrt{C_1 C_2}}; Q = \frac{2}{3}\sqrt{\frac{C1}{C2}}$$

$$C_1 = \frac{3Q}{2\omega 0 R}$$

$$C_2 = \frac{2}{3Q\omega 0 R}$$

f0 [Hz]	w0[rad/sec]	Q	H0[V/V]
2,00E+03	1,26E+04	1,73E+00	1,00E+00
	varianta 1		
	C1[F]	set C2[F]	set R[ohm]
	1,03E-07	1,53E-08	2,00E+03

2.3 Dimensionare PGA-Switch-uri in calea de semnal, conexiune în paralel

AO-inversor=>$A_v = -\frac{R_F}{R_G}$

$A_{minim} = 7dB$

$A_{maxim} = 19\ dB$

$Pas\ minim\ (rezolutie) = 3dB$

$Numar\ pasi: 5$

$Rin_{min} = 4k\Omega$

$A_v = \{7,10,13,16,19\}[dB]$

Formula de transformare din dB in liniar:

$A_{lin} = 10^{\frac{AdB}{20}}$

$Pentru\ A = 7dB => A = 2.23\ {}^{V}/_{V}$

$Pentru\ A = 10dB => A = 3.16\ {}^{V}/_{V}$

$Pentru\ A = 13dB => A = 4.5\ {}^{V}/_{V}$

$Pentru\ A = 16dB => A = 6.3\ {}^{V}/_{V}$

$Pentru\ A = 19dB => A = 8.9\ {}^{V}/_{V}$

$A_V = \{2.23; 3.16; 4.5; 6.3; 8.9\}\ {}^{V}/_{V}$

1.

$SW_1 - ON, SW_2, SW_3, SW_4, SW_5 - OFF$

$R_{IN} = R_G => R_G = 4E + 03$

Lucram in modul=>$|A| = \frac{R_F}{R_G}$

$2.23 = \frac{R_F}{4} => R_F = 8.92k\Omega$

2.

$SW_2 - ON, SW_1, SW_3, SW_4, SW_5 - OFF$

$R_{IN} = R_G => R_G = 4E + 03$

Lucram in modul=>$|A| = \frac{R_F}{R_G}$

$3.16 = \frac{R_F}{4} => R_F = 12.64k\Omega$

3.

$SW_3 - ON, SW_1, SW_2, SW_4, SW_5 - OFF$

$R_{IN} = R_G => R_G = 4E + 03$

Lucram in modul=>$|A| = \frac{R_F}{R_G}$

$4.5 = \frac{R_F}{4} => R_F = 18k\Omega$

4.

$SW_4 - ON, SW_1, SW_2, SW_3, SW_5 - OFF$

$R_{IN} = R_G => R_G = 4E + 03$

Lucram in modul=>$|A| = \frac{R_F}{R_G}$

$6.3 = \frac{R_F}{4} => R_F = 25.2k\Omega$

5.

$SW_5 - ON, SW_1, SW_2, SW_3, SW_4 - OFF$

$R_{IN} = R_G => R_G = 4E + 03$

Lucram in modul=>$|A| = \frac{R_F}{R_G}$

$8.9 = \frac{R_F}{4} => R_F = 35.6k\Omega$

2.4 Dimensionare Redresor Dubla Alternanta

Cazul 1

Presupunem ca $D_1 \; si \; D_2 - OFF$

$V_{IN} \downarrow V_{SS}$

$V_1^+ \downarrow V_{SS}$

$V_1^- = 0$

$Deoarece \; V_2^- = V_2^+ = 0$

Din ecuatiile de mai sus =>

$V_1^+ < V_1^- => \; V_{OA} \downarrow V_{SS} => D_1 - ON \; si \; D_2 - OFF$

Avem reactie negativa in jurul lui AO1 prin D_1

$V_1^- = V_1^+ = V_{IN}$

$i_{R1} = i_{R2} = \frac{V_{IN}}{R_1}$

$V_2^- = V_2^+$=0

$V_{OUT} = 0 - i_{R2} * R_2 => V_{OUT} = -\frac{R_2}{R_1} * V_{IN}$

$i_{D1} = i_{R1} = \frac{V_{IN}}{R_1}$

$D_1 - ON <=> i_{D1}$>0

Din ultimele doua ecuatii => $V_{IN} < 0$

=>$V_{OUT} = -\frac{R_2}{R_1} * V_{IN}, V_{IN} < 0$

Cazul 2

Presupunem ca $D_1 \; si \; D_2 - OFF$

$V_{IN} \uparrow V_{DD}$

$V_1^+ \uparrow V_{DD}$

$V_1^- = 0$

Deoarece $V_2^- = V_2^+ = 0$

Din ecuatiile de mai sus =>

$V_1^+ > V_1^- => V_{OA} \uparrow V_{DD} => D_1 - OFF \; si \; D_2 - ON$

Avem reactie negativ in jurul AO1 prin $R_1 \; si \; D_2$

$V_1^- = V_1^+ = V_{IN}$ (1)

$i_{R1} = 0$ (2)

($\nexists \; ochi \; de \; circuit$)

$V_2^+ = V_2^-$ (3)

Din 1,2,3 => $V_2^- = V_{IN}$ (4)

$i_{R2} = 0$ (5)

($\nexists \; ochi \; de \; circuit$)

Din 4 si 5 => $V_{OUT} = V_{IN}$

$i_{D2} = i_{R3} = -\frac{V_{IN}}{R3}$ (6)

$D_2 - ON <=> \; i_{D2} > 0$ (7)

Din 6 si 7 => $V_{IN} > 0$

$=> V_{OUT} = V_{IN}, V_{IN} > 0$

$$V_{OUT} = \begin{cases} V_{IN}, & V_{IN} > 0 \\ -\frac{R_2}{R_1} * V_{IN}, & V_{IN} < 0 \end{cases}$$

Egalam $\frac{R_2}{R_1} = 1$ => $R_1 = R_2 = R$

Aleg R=20kΩ

Aleg $R_3 = 1k\Omega$

$V_{OA} = V_{IN} - V_D, \; V_{IN} > 0$ (1)

$V_{OA} = -V_{IN} + V_D, \quad V_{IN} < 0$ (2)

Tensiunea de saturatie pentru ADA4627: $V_{OA} = 5V\ (datasheet)$

$V_D = 0.6V$

Din (1) => 5V=$V_{IN} - 0.6V$

=>$V_{IN} = 5 + 0.6$

=>$V_{IN} = 5.6V$

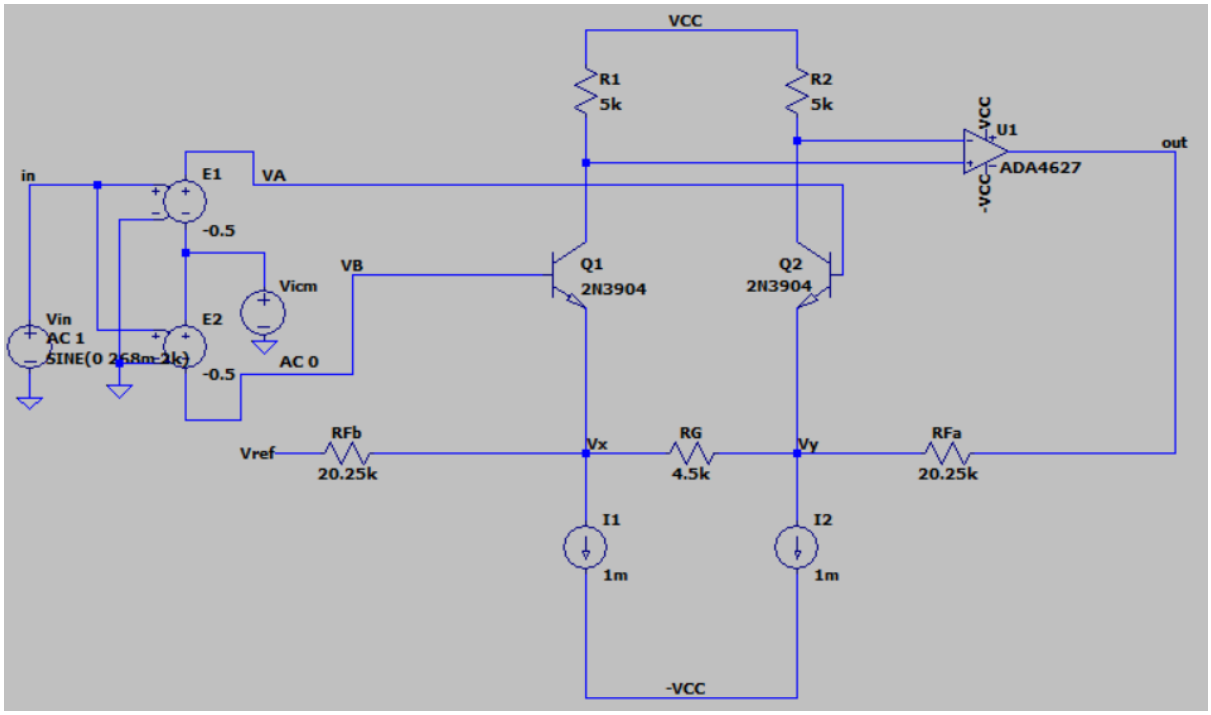
Din (2) => $5V = -V_{IN} + 0.6V$

=>$V_{IN} = 5 - 0.6$

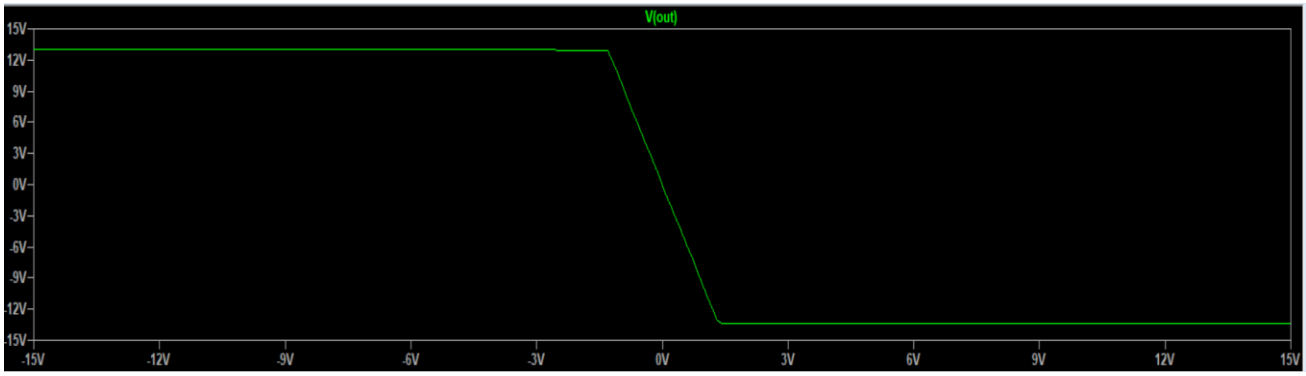
=>$V_{IN} = 4.4V$

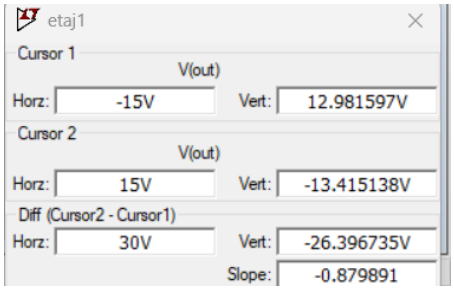
3.Simulari

3.1. Simulari pentru primul etaj



1.Analiza DCOP



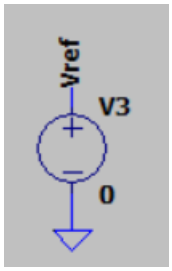


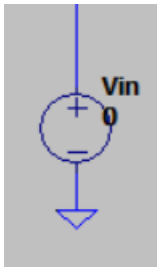
PSF

```
        --- Operating Point ---

V(n002):        10.1756         voltage
V(n001):        10.1754         voltage
V(-vcc):        -15             voltage
V(vcc):         15              voltage
V(out):         -0.000855788    voltage
V(vx):          -0.6519         voltage
V(vref):        0               voltage
V(vy):          -0.651901       voltage
V(vb):          0               voltage
V(va):          0               voltage
V(n003):        0               voltage
V(in):          0               voltage
```

Compensare/ajustare nivel DC la iesire:

Pentru compensarea nivelului DC la iesirea din circuit am setat toate sursele 0 si am observant valorea tensiunii de iesire in acest caz:

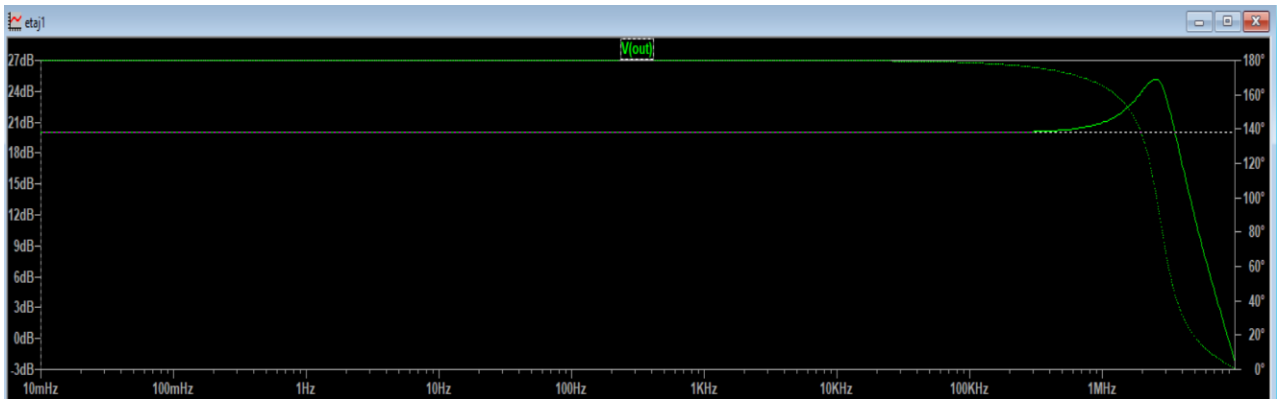


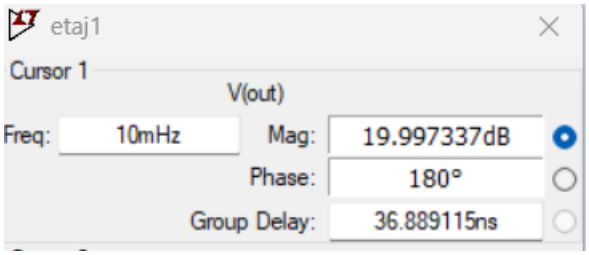



```
V(out):         -0.000855788    voltage
```

2.Analiza AC

Castigul la joasa frecventa

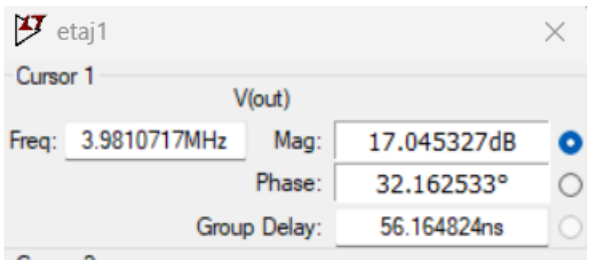




$A_{dB} \approx 20dB$

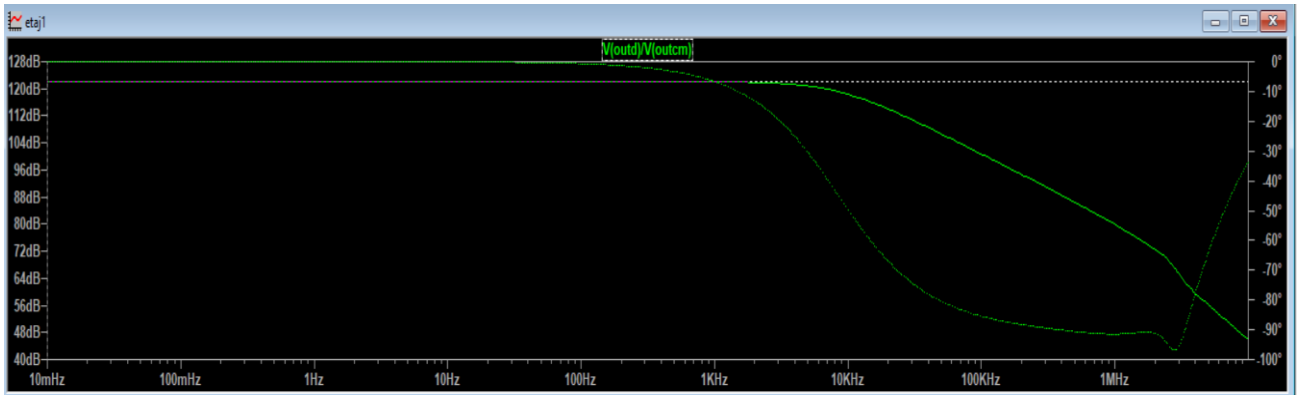
$$A_{lin} = 10^{\frac{A_{dB}}{20}} \approx 10$$

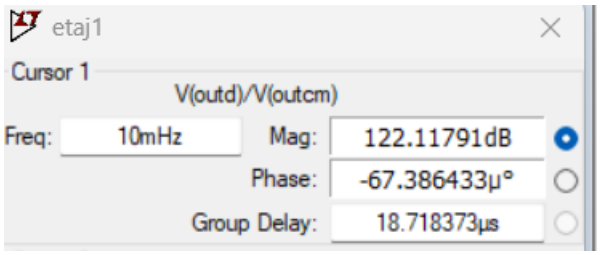
Banda > banda filtru(2k)



CMRR

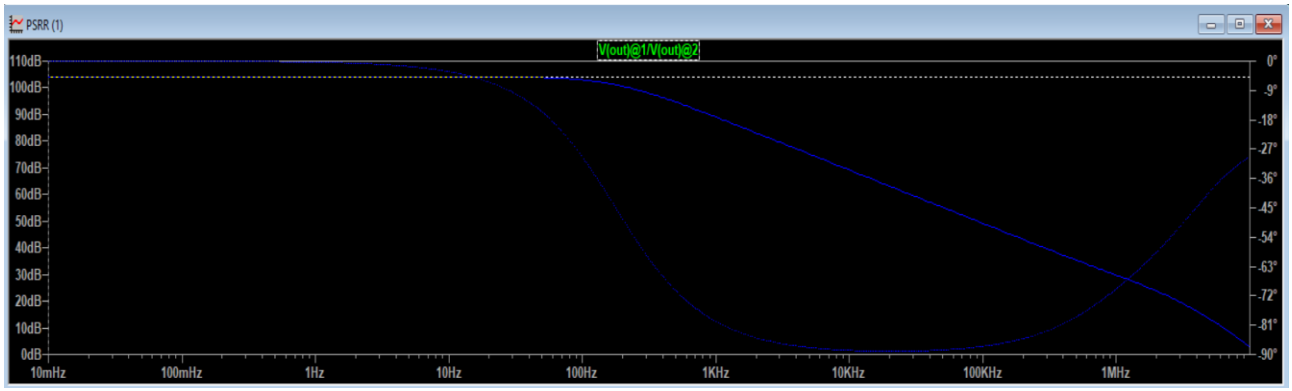
Tipic pentru ADA4627=116dB

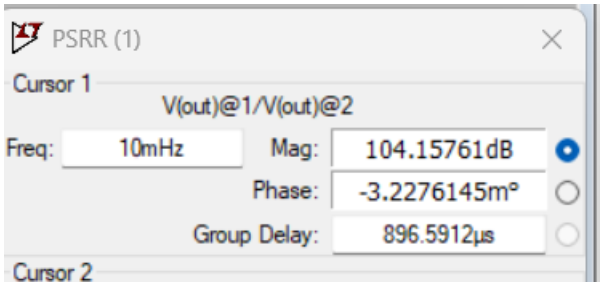




PSRR

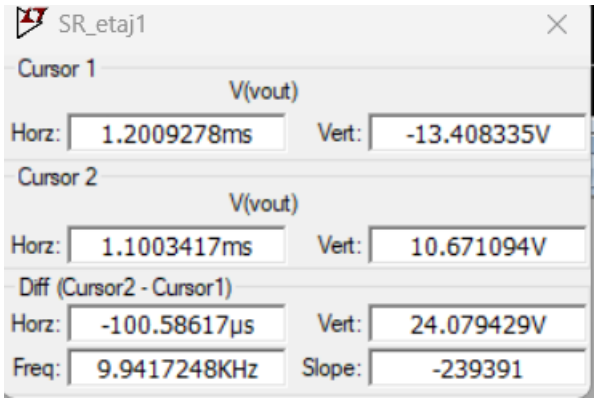
Tipic pentru ADA4627:112dB





3.Analiza Transient

SR



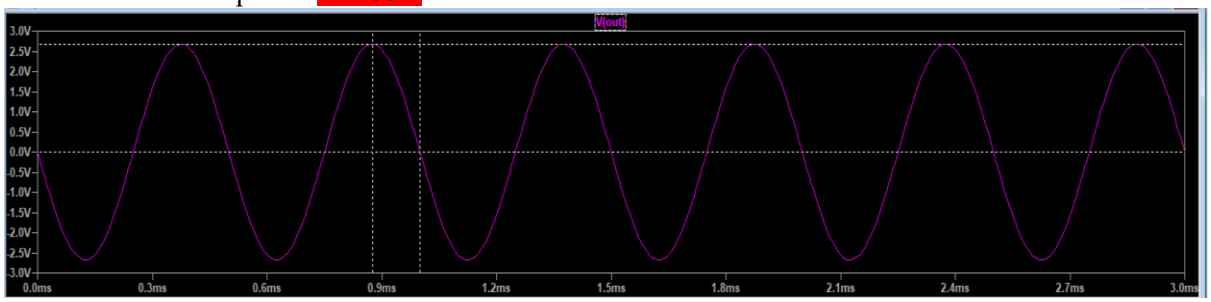
$$SR = \frac{24{,}079429V}{100{,}58617us} = 0{,}23\ [\frac{V}{us}]$$

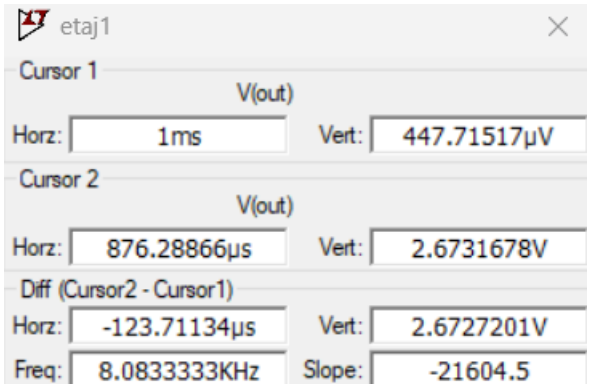
SR calculat:

$$SR = \frac{\Delta Vout}{\Delta t} = A_1 * V_{INmax} * sin2\pi f_0 t = 268mV * 2\pi * 2k = 3366V * Hz = 3366V/s$$

SR=0.003366V/us

Tensiunea de iesire pentru A=268m este:

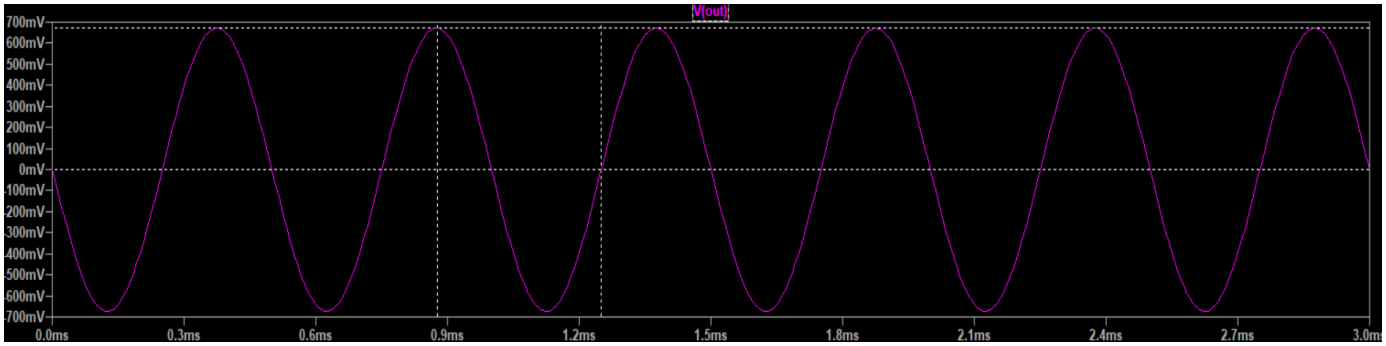


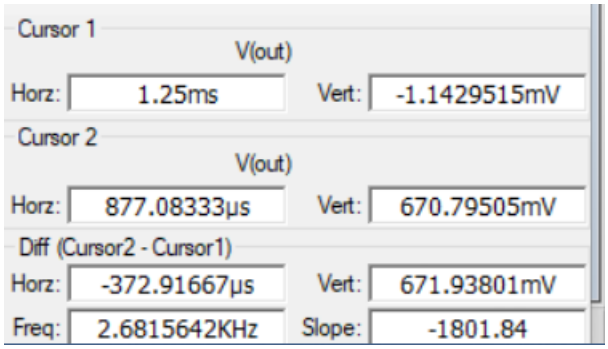


$V_{OUT} \approx 2.6V$

```
Partial Harmonic Distortion: 0.014094%
Total Harmonic Distortion:   0.045455%
```

Tensiunea de iesire pentru A=67.3V este:

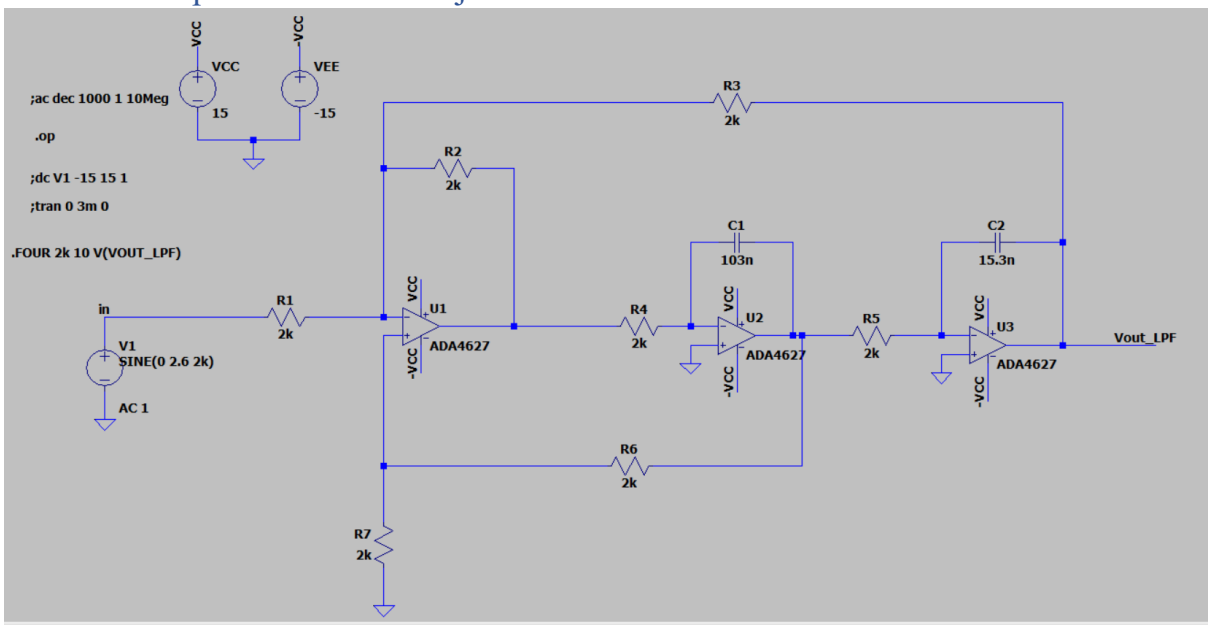




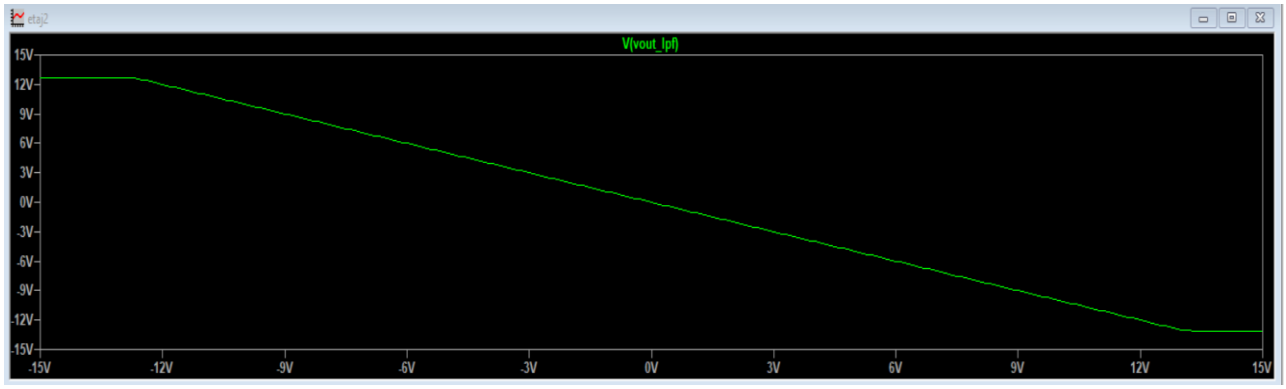
$V_{OUT} \approx 671mV$

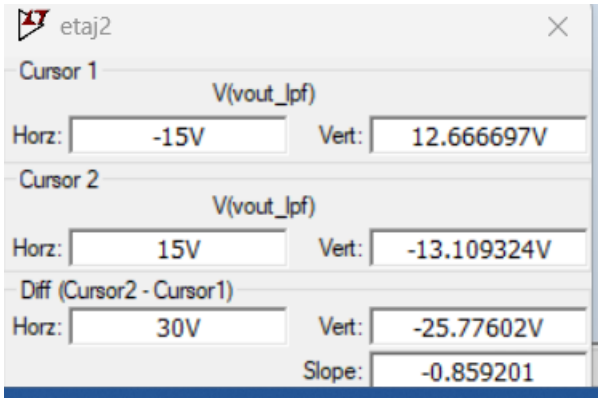
```
Partial Harmonic Distortion: 0.032009%
Total Harmonic Distortion:   0.054935%
```

3.2. Simulări pentru al doilea etaj



1.Analiza DCOP





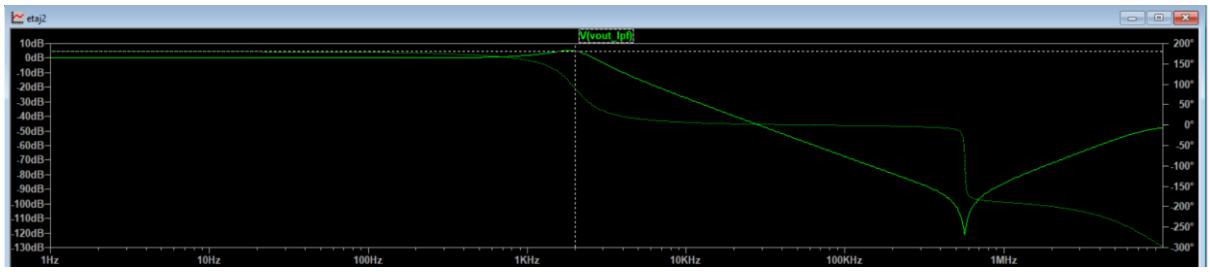
* C:\Users\amali\Desktop\SCIA PROIECT\ETAJ2\etaj2.asc

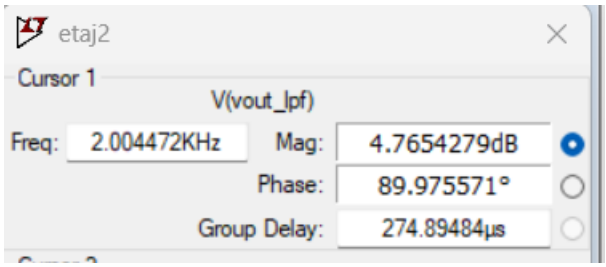
--- Operating Point ---

V(vcc):	15	voltage
V(-vcc):	-15	voltage
V(n001):	-0.000438468	voltage
V(in):	0	voltage
V(n002):	-0.000292343	voltage
V(n003):	-0.000292312	voltage
V(n005):	-0.000292308	voltage
V(n004):	-0.000292339	voltage
V(vout_lpf):	-0.00102309	voltage
V(n006):	-0.000146155	voltage

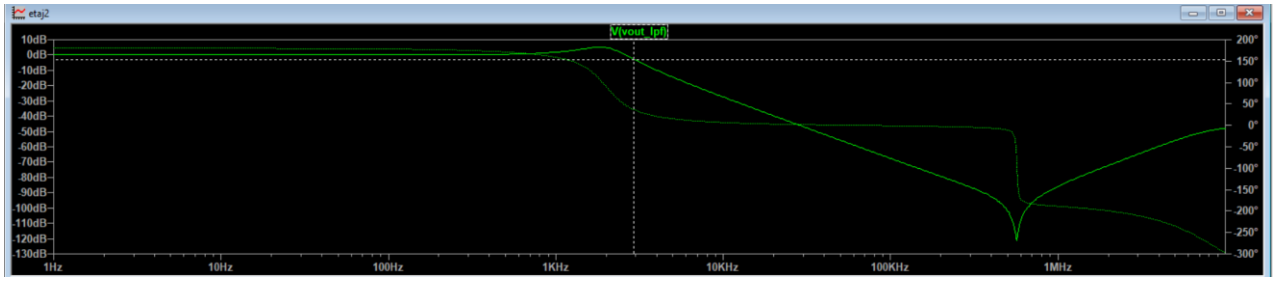
2.Analiza AC

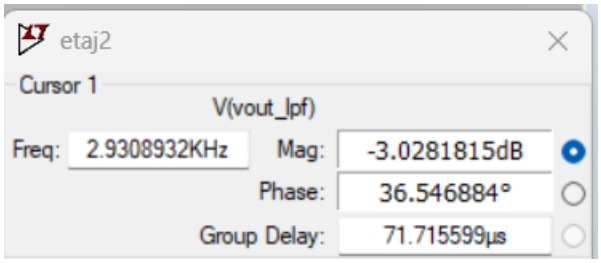
Câștigul la frecvența f0



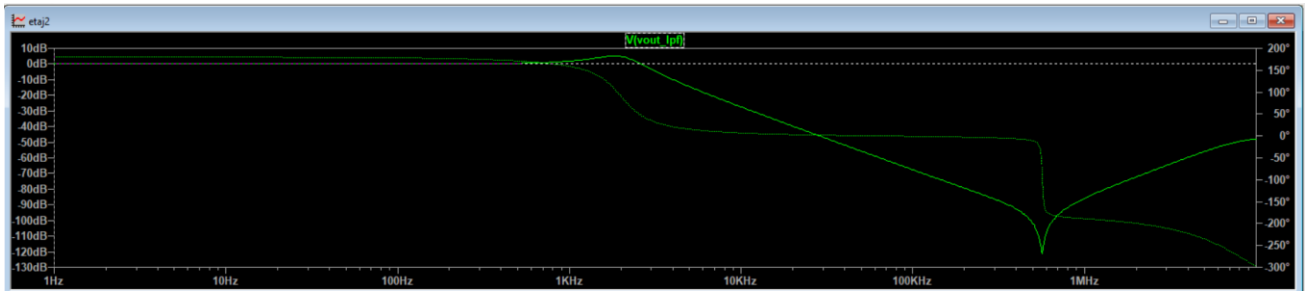


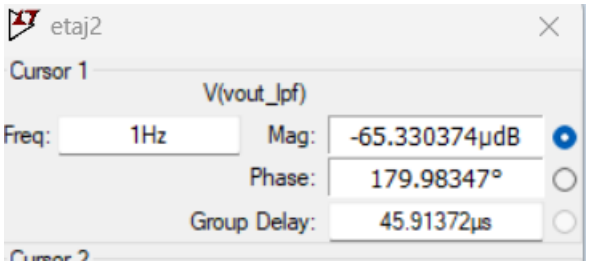
Banda la -3dB





|H0| câștig liniar în banda de trecere: 1=> aproximativ 0dB

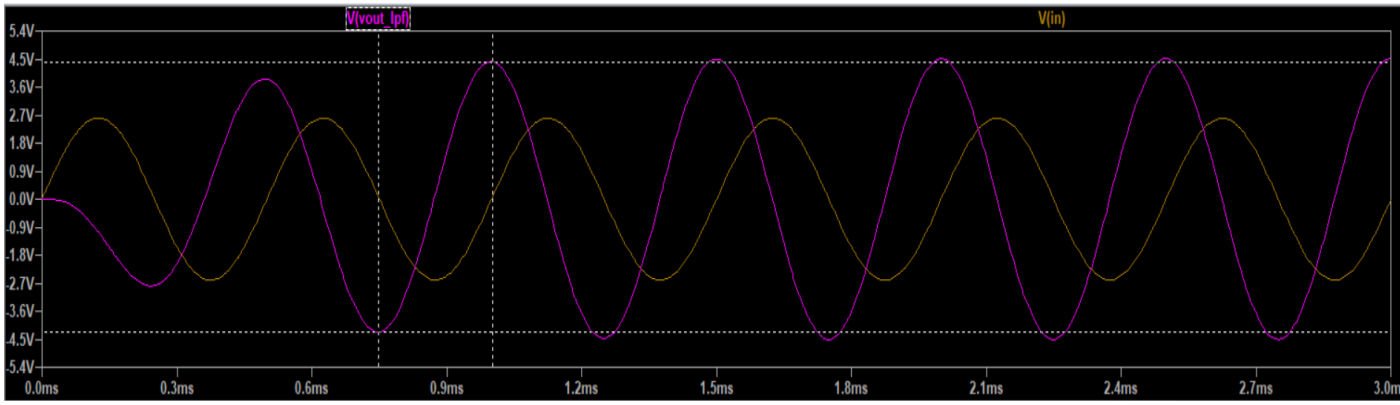


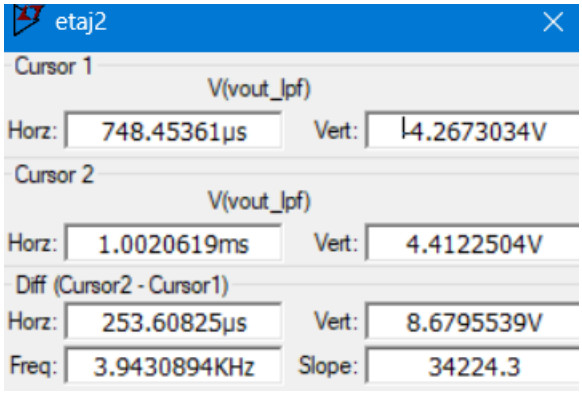


$$A_{lin} = 10^{\frac{A_{dB}}{20}} \approx 1$$

3.Analiza Transient

1. Pentru amplitudinea semnalului de intrare = 2.6V

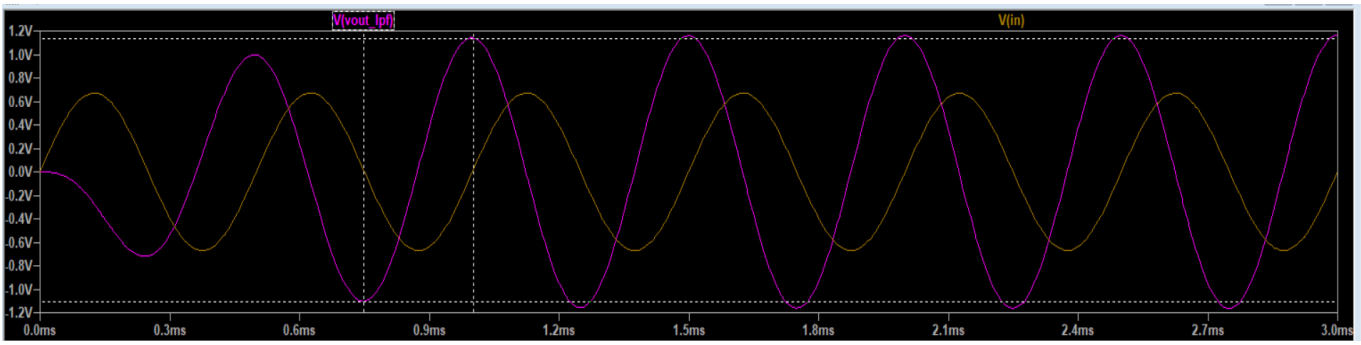


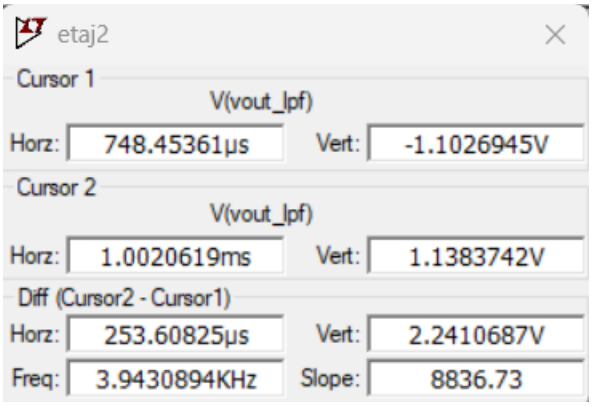


$V_{pp} \approx 8.6V \Rightarrow V_{OUT} = 4.3V$

```
Partial Harmonic Distortion: 0.030287%
Total Harmonic Distortion:   0.055094%
```

2. Pentru amplitudinea semnalului de intrare = 671mV

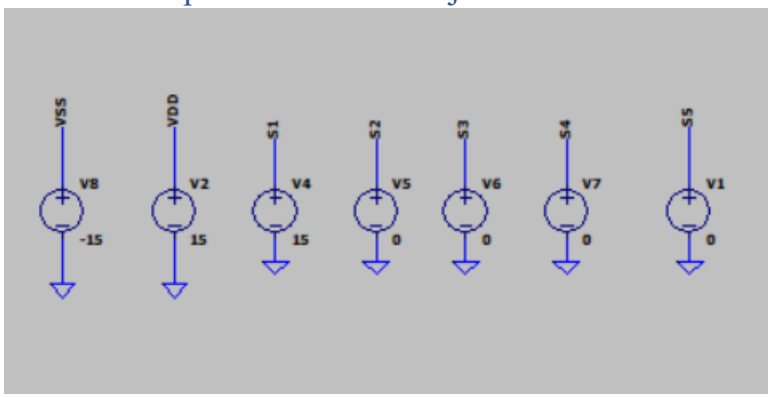


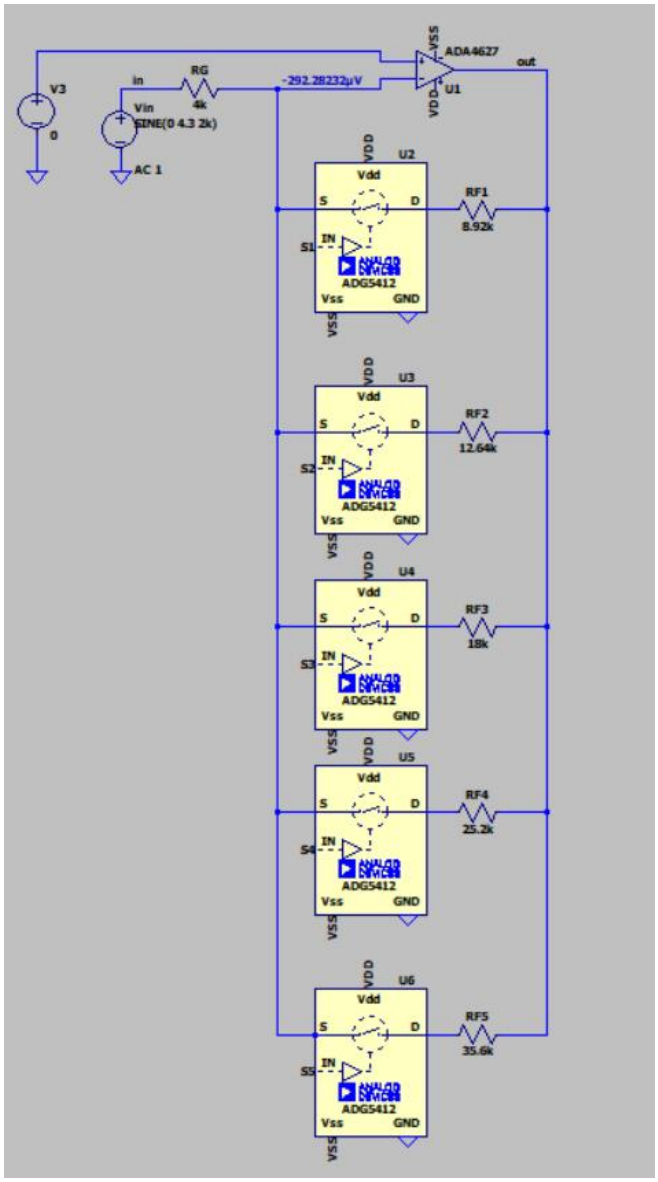


$V_{pp} \approx 2.24V \Rightarrow V_{OUT} = 1.12V$

```
Partial Harmonic Distortion: 0.032959%
Total Harmonic Distortion:   0.057758%
```

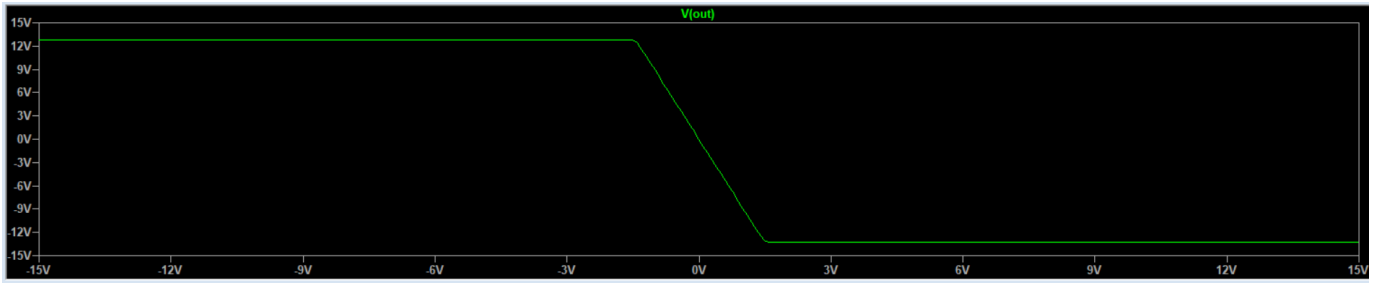
3.3 Simulări pentru al treilea etaj

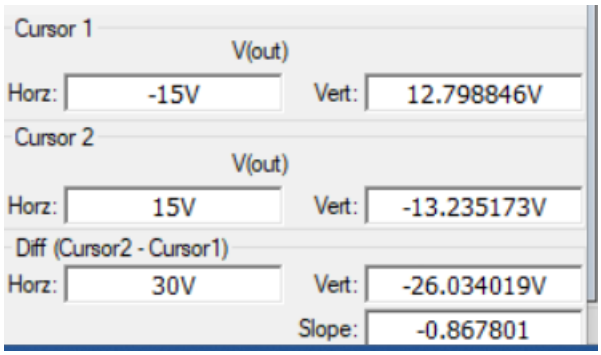




```
;tran 0 10m 0 100n
.lib tsmc180nmcmos.lib
.ac dec 100 1 10Meg
.op
;dc Vin 0 15 1m
```

1.Analiza DCOP



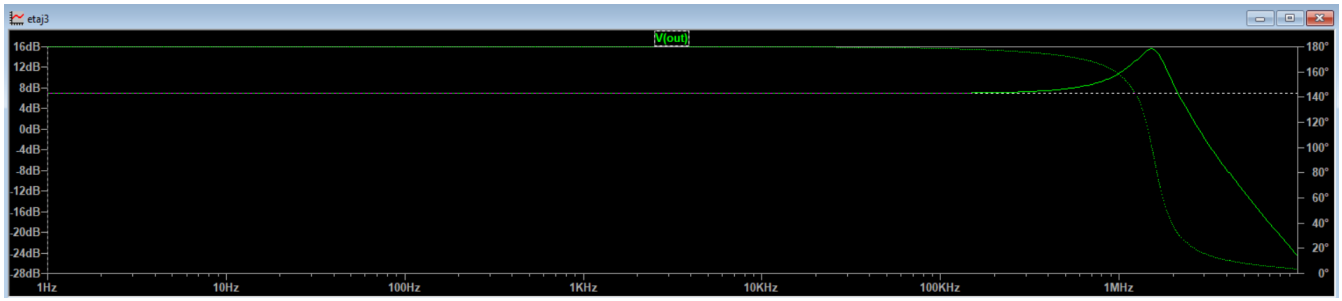


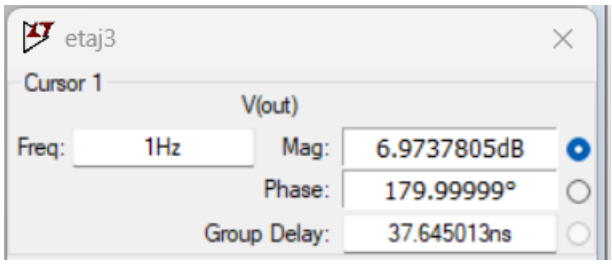

```
* C:\Users\amali\Desktop\SCIA PROIECT\ETAJ3\etaj3.asc

        --- Operating Point ---

V(vdd):         15              voltage
V(n002):        -0.000292297    voltage
V(in):          0               voltage
V(out):         -0.000945126    voltage
V(n003):        -0.000292885    voltage
V(s1):          15              voltage
V(s2):          0               voltage
V(s3):          0               voltage
V(s4):          0               voltage
V(n001):        0               voltage
V(vss):         -15             voltage
V(s5):          0               voltage
V(n004):        0.225658        voltage
V(n005):        0.229747        voltage
V(n006):        0.232586        voltage
V(n007):        0.234704        voltage
```

2.Analiza AC

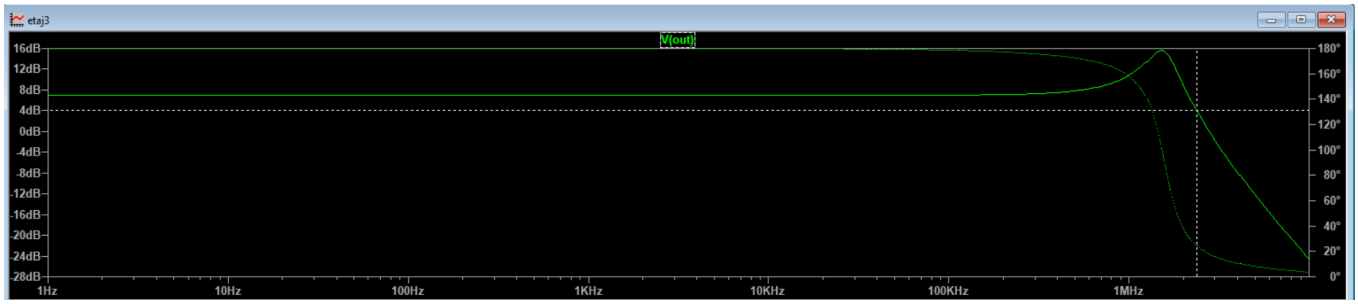
Trepte de câștig și banda(>banda filtru-2k)

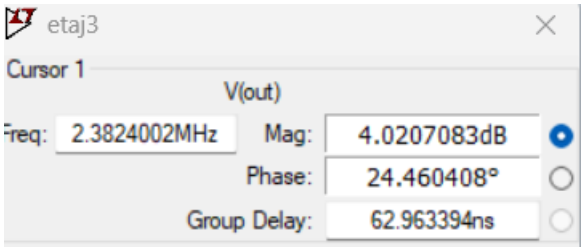
SW1-ON



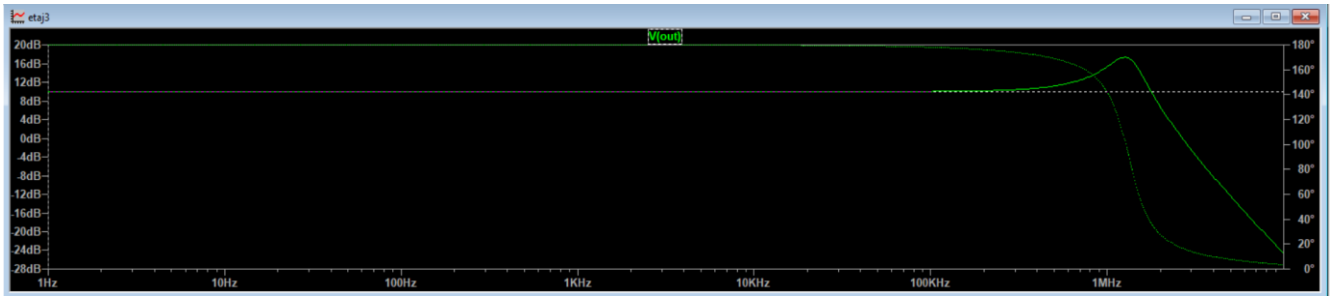


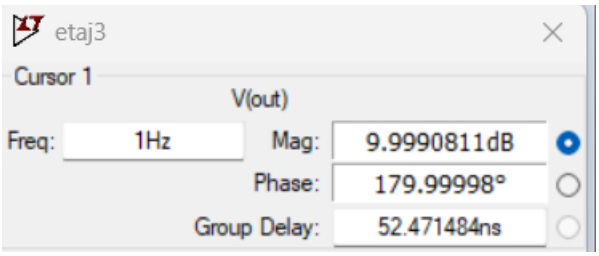
*)Banda la -3dB



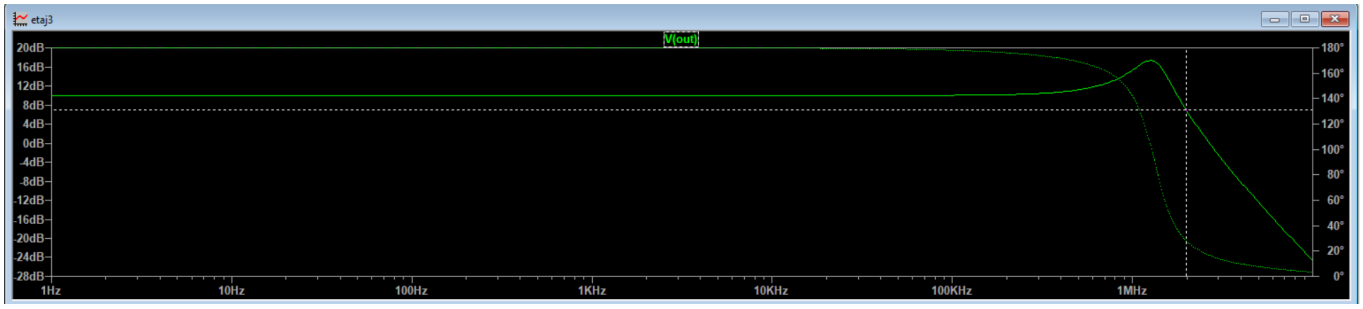


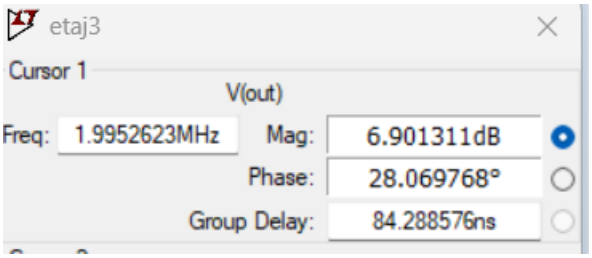
SW2-ON



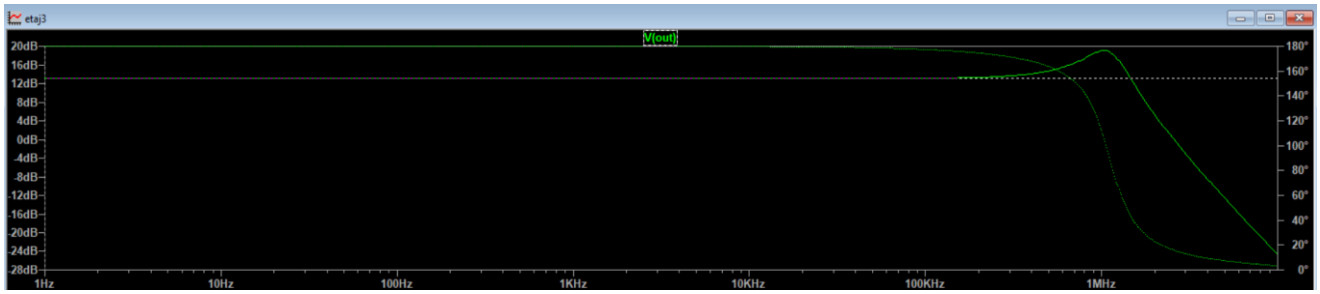


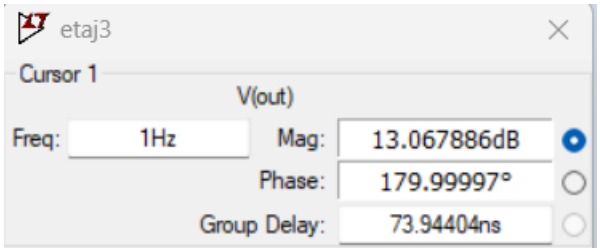
*)Banda la -3dB



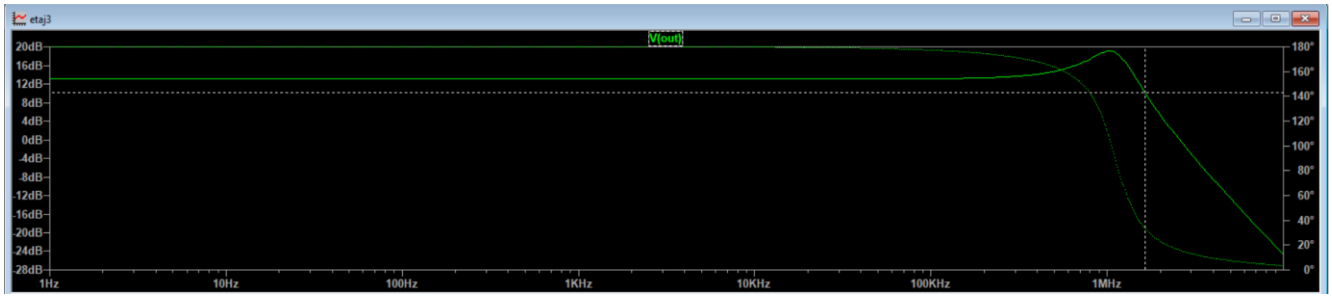


SW3-ON

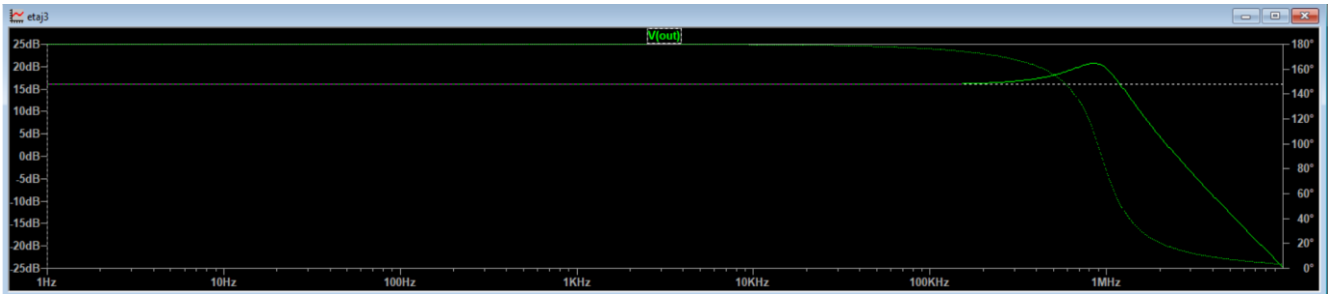


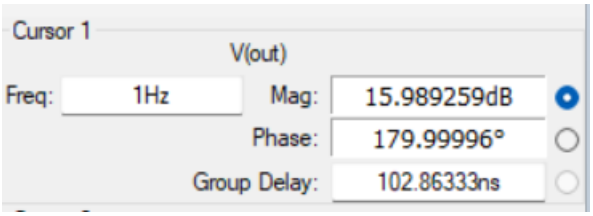


*)Banda la -3dB



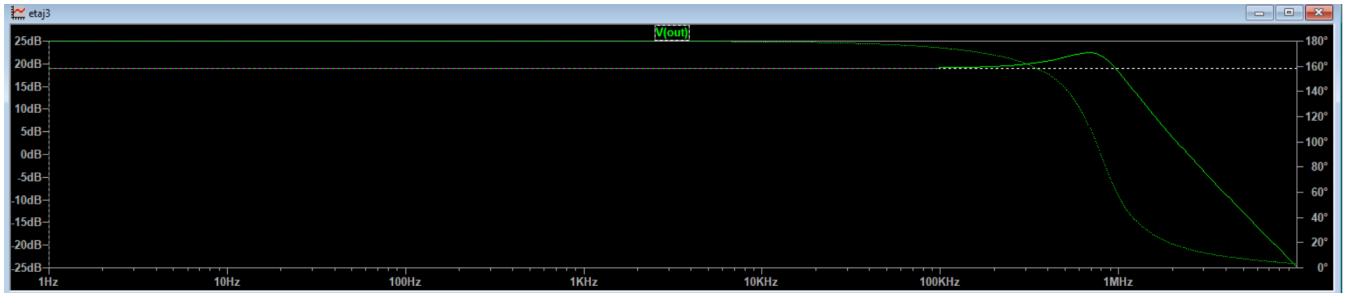
SW4-ON

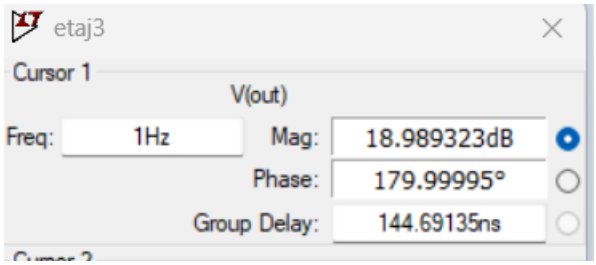




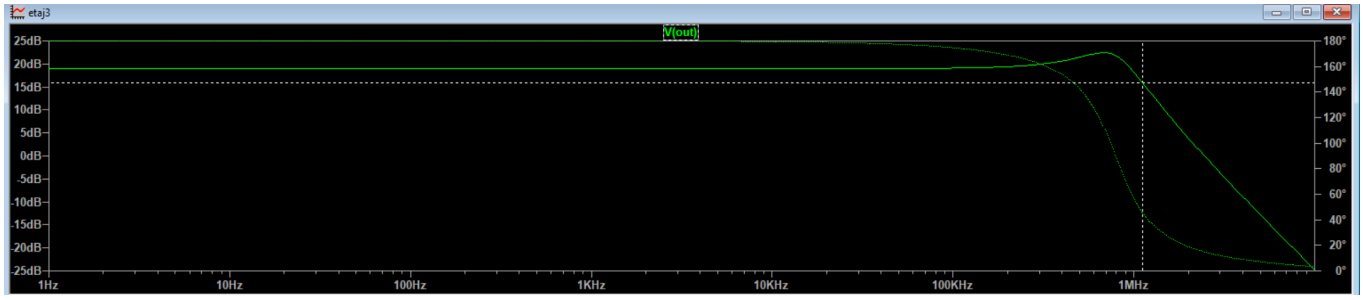
*)Banda la -3dB

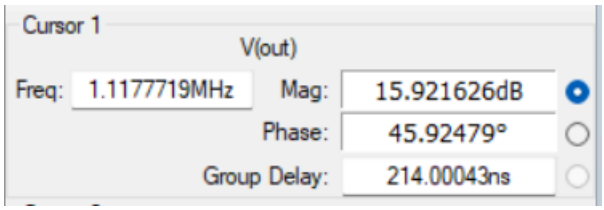
SW5-ON





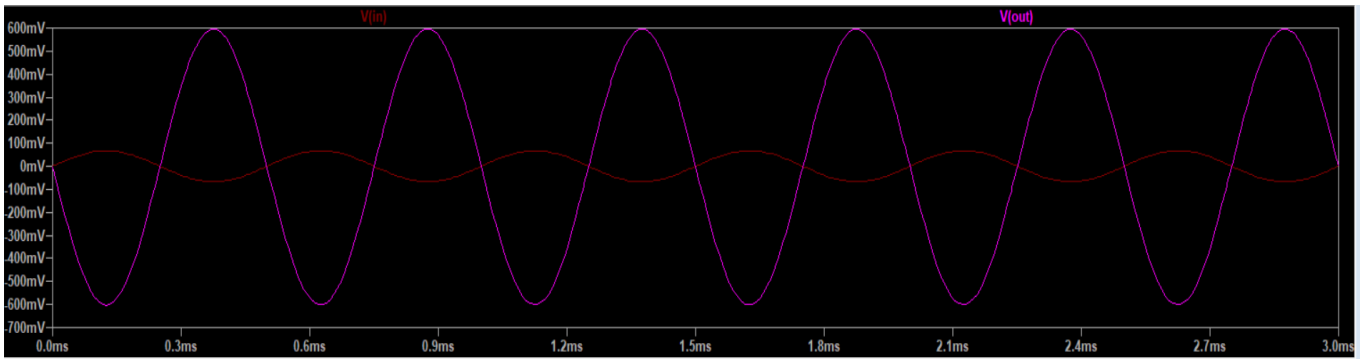
*)Banda la -3dB





3.Analiza Transient

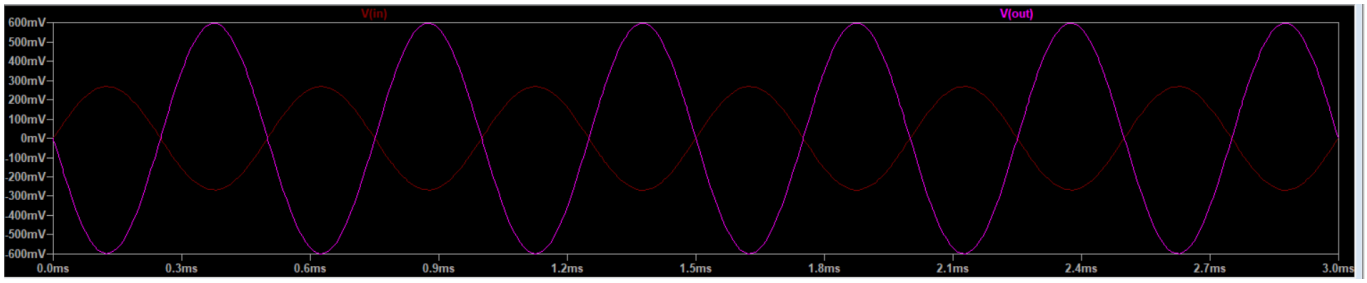
Pentru câștig maxim si ampltudine minimă



Harmonic Number	Frequency [Hz]	Fourier Component	Normalized Component
1	2.000e+3	5.983e-1	1.000e+0
2	4.000e+3	3.346e-5	5.591e-5
3	6.000e+3	9.562e-5	1.598e-4
4	8.000e+3	6.388e-5	1.068e-4
5	1.000e+4	1.197e-5	2.001e-5
6	1.200e+4	1.734e-5	2.898e-5
7	1.400e+4	8.414e-6	1.406e-5
8	1.600e+4	1.368e-5	2.286e-5
9	1.800e+4	1.851e-5	3.094e-5
10	2.000e+4	3.596e-5	6.010e-5

Partial Harmonic Distortion: 0.021585%
Total Harmonic Distortion: 0.044867%

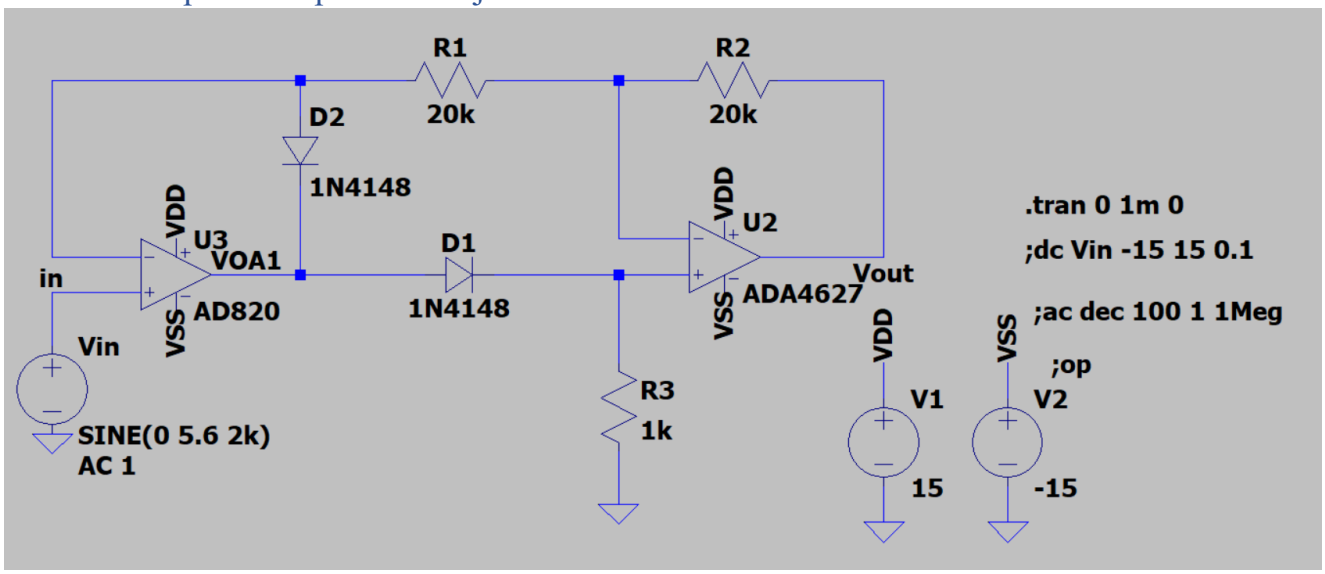
Pentru câștig minim și amplitudine maximă



Harmonic Number	Frequency [Hz]	Fourier Component	Normalized Component
1	2.000e+3	5.974e-1	1.000e+0
2	4.000e+3	3.344e-5	5.597e-5
3	6.000e+3	8.967e-5	1.501e-4
4	8.000e+3	6.000e-5	1.004e-4
5	1.000e+4	1.032e-5	1.728e-5
6	1.200e+4	8.334e-6	1.395e-5
7	1.400e+4	6.821e-6	1.142e-5
8	1.600e+4	5.385e-6	9.014e-6
9	1.800e+4	1.994e-5	3.337e-5
10	2.000e+4	3.021e-5	5.056e-5

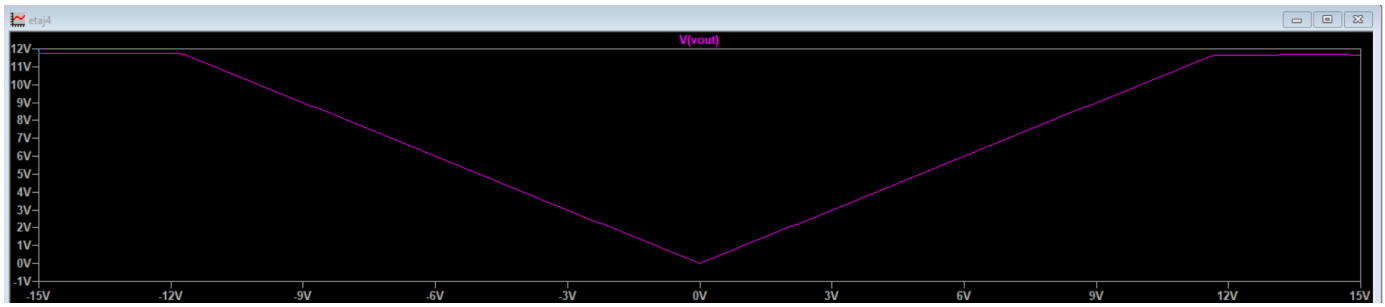
Partial Harmonic Distortion: 0.020030%
Total Harmonic Distortion: 0.043852%

3.4 Simulări pentru al patrulea etaj

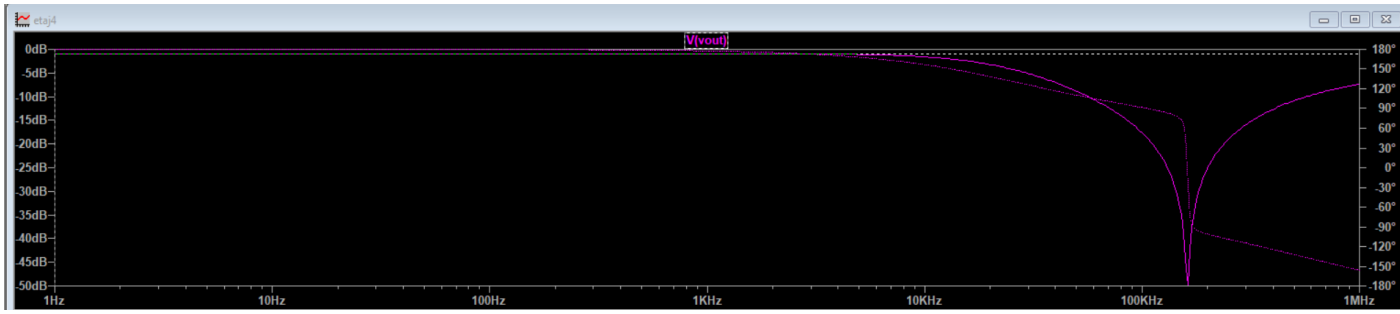


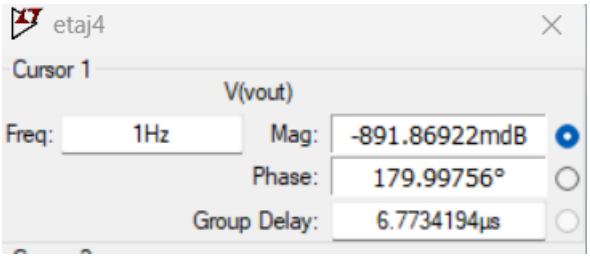
1. Analiza DCOP

```
* C:\Users\amali\Desktop\SCIA PROIECT\ETAJ4\etaj4.asc

        --- Operating Point ---

V(n004):        0               voltage
V(n001):        -0.000292311    voltage
V(vss):         -15             voltage
V(vdd):         15              voltage
V(voa1):        -0.000555374    voltage
V(n003):        -1.56722e-08    voltage
V(n002):        -0.000292328    voltage
V(vout):        -0.000292655    voltage
```



2.Analia AC

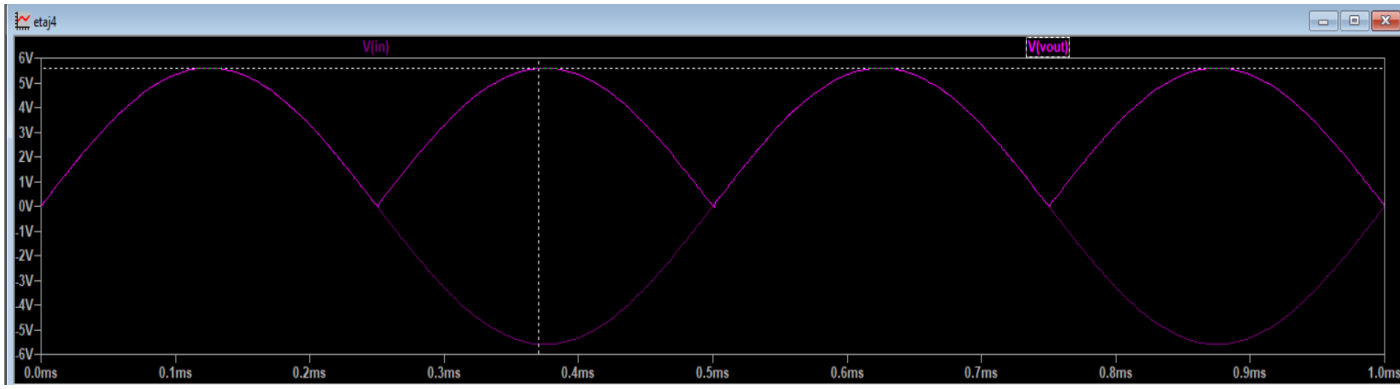


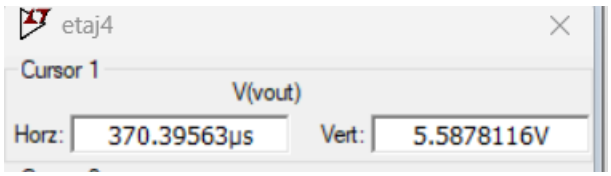


$$A_{lin} = 10^{\frac{A_{dB}}{20}} \approx 1{,}10815$$

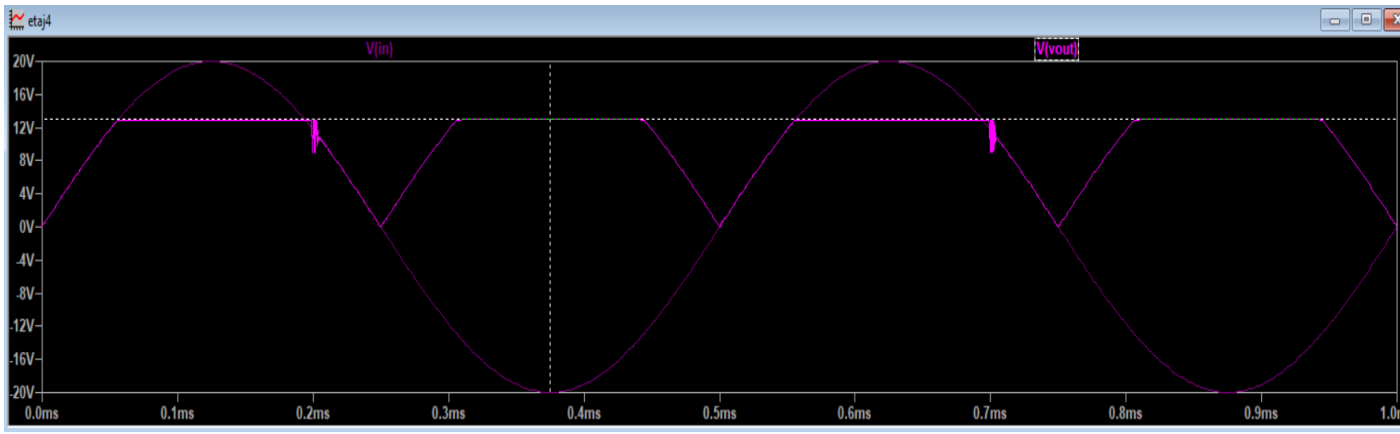
3.Analiza Transient

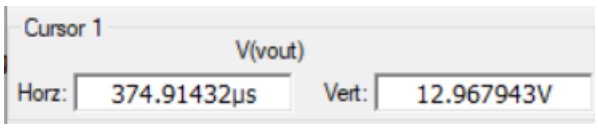
$V_{IN} = 5.6V$





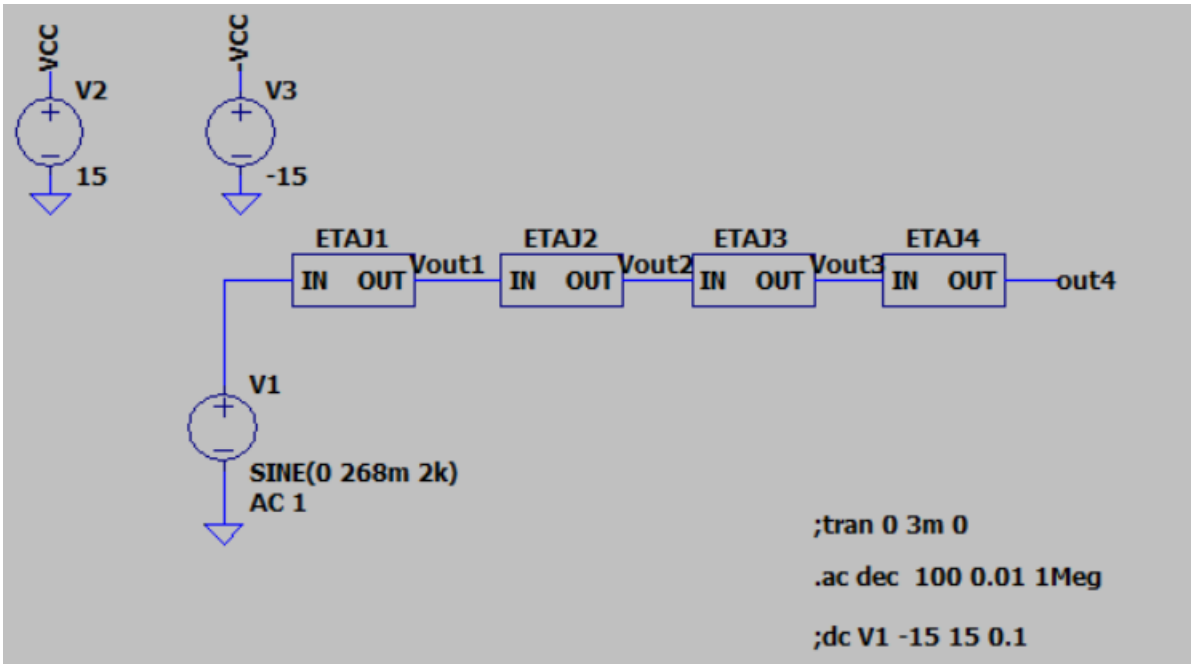
$V_{IN} = 20V$





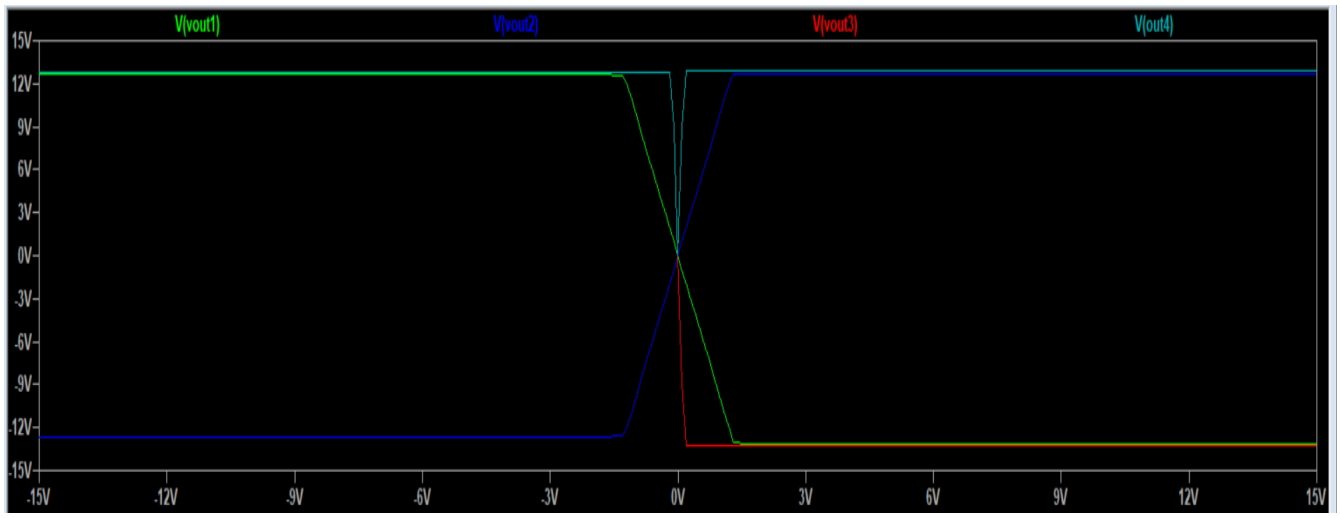
4. Toate etajele

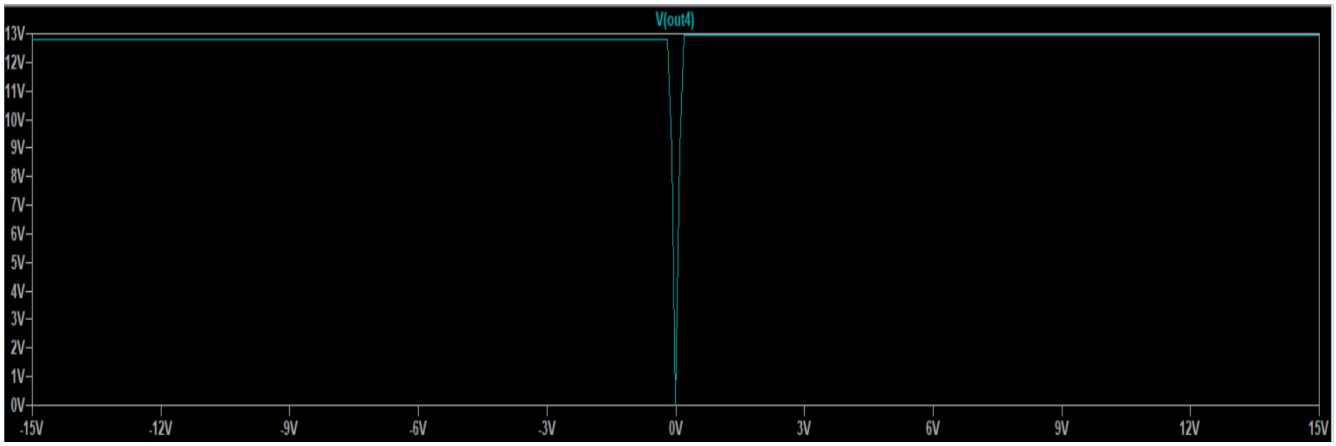
4.1 Schema de principiu



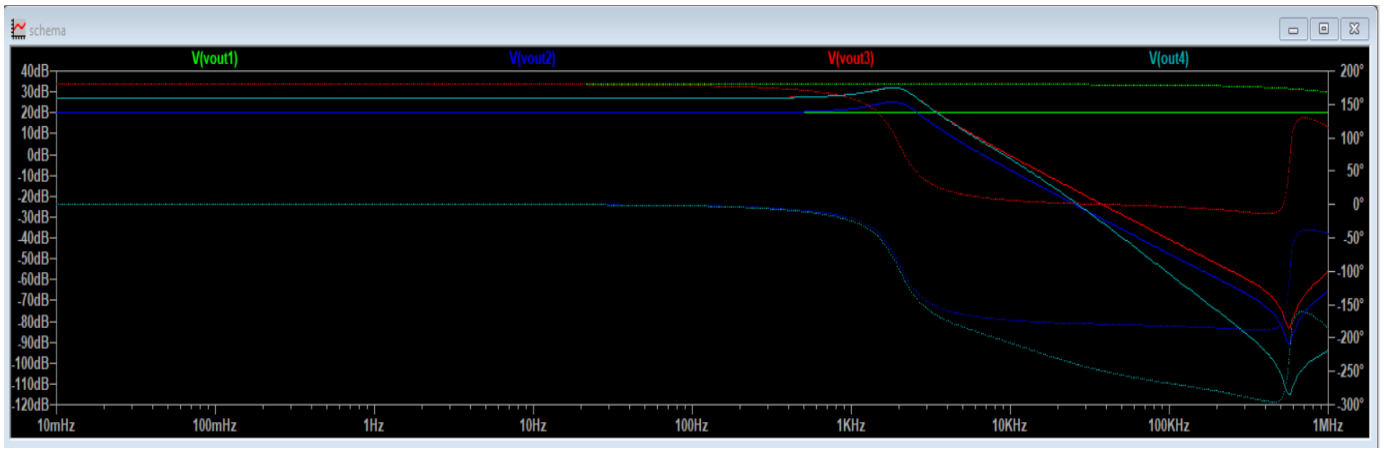
4.2 Simulări

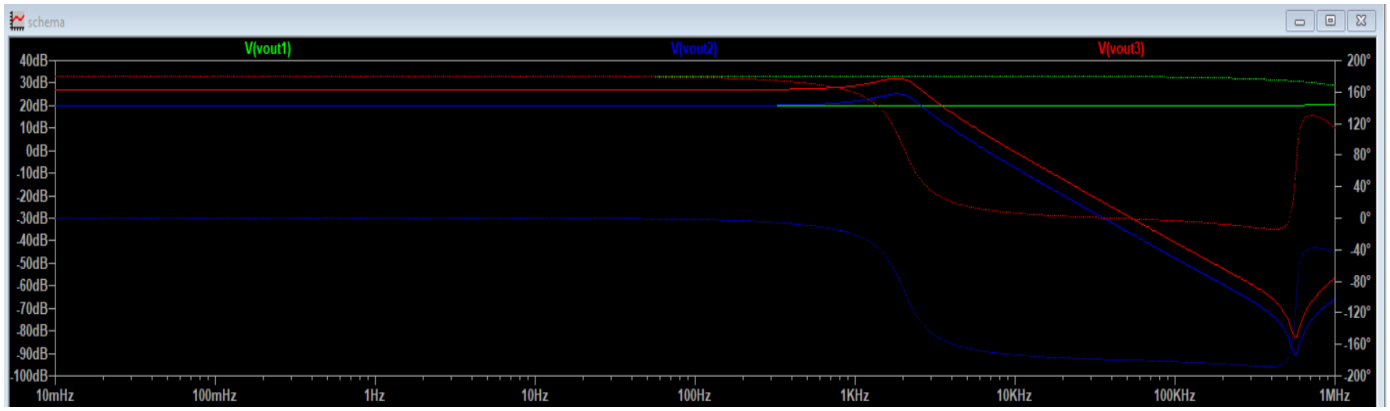
4.2.1 Analiza DC

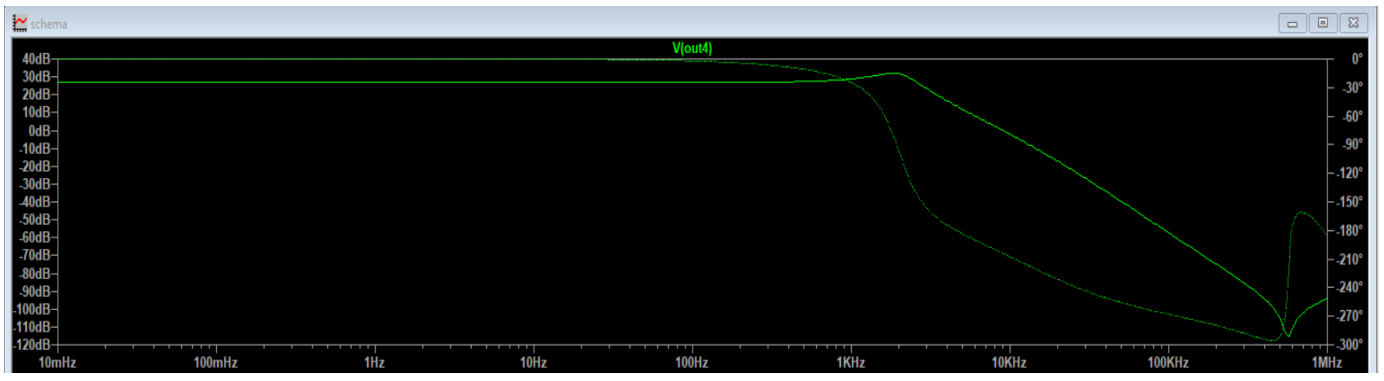




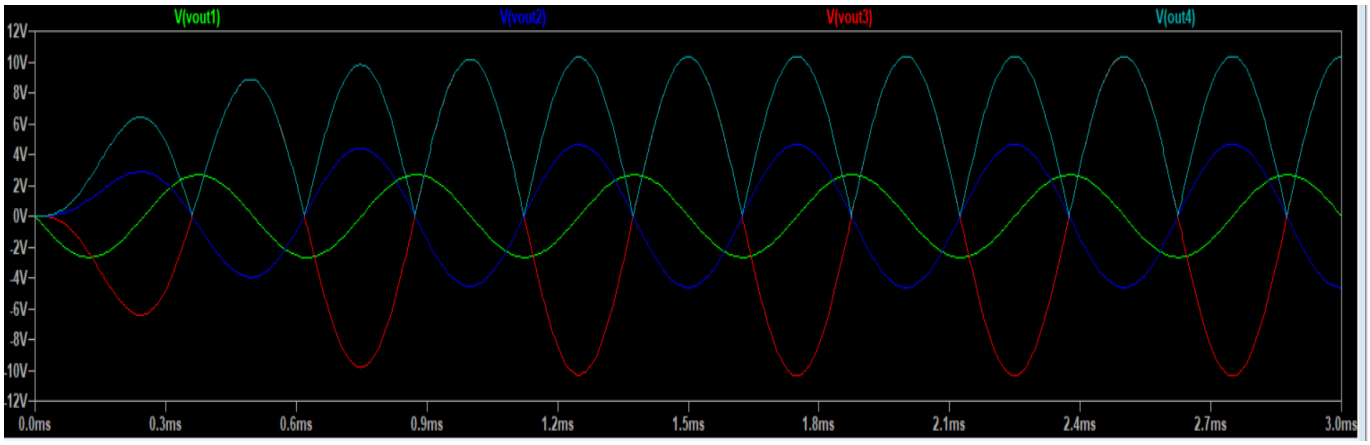
4.2.2 Analiza AC

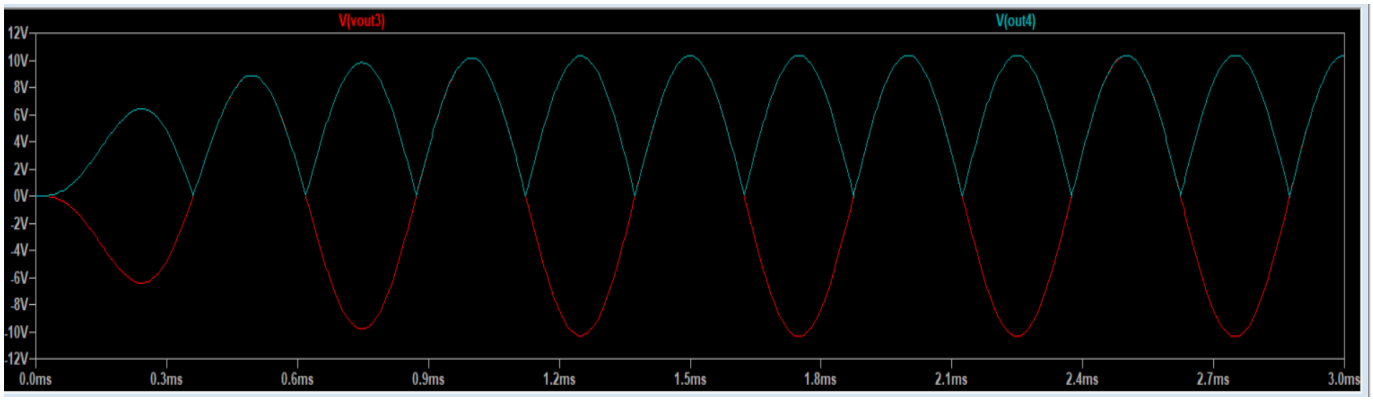






4.2.3 Analiza Transient





5. Concluzii

5.1. Etajul 1

ETAJUL 1			
Analiza AC			
		SPECIFICAȚII	MĂSURĂTORI
	câștig [V/V]	10	10
	Banda>banda filtru [Hz]	2k	3.98M
	CMRR [dB]	116	121
	PSRR [dB]	112	104
Analiza Tranisent			
		SPECIFICAȚII	MĂSURĂTORI
	fara distorsiuni la fin_max pt ampl_in*castig	SR<1	0.23 [V/us]
		THD<1	0.045455%

5.2. Etajul 2

ETAJUL 2			
Analiza AC			
		SPECIFICAȚII	MĂSURĂTORI
	|H0|	1	1
	Banda [Hz]	2k	2.93k
Analiza Tranisent			
		SPECIFICAȚII	MĂSURĂTORI
	fara distorsiuni la fin_max/10 pt ampl_in*castig	THD<1	0.055094%

5.3. Etajul 3

ETAJUL 3			
Analiza AC			
		SPECIFICAȚII	MĂSURĂTORI
	Av1 [dB]	7	6.973
	Av2 [dB]	10	9.999
	Av3 [dB]	13	13,06
	Av4 [dB]	16	15.989
	Av5 [dB]	19	18.989
	Banda Av1> Banda filtru	2,00E+03	2,38E+06
	Banda Av2> Banda filtru	2,00E+03	1,99E+06
	Banda Av3> Banda filtru	2,00E+03	1,64E+06
	Banda Av4> Banda filtru	2,00E+03	1,34E+06
	Banda Av5> Banda filtru	2,00E+03	1,11E+06
Analiza Tranisent			
		SPECIFICAȚII	MĂSURĂTORI
	Câștig minim și amplitudine maximă	THD<1	0,04%
	Câștig maxim și amplitudine minimă	THD<1	0,04%

5.4. Etajul 4

ETAJUL 4			
Analiza AC			
		SPECIFICAȚII	MĂSURĂTORI
	Câștig [V/V]	1	1,10815