

# PROIECT CIRCUITE INTEGRATE DIGITALE

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## 1. SURSA DE CURENT CU TRANZISTOR NMOS CU DEGENERARE REZISTIVĂ

Curent de iesire: 60uA

Tensiunea de iesire minima: 600 mV

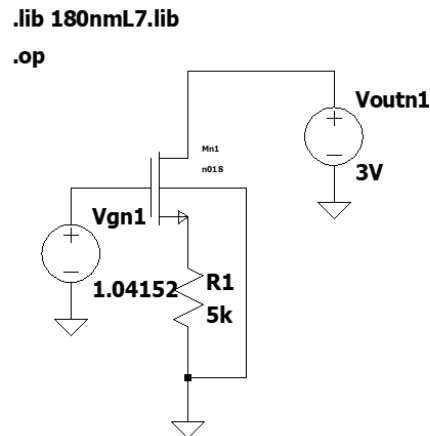


Figura 1. Schema electrică la nivel de tranzistor a sursei de curent după ajustare

SURSA DE CURENT CU DEGENERARE REZISTIVĂ DE TIP NMOS

$I_{out} = 60 \mu A$      $V_{out} = 600 \text{ mV}$

$$\frac{50 \mu}{60 \mu} = \frac{5 \mu / 1 \mu}{\frac{W}{L}} \cdot \left( \frac{240 \text{ m}}{200 \text{ m}} \right)^2 \Rightarrow \frac{W}{L} = \frac{60 \mu \cdot 5 \mu / 1 \mu}{50 \mu} \cdot 1,44 = 8,64$$

alegem  $L = 1 \mu$      $W = 8,64 \Rightarrow A_D = A_S = 0,2 \cdot W = 0,2 \cdot 8,64 = 1,728 \mu$   
 $P_D = P_S = (0,2 + W) \cdot 2 = 17,28 \mu$

$\rightarrow V_{DS} = V_{DSAT} + \Delta V = 200 + 100 = 300 \text{ mV}$

$\rightarrow V_{Gm} = V_{DSAT} + V_{th} + i_{out} R = 200 \text{ m} + 150 \text{ m} + 5 \cdot 10^3 \cdot 60 \cdot 10^{-6} = 950 \text{ mV}$

$\rightarrow V_{out} = i_{out} R + V_{DSAT} \Rightarrow i_{out} R = V_{out} - V_{DS} = 600 - 300 = 300 \text{ mV}$

$\rightarrow R = \frac{300 \text{ mV}}{60 \mu A} = 5 \text{ k}\Omega$

Ajustăm geometria     $\frac{W}{L} \Rightarrow \frac{W}{L} = 8,139 \Rightarrow A_D = A_S = 1,6278 \mu$   
 $P_D = P_S = 16,67 \mu$

Ajustăm  $V_{Gm} = 950 \text{ m} \Rightarrow V_{Gm} = 1.04152 \text{ V}$

Figura 2. Proiectarea sursei de curent după specificații

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SPICE Error Log: C:\Users\Asus\Desktop\PROEICT_CIA\Lab2-Sursecrt\PROEICT_CIA_SURSA.log
Circuit: * C:\Users\Asus\Desktop\PROEICT_CIA\Lab2-Sursecrt\PROEICT_CIA_SURSA.asc
Direct Newton iteration for .op point succeeded.
Semiconductor Device Operating Points:
    --- BSIM3 MOSFETS ---
Name:      mn1
Model:     n018
Id:        5.04e-05
Vgs:       6.98e-01
Vds:       2.75e+00
Vbs:       -2.52e-01
Vth:       5.18e-01
Vdsat:     1.78e-01
Gm:        4.34e-04
Gds:       3.94e-06
Gmb:       1.26e-04
Cbd:       1.17e-14
Cbs:       1.85e-14
Cgsov:     4.71e-15
Cgdov:     4.04e-15
Cgbov:     0.00e+00
dQgdVgb:   6.29e-14
dQgdVdb:   -4.04e-15
dQgdVsb:   -5.54e-14
dQddVgb:   -4.04e-15
dQddVdb:   1.57e-14
dQddVsb:   4.74e-18
dQbdVgb:   -8.85e-15
dQbdVdb:   -1.17e-14
dQbdVsb:   -2.54e-14

Date: Mon May 09 16:35:42 2022
Total elapsed time: 0.124 seconds.

tnom = 27
temp = 27
method = trap
totiter = 5
traniter = 0
tranpoints = 0
accept = 0
rejected = 0
matrix size = 5
fillins = 0
solver = Normal
Matrix Compiler1: 204 bytes object code size
Matrix Compiler2: 311 bytes object code size

```

Figura 3. Captură de ecran al fișierului de ieșire înainte de ajustare

```

SPICE Error Log: C:\Users\Asus\Desktop\PROEICT_CIA\Lab2-Sursecrt\PROEICT_CIA_SURSA.log
Circuit: * C:\Users\Asus\Desktop\PROEICT_CIA\Lab2-Sursecrt\PROEICT_CIA_SURSA.asc
Direct Newton iteration for .op point succeeded.
Semiconductor Device Operating Points:
    --- BSIM3 MOSFETS ---
Name:      mn1
Model:     n018
Id:        6.00e-05
Vgs:       7.42e-01
Vds:       2.70e+00
Vbs:       -3.00e-01
Vth:       5.31e-01
Vdsat:     2.00e-01
Gm:        4.53e-04
Gds:       4.48e-06
Gmb:       1.31e-04
Cbd:       1.17e-14
Cbs:       1.82e-14
Cgsov:     4.44e-15
Cgdov:     3.82e-15
Cgbov:     0.00e+00
dQgdVgb:   5.92e-14
dQgdVdb:   -3.82e-15
dQgdVsb:   -5.23e-14
dQddVgb:   -3.82e-15
dQddVdb:   1.55e-14
dQddVsb:   4.66e-18
dQbdVgb:   -8.27e-15
dQbdVdb:   -1.17e-14
dQbdVsb:   -2.45e-14

Date: Mon May 09 17:08:31 2022
Total elapsed time: 0.110 seconds.

tnom = 27
temp = 27
method = trap
totiter = 5
traniter = 0
tranpoints = 0
accept = 0
rejected = 0
matrix size = 5
fillins = 0
solver = Normal
Matrix Compiler1: 204 bytes object code size
Matrix Compiler2: 311 bytes object code size

```

Figura 4 . Captură de ecran al fișierului de ieșire după ajustare

Tranzistor	W/L	ID [uA]	Vdsat [mV]	Vds [mV]	Vth [mv]	Vgs [mv]	gm [uS]	gds [uS]
Mn1	8.139	60	200	2700	531	742	453	4.48

Tabelul 1. Parametrii tranzistoarelor după ajustare

$$\begin{aligned}
 R_{out} &= r_{DS} + R + (g_m + g_{mle}) r_{DS} R \\
 r_{DS} &= \frac{1}{g_{ds}} = \frac{1}{4.48 \cdot 10^{-6}} = 223 \text{ K}\Omega \\
 R_{out} &= 223 + 5 + (453 \mu + 131 \mu) \cdot 223 \cdot 5 \\
 &= 228 \text{ K} + 584 \mu \cdot 1115 \text{ K}\Omega \\
 &= 485,5 \text{ K} = 0,48 \text{ M}\Omega \\
 slope &= \frac{1}{R} = 1,4
 \end{aligned}$$

Figura 5. Calculul rezistenței de ieșire

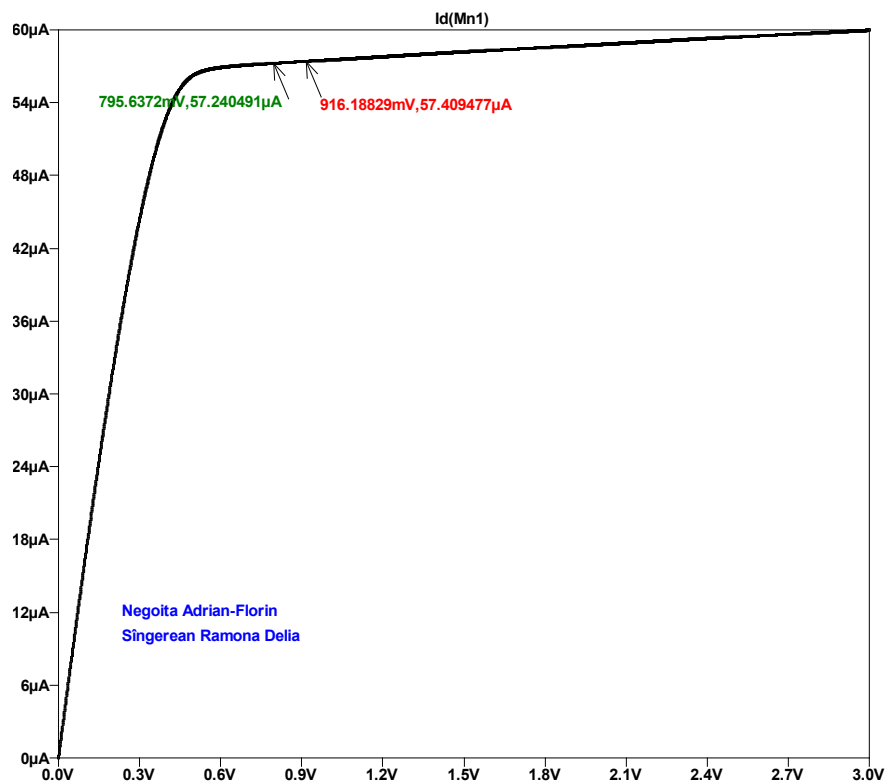


Figura 6. Caracteristica de ieșire

Parametru	Calculat	Măsurat
Rout [M $\Omega$ ]	0.7	0.713

Tabel 2 . Valorile calculate și măsurate ale rezistenței de ieșire

## 2.AMPLIFICATOR DIFERENTIAL DE TIP P CU SARCINA SURSA

Produs de amplificare banda: 35 MHz

Capacitate de sarcina: 3pF

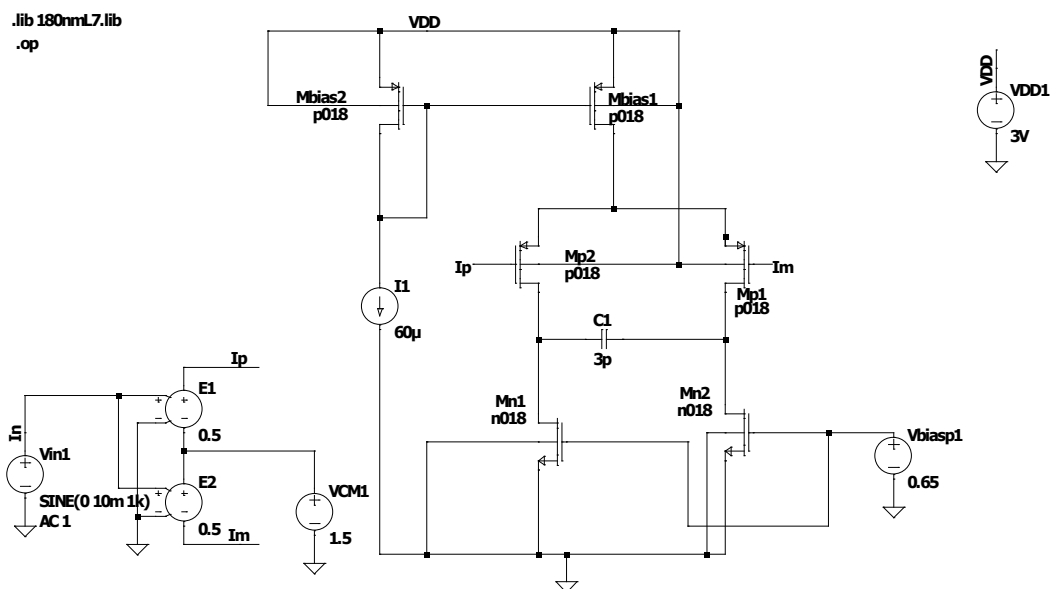


Figura 7. Schema electrică la nivel de tranzistor a amplificatorului diferențial

# AMPLIFICATOR DIFERENȚIAL DE TIP P CU SARCINĂ SURSĂ

Date  $C = 3 \text{ pF}$   $GBW_{\min} = 35 \text{ MHz}$

## Dimensionare

$$GBW = \frac{G_m}{2\pi C} \Rightarrow G_m = GBW \cdot 2\pi C = 40 \cdot 10^6 \cdot 2 \cdot 3,14 \cdot 3 \cdot 10^{-12} = 1318,8 \mu S$$

$$GBW = 2 \cdot 25 = 50 \text{ MHz}$$

$$g_m = 2 G_m = 2 \cdot 1318,8 \mu S = 2,637 \text{ mS}$$

$$g_m = \frac{2i_D}{V_{DSAT}} \Rightarrow i_D = 263,7 \mu A$$

→  $M_{n1}, M_{n2}$

$$\frac{i_{Dref}}{i_D} = \frac{\left(\frac{W}{L}\right)_{ref}}{\frac{W}{L}} \left(\frac{V_{Dref}}{V_{DSAT}}\right)^2 \Rightarrow \frac{50 \mu}{263,7 \mu} = \frac{5 \mu / 1 \mu}{\left(\frac{W}{L}\right)} \cdot \left(\frac{240 \text{ m}}{200 \text{ m}}\right)^2 \Rightarrow \frac{W}{L} = 37,97$$

alegem  $L = 1 \mu$   $W = 37,97 \Rightarrow A_D = A_S = 0,2 \cdot 37,97 = 7,59 \mu$

$$P_D = P_S = 2(0,2 + 37,97) = 46,34 \mu$$

→  $M_{p1}, M_{p2}$   $i_{Dn1}, i_{Dn2} = i_{Dp1}, i_{Dp2} = 263,7 \mu A$

$$\frac{50 \mu}{263,7 \mu} = \frac{15 \mu / 1 \mu}{\frac{W}{L}} \cdot \left(\frac{257 \text{ m}}{200 \text{ m}}\right)^2 \Rightarrow \frac{W}{L} = 130,53$$

alegem  $L = 1 \mu$   $W = 130,53 \Rightarrow A_D = A_S = 0,2 \cdot 130,53 = 26,10 \mu$

$$P_D = P_S = 2(0,2 + 130,53)$$

$$= 261,46 \mu$$

→  $M_{bias2}$

$$V_{unitate} = 50 \mu$$

$$\frac{50 \mu}{60 \mu} = \frac{15 \mu / 1 \mu}{\frac{W}{L}} \cdot \left(\frac{257 \text{ m}}{200 \text{ m}}\right)^2 \Rightarrow \left(\frac{W}{L}\right)_{bias} = 24,75$$

alegem  $L = 1 \mu$   $W = 24,75 \mu$

$$A_D = A_S = 0,2 \cdot 24,75 = 4,95 \mu$$

$$P_D = P_S = 2(0,2 + 24,75) = 49,9 \mu$$

Figura 8. Proiectarea amplificatorului diferențial după specificații

Circuit: \* C:\Users\Asus\Desktop\PROIECT\_CIA\Lab2-Sursecrt\PROIECT\_CIA\_AO.asc

Direct Newton iteration for .op point succeeded.

Semiconductor Device Operating Points:

--- BSIM3 MOSFETS ---

Name:	mbias2	mbias1	mp2	mp1	mn2
Model:	p018	p018	p018	p018	n018
Id:	-5.00e-05	-5.20e-04	-2.60e-04	-2.60e-04	2.60e-04
Vgs:	-7.31e-01	-7.31e-01	-8.83e-01	-8.83e-01	6.50e-01
Vds:	-7.31e-01	-6.17e-01	-5.53e-01	-5.53e-01	1.83e+00
Vbs:	0.00e+00	0.00e+00	6.17e-01	6.17e-01	0.00e+00
Vth:	-4.46e-01	-4.46e-01	-6.03e-01	-6.03e-01	4.46e-01
Vdsat:	-2.04e-01	-2.04e-01	-2.17e-01	-2.17e-01	1.92e-01
Gm:	3.43e-04	3.57e-03	1.76e-03	1.76e-03	2.05e-03
Gds:	6.13e-06	6.56e-05	3.21e-05	3.21e-05	2.16e-05
Gmb:	9.29e-05	9.67e-04	3.95e-04	3.95e-04	6.57e-04
Cbd:	5.91e-14	6.41e-13	2.77e-13	2.77e-13	5.78e-14
Cbs:	7.87e-14	8.24e-13	3.21e-13	3.21e-13	8.80e-14
Cgsov:	1.35e-14	1.42e-13	7.11e-14	7.11e-14	2.07e-14
Cgdov:	1.33e-14	1.41e-13	7.10e-14	7.10e-14	1.84e-14
Cgbov:	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
dQgdVgb:	1.85e-13	1.96e-12	9.64e-13	9.64e-13	2.79e-13
dQgdVdb:	-1.34e-14	-1.43e-13	-7.19e-14	-7.19e-14	-1.84e-14
dQgdVsb:	-1.63e-13	-1.72e-12	-8.52e-13	-8.52e-13	-2.44e-13
dQddVgb:	-1.36e-14	-1.46e-13	-7.44e-14	-7.44e-14	-1.85e-14
dQddVdb:	7.26e-14	7.86e-13	3.50e-13	3.50e-13	7.63e-14
dQddVsb:	1.85e-16	2.66e-15	1.58e-15	1.58e-15	4.97e-17
dQbdVgb:	-3.19e-14	-3.35e-13	-1.52e-13	-1.52e-13	-4.04e-14
dQbdVdb:	-5.92e-14	-6.42e-13	-2.77e-13	-2.77e-13	-5.79e-14
dQbdVsb:	-9.27e-14	-9.72e-13	-3.59e-13	-3.59e-13	-1.25e-13

Name: mn1

SPICE Error Log: C:\Users\Asus\Desktop\PROIECT\_CIA\Lab2-Sursecrt\PROIECT\_CIA\_AO.log

Name:	mn1
Model:	n018
Id:	2.60e-04
Vgs:	6.50e-01
Vds:	1.83e+00
Vbs:	0.00e+00
Vth:	4.46e-01
Vdsat:	1.92e-01
Gm:	2.05e-03
Gds:	2.16e-05
Gmb:	6.57e-04
Cbd:	5.78e-14
Cbs:	8.80e-14
Cgsov:	2.07e-14
Cgdov:	1.84e-14
Cgbov:	0.00e+00
dQgdVgb:	2.79e-13
dQgdVdb:	-1.84e-14
dQgdVsb:	-2.44e-13
dQddVgb:	-1.85e-14
dQddVdb:	7.63e-14
dQddVsb:	4.97e-17
dQbdVgb:	-4.04e-14
dQbdVdb:	-5.79e-14
dQbdVsb:	-1.25e-13

Date: Tue May 10 13:27:00 2022  
Total elapsed time: 0.118 seconds.

tnom = 27  
temp = 27  
method = trap  
totiter = 13  
traniter = 0  
tranpoints = 0  
accept = 0  
rejected = 0  
matrix size = 16  
fillins = 0  
solver = Normal

Figura 9. Captura de ecran a fişierului de ieşire înainte de ajustare

SPICE Error Log: C:\Users\Asus\Desktop\PROIECT\_CIA\Lab2-Sursecrt\PROIECT\_CIA\_AO.log

Circuit: \* C:\Users\Asus\Desktop\PROIECT\_CIA\Lab2-Sursecrt\PROIECT\_CIA\_AO.asc

Direct Newton iteration for .op point succeeded.

Semiconductor Device Operating Points:

--- BSIM3 MOSFETS ---

Name:	mbias2	mbias1	mp2	mp1	mn2
Model:	p018	p018	p018	p018	n018
Id:	-6.00e-05	-5.25e-04	-2.63e-04	-2.63e-04	2.63e-04
Vgs:	-7.30e-01	-7.30e-01	-8.86e-01	-8.86e-01	6.50e-01
Vds:	-7.30e-01	-6.14e-01	-4.36e-01	-4.36e-01	1.95e+00
Vbs:	0.00e+00	0.00e+00	6.14e-01	6.14e-01	0.00e+00
Vth:	-4.46e-01	-4.46e-01	-6.02e-01	-6.02e-01	4.46e-01
Vdsat:	-2.04e-01	-2.04e-01	-2.20e-01	-2.20e-01	1.92e-01
Gm:	4.12e-04	3.61e-03	1.75e-03	1.75e-03	2.07e-03
Gds:	7.36e-06	6.63e-05	3.61e-05	3.61e-05	2.16e-05
Gmb:	1.12e-04	9.78e-04	3.93e-04	3.93e-04	6.62e-04
Cbd:	7.10e-14	6.48e-13	2.85e-13	2.85e-13	5.69e-14
Cbs:	9.45e-14	8.33e-13	3.21e-13	3.21e-13	8.80e-14
Cgsov:	1.62e-14	1.44e-13	7.11e-14	7.11e-14	2.07e-14
Cgdov:	1.60e-14	1.43e-13	7.10e-14	7.10e-14	1.83e-14
Cgbov:	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
dQgdVgb:	2.23e-13	1.98e-12	9.65e-13	9.65e-13	2.79e-13
dQgdVdb:	-1.61e-14	-1.44e-13	-7.34e-14	-7.34e-14	-1.83e-14
dQgdVsb:	-1.97e-13	-1.75e-12	-8.52e-13	-8.52e-13	-2.44e-13
dQddVgb:	-1.64e-14	-1.48e-13	-7.82e-14	-7.82e-14	-1.83e-14
dQddVdb:	8.72e-14	7.95e-13	3.62e-13	3.62e-13	7.52e-14
dQddVsb:	2.23e-16	2.72e-15	2.20e-15	2.20e-15	4.36e-17
dQbdVgb:	-3.83e-14	-3.39e-13	-1.51e-13	-1.51e-13	-4.04e-14
dQbdVdb:	-7.10e-14	-6.49e-13	-2.87e-13	-2.87e-13	-5.69e-14
dQbdVsb:	-1.11e-13	-9.82e-13	-3.60e-13	-3.60e-13	-1.25e-13

Name: mn1

SPICE Error Log: C:\Users\Asus\Desktop\PROIECT\_CIA\Lab2-Sursecrt\PROIECT\_CIA\_AO.log

Name:	mn1
Model:	n018
Id:	2.63e-04
Vgs:	6.50e-01
Vds:	1.95e+00
Vbs:	0.00e+00
Vth:	4.46e-01
Vdsat:	1.92e-01
Gm:	2.07e-03
Gds:	2.16e-05
Gmb:	6.62e-04
Cbd:	5.69e-14
Cbs:	8.80e-14
Cgsov:	2.07e-14
Cgdov:	1.83e-14
Cgbov:	0.00e+00
dQgdVgb:	2.79e-13
dQgdVdb:	-1.83e-14
dQgdVsb:	-2.44e-13
dQddVgb:	-1.83e-14
dQddVdb:	7.52e-14
dQddVsb:	4.36e-17
dQbdVgb:	-4.04e-14
dQbdVdb:	-5.69e-14
dQbdVsb:	-1.25e-13

Date: Fri May 13 15:46:27 2022  
Total elapsed time: 0.063 seconds.

Figura 10. Captura de ecran a fişierului de ieşire după ajustare



Tranzistor	W/L	ID [uA]	Vdsat [mV]	Vds [mV]	Vth [mv]	Vgs [mv]	gm [uS]	gds [uS]
Mbias2	24.55	60	204	731	446	731	343	6.13
Mbias1	264.78	525	204	614	446	731	3600	66.5
Mp2	130.53	263	220	440	602	886	1750	35.9
Mp1	130.53	263	220	440	602	886	1750	35.9
Mn2	38	263	192	1950	446	650	2070	21.6
Mn1	38	263	192	1950	446	650	2070	21.6

Tabelul 3. Parametrii tranzistoarelor după ajustare

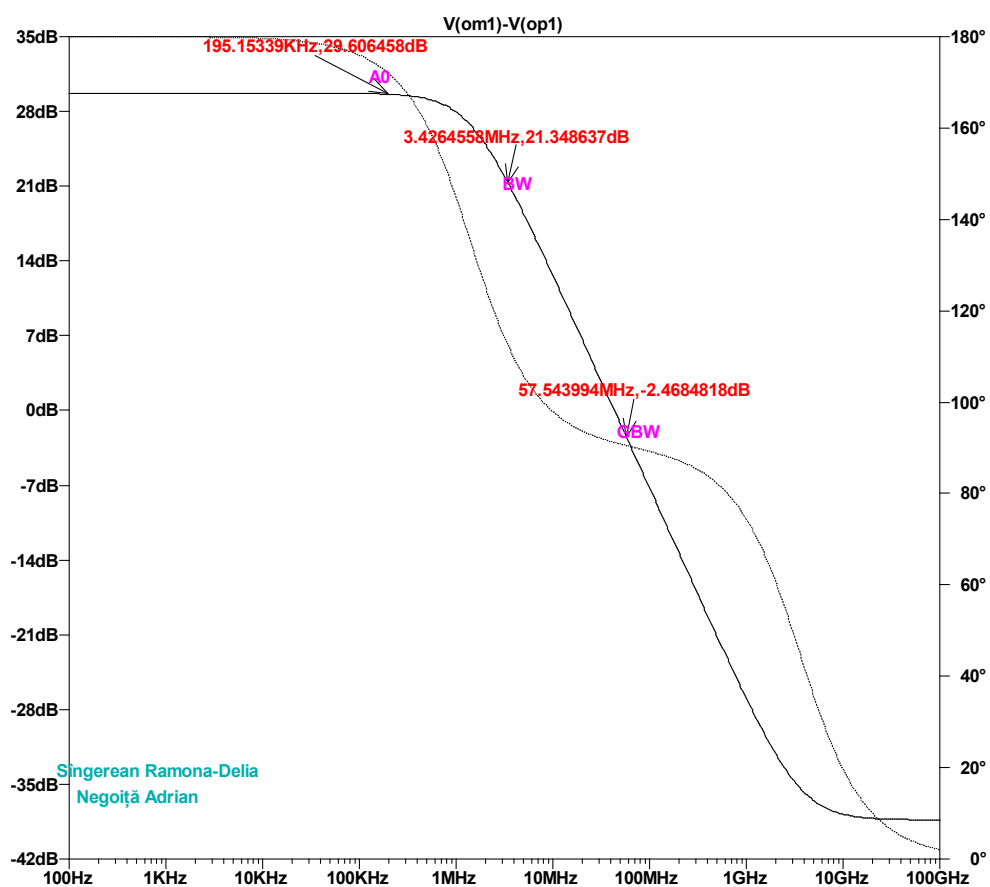


Figura 11. Caracteristica de modul și fază

$$\begin{aligned}
 R_{out} &= r_{ds} + r_{ds} m_1 m_2 = \frac{1}{\frac{1}{r_{ds}} + \frac{1}{r_{ds} m_1 m_2}} = \frac{1}{\frac{1}{35,9} + \frac{1}{21,6}} = \frac{1}{57,5 \mu} \\
 R_{out} &= 17,39 \text{ K} \\
 A_o &= \frac{g_{m_{m1m2}}}{2} \cdot 2 R_{out} = 30 \text{ dB} \\
 &= 17,39 \cdot 10^3 \cdot 2070 \mu = 34,72 \\
 BW &= \frac{1}{2\pi R_{out} C_L} = \frac{1}{2\pi \cdot 17,39 \cdot 10^3 \cdot 3 \cdot 10^{-12}} = 3 \text{ M} \\
 GBW &= \frac{g_{m_{m1m2}}}{2\pi C_L} = 57,3 \text{ Meg.}
 \end{aligned}$$

Figura 12. Calculul parametrilor A0, GBW, fpol

Parametru	Calculat	Măsurat
A0 [dB]	34.72	29.6
fpol [KHz]	3000	3426
GBW [MHz]	57.3	57.54

Tabel 4. Valorile calculate și măsurate ale parametrilor

### 3.OGLINZI DE CURENR WILSON ASIMETRICA

-> folosim 2 oglinzi, una Nmos si una Pmos

#### OGLINDA WILSON ASIMETRICA PMOS

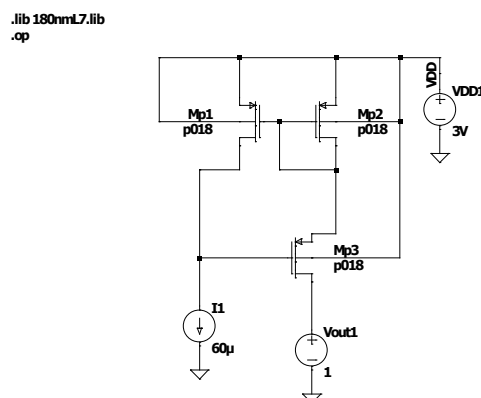


Figura 13. Schema electrică a oglinzii Wilson de tip PMOS

OGLINZI DE CURENT Vibron asimetrie

→ 2 oglonzi, una NMOS, una de tip P.

Date: curent  $60\mu$   $V_{DSAT} = 200\text{ mV}$

Dimensionare tranzistoarele PMOS

$$\frac{50\mu}{60\mu} = \frac{15\mu/1\mu}{\frac{W}{L}} \cdot \left(\frac{254\text{ m}}{200\text{ m}}\right)^2 \Rightarrow \frac{W}{L} = 29,7$$

alegem  $L = 1\mu$   $W = 29,7\mu$

$$A_D = A_S = 0,2\mu \cdot 29,7\mu = 5,94\mu$$

$$P_D = P_S = 2(0,2 + 29,7) = 59,8\mu$$

Ajustare oglondă PMOS

→ ajustăm geometria lui  $H_{P2}$  și  $H_{P3} \Rightarrow \frac{W}{L} = 32,89$

$$A_D = A_S = 0,2 \cdot 32,89 = 6,57\mu$$

$$P_D = P_S = 2(0,2 + 32,89) = 66,48\mu$$

Figura 14. Proiectarea circuitului după valorile alese

```
SPICE Error Log: C:\Users\Asus\Desktop\PROIECT_CIA\Lab2-Sursect\PROIECT_CIA_OGLINDA_PMO5_OP.log
Circuit: * C:\Users\Asus\Desktop\PROIECT_CIA\Lab2-Sursect\PROIECT_CIA_OGLINDA_PMO5_OP.asc
Direct Newton iteration for .op point succeeded.
Semiconductor Device Operating Points:
--- BSIM3 MOSFETS ---
Name:      mp3      mp2      mp1
Model:     p018     p018     p018
Id:        -6.00e-05 -6.00e-05 -6.00e-05
Vgs:       -8.81e-01 -7.16e-01 -7.16e-01
Vds:       -1.28e+00 -7.16e-01 -1.60e+00
Vbs:       7.16e-01  0.00e+00  0.00e+00
Vth:       -6.25e-01 -4.46e-01 -4.46e-01
Vdsat:     -2.02e-01 -1.95e-01 -1.95e-01
Gm:        4.45e-04  4.37e-04  4.33e-04
Gds:       6.51e-06  7.45e-06  6.61e-06
Gmb:       9.75e-05  1.19e-04  1.18e-04
Cbd:       5.40e-14  7.11e-14  5.79e-14
Cbs:       7.11e-14  9.43e-14  9.43e-14
Cgsbv:     1.79e-14  1.79e-14  1.62e-14
Cgdov:     1.69e-14  1.77e-14  1.46e-14
Cgbv:      0.00e+00  0.00e+00  0.00e+00
dQgdVgb:   2.41e-13  2.47e-13  2.21e-13
dQgdVdb:   -1.69e-14 -1.78e-14 -1.46e-14
dQgdVsb:   -2.14e-13 -2.17e-13 -1.96e-13
dQddVgb:   -1.70e-14 -1.81e-14 -1.47e-14
dQddVdb:   7.10e-14  8.91e-14  7.26e-14
dQddVsb:   7.77e-17  2.56e-16  4.74e-17
dQbdVgb:   -3.83e-14 -4.24e-14 -3.83e-14
dQbdVdb:   -5.40e-14 -7.12e-14 -5.79e-14
dQbdVsb:   -7.98e-14 -1.13e-13 -1.11e-13

Date: Wed May 11 01:18:22 2022
Total elapsed time: 0.116 seconds.
```

Figura 15. Fișierul de ieșire după ajustare

Tranzistor	W/L	ID [uA]	Vdsat [mV]	Vds [mV]	Vth [mv]	Vgs [mv]	gm [uS]	gds [uS]
Mp3	32.89	60	202	1280	625	881	445	6.51
Mp2	32.89	60	195	716	446	716	437	7.45
Mp1	29.7	60	195	1600	446	716	433	6.61

Tabelul 5. Parametrii tranzistoarelor după ajustare

$P_{MOS}$   
 $g_{m1} = 433 \mu S \quad g_{m2} = 437 \mu S \quad g_{m3} = 449 \mu S$   
 $r_{DS1} = \frac{1}{g_{ds1}} = \frac{1}{6,61 \cdot 10^{-6}} = 0,15 \text{ M}\Omega$   
 $r_{DS3} = \frac{1}{g_{ds3}} = \frac{1}{6,51 \cdot 10^{-6}} = 0,15 \text{ M}\Omega$   
 $R_{in} = \frac{g_{m2} + g_{m3}}{g_{m1} g_{m3}} = \frac{437 \cdot 10^{-6} + 449 \cdot 10^{-6}}{433 \cdot 10^{-6} \cdot 445 \cdot 10^{-6}} = 4,54 \text{ k}\Omega$   
 $R_{out} = \frac{g_{m1} g_{m3} r_{DS1} r_{DS3}}{g_{m2}} = \frac{433 \cdot 449 \cdot 0,15 \cdot 0,15}{437} \cdot 10^6 = 9,92 \text{ M}\Omega$   
 $\frac{1}{R_{in}} = \frac{1}{4,54 \cdot 10^3} = 0,21 \text{ m}$   
 $\frac{1}{R_{out}} = \frac{1}{9,92 \cdot 10^6} = 0,1 \mu.$

Figura 16. Calculul rezistenței de intrare ( $R_{in}$ ) și de ieșire ( $R_{out}$ );

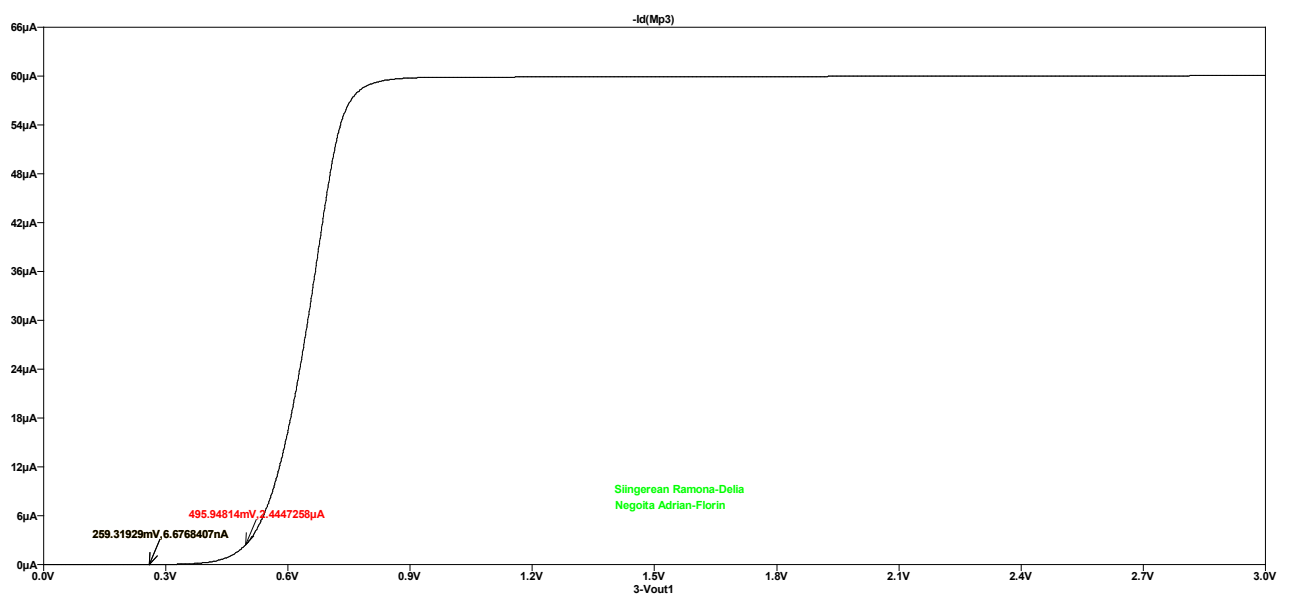


Figure 17. Caracteristica rezistenței de ieșire

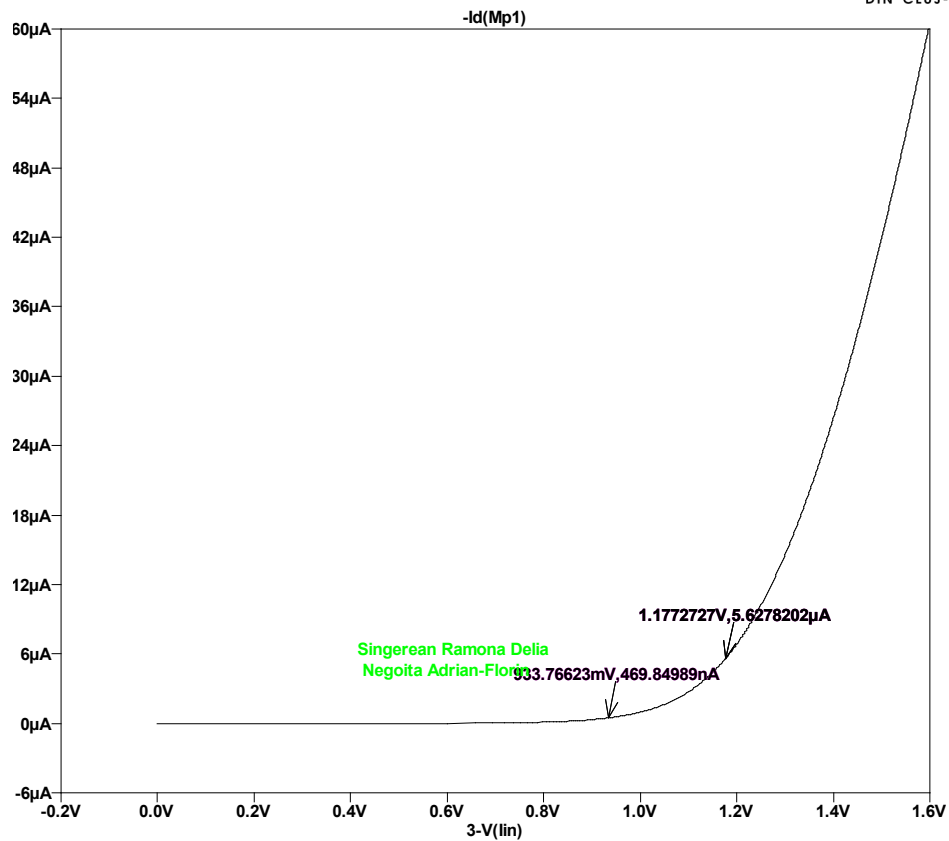


Figura 18. Caracteristica rezistenței de intrare

Parametru	Calculat	Măsurat
Rin [K Ω]	4.57	4.749
Rout [MΩ]	9.92	9.7

Tabel 6. Valorile calculate și măsurate ale rezistenței de ieșire și intrare

## OGLINDA WILSON ASIMETRICA NMOS

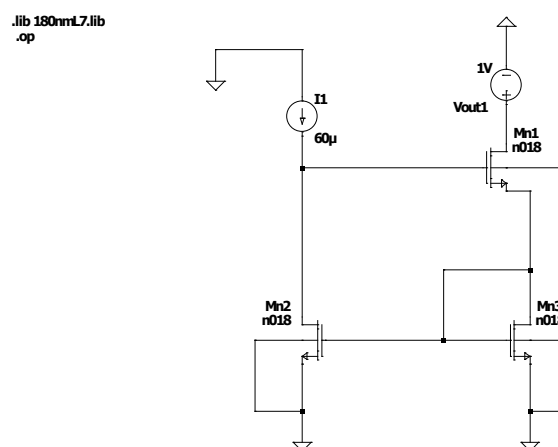


Figura 19 .Schema electrica la nivel de tranzistor a oglinzii Wilson asimetrică de tip NMOS

$= 66,48 \mu$

Dimensionăm tranzistoarele NMOS.

$$\frac{50 \mu}{60 \mu} = \frac{5 \mu / 1 \mu}{\frac{W}{L}} \left( \frac{240 \text{ m}}{200 \text{ m}} \right)^2 = 1, \quad \frac{W}{L} = 8,64 \quad \text{alegem } L = 1 \mu \quad W = 8,64 \mu$$

$$A_D = A_S = 0,2 \cdot 8,64 = 1,728 \mu$$

$$P_D = P_S = 2(0,2 + 8,64) = 17,68 \mu$$

→ ajustăm geometria lui  $M_{n1}$  și  $M_{n3}$

$$1) \quad \frac{W}{L} = 9,31 \mu \quad \text{alegem } L = 1 \mu \quad W = 9,31 \mu$$

$$A_D = A_S = 0,2 \cdot 9,31 = 1,862 \mu$$

$$P_D = P_S = 2(0,2 + 9,31) = 19,2 \mu$$

Figura 20. Proiectare circuitului după valorile alese

```

SPICE Error Log: C:\Users\Asus\Desktop\PROIECT_CIA\Lab2-Surseert\PROIECT_CIA_OGLINDA_NMOS_OP.log
Circuit: * C:\Users\Asus\Desktop\PROIECT_CIA\Lab2-Surseert\PROIECT_CIA_OGLINDA_NMOS_OP.asc

Direct Newton iteration for .op point succeeded.
Semiconductor Device Operating Points:
--- BSIM3 MOSFETS ---
Name:      mn3      mn2      mn1
Model:     n018     n018     n018
Id:        5.57e-05  6.00e-05  5.57e-05
Vgs:       6.55e-01  6.55e-01  8.47e-01
Vds:       6.55e-01  1.50e+00  3.45e-01
Vbs:       0.00e+00  0.00e+00  -6.55e-01
Vth:       4.46e-01  4.46e-01  6.19e-01
Vdsat:     1.96e-01  1.96e-01  2.15e-01
Zm:        4.39e-04  4.66e-04  4.06e-04
Zds:       5.20e-06  5.08e-06  7.69e-06
Zmb:       1.40e-04  1.49e-04  1.06e-04
Zbd:       1.65e-14  1.40e-14  1.53e-14
Zbs:       2.03e-14  2.03e-14  1.65e-14
Zgsbv:     4.71e-15  4.71e-15  4.71e-15
Zgdov:     4.66e-15  4.28e-15  4.71e-15
Zgbv:      0.00e+00  0.00e+00  0.00e+00
iQgdVgb:   6.40e-14  6.35e-14  6.37e-14
iQgdVdb:   -4.69e-15  -4.28e-15  -5.04e-15
iQgdVsb:   -5.55e-14  -5.55e-14  -5.58e-14
iQddVgb:   -4.78e-15  -4.30e-15  -5.62e-15
iQddVdb:   2.12e-14  1.83e-14  2.08e-14
iQddVsb:   9.67e-17  1.70e-17  3.26e-16
iQbdVgb:   -9.15e-15  -9.18e-15  -8.30e-15
iQbdVdb:   -1.65e-14  -1.40e-14  -1.55e-14
iQbdVsb:   -2.88e-14  -2.88e-14  -2.16e-14

Date: Wed May 11 01:27:07 2022
Total elapsed time: 0.163 seconds.

```

Figura 21. Fișierul de ieșire înainte de ajustare

SPICE Error Log: C:\Users\Asus\Desktop\PROIECT\_CIA\Lab2-Sursecr\PROIECT\_CIA\_OGLINDA\_NMOS\_OP.log

Circuit: \* C:\Users\Asus\Desktop\PROIECT\_CIA\Lab2-Sursecr\PROIECT\_CIA\_OGLINDA\_NMOS\_OP.asc

Direct Newton iteration for .op point succeeded.

Semiconductor Device Operating Points:

--- BSIM3 MOSFETS ---

Name:	mn3	mn2	mn1
Model:	n018	n018	n018
Id:	6.00e-05	6.00e-05	6.00e-05
Vgs:	6.55e-01	6.55e-01	8.47e-01
Vds:	6.55e-01	1.50e+00	3.45e-01
Vbs:	0.00e+00	0.00e+00	-6.55e-01
Vth:	4.46e-01	4.46e-01	6.19e-01
Vdsat:	1.96e-01	1.96e-01	2.15e-01
gm:	4.73e-04	4.66e-04	4.38e-04
gds:	5.60e-06	5.08e-06	8.29e-06
gmb:	1.51e-04	1.49e-04	1.14e-04
cbd:	1.65e-14	1.40e-14	1.53e-14
cbs:	2.03e-14	2.03e-14	1.65e-14
cgsov:	5.08e-15	4.71e-15	5.08e-15
cgdov:	5.03e-15	4.28e-15	5.08e-15
cgbv:	0.00e+00	0.00e+00	0.00e+00
qgddvgb:	6.90e-14	6.35e-14	6.86e-14
qgddvdb:	-5.05e-15	-4.28e-15	-5.44e-15
qgddvdb:	-5.99e-14	-5.55e-14	-6.02e-14
qgddvdb:	-5.16e-15	-4.30e-15	-6.05e-15
qgddvdb:	2.16e-14	1.83e-14	2.12e-14
qgddvdb:	1.04e-16	1.70e-17	3.52e-16
qgddvdb:	-9.87e-15	-9.18e-15	-8.95e-15
qgddvdb:	-1.65e-14	-1.40e-14	-1.55e-14
qgddvdb:	-2.95e-14	-2.88e-14	-2.21e-14

Date: Wed May 11 01:33:22 2022

Total elapsed time: 0.138 seconds.

Figura 22. Fișierul de ieșire după ajustare

Tranzistor	W/L	ID [uA]	Vdsat [mV]	Vds [mV]	Vth [mv]	Vgs [mv]	gm [uS]	gds [uS]
Mn3	9.315	60	196	655	446	655	473	5.60
Mn2	8.64	60	196	1500	446	655	466	5.08
Mn1	9.315	60	201	345	619	847	438	8.29

Tabel 7. Parametrii tranzistoarelor după ajustare

$$g_{m1} = 438 \mu S \quad g_{m2} = 466 \mu S \quad g_{m3} = 473 \mu S$$

$$r_{DS1} = \frac{1}{g_{DS1}} = \frac{1}{8.29 \cdot 10^{-6}} = 9.42 \cdot 10^4 \Omega$$

$$r_{DS3} = \frac{1}{g_{DS3}} = \frac{1}{5.60 \cdot 10^{-6}} = 0.177 \cdot 10^6 \Omega$$

$$R_{in} = \frac{g_{m1} + g_{m3}}{g_{m2} \cdot g_{m1}} = \frac{911 \cdot 10^{-6}}{466 \cdot 10^{-6} \cdot 438 \cdot 10^{-6}} = 4.46 \cdot 10^6 \Omega$$

$$R_{out} = \frac{g_{m1} \cdot g_{m2} \cdot r_{DS1} \cdot r_{DS2}}{g_{m3}} = \frac{4653.66}{473} \cdot 10^6 = 9.83 \cdot 10^6 \Omega$$

Figura 23. Calculul rezistențelor de intrare și ieșire

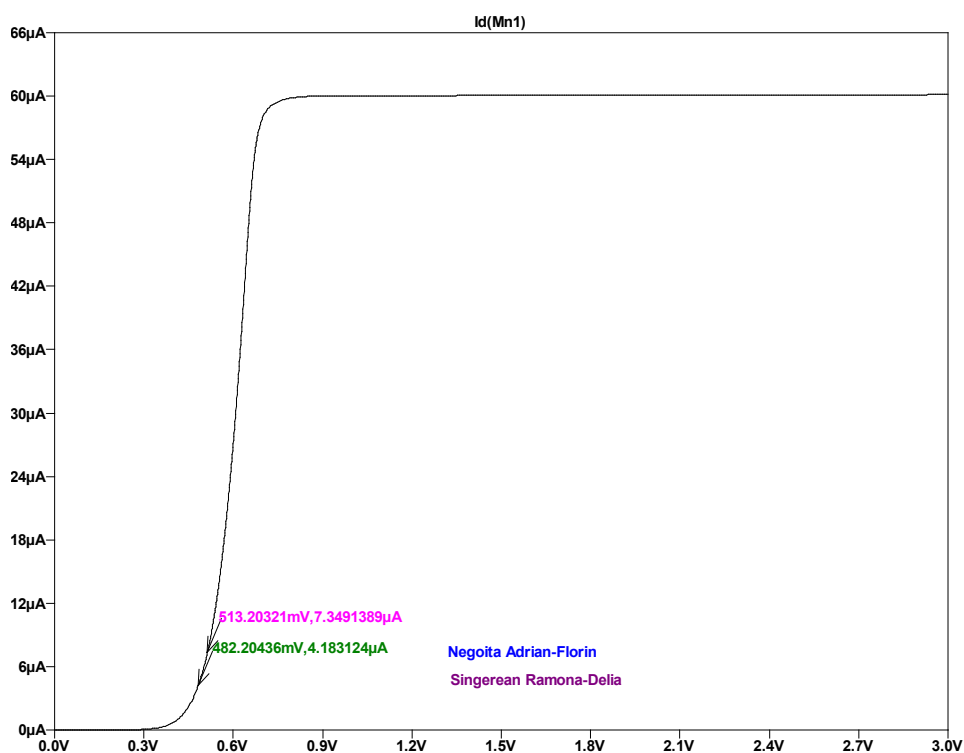


Figura 24. Caracteristica rezistenței de ieșire

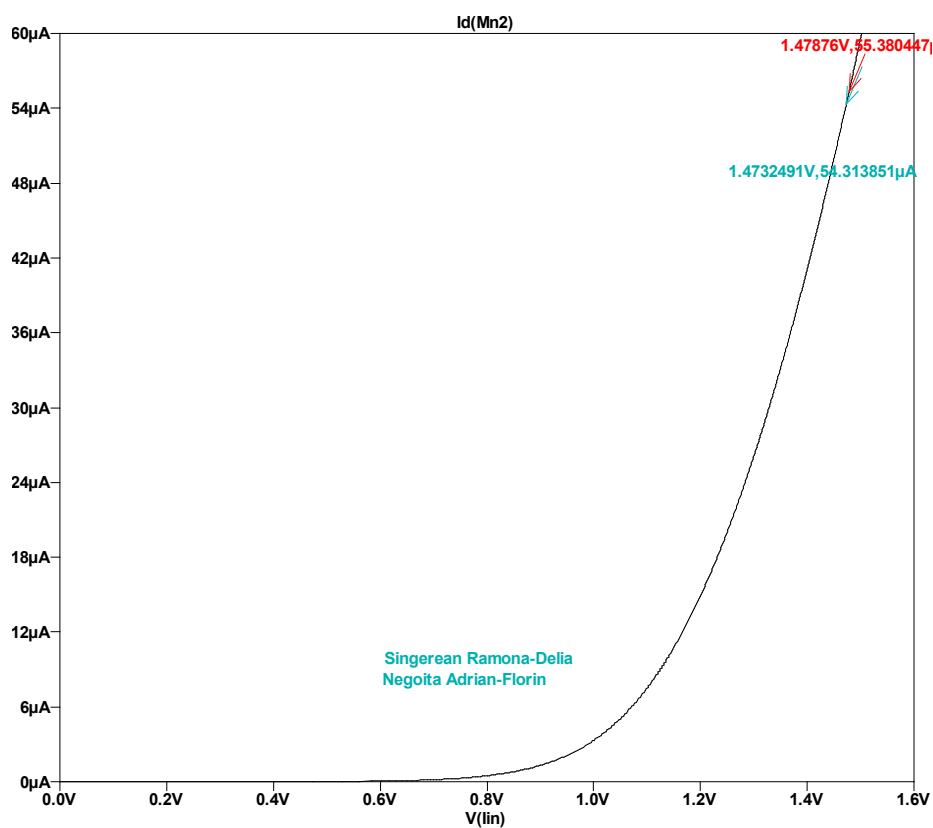


Figura 25. Caracteristica rezistenței de intrare



Parametru	Calculat	Măsurat
Rin [K $\Omega$ ]	4.46	5.16
Rout [M $\Omega$ ]	9.83	

Tabelul 8: Valorile calculate și măsurate ale rezistenței de ieșire și intrare

#### 4.CIRCUITUL COMPLET

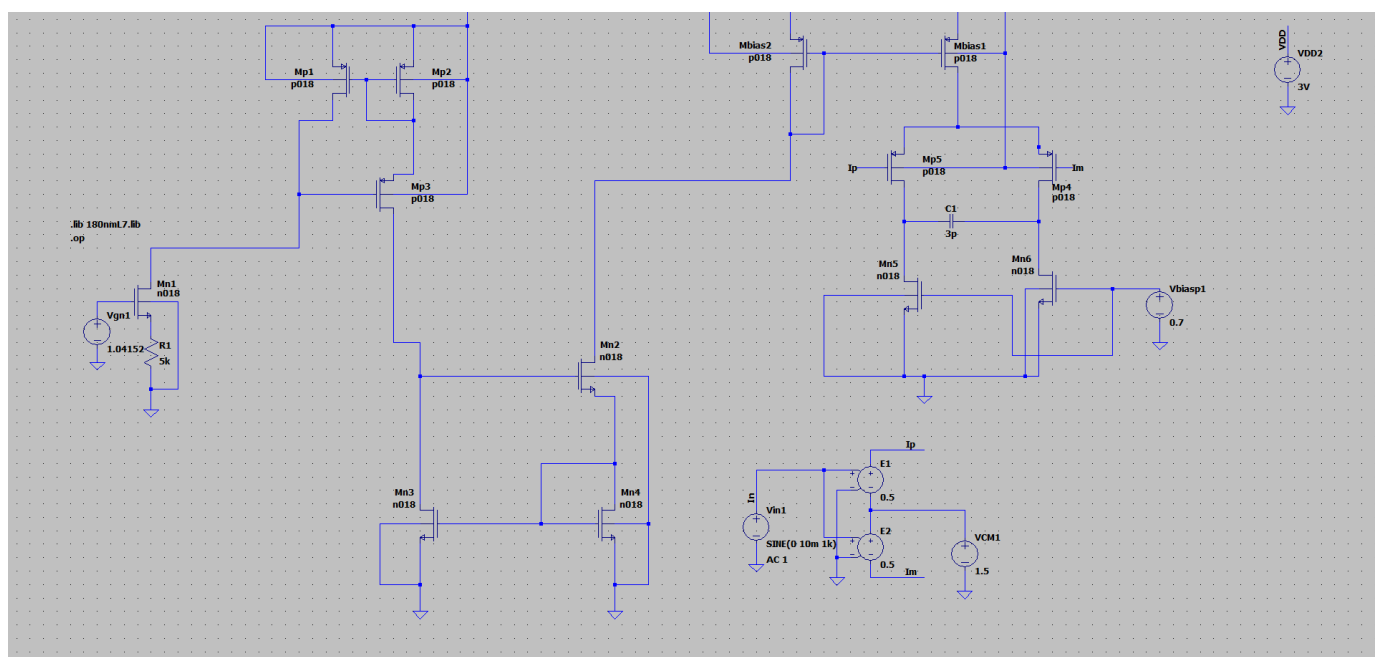


Figura 26 :Schema electrică a circuitului complet

Circuit: \* C:\Users\Adi\Downloads\PROIECT\_CIA\Lab2-Sursecrt\PROIECT\_CIA\_CIRCUIT\_COMPLET\_VERSIUNEA\_2.asc

Direct Newton iteration for .op point succeeded.

Semiconductor Device Operating Points:

--- BSIM3 MOSFETS ---

Name:	mbias2	mbias1	mp5	mp4	mp3
Model:	p018	p018	p018	p018	p018
Id:	-5.81e-05	-5.59e-04	-2.79e-04	-2.79e-04	-5.80e-05
Vgs:	-7.53e-01	-7.53e-01	-1.28e+00	-1.28e+00	-8.83e-01
Vds:	-7.53e-01	-2.22e-01	-4.96e-02	-4.96e-02	-8.10e-01
Vbs:	0.00e+00	0.00e+00	2.22e-01	2.22e-01	7.12e-01
Vth:	-4.46e-01	-4.46e-01	-5.07e-01	-5.07e-01	-6.24e-01
Vdsat:	-2.18e-01	-2.18e-01	-5.07e-01	-5.07e-01	-2.04e-01
Gm:	3.63e-04	3.30e-03	3.36e-04	3.36e-04	4.28e-04
Gds:	6.97e-06	4.93e-04	5.35e-03	5.35e-03	6.71e-06
Gmb:	9.85e-05	9.01e-04	1.12e-04	1.12e-04	9.36e-05
Cbd:	5.87e-14	7.48e-13	3.63e-13	3.63e-13	6.50e-14
Cbs:	7.87e-14	8.33e-13	3.71e-13	3.71e-13	7.88e-14
Cgsov:	1.35e-14	1.44e-13	7.11e-14	7.11e-14	1.79e-14
Cgdov:	1.33e-14	1.43e-13	7.11e-14	7.11e-14	1.78e-14
Cgbov:	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
dQgdVgb:	1.85e-13	2.02e-12	1.14e-12	1.14e-12	2.42e-13
dQgdVdb:	-1.34e-14	-2.16e-13	-5.25e-13	-5.25e-13	-1.78e-14
dQgdVsb:	-1.64e-13	-1.73e-12	-6.13e-13	-6.13e-13	-2.14e-13
dQddVgb:	-1.36e-14	-2.85e-13	-5.63e-13	-5.63e-13	-1.81e-14
dQddVdb:	7.22e-14	1.10e-12	1.72e-12	1.72e-12	8.30e-14
dQddVsb:	1.74e-16	-3.36e-14	-6.76e-13	-6.76e-13	1.95e-16
dQbdVgb:	-3.18e-14	-2.94e-13	-4.66e-15	-4.66e-15	-3.82e-14
dQbdVdb:	-5.88e-14	-8.17e-13	-7.69e-13	-7.69e-13	-6.51e-14
dQbdVsb:	-9.25e-14	-9.70e-13	-2.20e-13	-2.20e-13	-8.76e-14

SPICE Error Log: C:\Users\Adi\Downloads\PROIECT\_CIA\Lab2-Sursecrt\PROIECT\_CIA\_CIRCUIT\_COMPLET\_VERSIUNEA\_2.log

dQbdVgb:	-3.18e-14	-2.94e-13	-4.66e-15	-4.66e-15	-3.82e-14
dQbdVdb:	-5.88e-14	-8.17e-13	-7.69e-13	-7.69e-13	-6.51e-14
dQbdVsb:	-9.25e-14	-9.70e-13	-2.20e-13	-2.20e-13	-8.76e-14
Name:	mp2	mp1	mn6	mn5	mn4
Model:	p018	p018	n018	n018	n018
Id:	-5.80e-05	-5.81e-05	2.79e-04	2.79e-04	5.81e-05
Vgs:	-7.12e-01	-7.12e-01	6.50e-01	6.50e-01	6.51e-01
Vds:	-7.12e-01	-1.59e+00	2.73e+00	2.73e+00	6.51e-01
Vbs:	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vth:	-4.46e-01	-4.46e-01	4.46e-01	4.46e-01	4.46e-01
Vdsat:	-1.92e-01	-1.92e-01	1.92e-01	1.92e-01	1.93e-01
Gm:	4.31e-04	4.27e-04	2.17e-03	2.17e-03	4.66e-04
Gds:	7.24e-06	6.42e-06	2.16e-05	2.16e-05	5.46e-06
Gmb:	1.17e-04	1.16e-04	6.98e-04	6.98e-04	1.48e-04
Cbd:	7.88e-14	5.80e-14	5.20e-14	5.20e-14	1.79e-14
Cbs:	1.04e-13	9.43e-14	8.80e-14	8.80e-14	2.20e-14
Cgsov:	1.79e-14	1.62e-14	2.07e-14	2.07e-14	5.08e-15
Cgdov:	1.77e-14	1.46e-14	1.77e-14	1.77e-14	5.03e-15
Cgbov:	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
dQgdVgb:	2.47e-13	2.21e-13	2.78e-13	2.78e-13	6.90e-14
dQgdVdb:	-1.78e-14	-1.46e-14	-1.77e-14	-1.77e-14	-5.05e-15
dQgdVsb:	-2.17e-13	-1.96e-13	-2.44e-13	-2.44e-13	-5.98e-14
dQddVgb:	-1.81e-14	-1.47e-14	-1.78e-14	-1.78e-14	-5.16e-15
dQddVdb:	9.68e-14	7.26e-14	6.98e-14	6.98e-14	2.30e-14
dQddVsb:	2.59e-16	4.75e-17	2.19e-17	2.19e-17	1.05e-16
dQbdVgb:	-4.24e-14	-3.84e-14	-4.04e-14	-4.04e-14	-9.87e-15
dQbdVdb:	-7.89e-14	-5.80e-14	-5.20e-14	-5.20e-14	-1.79e-14
dQbdVsb:	-1.23e-13	-1.11e-13	-1.25e-13	-1.25e-13	-3.12e-14
Name:	mn3	mn2	mn1		

SPICE Error Log: C:\Users\Adi\Downloads\PROIECT\_CIA\Lab2-Sursect\PROIECT\_CIA\_CIRCUIT\_COMPLET\_VERSIUNEA\_2.log

Name:	mn3	mn2	mn1
Model:	n018	n018	n018
Id:	5.80e-05	5.81e-05	5.81e-05
Vgs:	6.51e-01	8.27e-01	7.51e-01
Vds:	1.48e+00	1.60e+00	1.12e+00
Vbs:	0.00e+00	-6.51e-01	-2.90e-01
Vth:	4.46e-01	6.18e-01	5.28e-01
Vdsat:	1.93e-01	2.01e-01	2.09e-01
Gm:	4.58e-04	4.50e-04	4.28e-04
Gds:	4.95e-06	4.60e-06	4.85e-06
Gmb:	1.46e-04	1.17e-04	1.24e-04
Cbd:	1.40e-14	1.37e-14	1.42e-14
Cbs:	2.03e-14	1.79e-14	1.82e-14
Cgsov:	4.71e-15	5.08e-15	4.44e-15
Cgdov:	4.29e-15	4.64e-15	4.21e-15
Cgbov:	0.00e+00	0.00e+00	0.00e+00
dQgdVgb:	6.35e-14	6.78e-14	5.97e-14
dQgdVdb:	-4.29e-15	-4.64e-15	-4.22e-15
dQgdVsb:	-5.55e-14	-6.00e-14	-5.23e-14
dQddVgb:	-4.30e-15	-4.66e-15	-4.25e-15
dQddVdb:	1.83e-14	1.84e-14	1.84e-14
dQddVsb:	1.76e-17	1.53e-17	2.92e-17
dQbdVgb:	-9.18e-15	-9.19e-15	-8.26e-15
dQbdVdb:	-1.40e-14	-1.37e-14	-1.42e-14
dQbdVsb:	-2.88e-14	-2.34e-14	-2.46e-14

Date: Sat May 14 10:56:35 2022  
Total elapsed time: 0.165 seconds.

Figura 27: Fișierul de ieșire înainte de ajustare

Tranzistor	W/L	ID [uA]	Vdsat [mV]	Vds [mV]	Vth [mv]	Vgs [mv]	gm [uS]	gds [uS]
Sursă de curent								
Mn1	8.139	58.1	209	1120	528	751	428	4.85
Oglindă/oglinzi de curent								
Mp3	32.89	58	204	810	624	883	428	6.71
Mp2	32.89	58	192	712	446	712	431	7.24
Mp1	29.7	58.1	192	1590	446	712	427	6.42
Mn2	9.315	58.1	201	1600	618	827	450	4.60
Mn3	8.64	58	193	1480	446	651	458	4.95
Mn4	9.315	58.1	193	651	446	651	466	5.46
Amplificator diferențial								
Mbias2	24.55	58.6	218	753	446	753	363	6.97
Mbias1	264.78	559	218	222	446	753	3300	493
Mp5	130.53	279	507	49.6	507	1280	336	53.5
Mp4	130.53	279	507	49.6	507	1290	336	53.5
Mn6	38	279	192	2730	446	650	2170	21.6
Mn5	38	279	192	2730	446	650	2170	21.6

Tabel 9. Parametrii tranzistoarelor

### Calcul circuit final

Rout pentru tranzistorul de curent (Routs)

$$g_m = 428 \mu S$$

$$g_{mle} = 124 \mu S$$

$$r_{ds} = \frac{1}{g_{ds}} = \frac{1}{4,85} \cdot 10^6 = 0,2 \text{ M}\Omega$$

$$\begin{aligned} R_{out} &= r_{ds} + R_L + (g_m + g_{mle}) r_{ds} R_L = \\ &= 0,2 \cdot 10^6 + 5 \cdot 10^3 + (124 \mu + 428 \mu) \cdot 0,2 \cdot 5 \cdot 10^9 = \\ &= 205 \cdot 10^3 + 552 \cdot 10^{-6} \cdot 10^9 = 205 \cdot 10^3 + 552 \cdot 10^3 = \\ &= 0,757 \text{ M}\Omega \end{aligned}$$

Rin, Rout (circuitul Pmos)

$$g_{m3} = 428 \mu S$$

$$g_{ds3} = 6,74 \mu S$$

$$g_{m2} = 431 \mu S$$

$$g_{ds2} = 7,24 \mu S$$

$$g_{m1} = 424 \mu S$$

$$g_{ds1} = 6,42 \mu S$$

$$r_{ds1} = \frac{1}{g_{ds1}} = \frac{1}{6,42} \cdot 10^6 = 0,15 \text{ M}\Omega$$

$$r_{ds2} = \frac{1}{g_{ds2}} = 0,13 \text{ M}\Omega$$

$$r_{ds3} = \frac{1}{g_{ds3}} = 0,14 \text{ M}\Omega$$

$$R_{in} = \frac{g_{m2} + g_{m3}}{g_{m1} g_{m3}} = \frac{(431 + 428) \cdot 10^{-6}}{424 \cdot 428 \cdot 10^{-12}} = \frac{859}{182456} \cdot 10^6 =$$

$$= 4,7 \text{ k}\Omega$$

$$R_{out} = \frac{g_{m1} g_{m3} r_{ds1} r_{ds3}}{g_{m2}} = \frac{424 \cdot 428 \cdot 0,15 \cdot 0,14}{431 \cdot 10^{-6}} = 8,9 \text{ M}\Omega$$

Find, Rout, Caglinclă Pmo Nmos)

$$g_{m2} = 450 \mu S \quad r_{ds2} = \frac{1}{g_{ds2}} = \frac{1}{4,6} \cdot 10^6 = 0,21 M\Omega$$

$$g_{m3} = 458 \mu S \quad r_{ds3} = \frac{1}{g_{ds3}} = \frac{1}{4,95} \cdot 10^6 = 0,2 M\Omega$$

$$g_{m4} = 466 \mu S \quad r_{ds4} = \frac{1}{g_{ds4}} = 0,18 M\Omega$$

$$R_{in} = \frac{g_{m4} + g_{m2}}{g_{m3} \cdot g_{m2}} = \frac{916 \cdot 10^{-6}}{206 \cdot 100 \cdot 10^{-12}} = 4,44 K\Omega$$

$$R_{out} = \frac{g_{m3} \cdot g_{m2} \cdot r_{ds3} \cdot r_{ds2}}{g_{m4}} = \frac{8656,2}{466 \cdot 10^{-6}} = 18,57 M\Omega$$

Ao, BW, GBW:

$$R_{out} = r_{ds5} + r_{ds6} = \frac{1}{g_{ds5} + g_{ds6}} = \frac{1}{53,5 + 21,6} = \frac{1}{75,1 \cdot 10^{-6}} = 13,3 K\Omega$$

$$A_o = \frac{g_{m5} \cdot r_{ds6}}{2} \cdot 2 R_{out} = 21,6 \cdot 10^{-6} \cdot 13,3 \cdot 10^3 = 287,28$$

$$BW = \frac{1}{2\pi R_{out} \cdot C_L} = \frac{1}{250,572 \cdot 10^{-9}} = 3,99 M\Omega$$

$$GBW = \frac{g_{m5} \cdot r_{ds6}}{2\pi C_L} = \frac{21,6 \cdot 10^{-6}}{18,84 \cdot 10^{-9}} = 1,14 K\Omega$$

Figura 28 :Calculul parametrilor

Parametru	Calculat	Masurat
<b>Sursa de curent</b>		
Rout [Mohm]	0.757	
<b>Oglinda NMOS</b>		
Rin [Kohm]	4.44	
Rout [Mohm]	18.57	
<b>Oglinda PMOS</b>		
Rin [Kohm]	4.7	
Rout [Mohm]	8.9	
<b>Amplificator diferential</b>		
A0 [db]	50	
F <sub>pol</sub> [kHz]	3.99	
GBW [MHz]	1	

Tabel 10. Valorile calculate și măsurate ale parametrilor sursei de curent, oglinzilor și amplificatorului