Komparatorentwurf und Verifizierung

Komparator-Design

- Theoretisches Design nach Allan-Holberg
- Schematic
- Verifizierung
- Scalable Devices einbinden
- Verifizierung
- Layout
- Verifizierung

Vorgabe:

Open Loop Gain	75		Output swing -	-0,35
Gain Bandwidth	1,00E+07		Output swing +	0,35
Phase margin	-		Cmrr	80
Settling Time	1,00E-06		Power dissipation	0,0010
Slew Rate	10		Voltage Supply -	-1,65
Offset	1,00E-06		Voltage Supply +	1,65
CMR -	-0,5		Load Capacitance	5,00E-12
CMR +	1		Load Resistance	100000

Designplan nach Allen-Holberg

$$I_7 = I_6 = C_{II}\frac{dv_{out}}{dt} = C_{II}\frac{(V_{OH} - V_{OL})}{t_p} = 3{,}5 \cdot 10^{-6}\,A$$

$$\frac{W_6}{L_6} = \frac{2 \cdot I_6}{K'_p (V_{SD6}(sat))^2} = 0{,}07$$

$$\frac{W_7}{L_7} = \frac{2 \cdot I_7}{K'_n (V_{DS7}(sat))^2} = 0{,}02$$

$$I_5 = C_I\frac{dv_{out}}{dt} = C_I\frac{(V_{OH} - V_{OL})}{t_p} = 1{,}65 \cdot 10^{-6}\,A \qquad mit\ C_I \approx 0{,}5\ pF$$

Designplan nach Allen-Holberg II

$$\frac{W_3}{L_3}=\frac{W_4}{L_4}=\frac{I_5}{K_p'(V_{SG3}-|V_{TP}|)^2}=0{,}04$$

$$g_{m1}=\frac{A_V(0)(g_{ds2}+g_{ds4})(g_{ds6}+g_{ds7})}{g_{m6}}=\frac{A_v(o)(\frac{I_5}{2}(\lambda_n+\lambda_p))(\frac{I_6}{2}(\lambda_n+\lambda_p))}{\sqrt{2K_p'\cdot I_6\cdot\frac{W_6}{L_6}}}=3{,}79\cdot10^{-6}S$$

$$\frac{W_1}{L_1}=\frac{W_2}{L_2}=\frac{g_{m1}^2}{K_n'\cdot I_5}=0{,}05 \qquad V_{gs1}=V_{tn}+\sqrt{\frac{2\cdot I_5}{2k_n'\cdot\frac{W_1}{L_1}}}=0{,}94\,V$$

$$V_{DS5}(sat)=V_{icm}^{--V_{GS1}}-V_{ss}=0{,}21\,V \Rightarrow \frac{W_5}{L_5}=\frac{2\cdot I_5}{K_N'(V_{ds5}(sat))^2}=0{,}42$$

Realisiert in einer ExcelTabelle

Open Loop Gain	75	95		I6	3,50E-006	2,76E-004
Gain Bandwidth	1,00E+07	1,00E+07		I7	3,50E-006	2,76E-004
Phase margin	-	-				
Settling Time	1,00E-06	3,98E-08		M6 W/L	0,07	31,5
Slew Rate	10000000	10000000		M7 W/L	0,02	10,75
Offset	1,00E-06	1,00E-06				
Input CMR -	-0,5	-0,5		I5	1,65E-006	4,14E-005
Input CMR +	1	1				
Output swing -	-0,35	-1,1		M³ W/L	0,04	0,98
Output swing +	0,35	1,1		M4 W/L	0,04	0,98
Cmrr	80	80				
Power dissipation	0	0		Gm1	3,79E-006	4,03E-004
Voltage Supply -	-1,65	-1,65				
Voltage Supply +	1,65	1,65		M1 W/L	0,05	23,05
Load Capacitance	5,00E-12	5,00E-12		M² W/L	0,05	23,05
Load Resistance	100000	100000				
K' n	1,70E-04	1,70E-04		Cgs6	3,24E-016	1,43E-013
K' p	5,80E-05	5,80E-05		Cgd2	2,33E-016	1,05E-013
Lambda n	0,01	0,01		Cgd4	1,78E-016	4,46E-015
Lambda p	0,03	0,03				
Vt n	0,5	0,5		C1_2	7,34E-016	2,52E-013
Vt p	-0,65	-0,65		C1_1 > C1_2	WAHR	WAHR
C1_1	5,00E-013	5,00E-013				
Cox	4,54E-015	4,54E-015		Vgs1	0,94	0,6
				Vds5	0,21	0,55
I6	3,50E-006	2,76E-004		M5 W/L	0,42	1,63
I7	3,50E-006	2,76E-004				10,86
				Power dissipation	0,00002	0,00105

Werte nach Allan-Holberg

M 1	0,05
M 2	0,05
M 3	0,04
M 4	0,04
M 5	0,42
M 6	0,07
M 7	0,02

=> Werte erhöhen

M 1	23
M 2	23
M 3	1
M 4	1
M 5	2
M 6	32
M 7	11

Werte nach Messungen

M 1	25
M 2	25
M 3	5
M 4	5
M 5	3
M 6	57
M 7	18

Werte ermittelt durch mehrmaliges messen und anpassen der Werte nach folgenden Gesichtspunkten:

Änderungskriterien:

Wichtige Eigenschaften:

1. Gain

$$A_V(0)=\frac{\sqrt{2K_p'\cdot I_6\frac{W_6}{L_6}}\cdot\sqrt{2K_n'\cdot I_2\frac{W_2}{L_2}}}{(\frac{I_5}{2}(\lambda_n+\lambda_p))(\frac{I_6}{2}(\lambda_n+\lambda_p))}$$

2. Slewrate

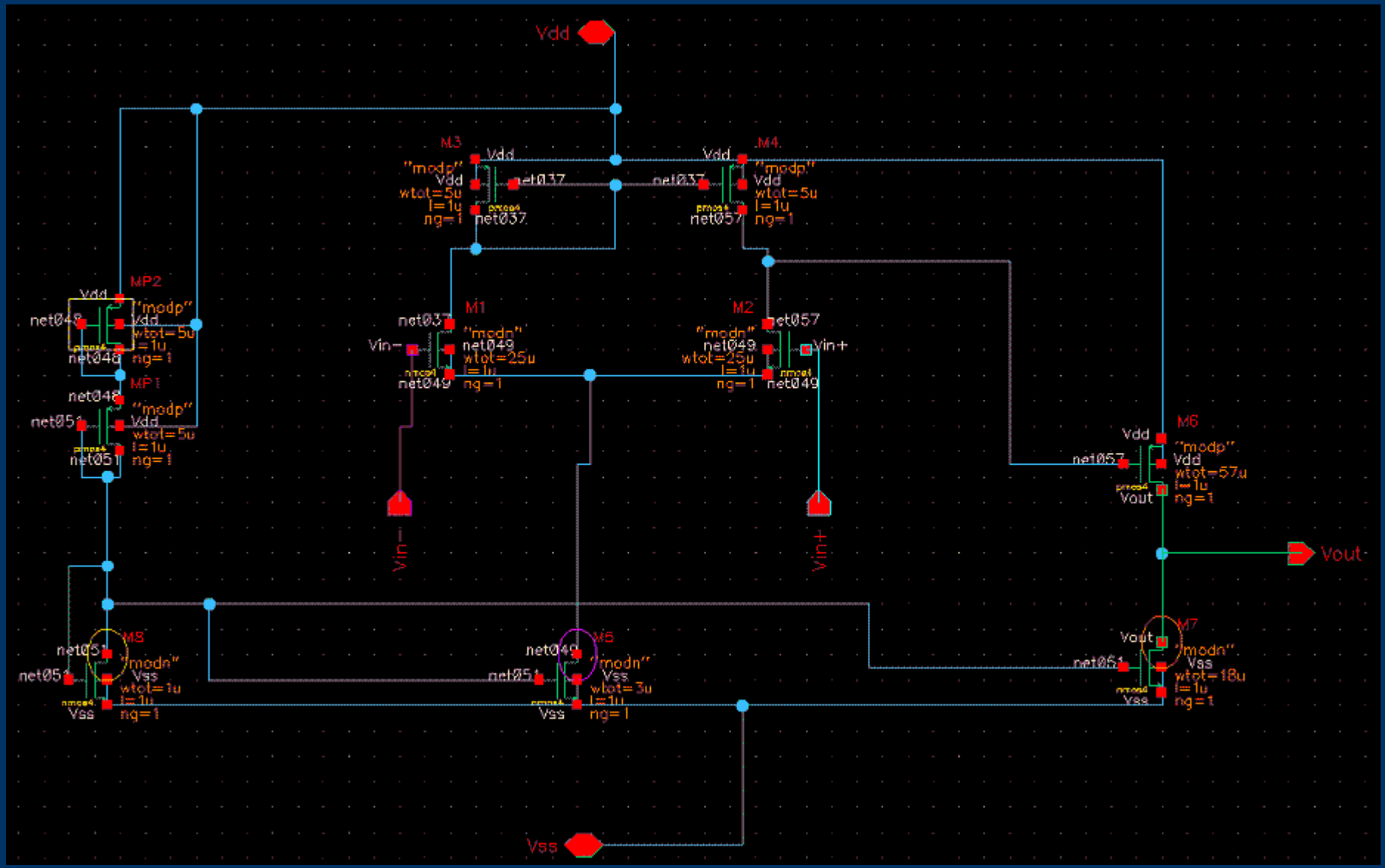
proportional zu :

$$I_6=\frac{1}{2}\cdot\frac{W_6}{L_6}\cdot K_p'(V_{SD6}(sat))^2$$

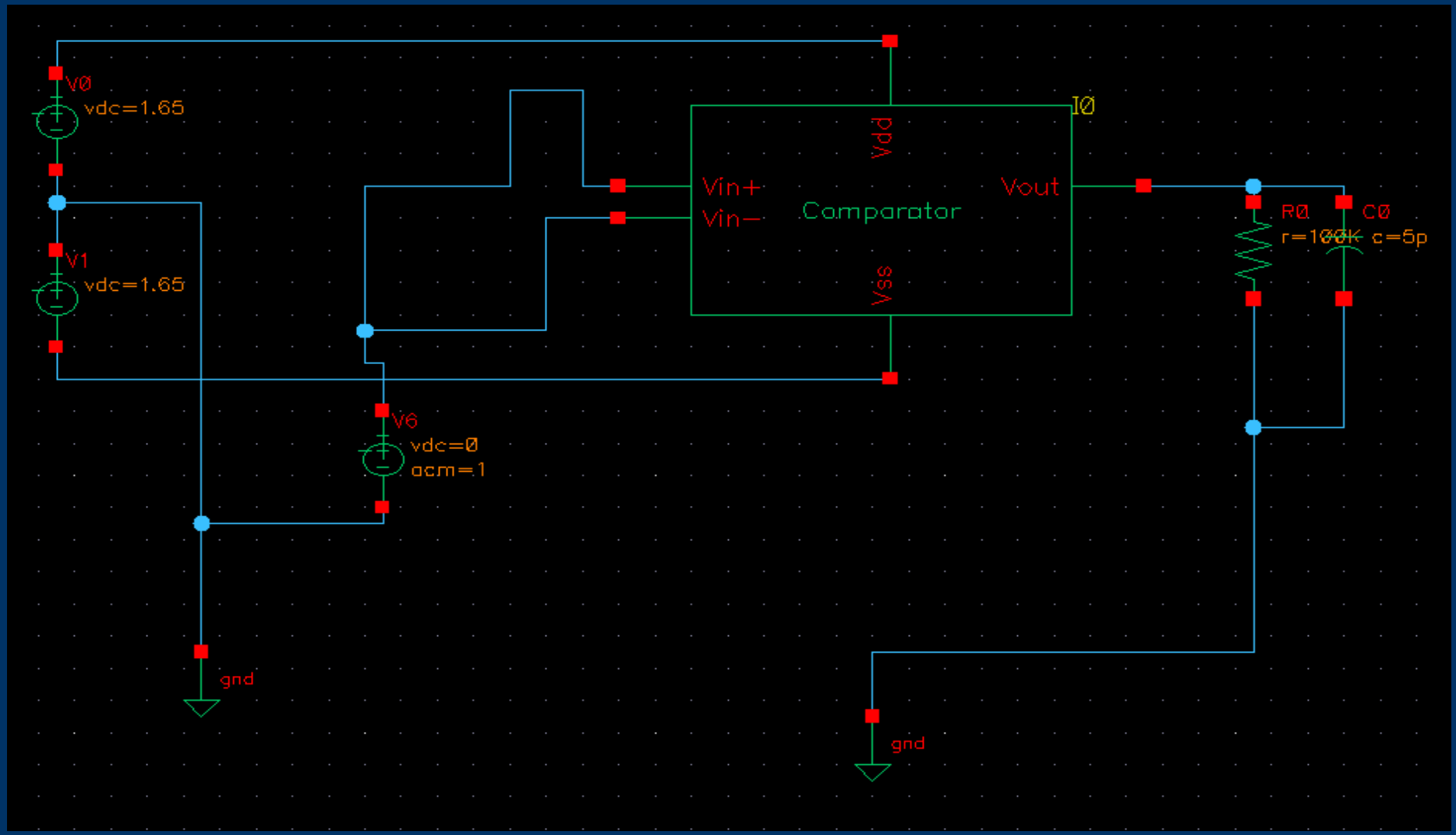
3. Powerconsumption

$$I_6+I_5=I_6+\frac{1}{2}\cdot\frac{W_5}{L_5}\cdot K_n'(V_{SD5}(sat))^2$$

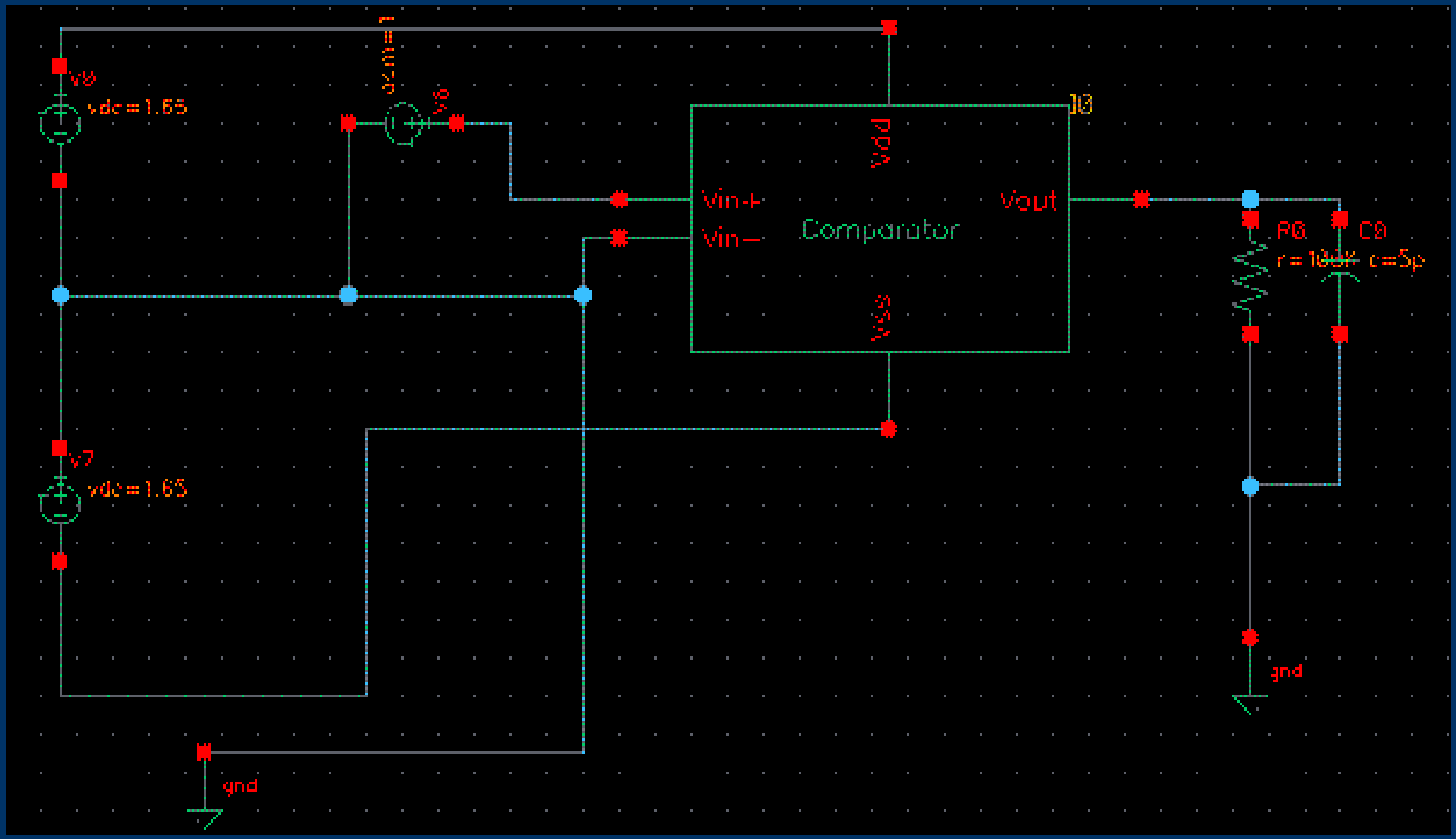
Schematic


Vdd
M3
"modp"
Vdd
wtot=5u
l=1u
ng=1
net037
M4
net057
MP2
net048
MP1
net051
M1
"modn"
net049
wtot=25u
Vin-
M2
Vin+
M6
wtot=57u
Vout
M8
Vss
wtot=1u
M5
wtot=3u
M7
wtot=18u
net061

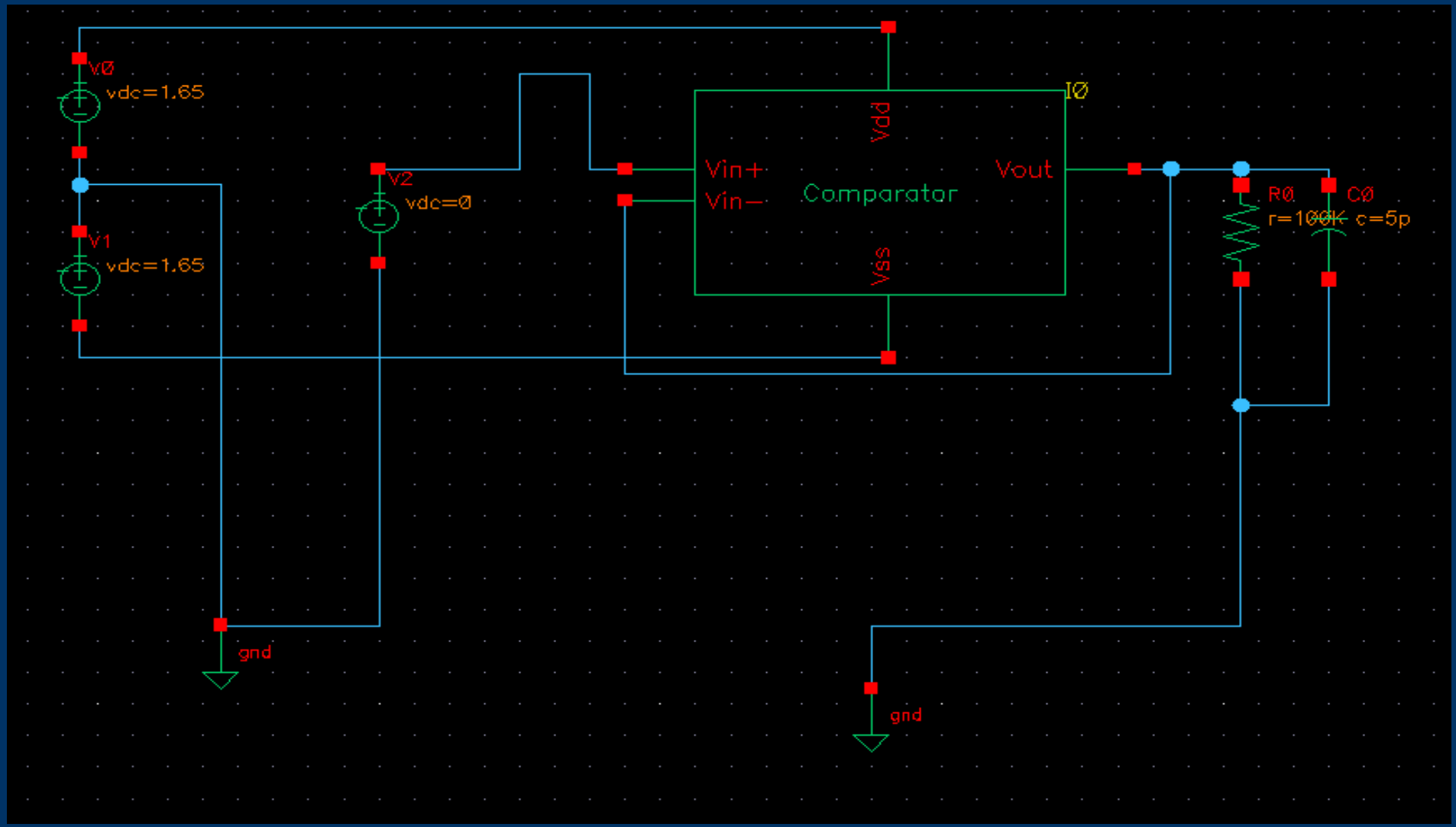
Testschaltung CMRR



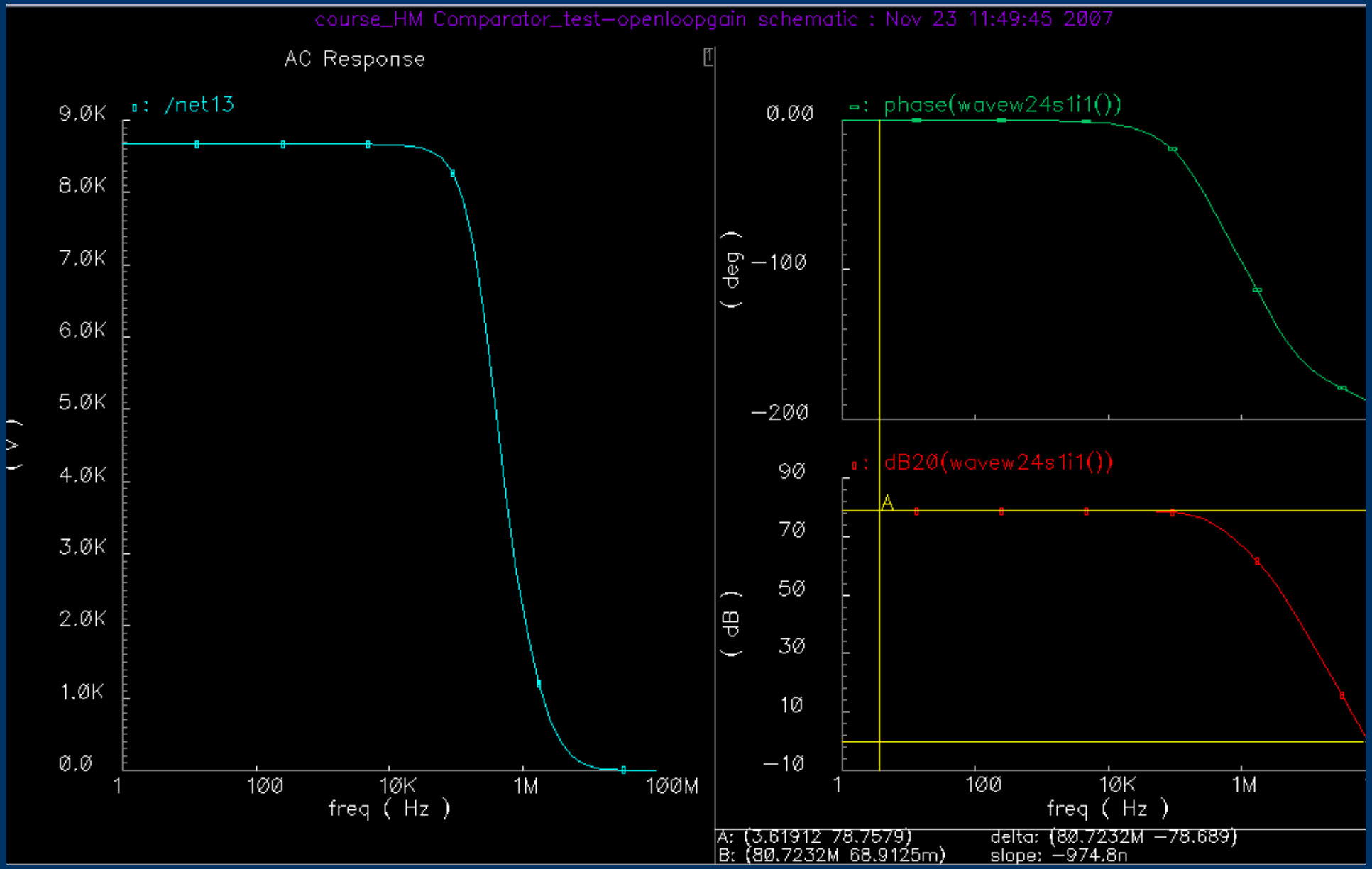
Testschaltung Bodeplot



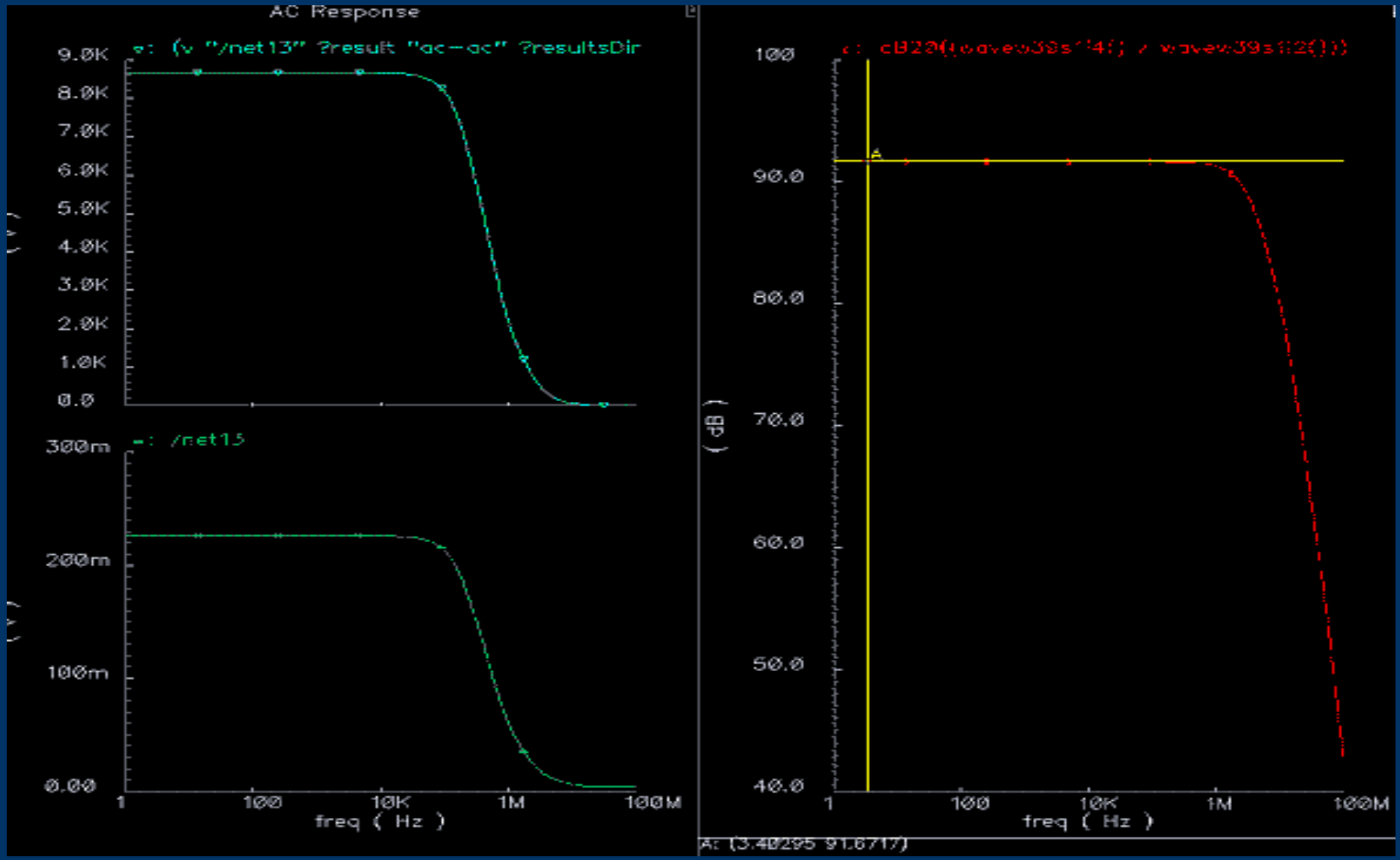
Testschaltung CMR



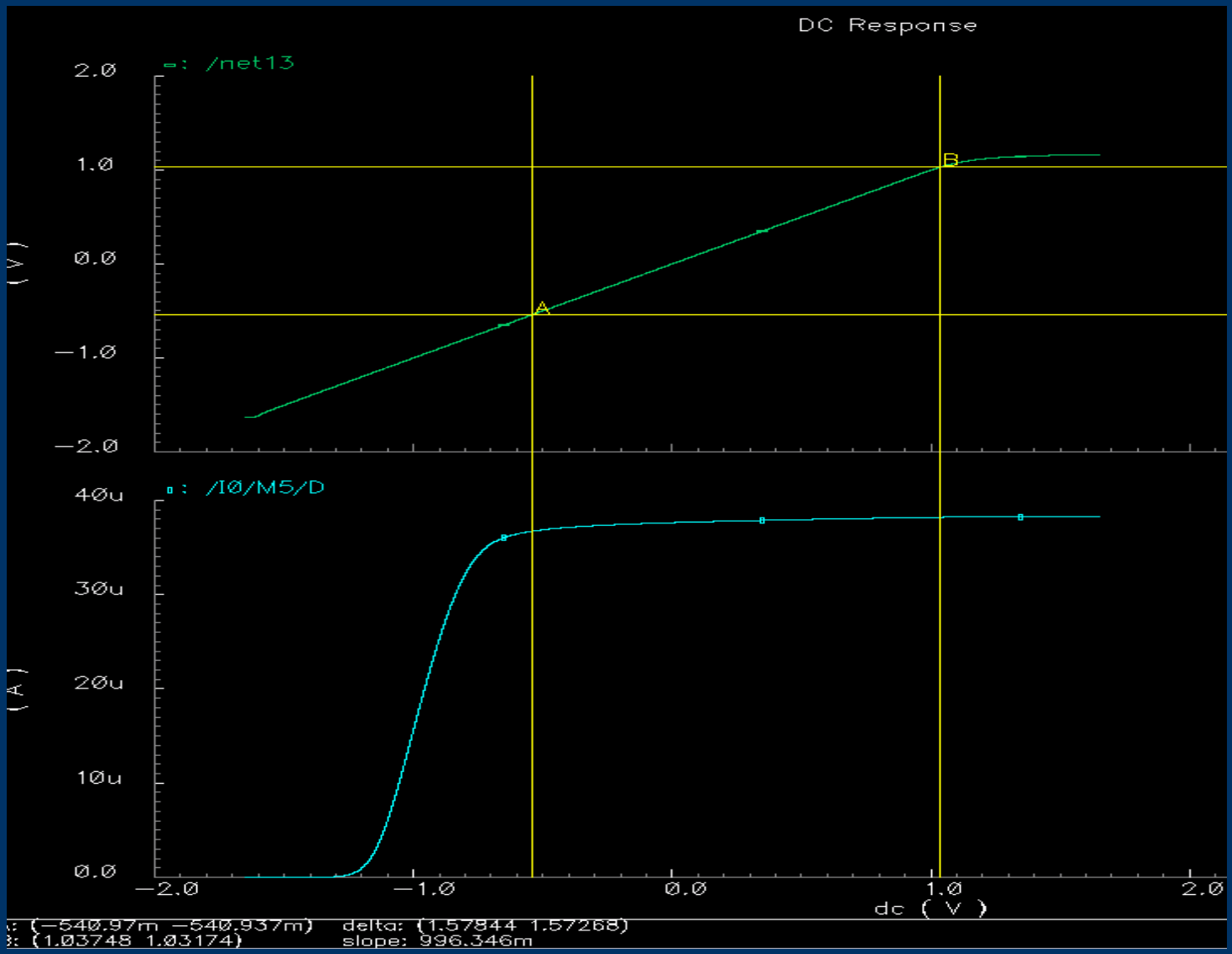
Verifizierung – Gain und GBW



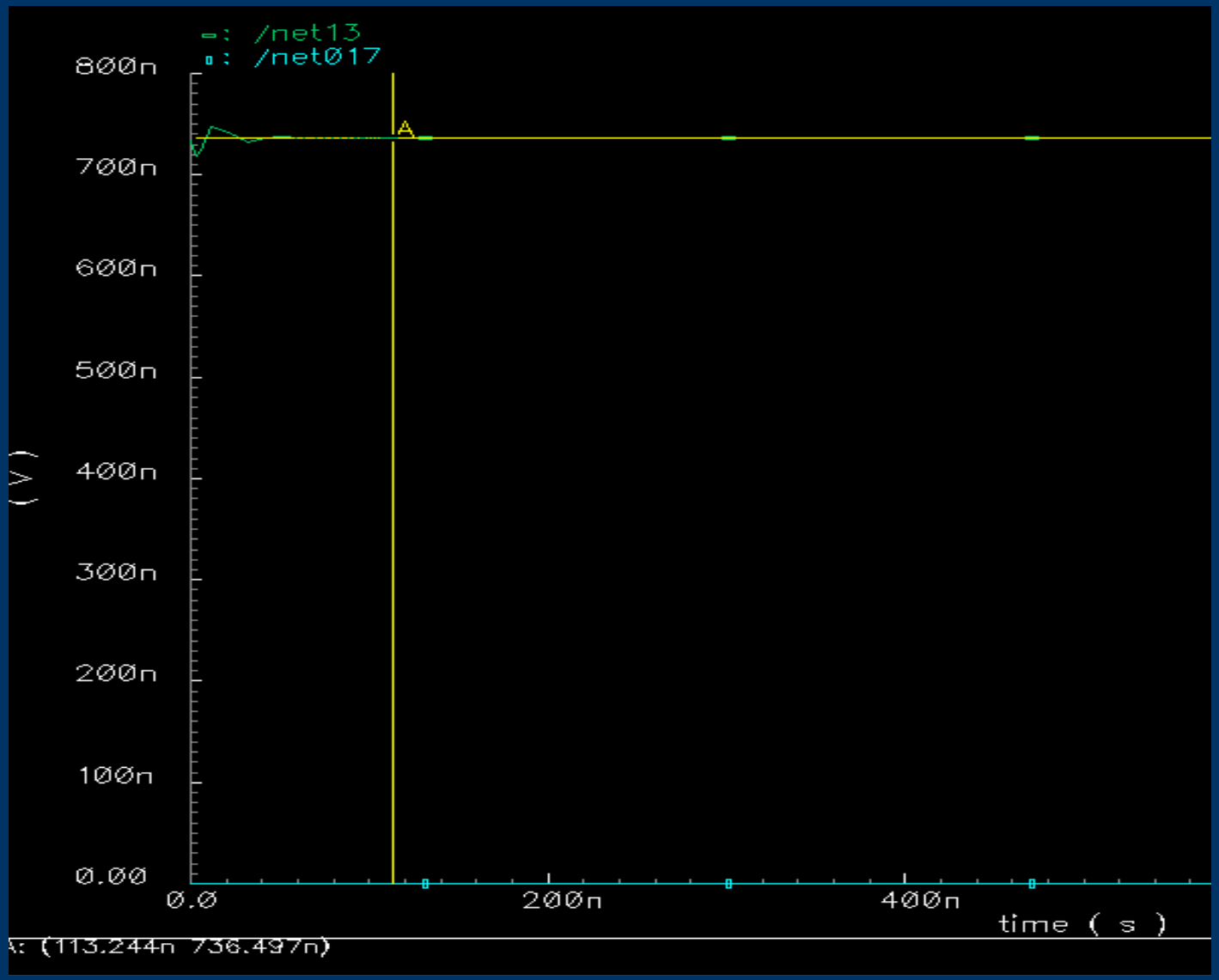
Verifizierung - CMRR



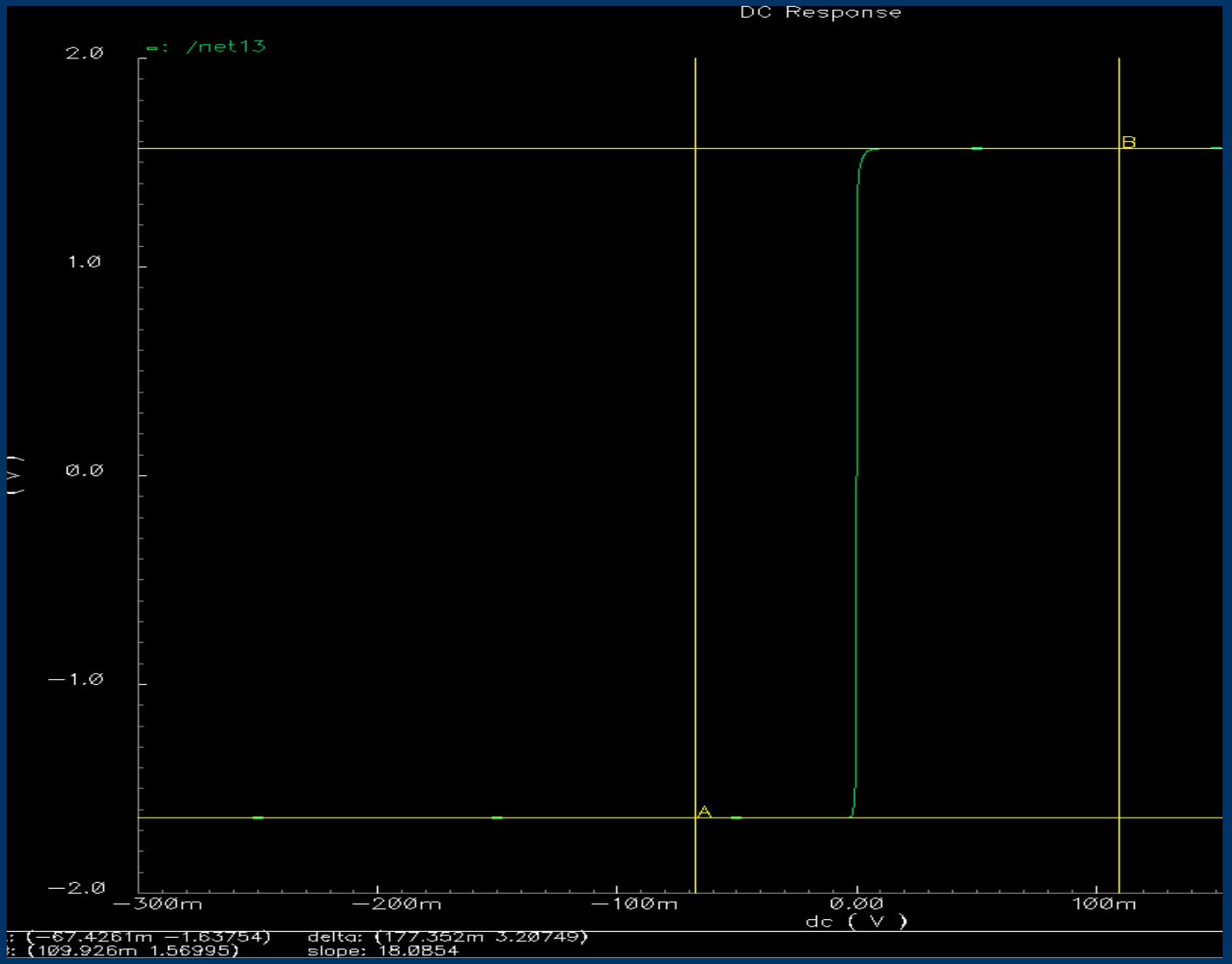
Verifizierung - CMR



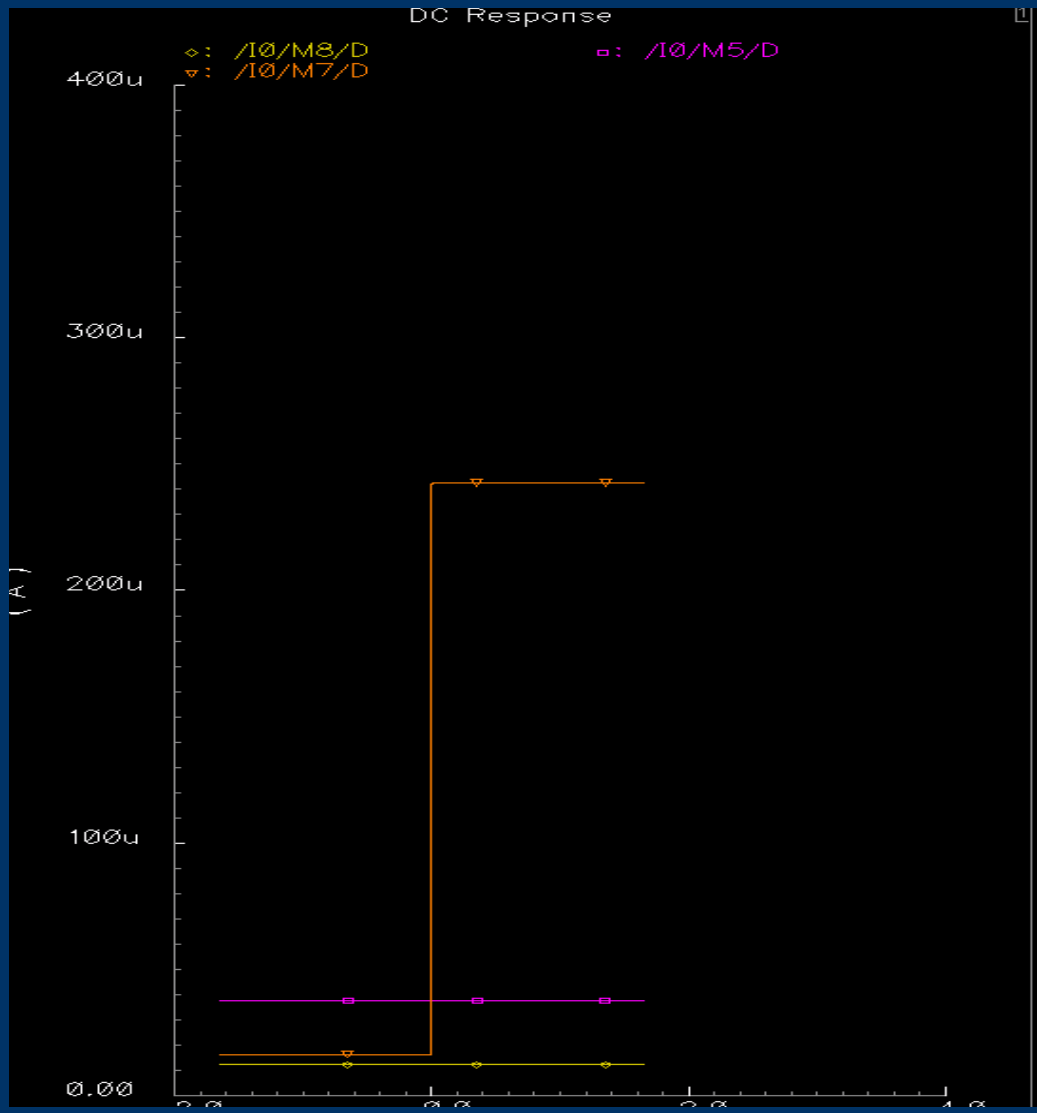
Verifizierung - Offset

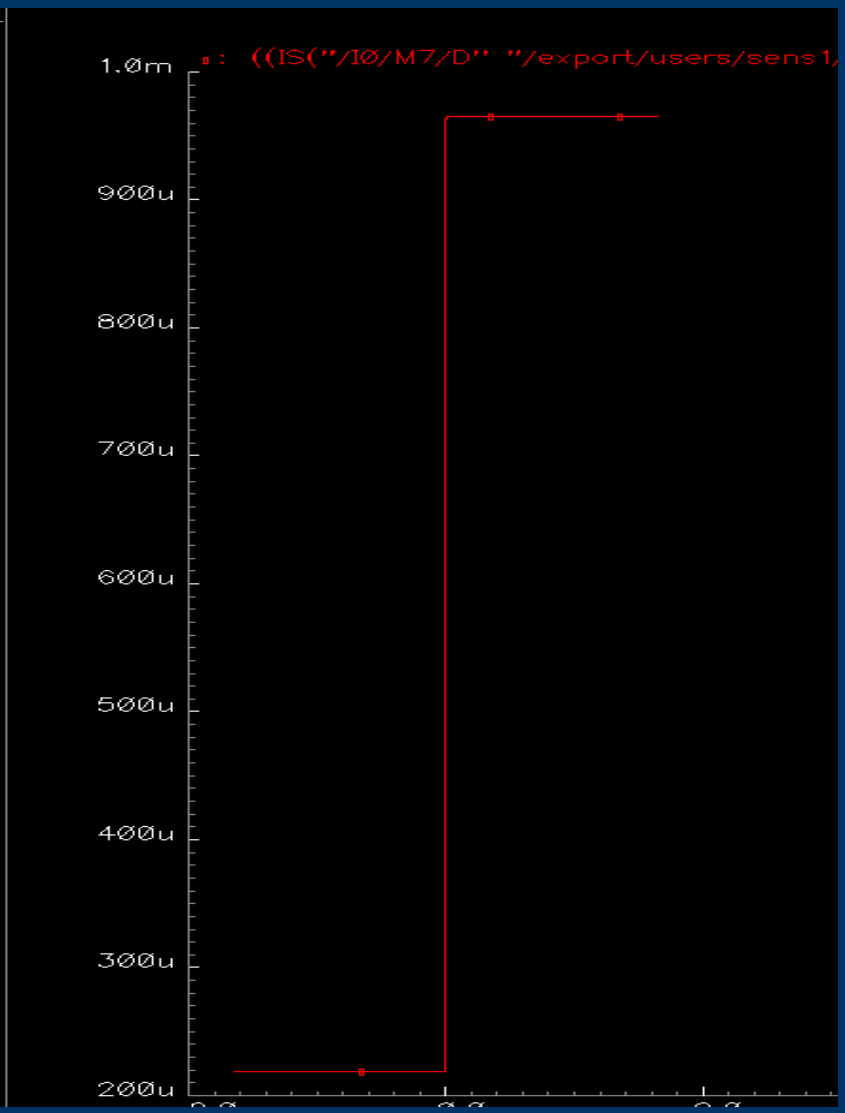


Verifizierung - Voltageswing

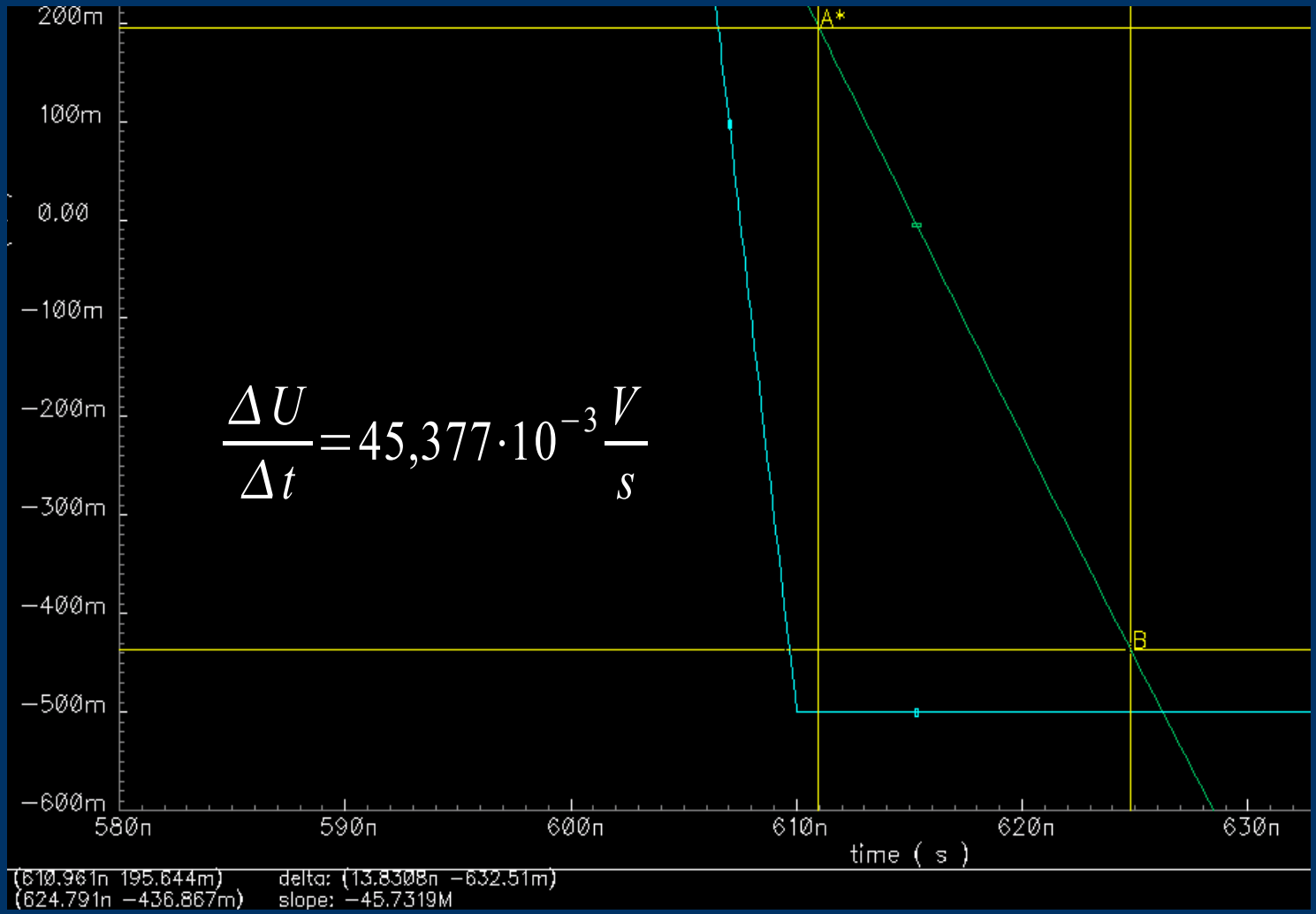


Verifizierung - Powerdissipation

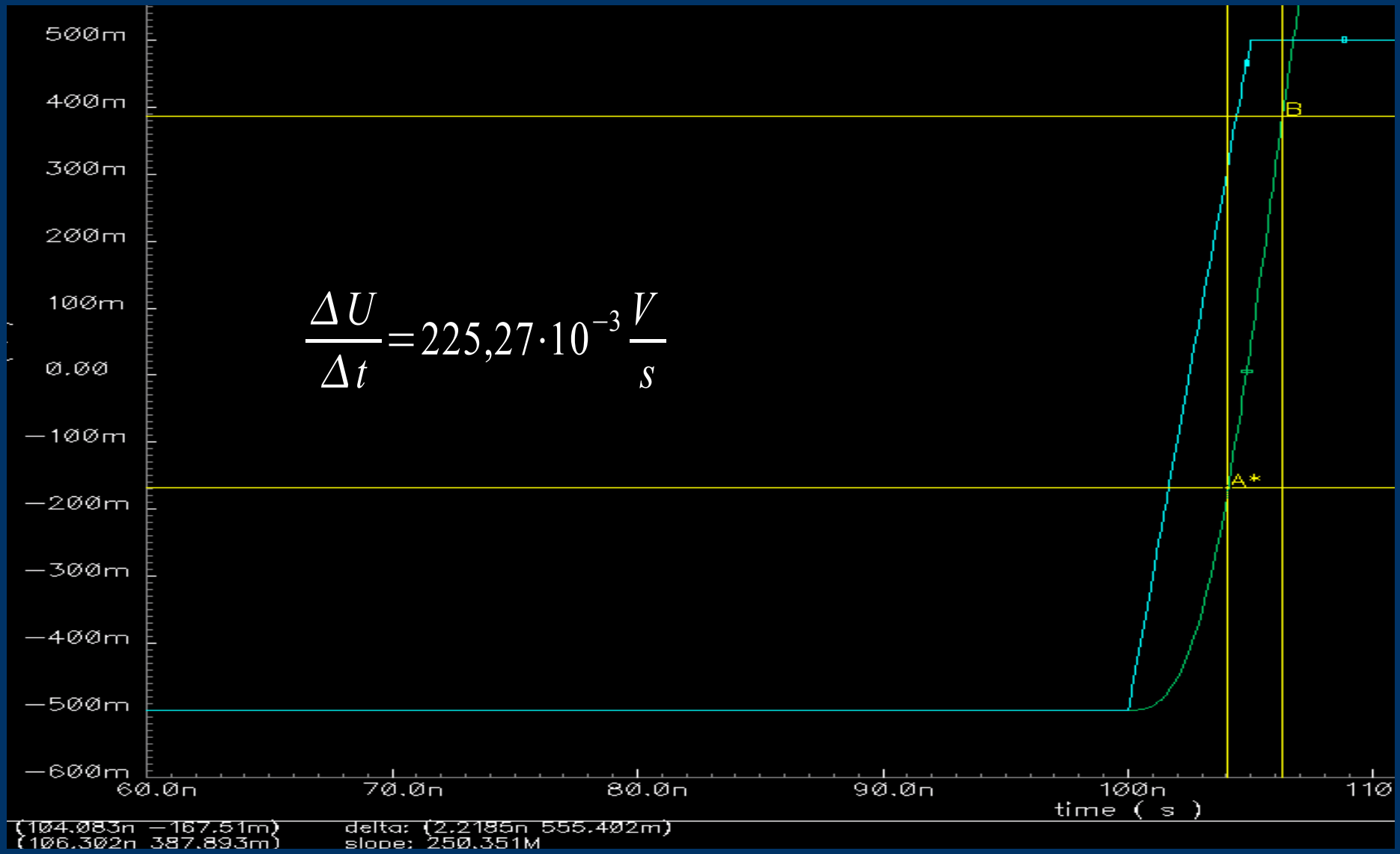




Verifizierung - Slewrate



Verifizierung – Slewrate II

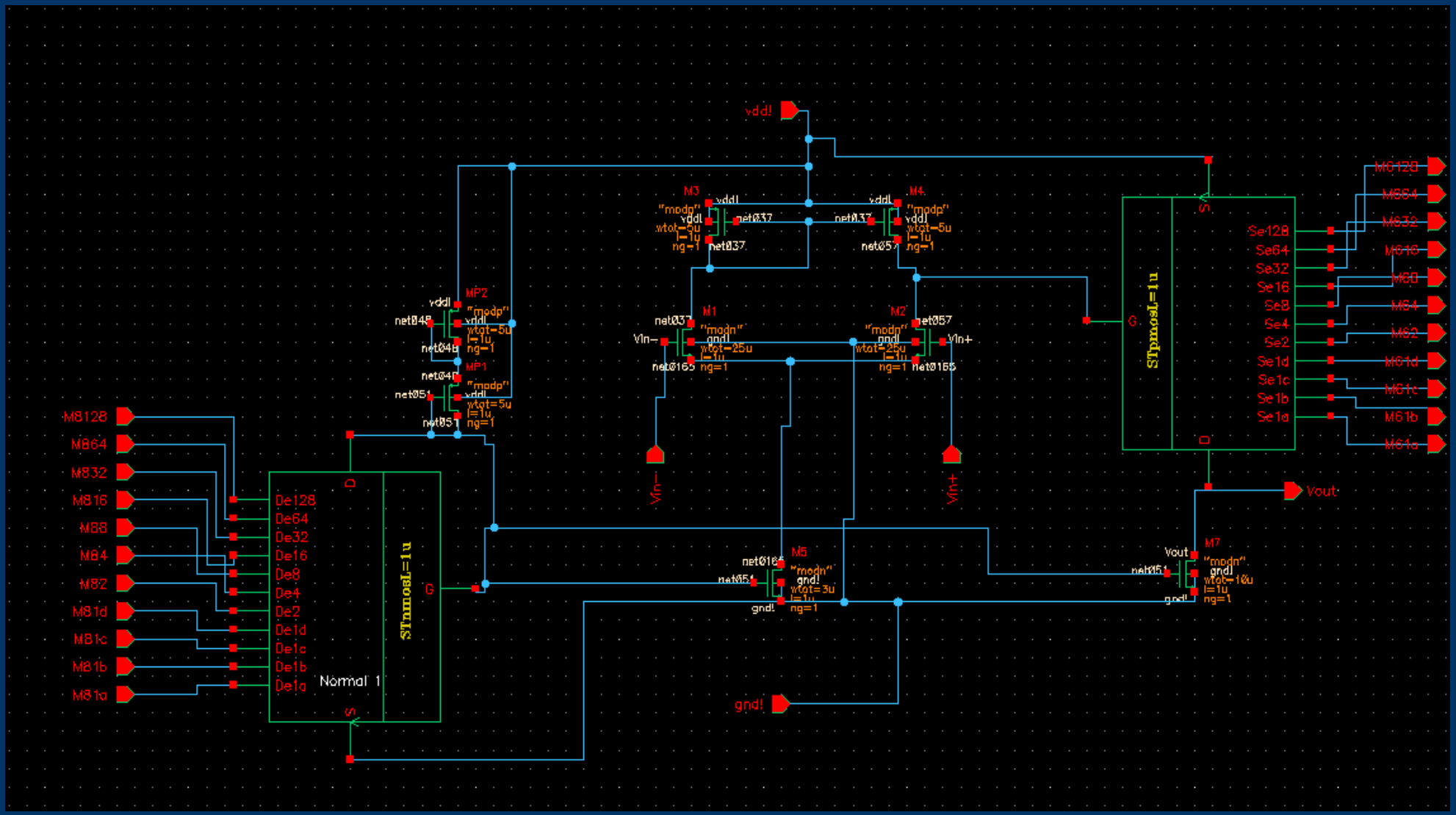


$$\frac{\Delta U}{\Delta t} = 225{,}27 \cdot 10^{-3} \frac{V}{s}$$

Verifizierung - Übersicht

Open Loop Gain	75	76,3
Gain Bandwidth	1,00E+07	7,87E+07
Slew Rate	10	45,37
Offset	1,00E-06	7,36E-07
CMR -	-0,5	-0,54
CMR +	1	1,03
Output swing -	-0,35	-1,6
Output swing +	0,35	1,5
Cmrr	80	91,6
Power dissipation	1,00E-03	9,70E-04

Scalable Devices

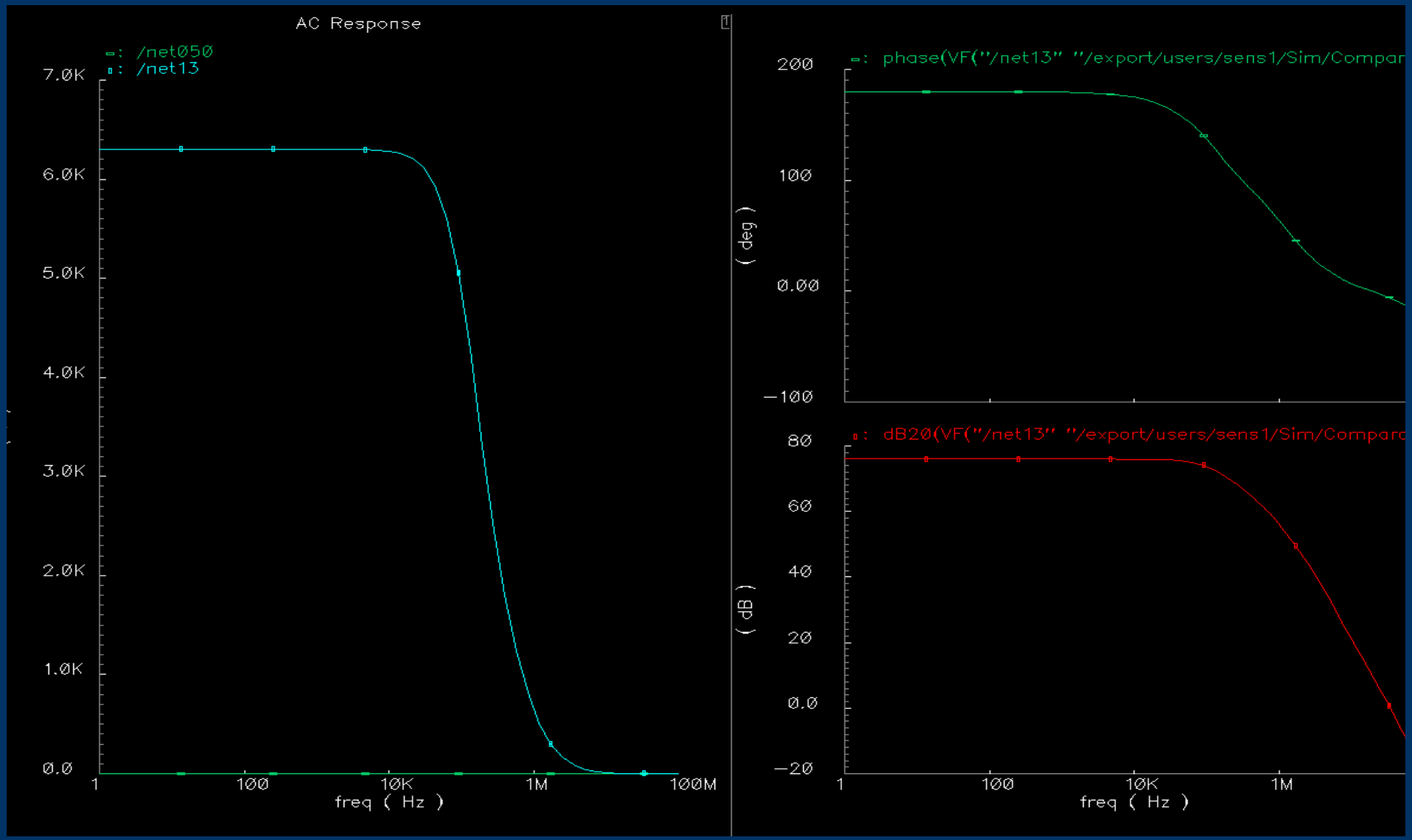


Scalable Devices

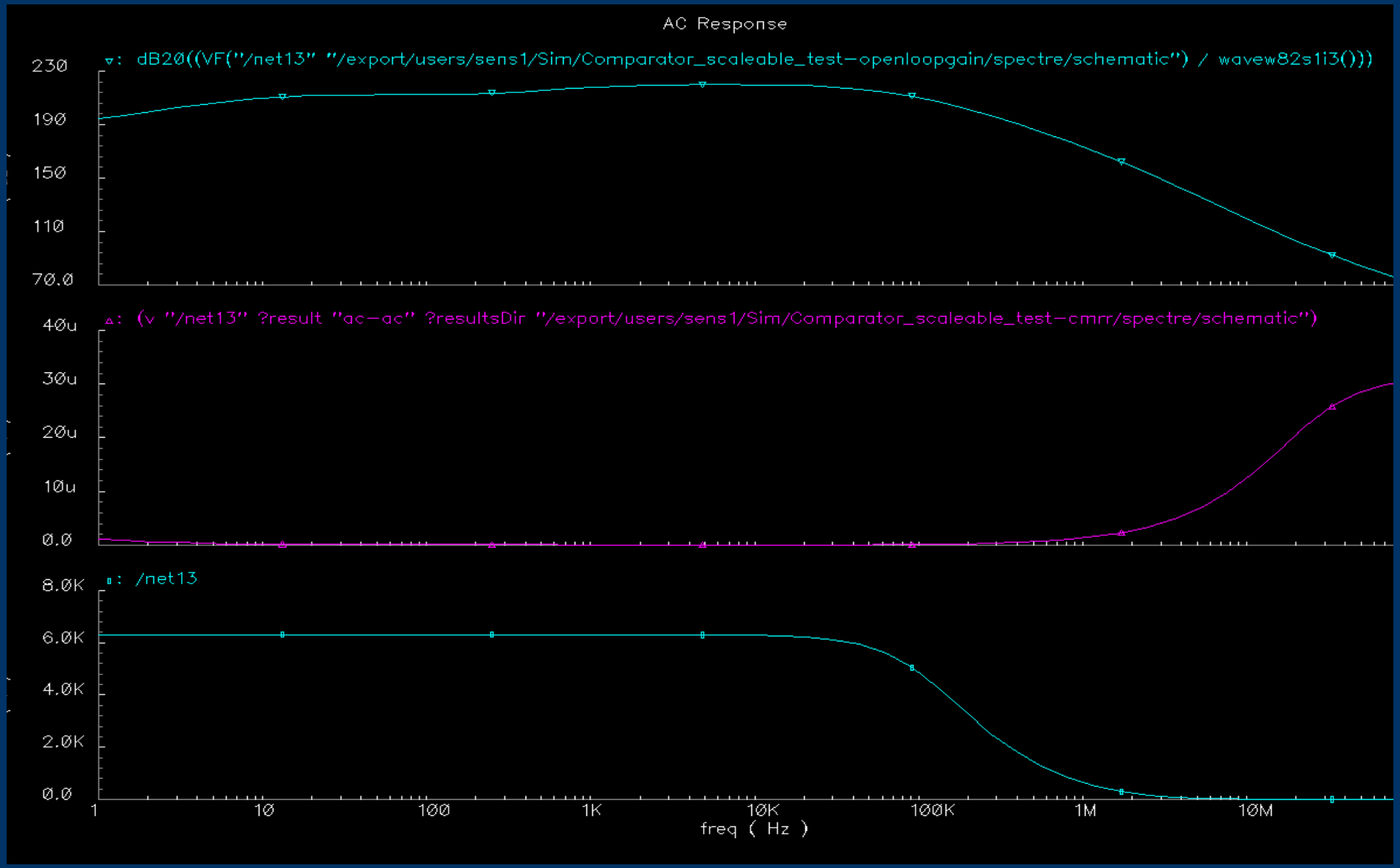
M 1	25
M 2	25
M 3	5
M 4	5
M 5	3
M 6	73
M 7	10

Werte nach einer Offsetanpassung aufgrund des hohen Innenwiderstands der SD's.

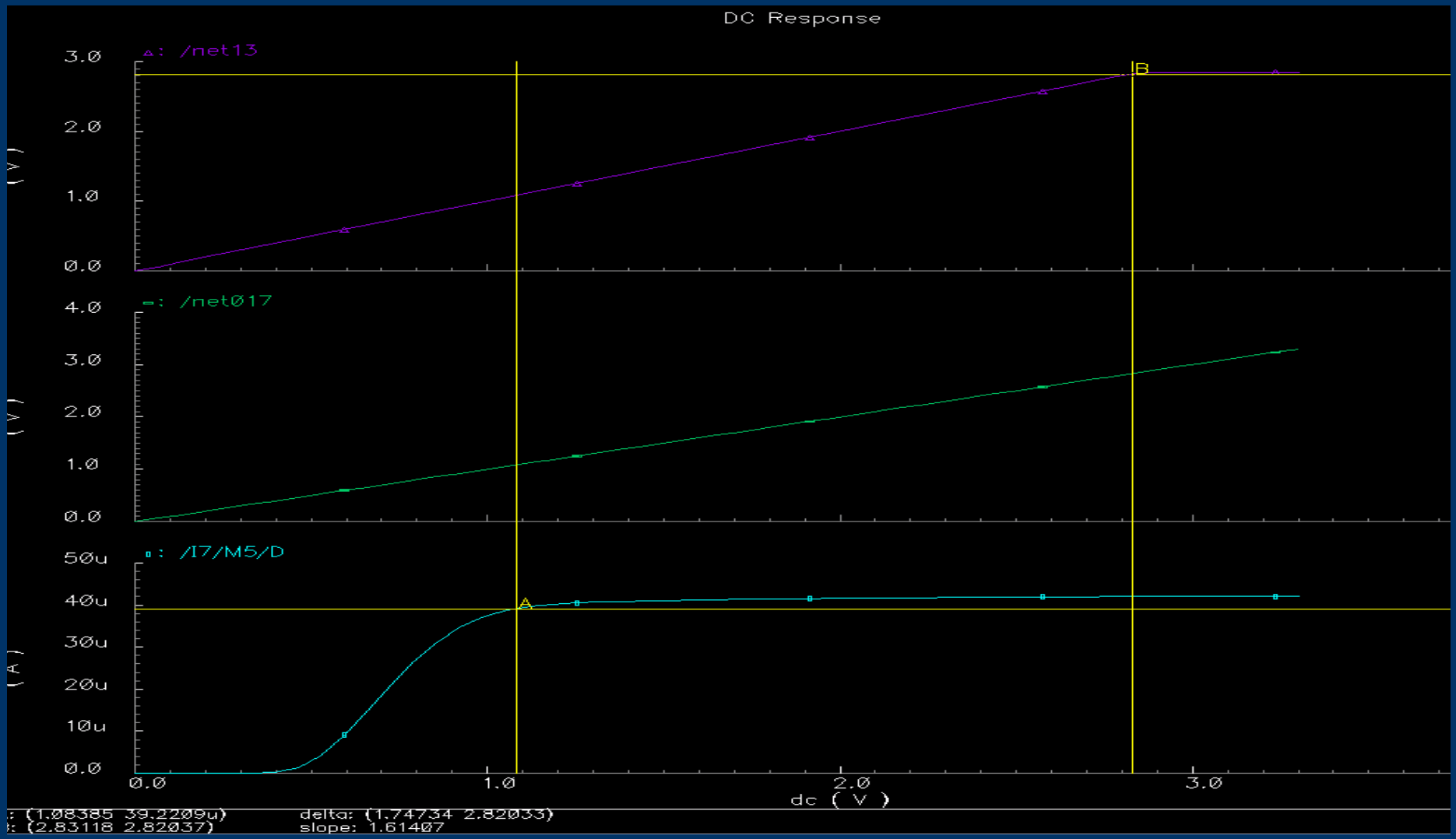
Verifizierung – Gain und GBW



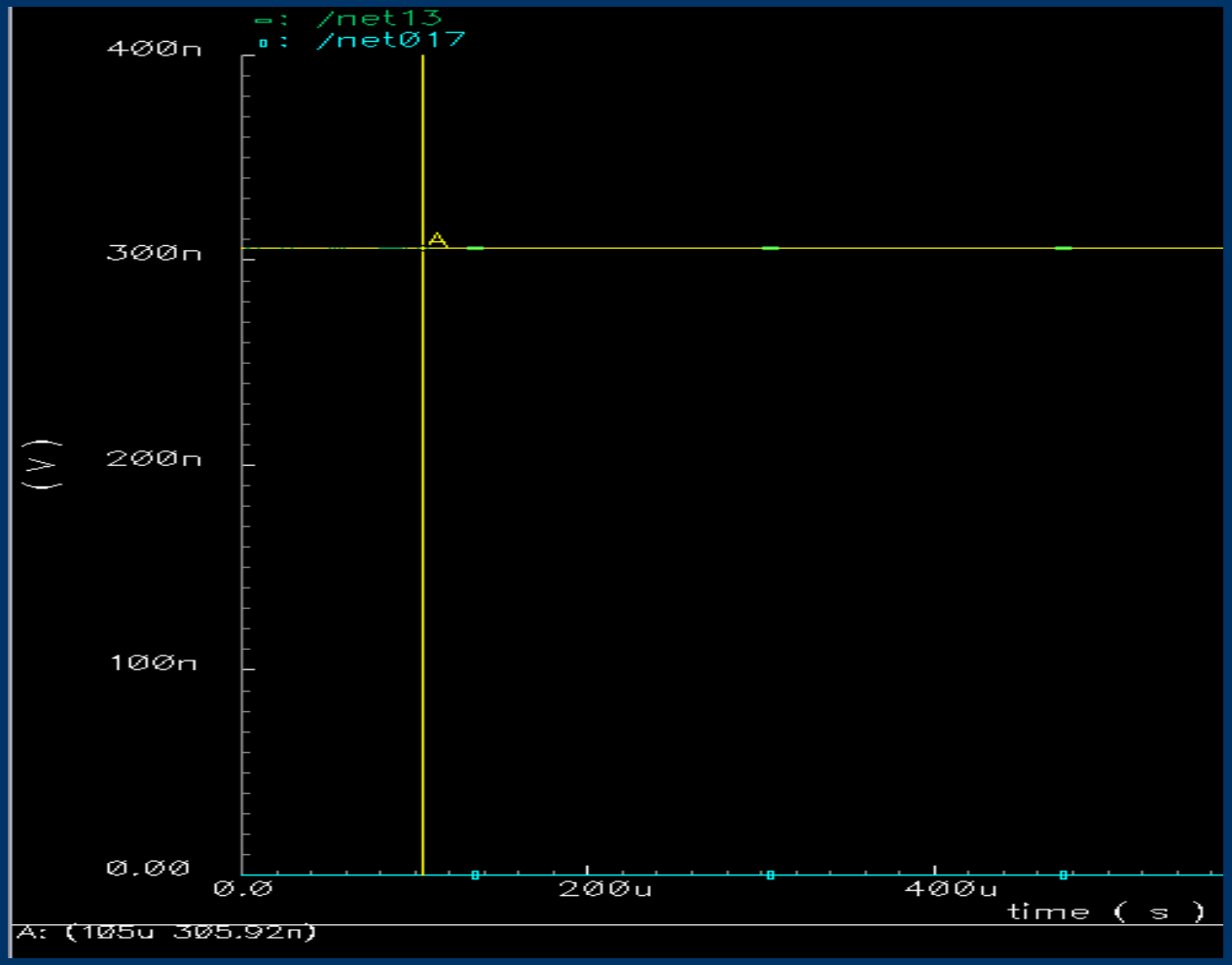
Verifizierung - CMRR



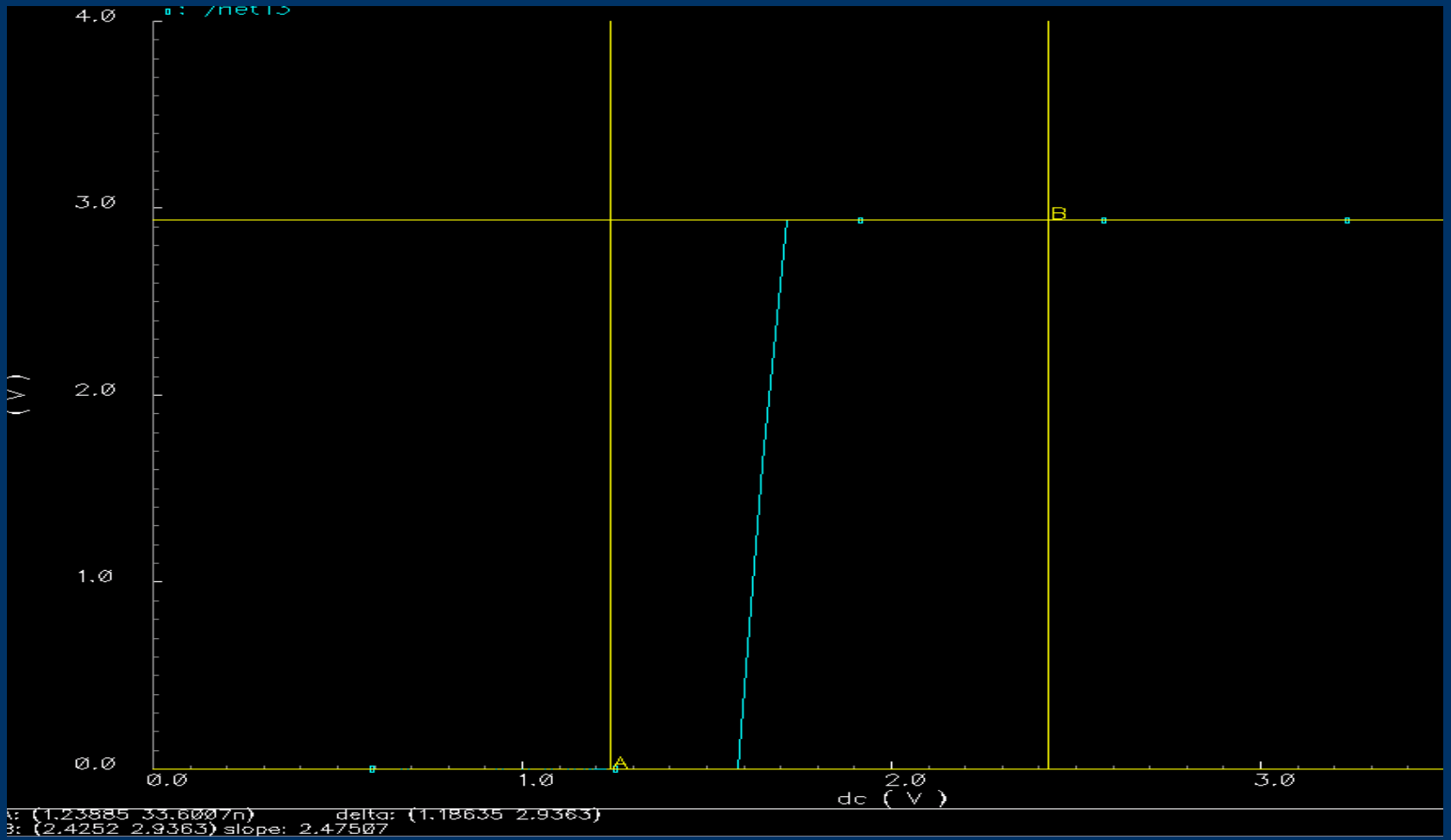
Verifizierung - CMR



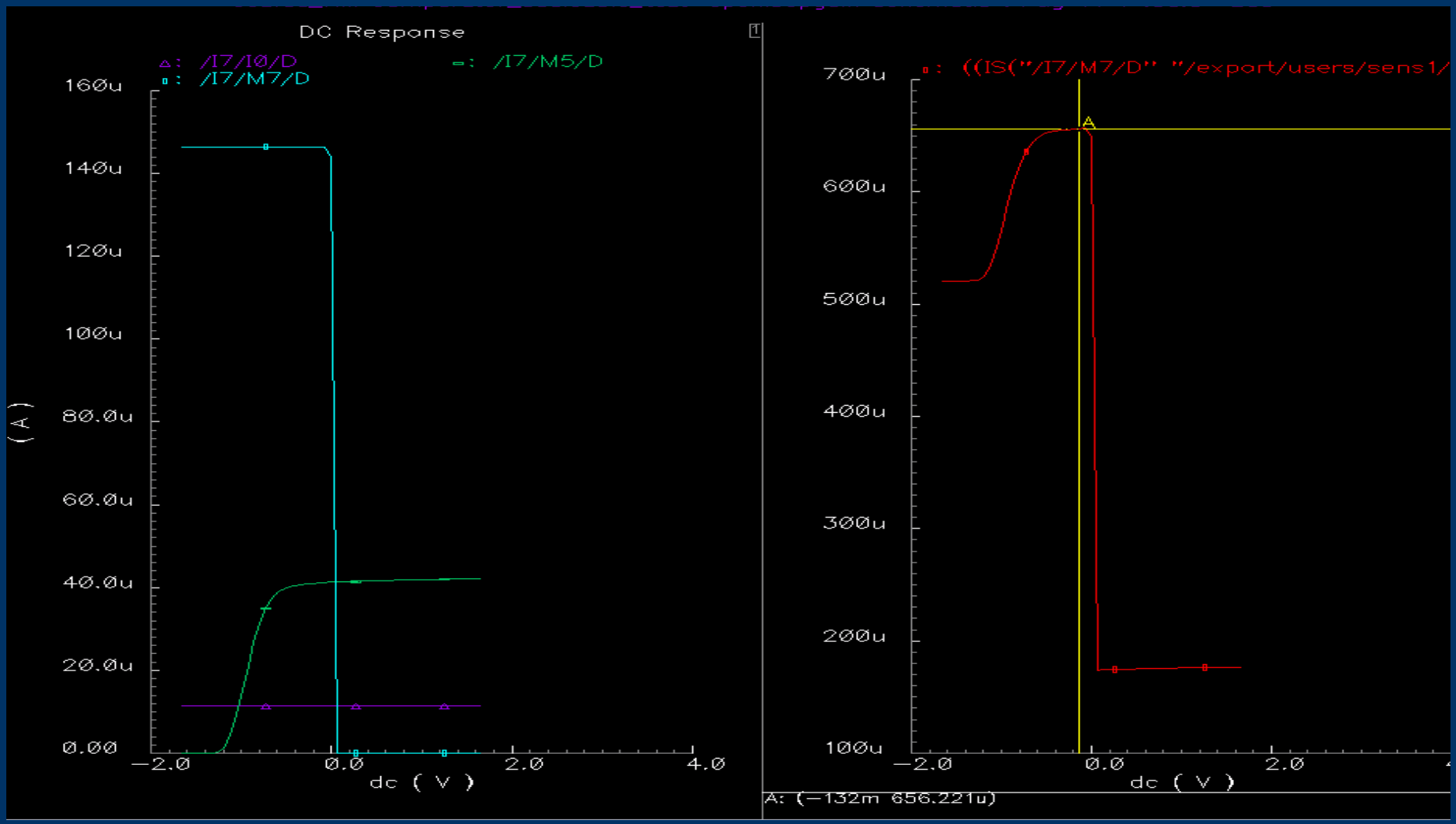
Verifizierung - Offset



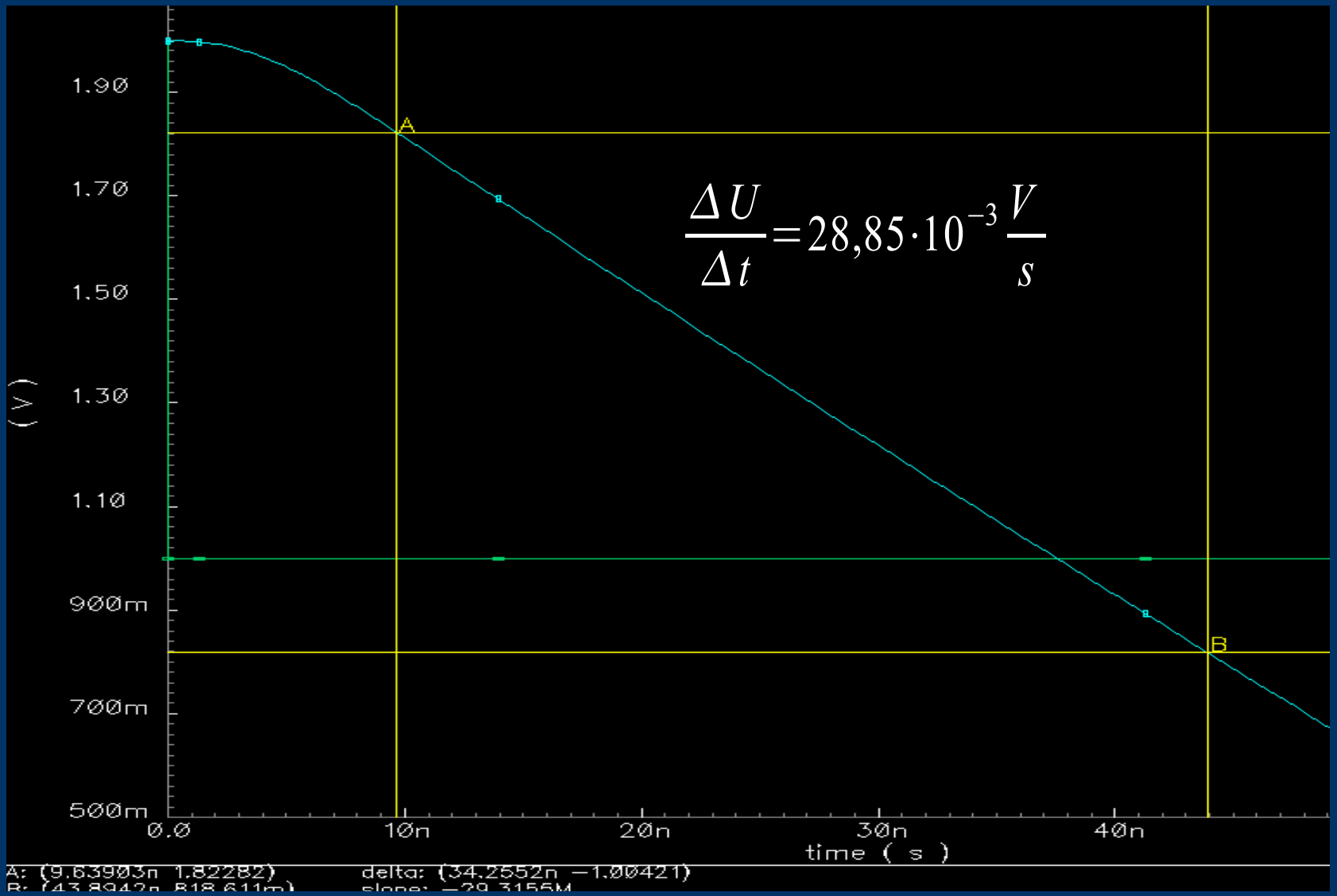
Verifizierung - Voltageswing



Verifizierung - Powerdissipation

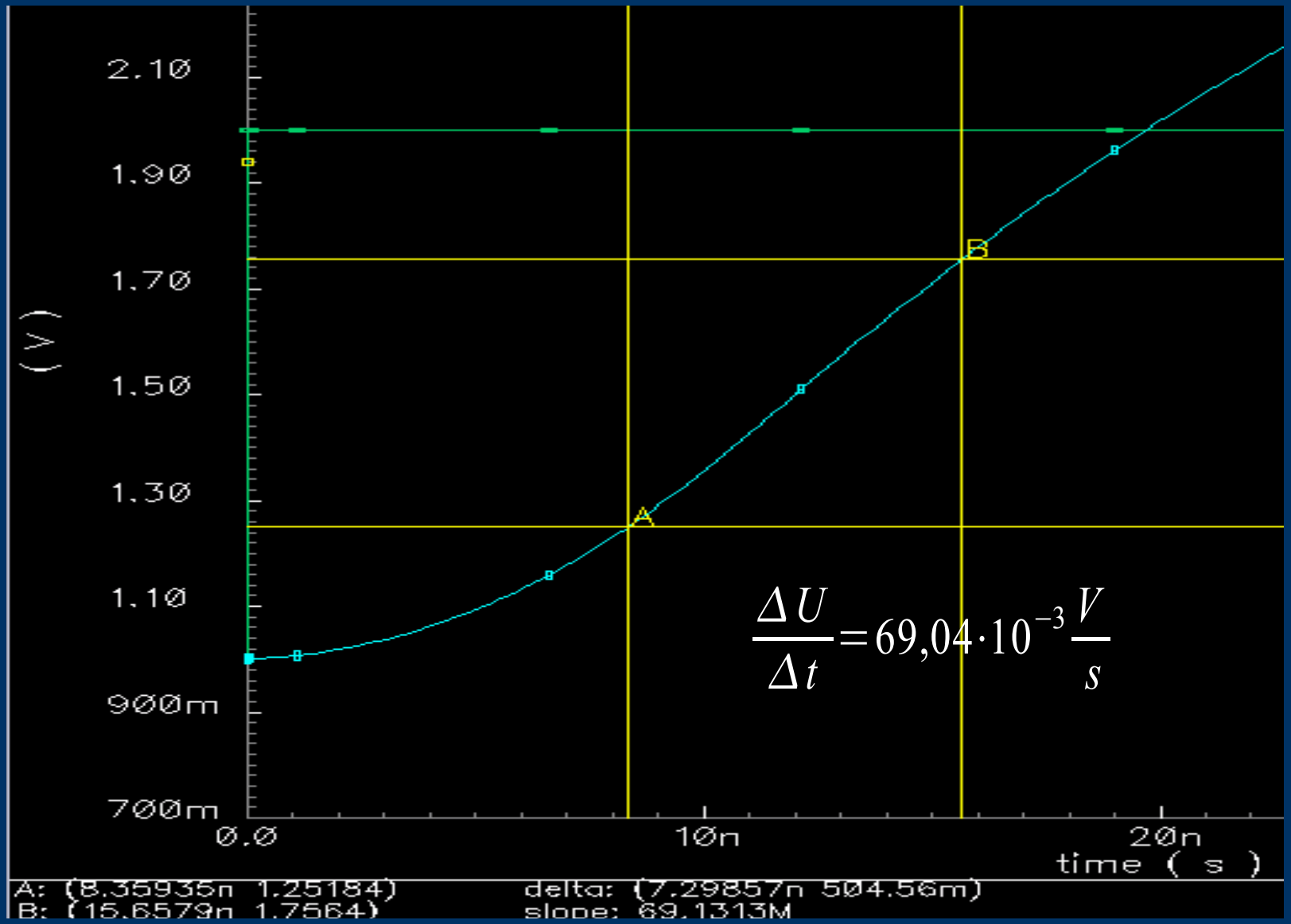


Verifizierung - Slewrate



$$\frac{\Delta U}{\Delta t} = 28{,}85 \cdot 10^{-3} \frac{V}{s}$$

Verifizierung - Slewrate

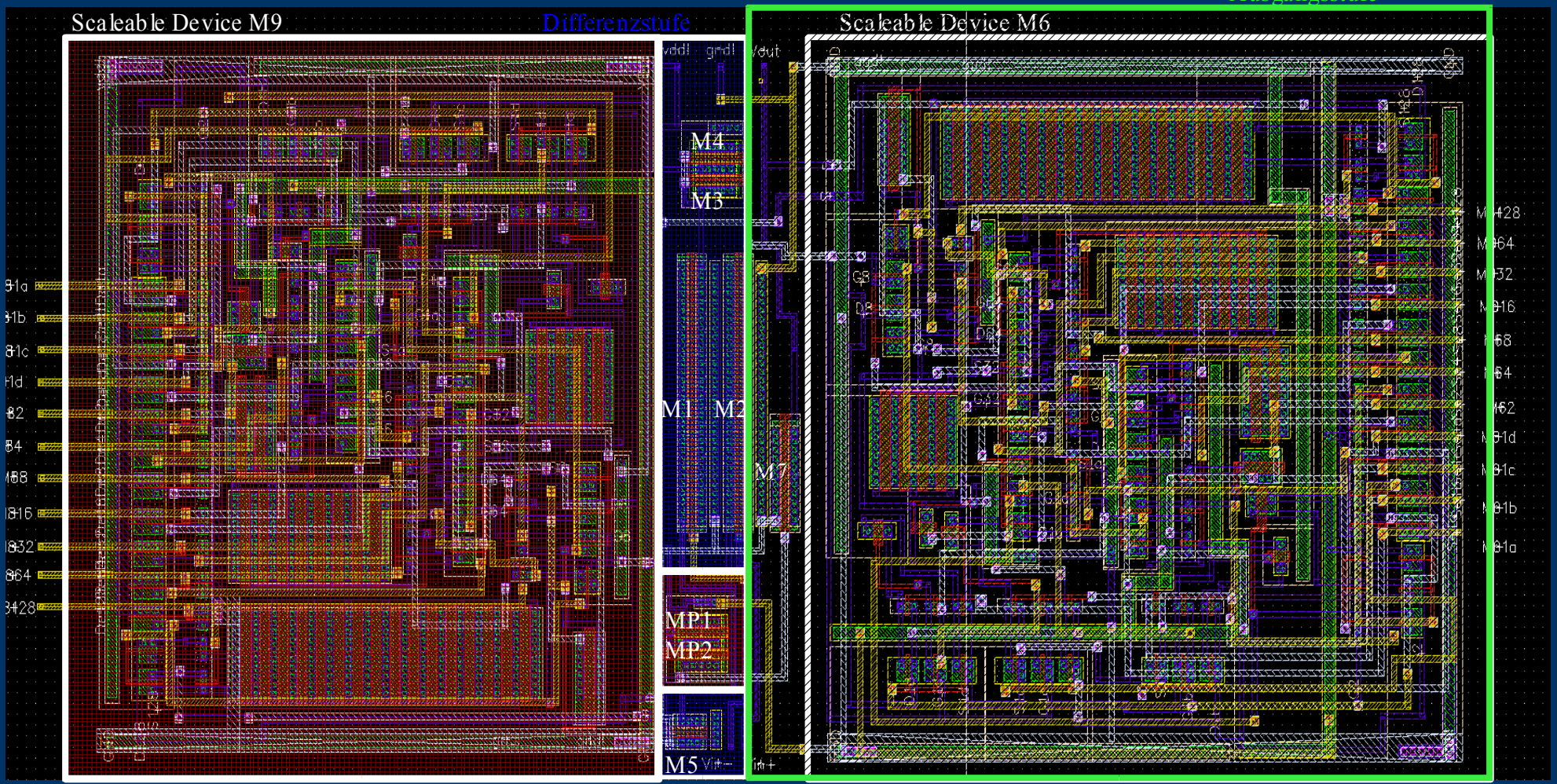


$$\frac{\Delta U}{\Delta t} = 69{,}04 \cdot 10^{-3} \frac{V}{s}$$

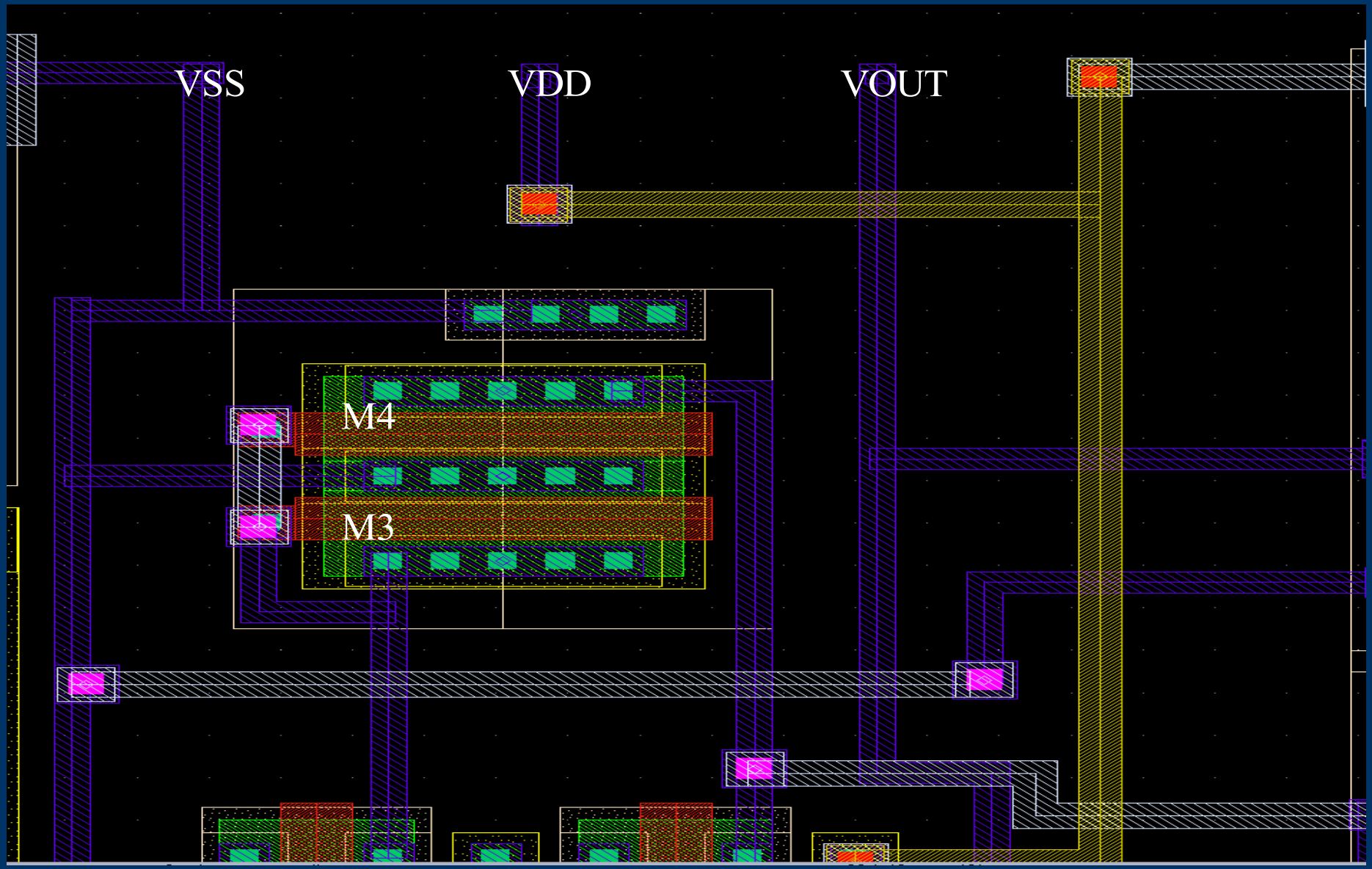
Verifizierung - Übersicht

	Vorgabe	Schematic	Scaleable
Open Loop Gain	75	76,3	78
Gain Bandwidth	1,00E+07	7,87E+07	~ 7,7E+07
Slew Rate	10	45,37	28,85
Offset	1,00E-06	7,36E-07	3,50E-07
CMR -	-0,5	-0,54	-0,56
CMR +	1	1,03	1,18
Output swing -	-0,35	-1,6	-1,64
Output swing +	0,35	1,5	1,28
Cmrr	80	91,6	~200
Power dissipation	1,00E-03	9,70E-04	6,50E-04

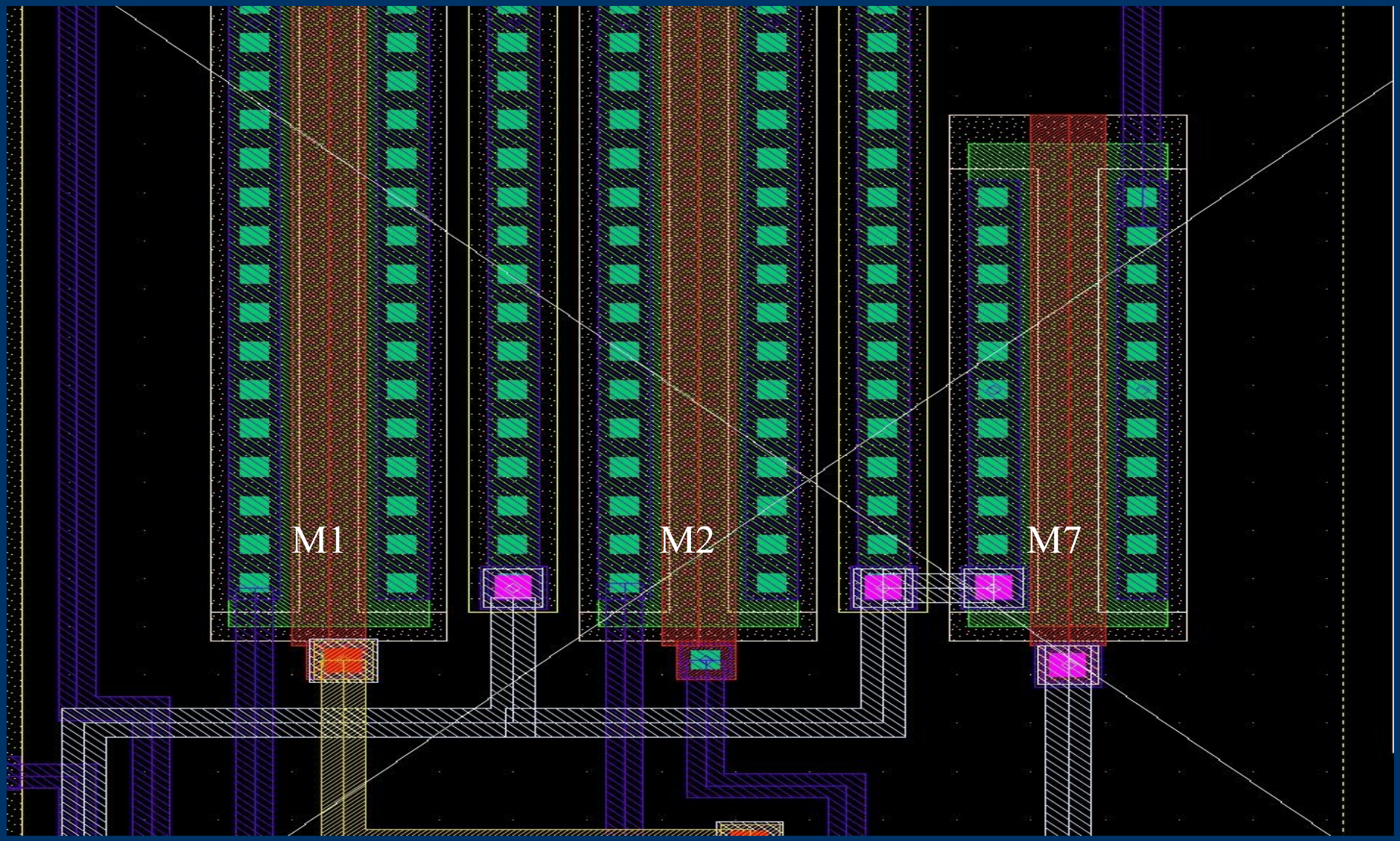
Layout


Ausgangsstufe
Scaleable Device M9
Differenzstufe
Scaleable Device M6
vdd!
gnd!
Vout
M4
M3
M1
M2
M7
MP1
MP2
M5
Vin-
Vin+
Biasing

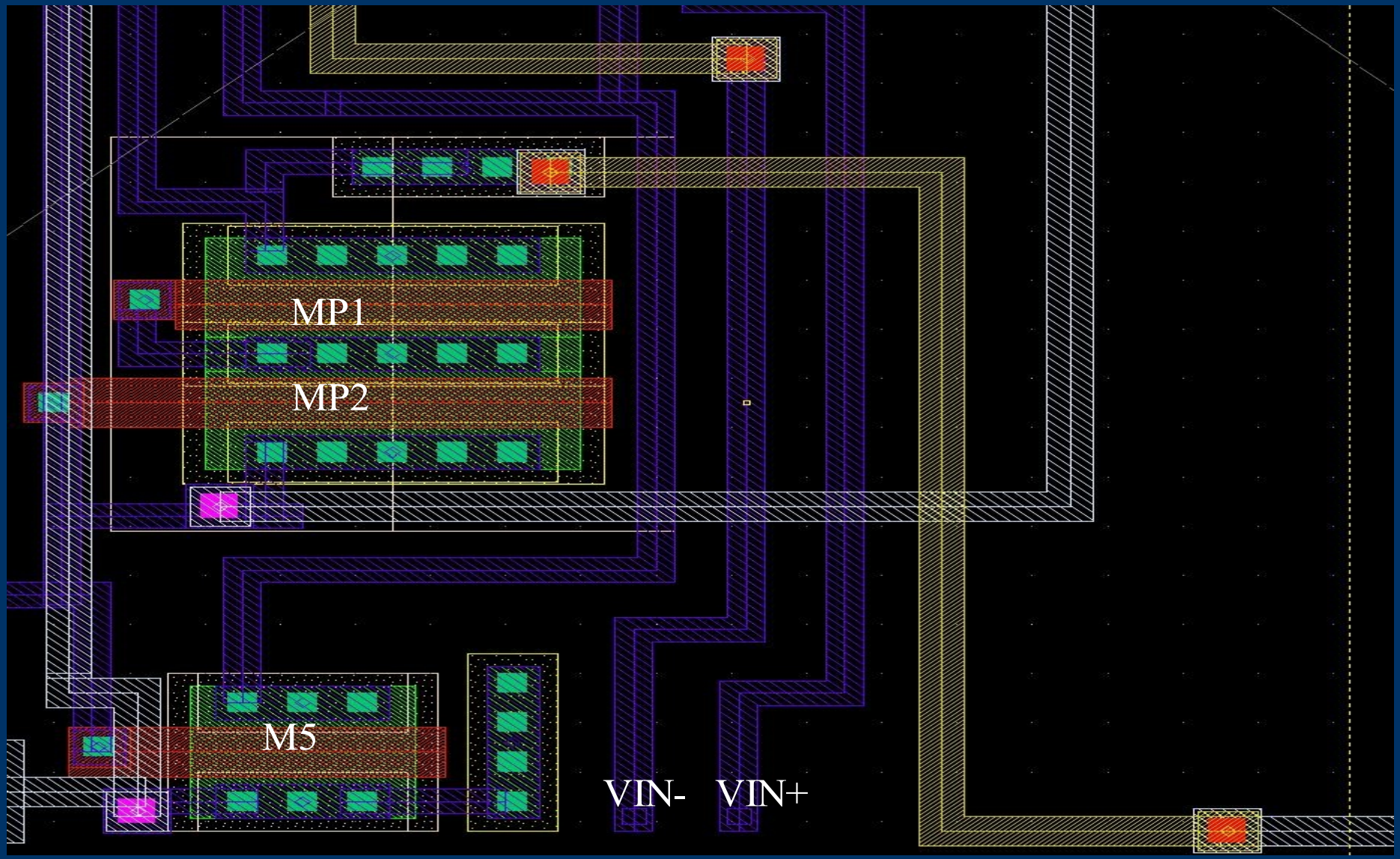
Layout - Detail



Layout - Detail



Layout - Detail



LVS-Check

```
Running simulation in directory: "/export/users/sens1/LVS".

Loading all available p-cell functions
ROD pcell code loaded

Begin netlist:    Nov  7 11:56:37 2007
    view name list   = ("auLvs" "extracted" "schematic" "symbol")
    stop name list   = ("auLvs")
    library name     = "course_HM"
    cell name = "Comparator_scaleable"
    view name        = "extracted"
    globals lib      = "basic"
Running Artist Flat Netlisting ...
End netlist:    Nov  7 11:56:38 2007

Moving original netlist to extNetlist
Removing parasitic components from netlist
    presistors removed:  0
    pcapacitors removed: 0
    pinductors removed:  0
    pdiodes removed:     11
    trans lines removed: 0
    100 nodes merged into 100 nodes

Begin netlist:    Nov  7 11:56:38 2007
    view name list   = ("auLvs" "schematic" "cmos_sch" "netlist" "symbol")
    stop name list   = ("auLvs")
    library name     = "course_HM"
    cell name = "Comparator_scaleable"
    view name        = "schematic"
    globals lib      = "basic"
Running Artist Flat Netlisting ...
End netlist:    Nov  7 11:56:39 2007

Moving original netlist to extNetlist
Removing parasitic components from netlist
    presistors removed:  0
    pcapacitors removed: 0
    pinductors removed:  0
    pdiodes removed:     0
    trans lines removed: 0
    130 nodes merged into 130 nodes
```

LVS-Check

Running netlist comparison program: LVS
Begin comparison: Nov 7 11:56:39 2007
LVS version 5.0.0 05/30/2003 19:44 (cds11939) $
Warning: Unknown device "zd2sm24" on a compareDeviceProperty command.
[...]
Warning: Unknown device "nd" on a permuteDevice command.

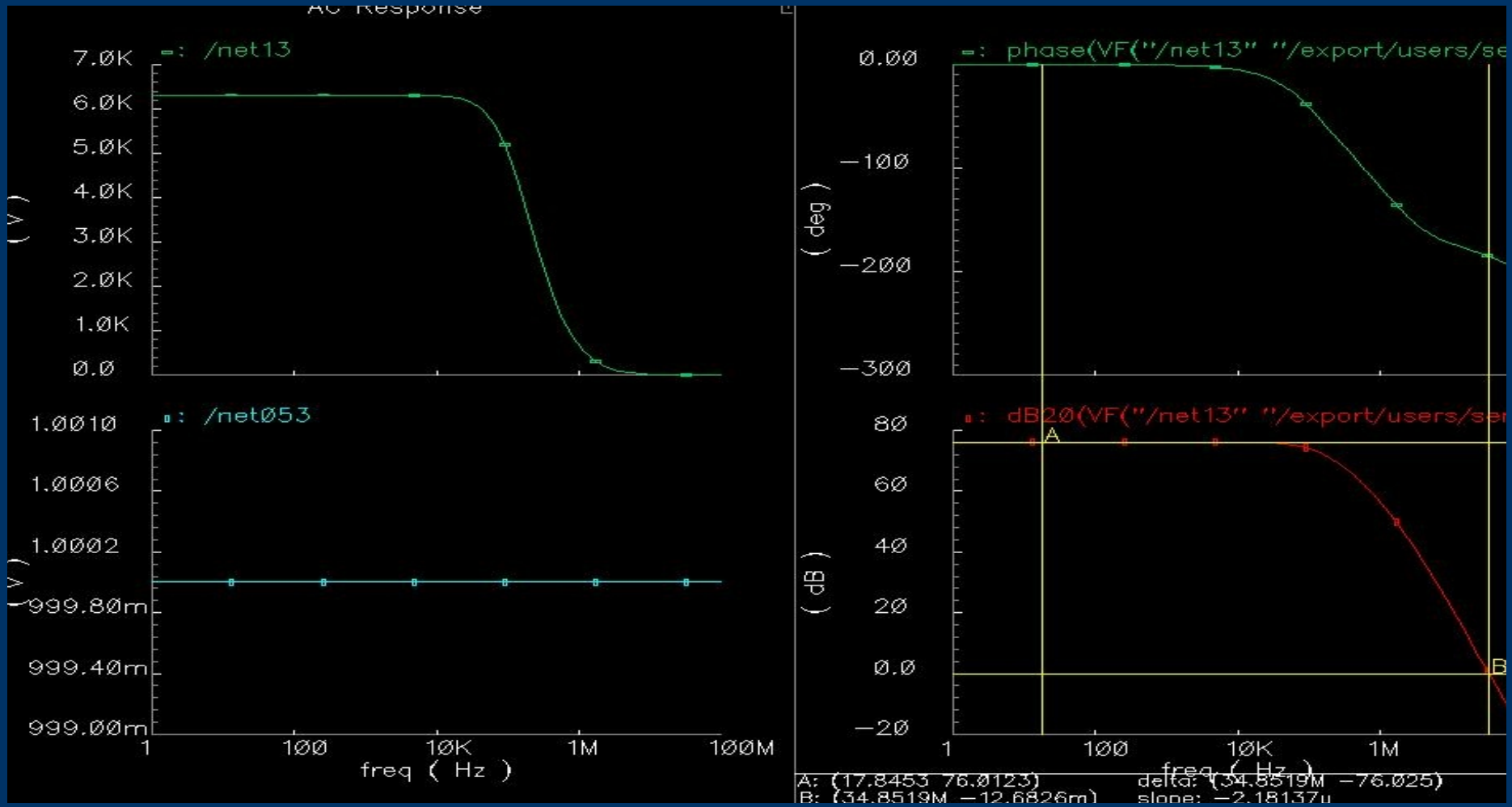
The net-lists match.

	layout	schematic
instances		
un-matched	0	0
rewired	0	0
size errors	0	0
pruned	0	0
active	258	206
total	258	206
nets		
un-matched	0	0
merged	0	0
pruned	0	0
active	100	100
total	100	100
terminals		
un-matched	0	0
matched but different type	0	0
total	27	27

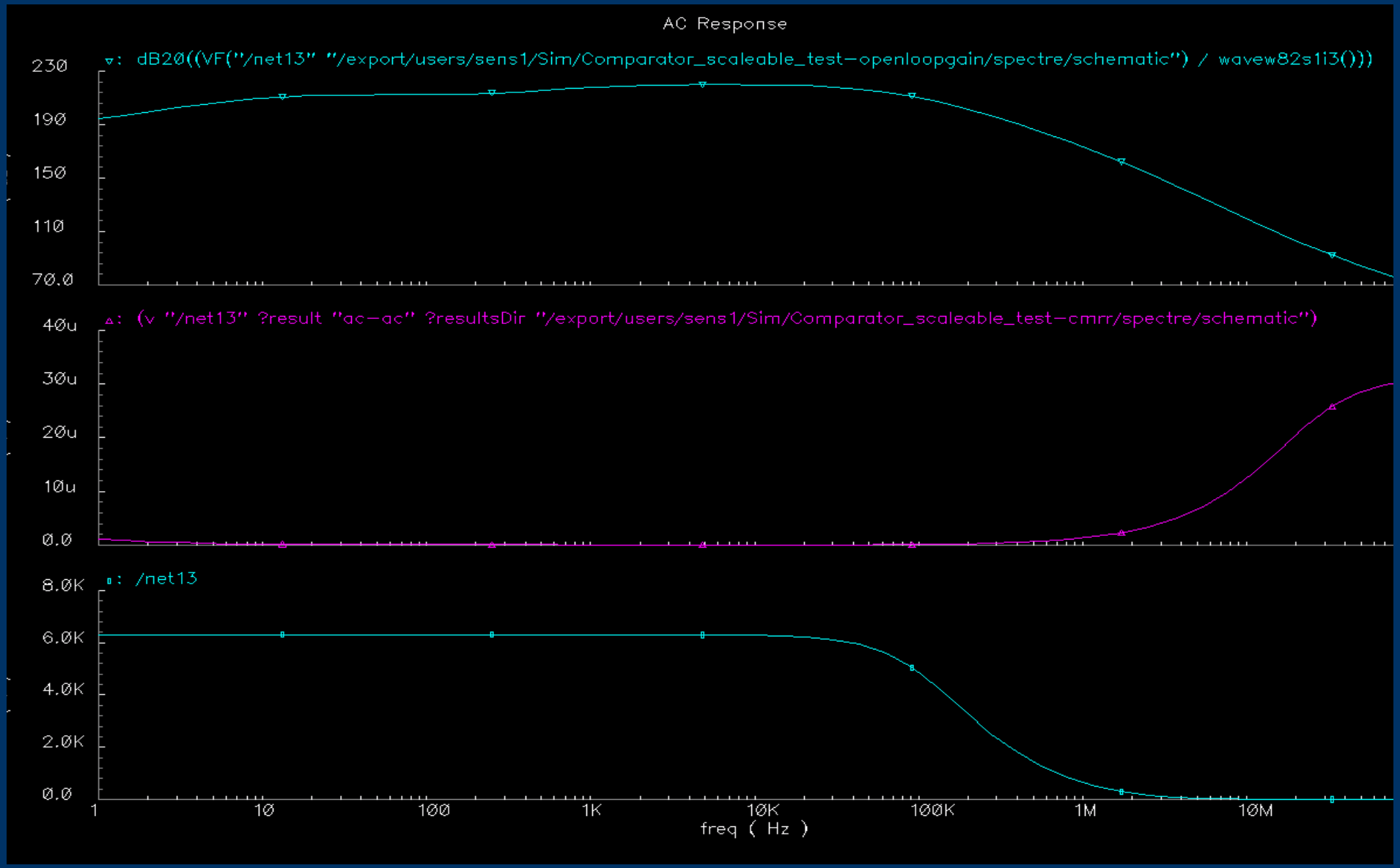
End comparison: Nov 7 11:56:39 2007

Comparison program completed successfully.

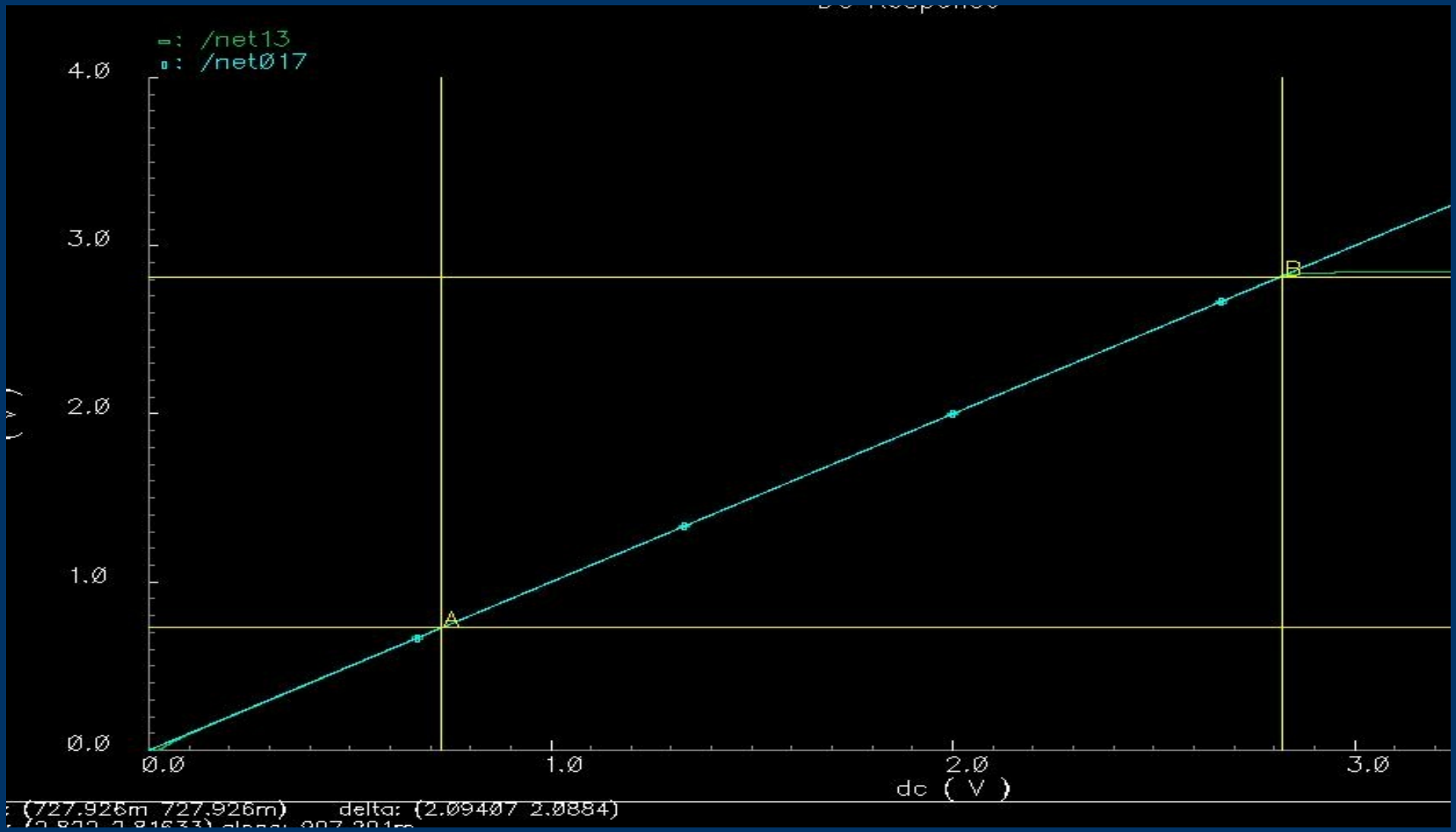
Verifizierung – Gain und GBW



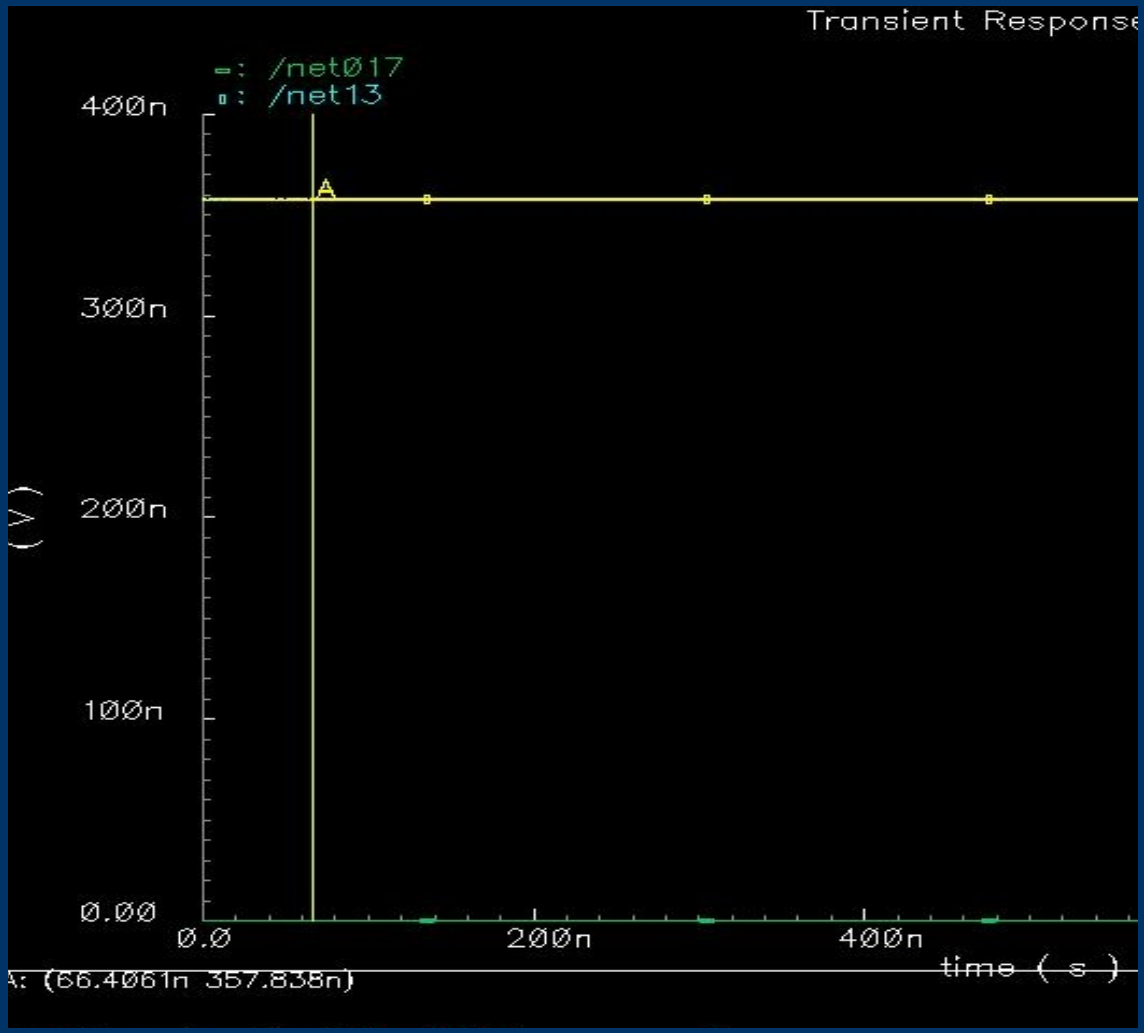
Verifizierung - CMRR



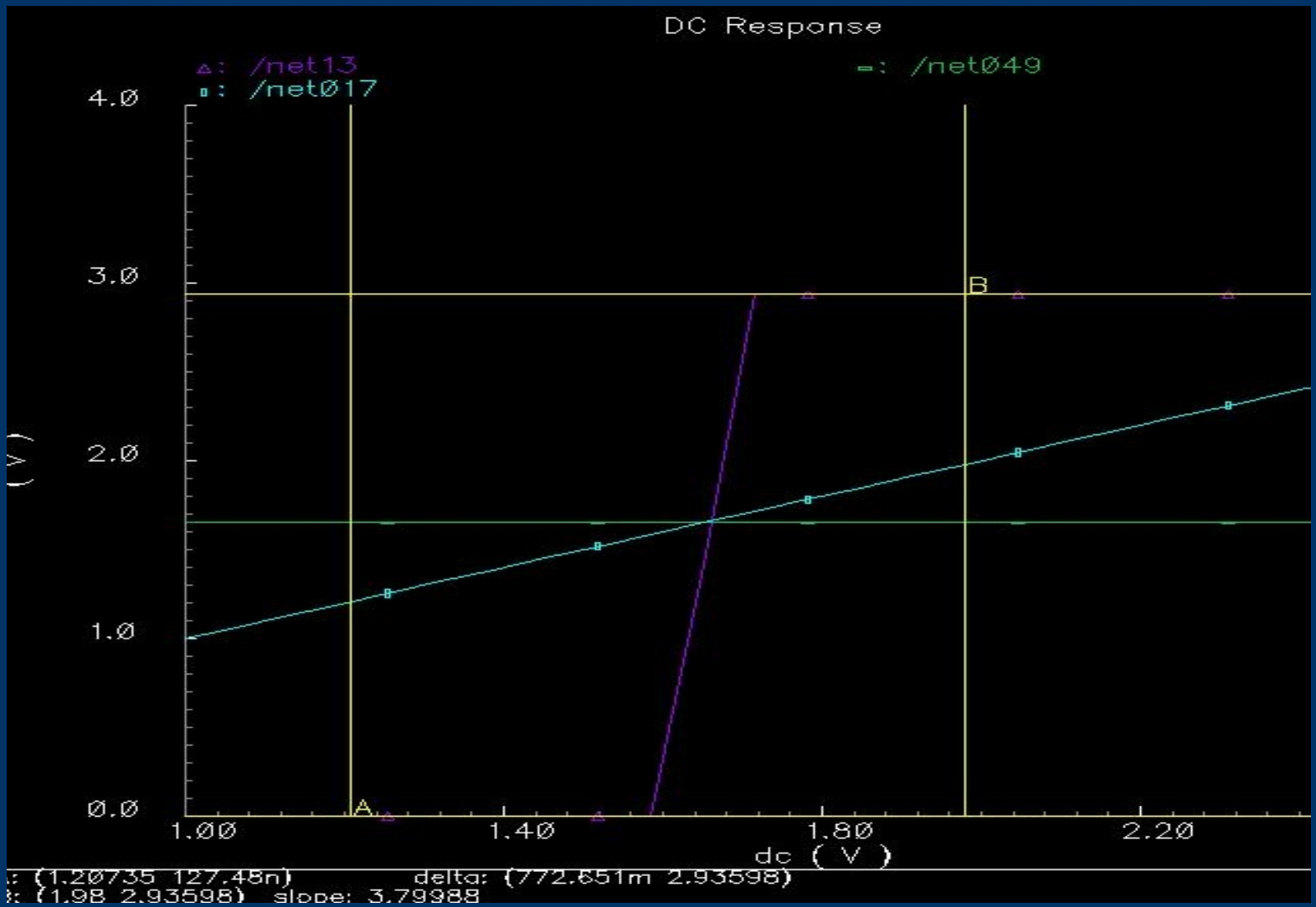
Verifizierung - CMR



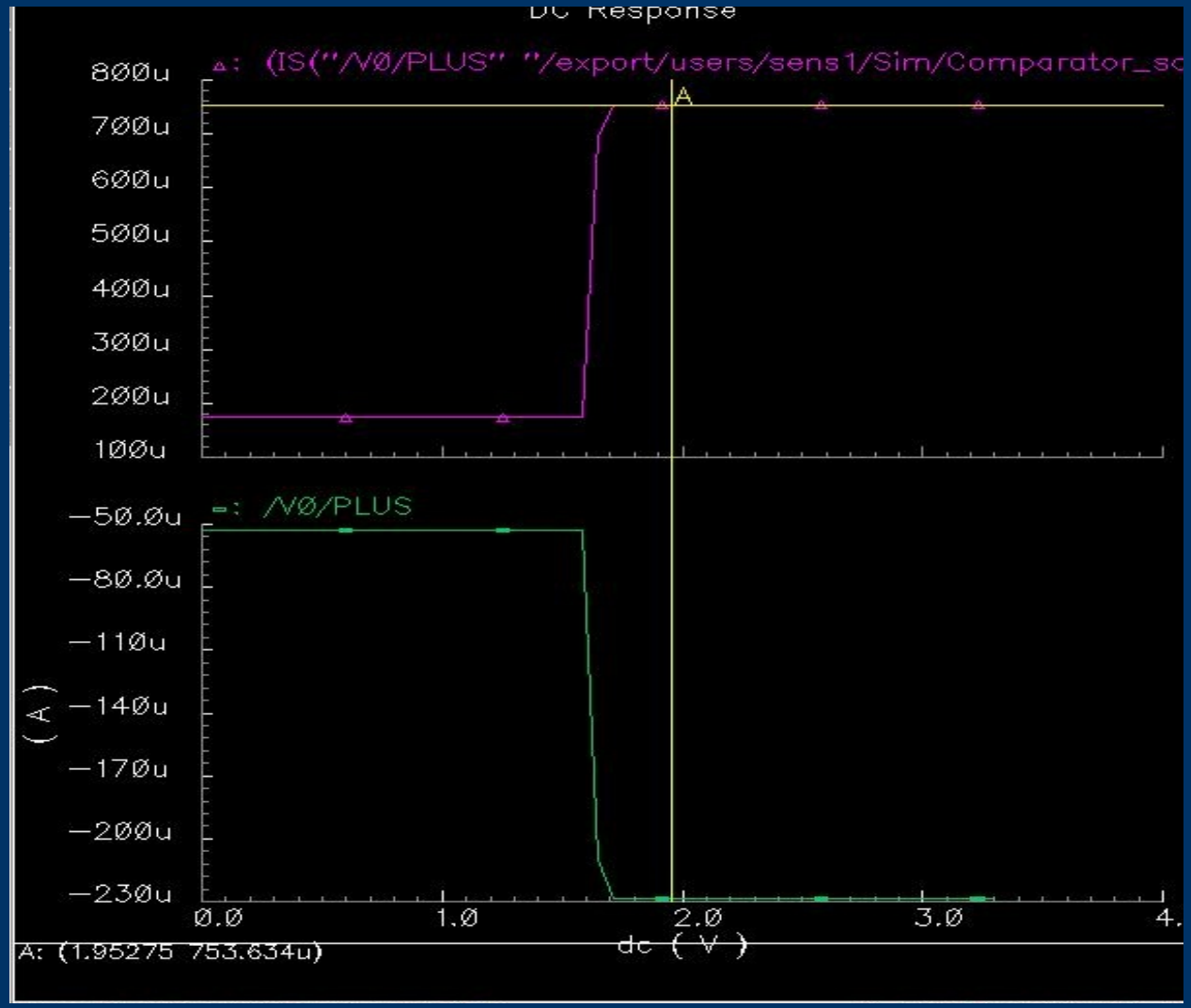
Verifizierung - Offset



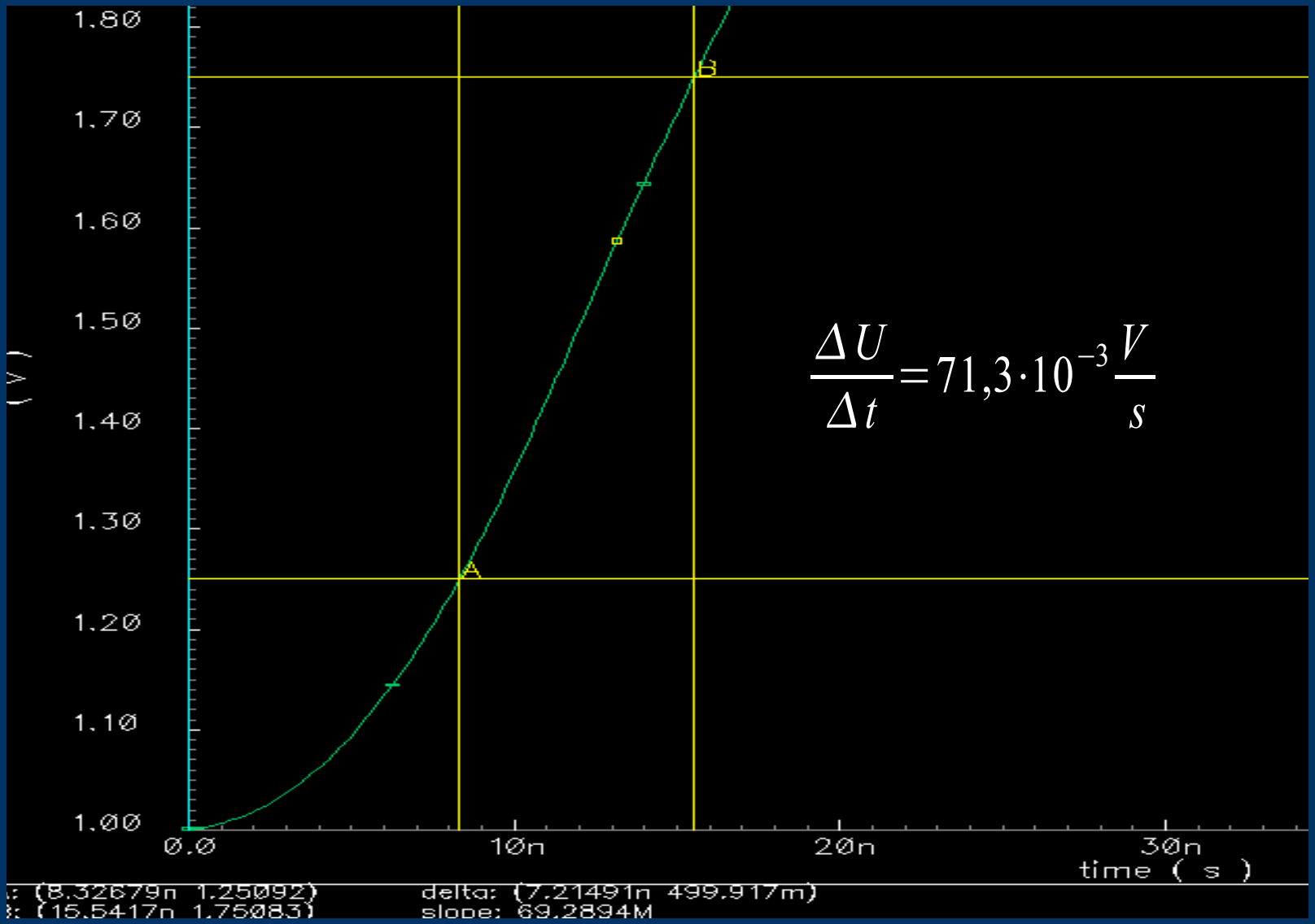
Verifizierung - Voltageswing



Verifizierung - Powerdissipation

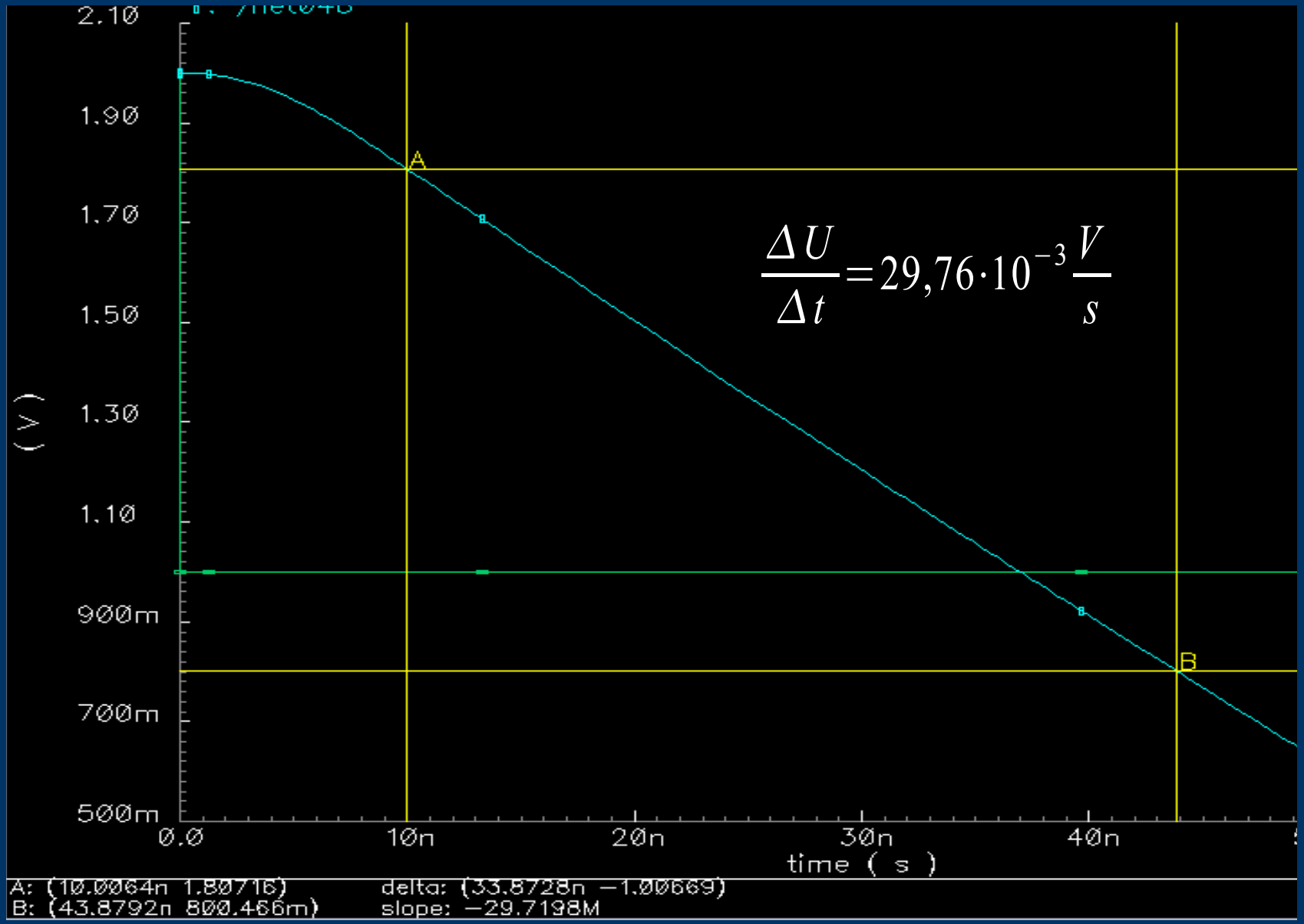


Verifizierung - Slewrate



$$\frac{\Delta U}{\Delta t} = 71{,}3 \cdot 10^{-3} \frac{V}{s}$$

Verifizierung - Slewrate



Verifizierung - Übersicht

	Vorgabe	Schematic	Scaleable	Extracted
Open Loop Gain	75	76,3	76	78,08
Gain Bandwidth	1,00E+07	7,87E+07	~7,7E+07	~7,6E+07
Slew Rate	10	45,37	28,85	29,76
Offset	1,00E-06	7,36E-07	3,50E-07	3,57E-07
CMR -	-0,5	-0,54	-0,56	~ -0,92
CMR +	1	1,03	1,18	1,17
Output swing -	-0,35	-1,6	-1,64	-1,64
Output swing +	0,35	1,5	1,28	1,28
Cmrr	80	91,6	~200	~200
Power dissipation	1,00E-03	9,70E-04	6,50E-04	7,50E-04