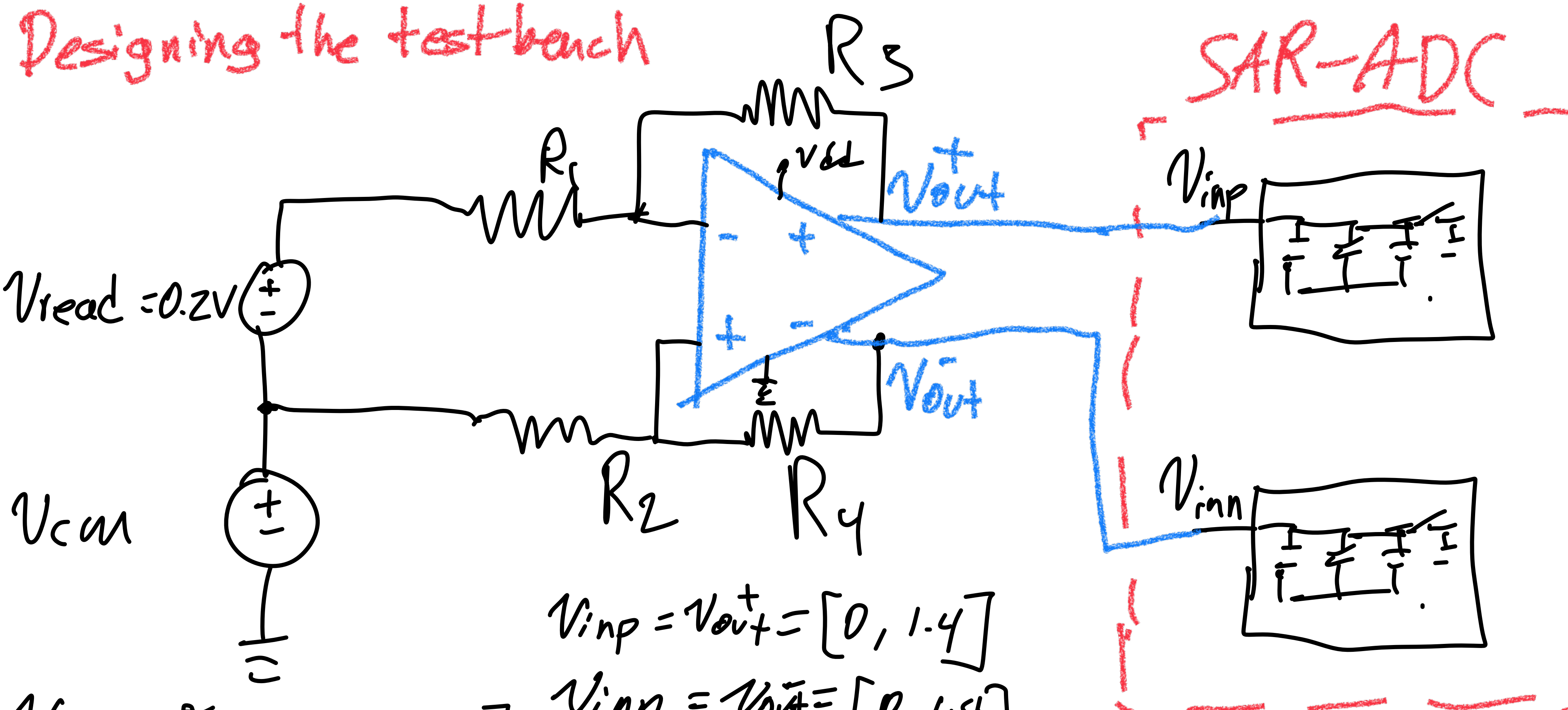
Associative Proc.

Activity Report

Alejandro Juárez Lora, December 4, 2023

Designing the testbench



$V_{inp} = V_{out}^+ = [0, 1.4]$

$V_{inn} = V_{out}^- = [0, 1.4]$

$V_{cm} = 0.7V$

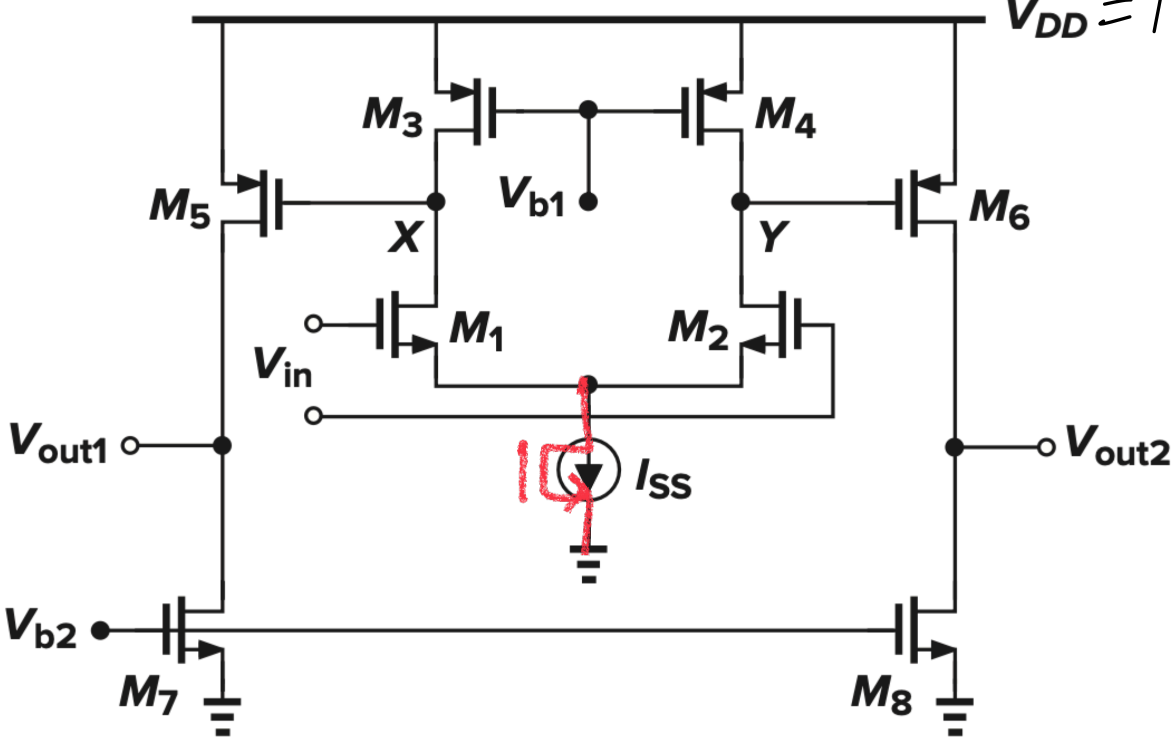
$V_{pp} \in [-1.4V, 1.4V]$

$V_{pp} = 2.8V$

Two stage opamp

$V_{SS} = 0$ $V_{PP} = 2.8\,V$

(from the ADC)



$=1.8\,V$

Figure 9.23 Simple implementation of a two-stage op amp.

$P_{budget} = 1\,\mu W$ (Proposed)

$|V_{th,p}| = V_{thn} = 0.65\,V$

(from Sky 130)

Computing Overdrive voltages

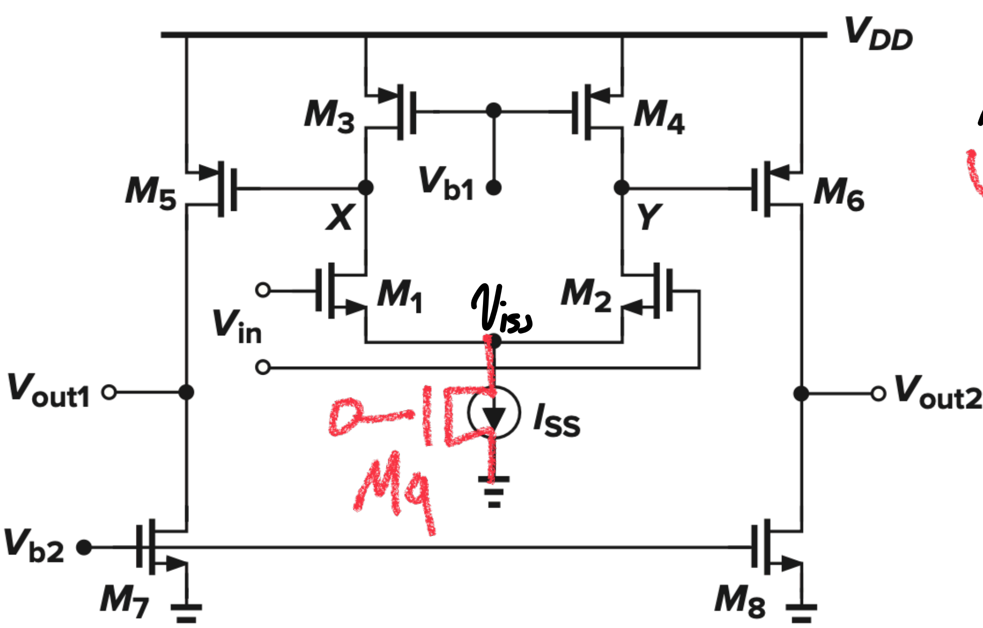


Figure 9.23 Simple implementation of a two-stage op amp.

Voltage at inner branch

$V_{DD} = |V_{OD3}| + V_X + V_{OD1} + V_{OD9}$

with $V_X = 0.1\, V_{PP} = 0.28$

$$\underbrace{V_{OD1} + |V_{OD3}| + V_{OD9}}_{V_{inbranch}} = 1.8V - 0.28$$

$V_{inbranch} = 1.52V$

Asigning $V_{OD9} = (0.2) \cdot 1.52 = 0.3V$

$V_{OD3} = (0.55) \cdot 1.52 = 0.83V$

$V_{OD1} = (0.25) \cdot 1.52 = 0.38V$

Computing Overdrive voltages

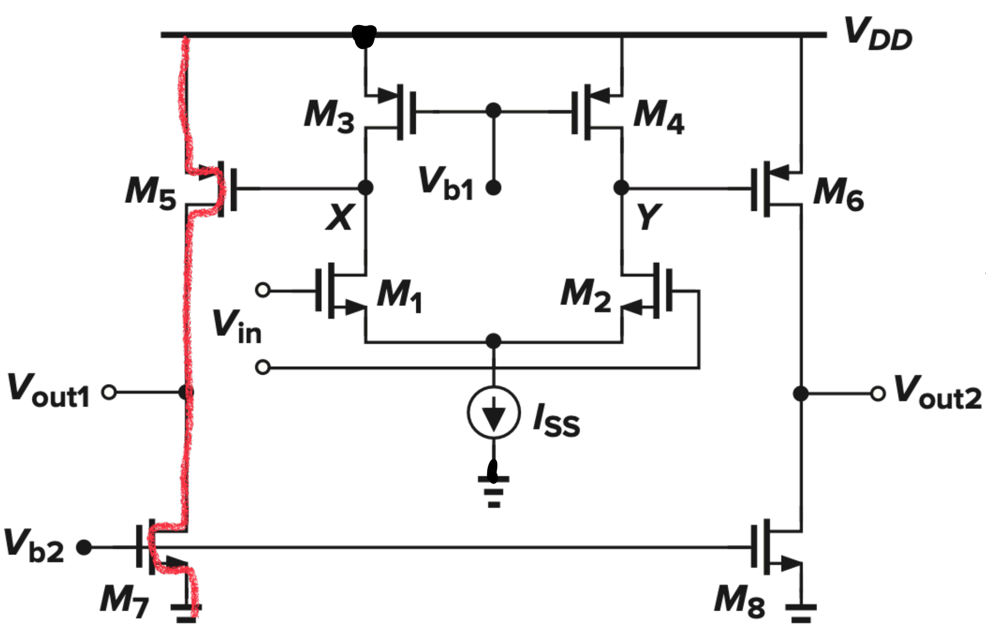


Figure 9.23 Simple implementation of a two-stage op amp.

Voltage at outer branch

$$V_{dd} - V_{SS} = |V_{OD5}| + V_{out1} + V_{OD7}$$

$$\therefore |V_{OD5}| + V_{OD7} = V_{DD} - V_{SS} - V_{out1}$$

Setting $V_{out1} = 0.5\,V_{pp} = 1.4\,V$

$$|V_{OD5}| + V_{OD7} = 1.8 - 0 - 1.4 = 0.4$$

Assigning

$$|V_{OD5}| = (1/4) \cdot 0.4 = \underline{0.1\,V}$$

$$V_{OD7} = (3/4) \cdot 0.4 = \underline{0.3\,V}$$

Computing Bias voltages

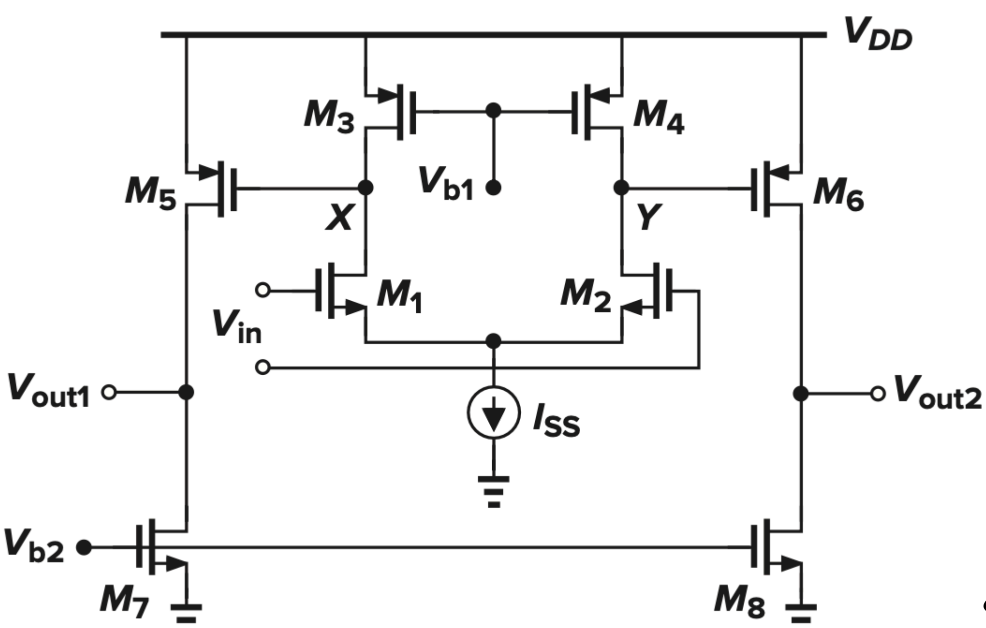


Figure 9.23 Simple implementation of a two-stage op amp.

$$V_{b1} = V_{dd} + V_{ss} - (V_{OD3} + V_{thp})$$

$$= 1.8V + 0V - (0.83V + 0.65V)$$

$$V_{b1} = 0.3159\,V$$

$$V_{b2} = V_{dd} + V_{ss} - (V_{OD5} + V_{OD7} + V_{thn})$$

$$V_{b2} = 0.75\,V$$

Assigning currents

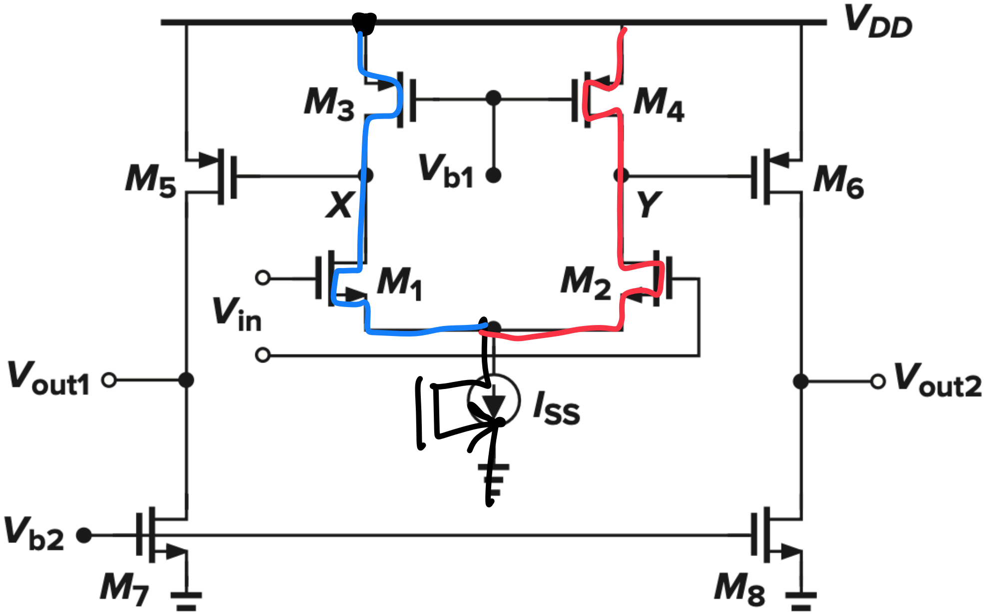


Figure 9.23 Simple implementation of a two-stage op amp.

Current in M_9 = $I_{left} + I_{right}$

Getting the available current

$$I_{budget} = \frac{10\,mW}{1.8\,V} = 5.5\,mA$$

Asigning bias current equally to M_1-M_8

$$I_{M_1-M_8} = \frac{I_{budget}}{8} = 69.4\,\mu A$$

$$= 2\cdot(69.4\,\mu A)$$

$$= 138.8\,\mu A$$

Computing Sizes

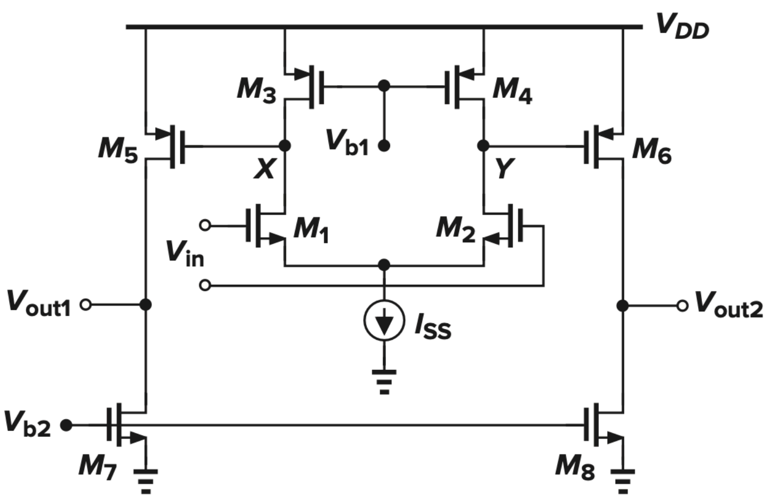


Figure 9.23 Simple implementation of a two-stage op amp.

$$I_D = \frac{1}{2}\mu_{n,p} C_{ox}\left(\frac{W}{L}\right)(\underbrace{V_{gs} - V_{th}}_{V_{OD}})^2$$

$$S = W/L = \frac{2I_D}{\mu_n C_{ox} V_{OD}^2}$$

with Sky130 param

$\mu_n = 0.03186 \frac{1}{V}$ $\mu_p = 0.01 \frac{1}{V}$

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = \frac{3.45 \times 10^{-11}}{4.148 \times 10^{-9}} = 8.3 \times 10^{-3}\ F/m^2$$

$\mu_n C_{ox} = 265e^{-6}$

$\mu_p C_{ox} = 83.2e^{-6}$

Exploring options

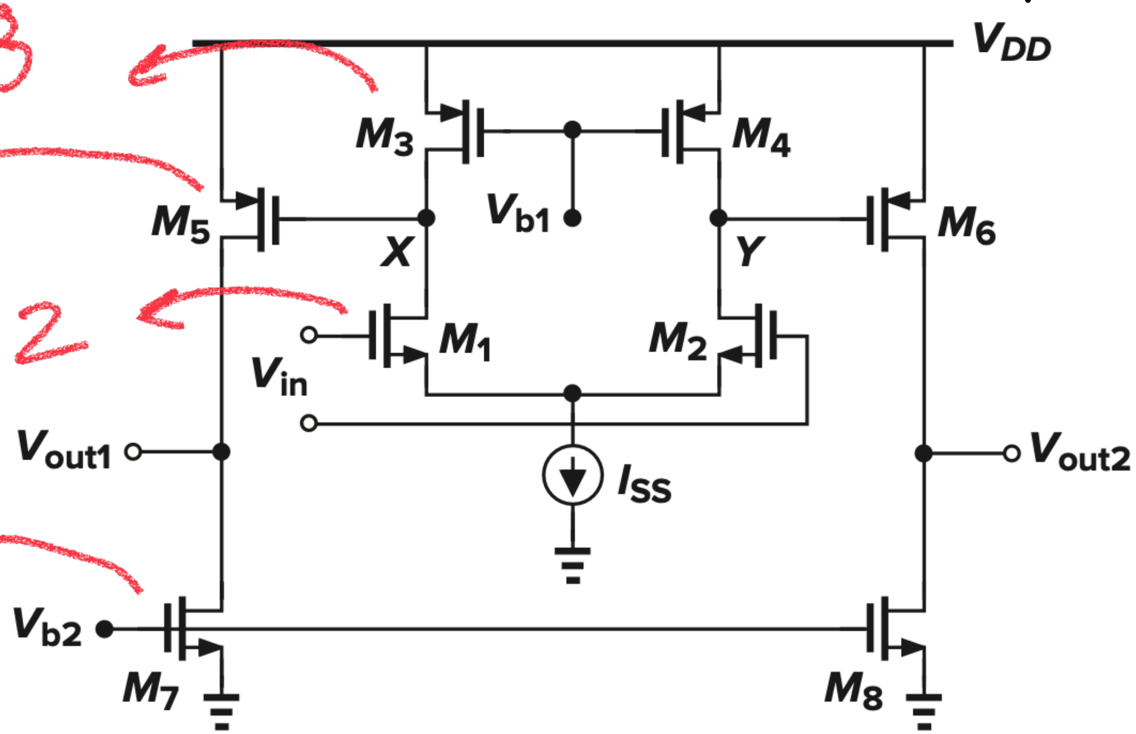
$$S = W/L = \frac{2I_D}{\mu_n C_{ox} V_{OD}^2}$$

$S_3 = 2.38$

$S_5 = 166.8$

$S_1 = 3.62$

$S_7 = 5.81$



$S_1 = S_2$

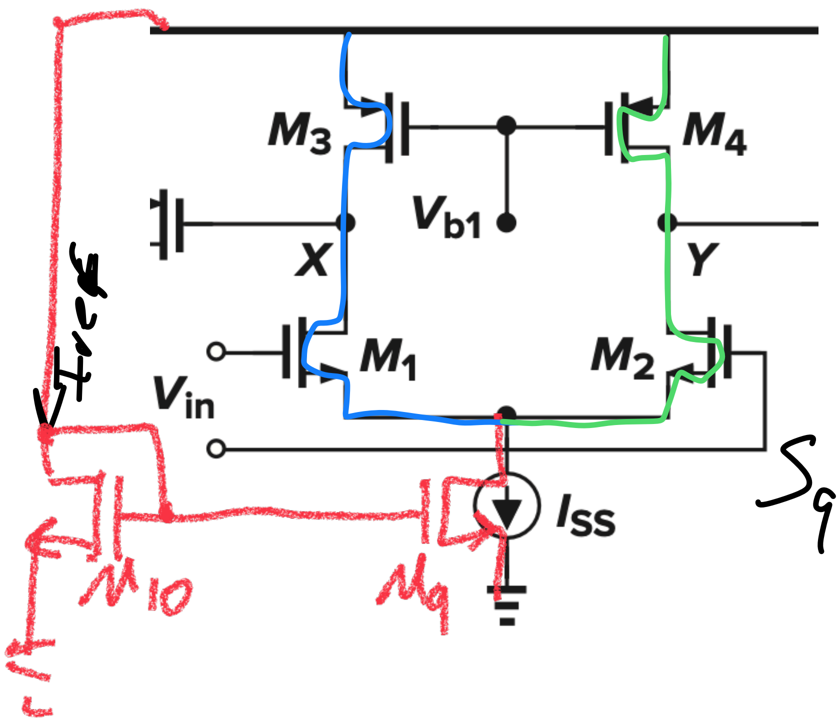
$S_3 = S_4$

$S_5 = S_6$

$S_7 = S_8$

Figure 9.23 Simple implementation of a two-stage op amp.

Designing the current mirror



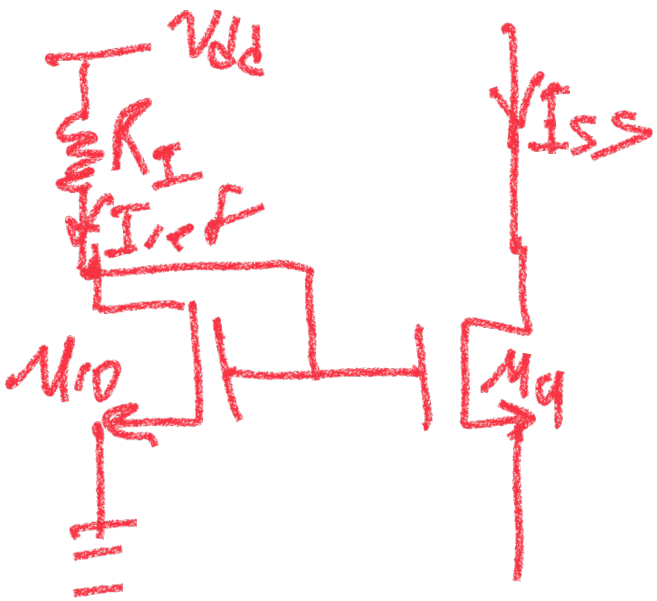
$I_{SS} = I_{M9} = I_{left} + I_{right}$

$= 138\,\mu A$

With $V_{OD9} = 0.3V$

$S_9 = \frac{2 I_D}{\mu_n C_{ox} V_{OD}^2} = \frac{2 I_{SS}}{\mu_n C_{ox} V_{OD}^2} = 11.33$

Designing the current mirror



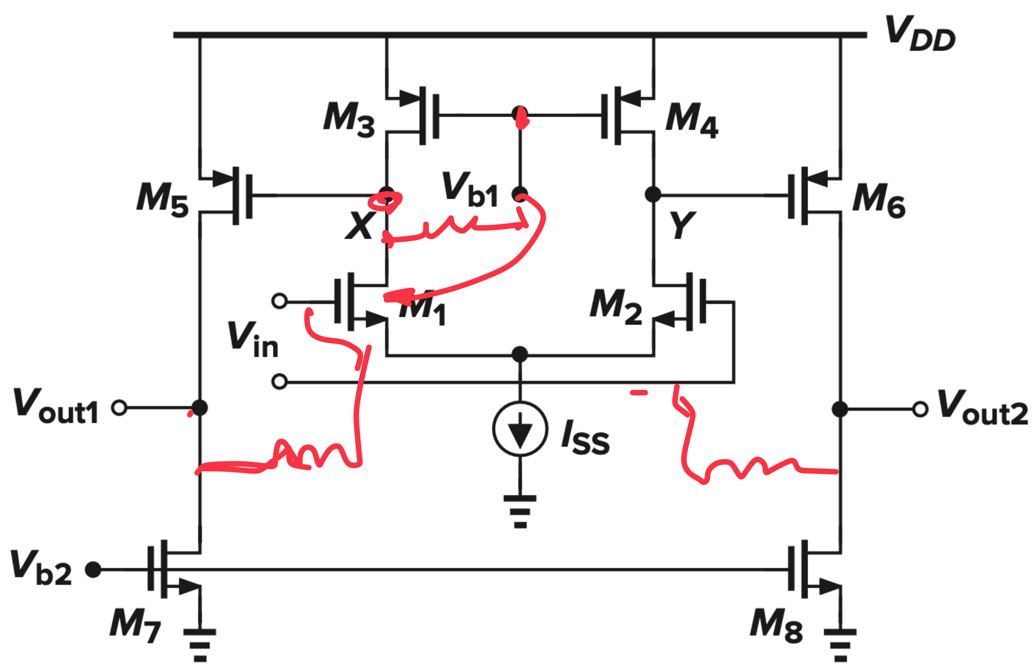
with

$$I_{SS} = \frac{(W/L)_9}{(W/L)_{10}} I_{ref} \qquad I_{ref} = \frac{V_{dd}}{R_1}$$

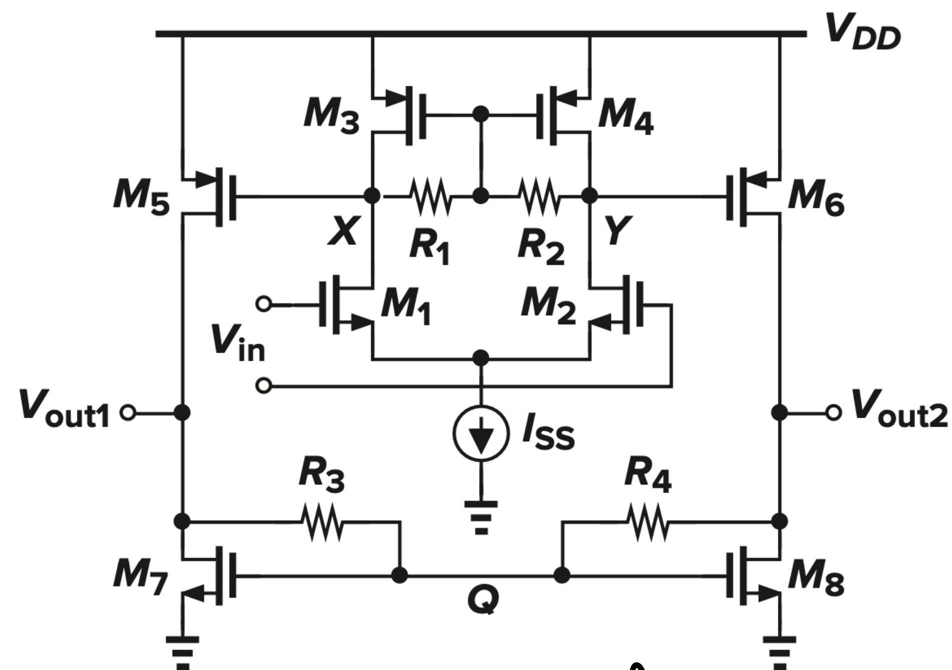
$$(W/L)_{10} = (W/L)_9 \frac{I_{ref}}{I_{SS}} = \frac{S_9 \cdot V_{dd}}{R_1 \cdot I_{M9}}$$

$$(W/L)_{10} = \frac{11.39 \quad (1.8V)}{\underbrace{1k\Omega}_{\text{Proposed}} \cdot 138nA} = 146.86$$

No feedback



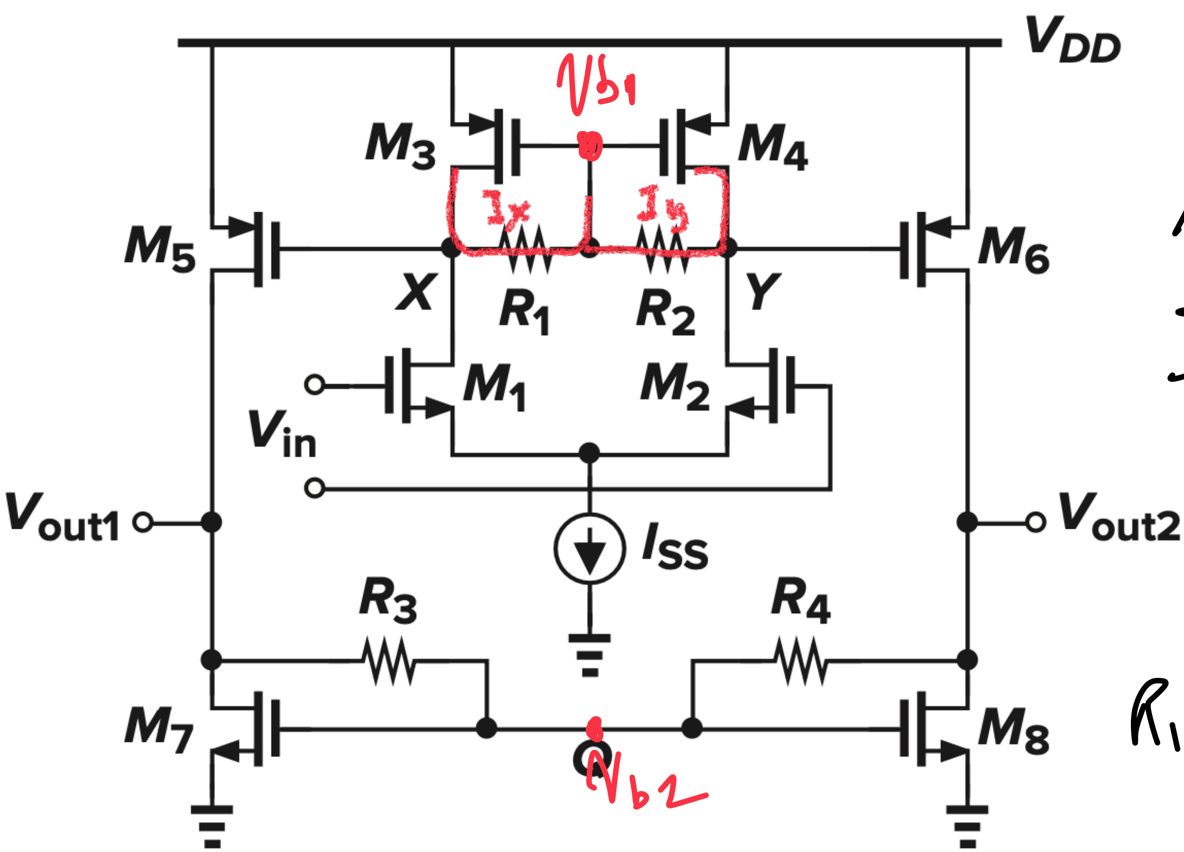
Feedback



– R_1 and R_2 provide Feedback for first stage – R_3 R_4 for the second

– R_1 and R_2 adjust $V_{GS3,4}$ until $|I_{D3}| = |I_{D4}| = \frac{I_{SS}}{2}$

Feedback



$V_{b1} = I_x \cdot R_1 + I_y \cdot R_2$

Setting $R_1 = R_2 = R_{12}$

$V_{b1} = (I_x + I_y) R_{12}$

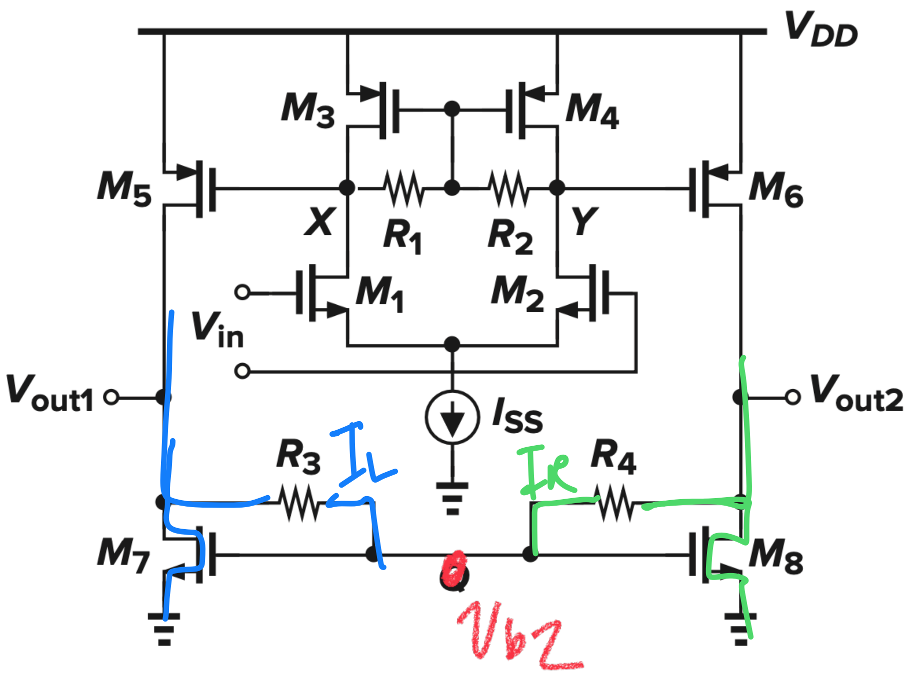
As $I_x \propto 1/I_y$ and $V_{b1} = 0.29V$

$I_y = I_x = \frac{I_{ss}}{2} = \frac{2.5mA}{2}$.

Then $V_{b1} = \left(\frac{I_{ss}}{2}\right) R_{12}$

$R_{1,2} = \frac{2V_{b1}}{I_{ss}} = \frac{2V_{b1}}{I_{mg}} = 4.5\,k\Omega$

Feedback



$V_{b2} = I_L \cdot R_3 + I_R \cdot R_4$

Setting $R_3 = R_4 = R_3$

$V_{b1} = (I_L + I_R) R_3$

$I_L = \frac{V_{out1}}{R_3} = I_R = \frac{V_{out2}}{R_4}$

As $V_{out1} \propto \frac{1}{V_{out2}}$ and $V_{b2} = 0.75V$

When $V_{out1} = 1.4$, $V_{out2} = 0$

$V_{b2} = I_L R_3 + I_R \cdot R_4$

With V_{OP_i}, I_i, $L = 0.5\,\mu m$, we can obtain g_m with

$$g_m = 2\left(\frac{I_d}{V_{gs} - V_{th}}\right) \qquad V_{OD} = V_{gs} - V_{th}$$

$g_{m1} = 360\,\Omega^{-1}$ $g_{m3} = 720\,\Omega^{-1}$ $g_{m5} = 81.81\,\Omega^{-1}$

$g_{m7} = 245\,\Omega^{-1}$

Also

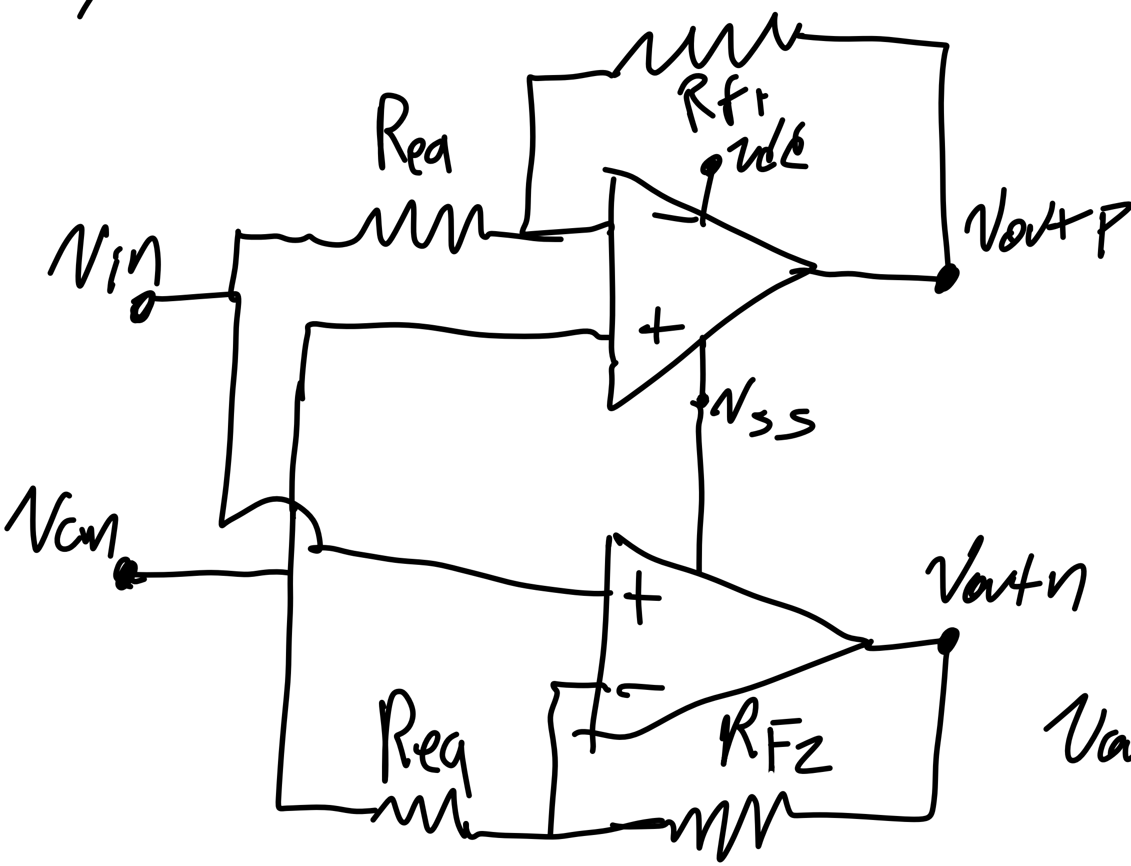
$$r_o = \frac{1}{\lambda |I_D|}$$

λ has to be derived!

$$A_v = g_{m1} g_{m7} (r_{O_N} \| r_{O_P})^2$$

From Razavi $\lambda_n = 0.1\ 1/V$ $\lambda_p = 0.2\ 1/V$ $A_v \approx 1010$

Or, we can use two single stage opamps



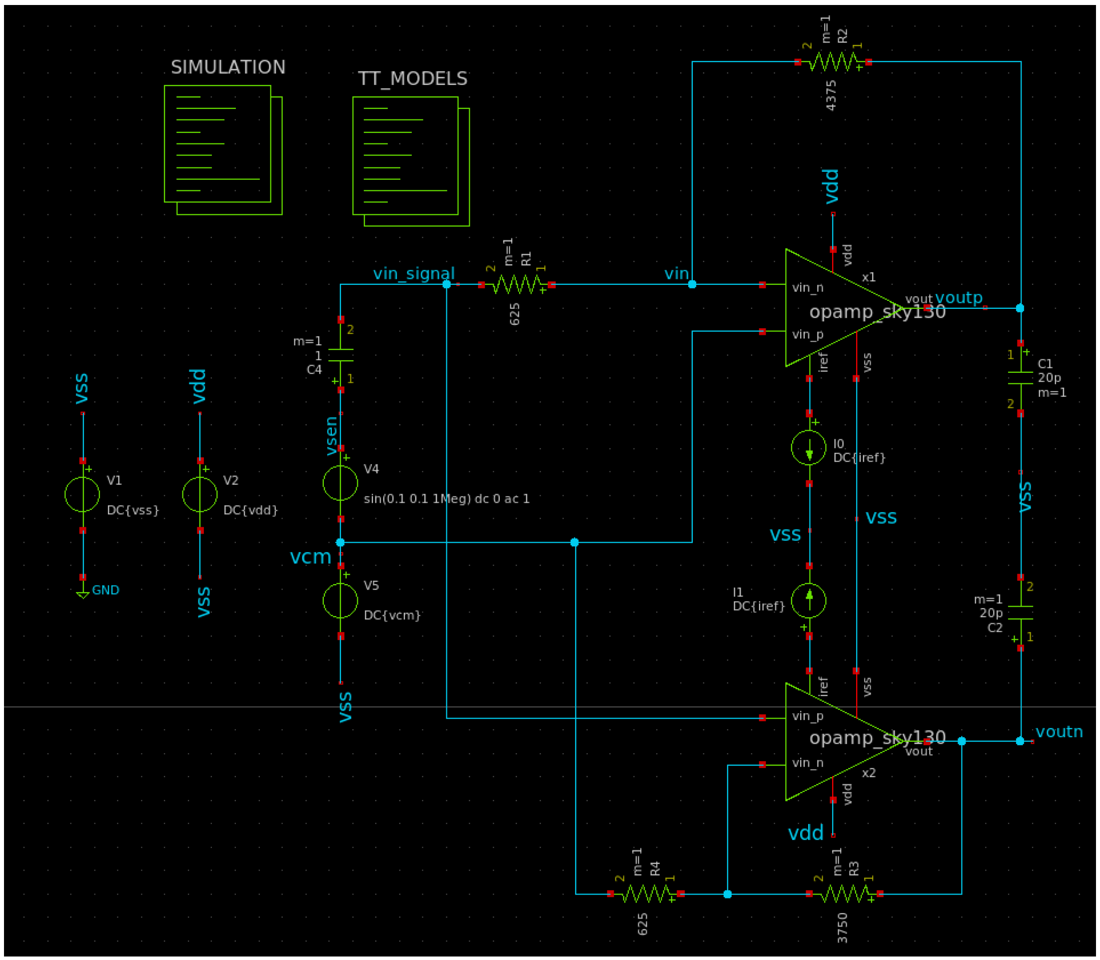
$$\frac{1}{R_{eq}} = \frac{1}{R_{M1}} + \frac{1}{R_{M2}} + \cdots + \frac{1}{R_{M16}}$$

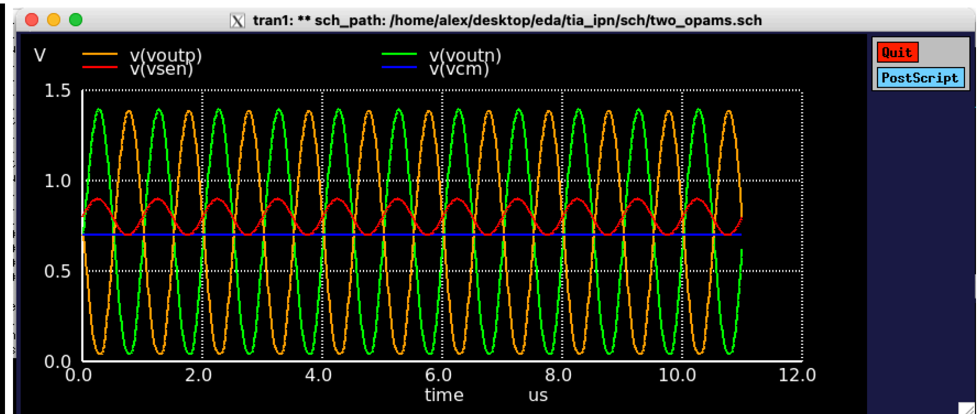
$$R_{eq} = \frac{V_{read}}{I_{read}} = \frac{0.2V}{0.32mA}$$

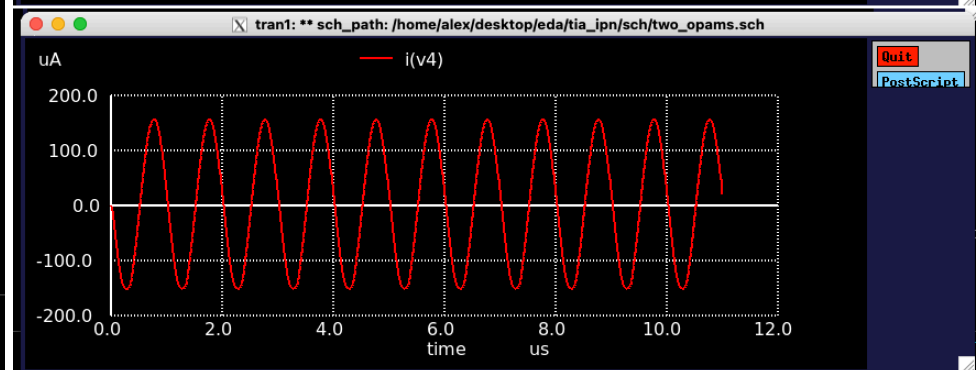
$$R_{eq} = 625\,\Omega$$

$$V_{out}^{+} = -\left(\frac{R_{F1}}{R_{eq}}\right) \cdot V_{in}$$

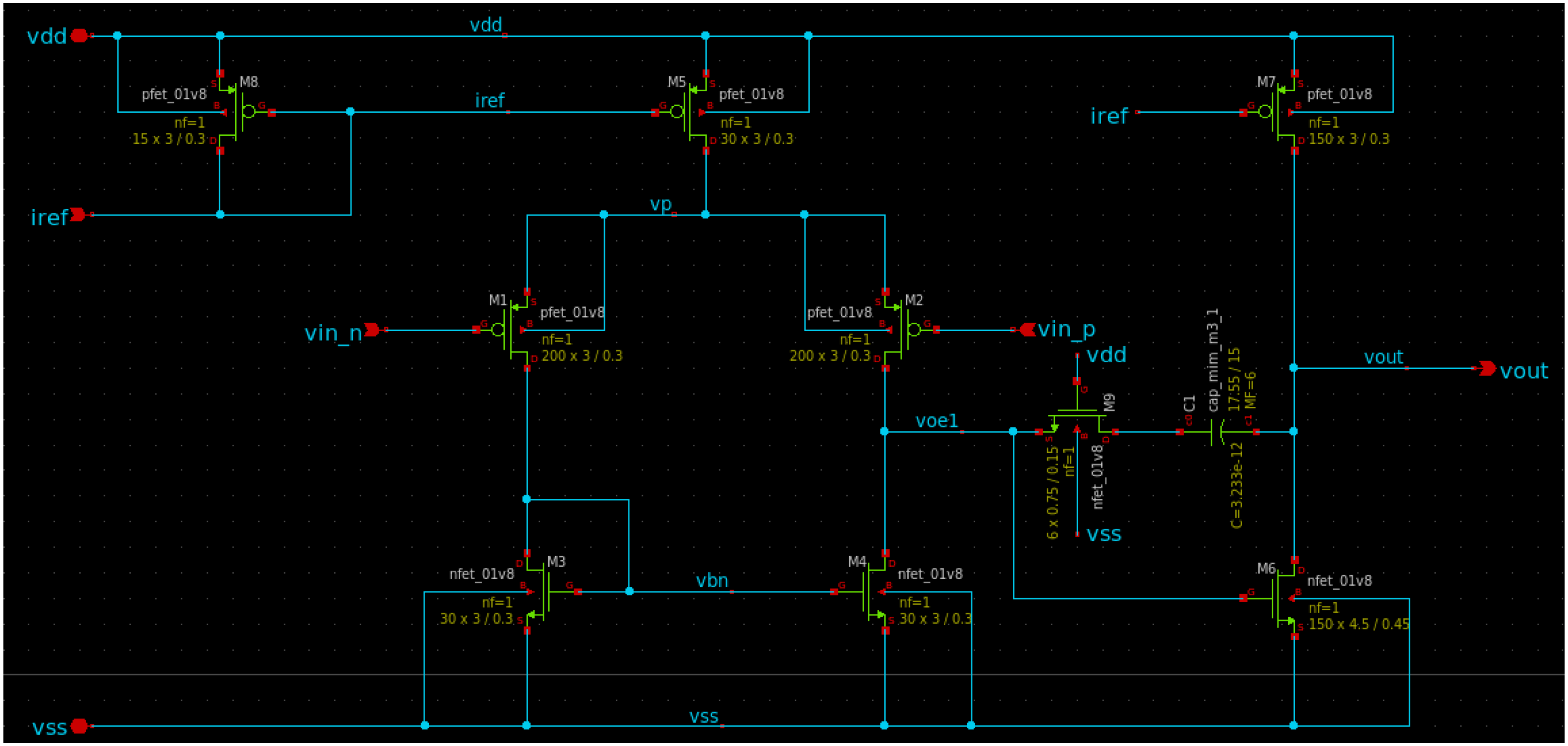
Schematic of the TIA, v2





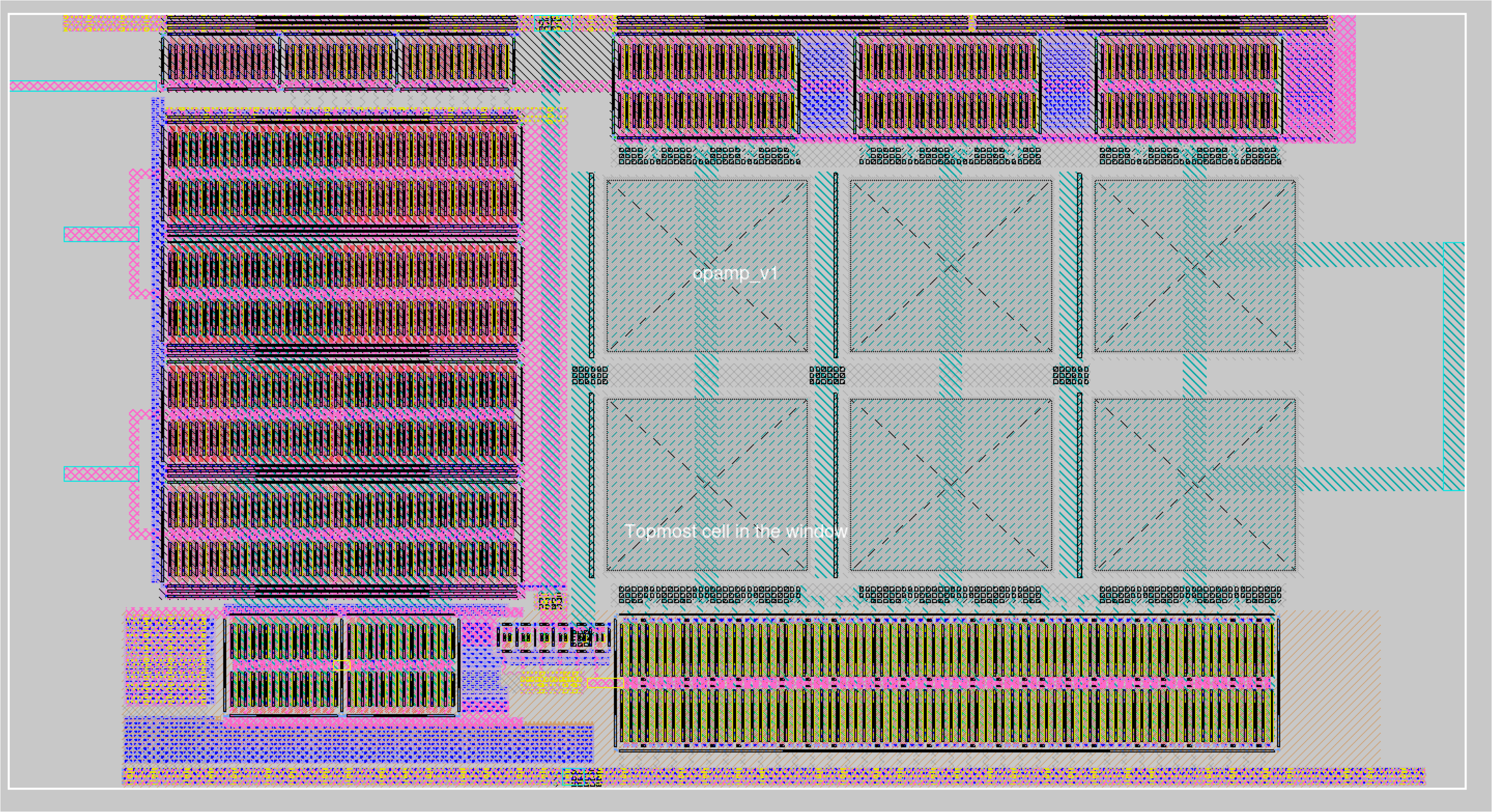


Schematic of the OPAMP



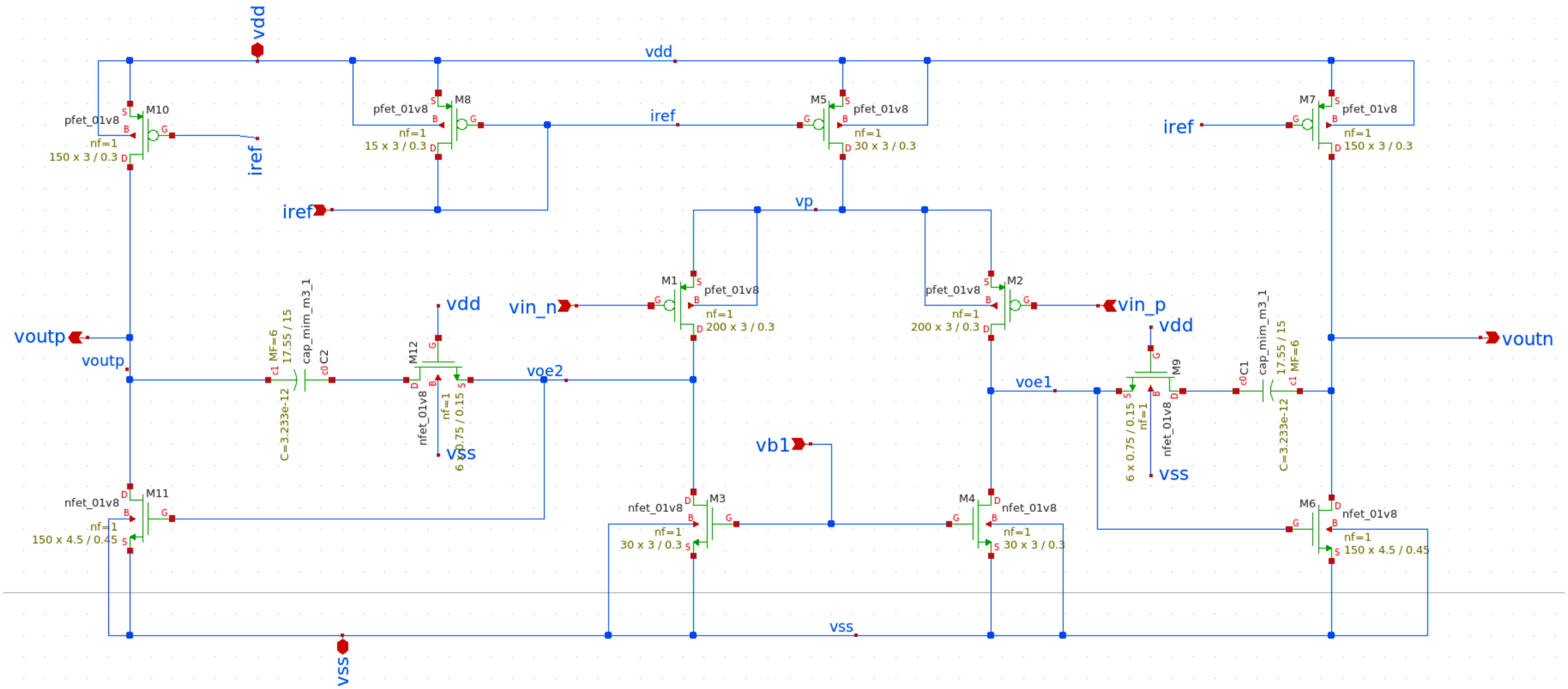
https://github.com/JuliaAlva/caravel_fulgor_opamp/tree/master

Layout of the OPAMP

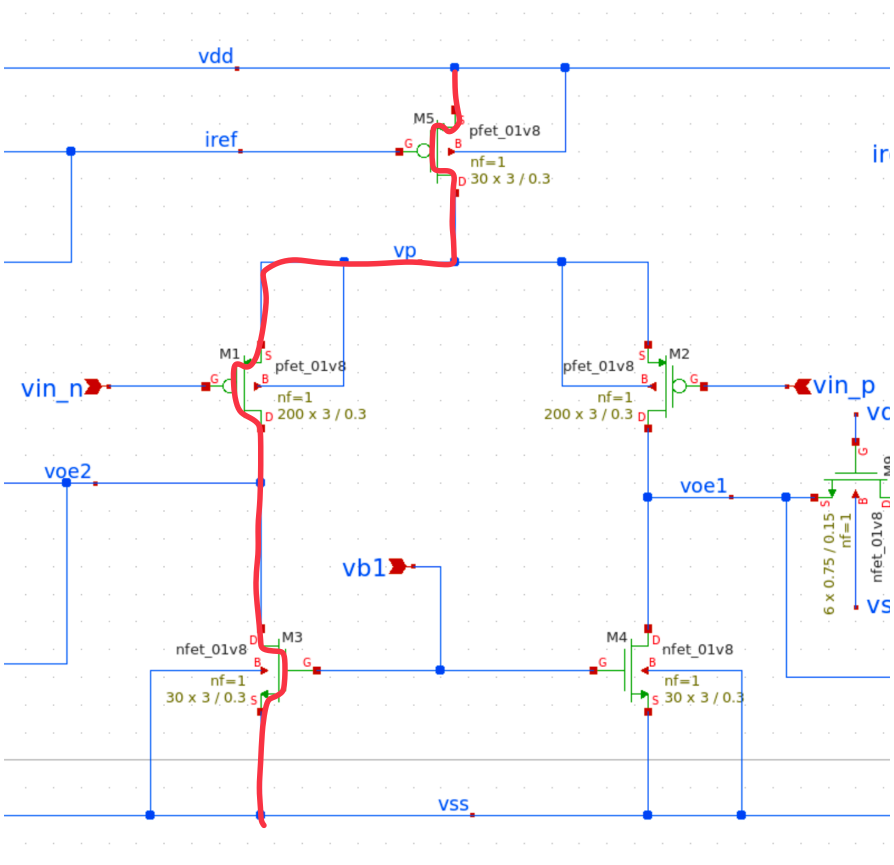


Post layout simulation of the OpAmps in the TIA tb

Schematic of the modified OPAMP



Finding vb1



$$V_{dd} - V_{ss} = V_{OD5} + V_{OD1} + V_{oe2} + V_{OD3}$$

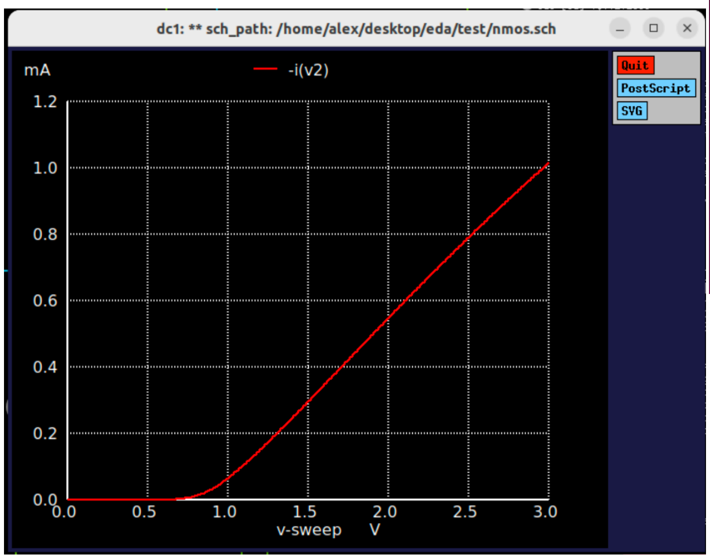
with $V_{b_1} = V_{g3}$ and V_{dd} 1.8

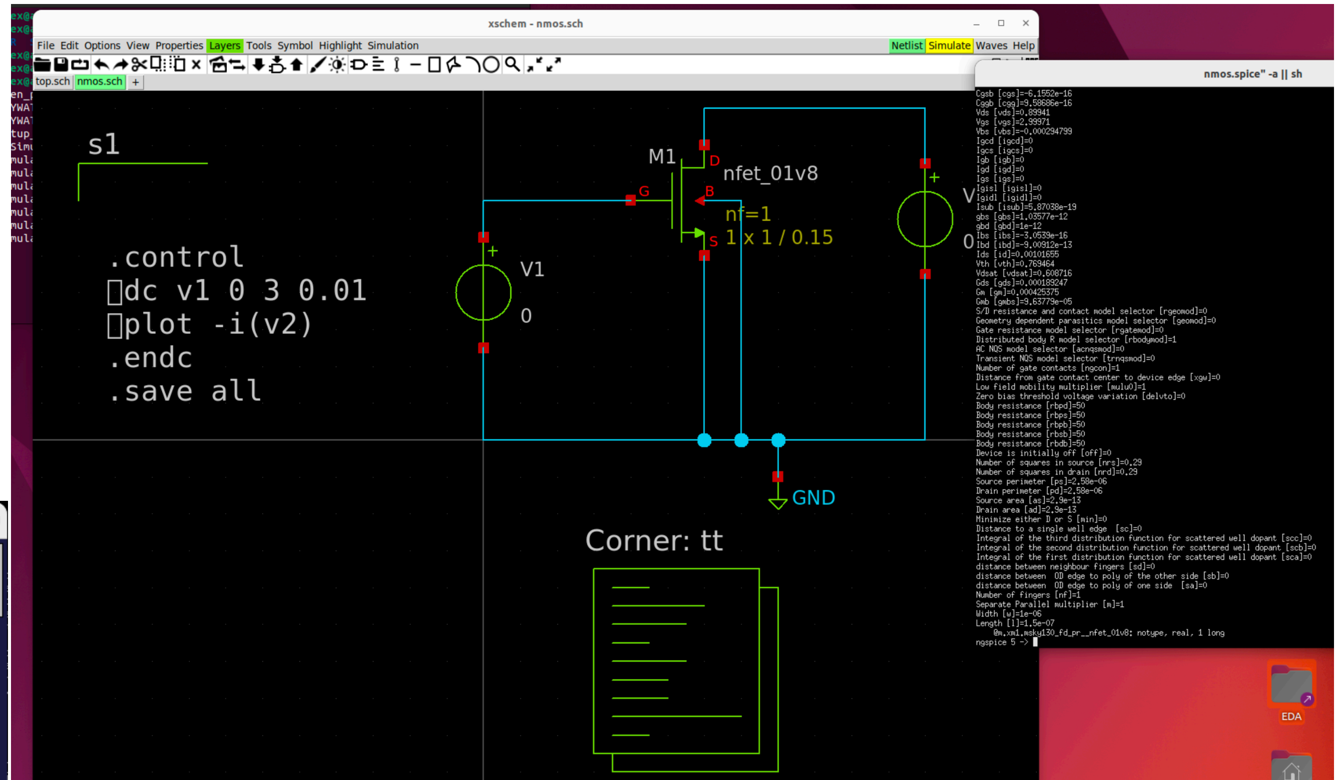
$$1.8 = V_{gs5} - V_{thp} + V_{gs1} - V_{thp} + V_{oe2} + V_{gs3} - V_{thn}$$

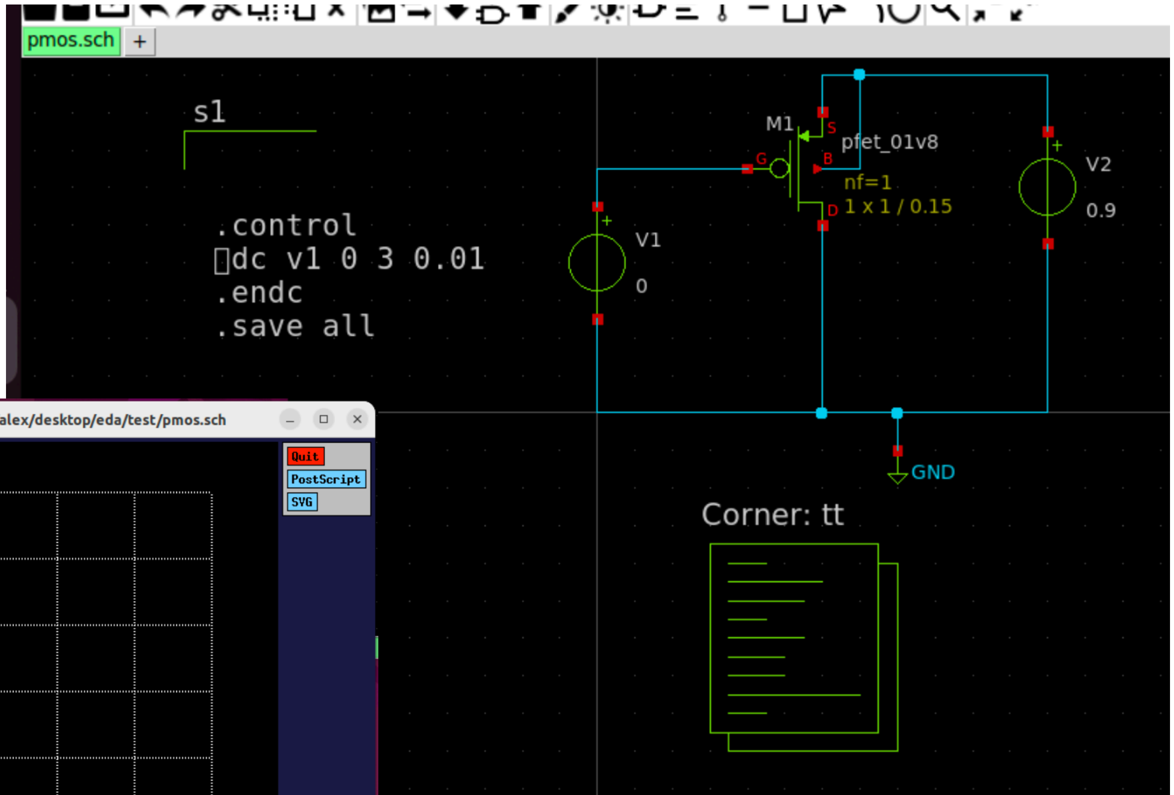
$$1.8 =$$

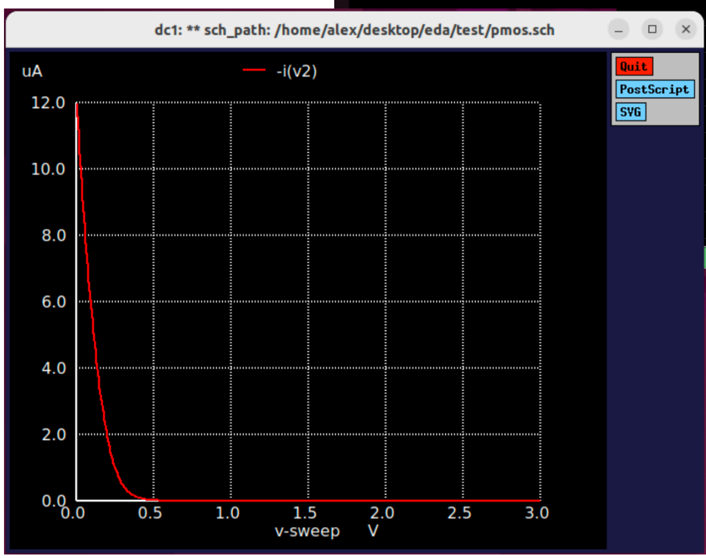
$$V_{thn} = 0.769\ V$$
$$\approx 0.75\ V$$

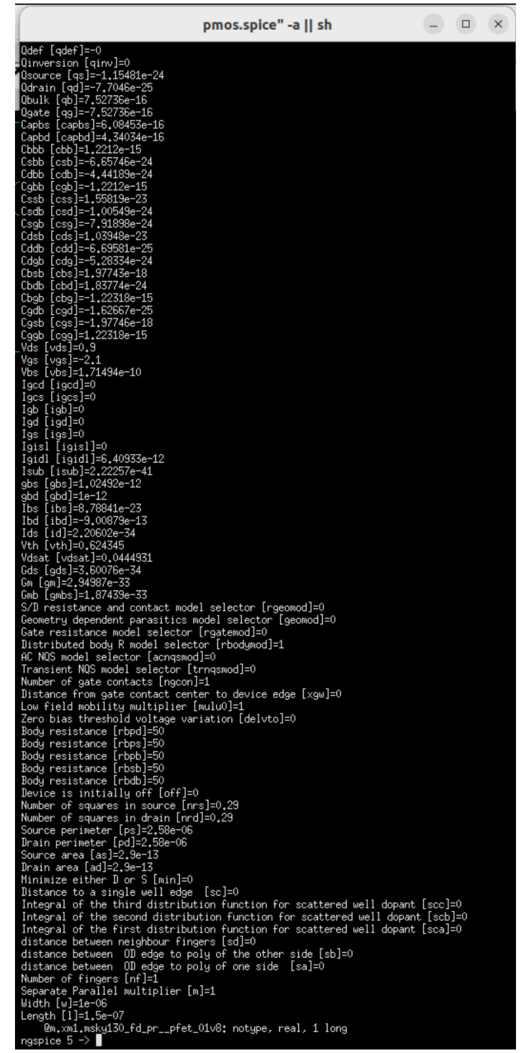
$$G_{m,n} = 0.4253 \times 10^{-3}$$









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Geometry dependent parasitics model selector [geomod]=0
Gate resistance model selector [rgatemod]=0
Distributed body R model selector [rbodymod]=1
AC NQS model selector [acnqsmod]=0
Transient NQS model selector [trnqsmod]=0
Number of gate contacts [ngcon]=1
Distance from gate contact center to device edge [xgw]=0
Low field mobility multiplier [mulu0]=1
Zero bias threshold voltage variation [delvto]=0
Body resistance [rbpd]=50
Body resistance [rbps]=50
Body resistance [rbpb]=50
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Body resistance [rbdb]=50
Device is initially off [off]=0
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Source area [as]=2.9e-13
Drain area [ad]=2.9e-13
Minimize either D or S [min]=0
Distance to a single well edge  [sc]=0
Integral of the third distribution function for scattered well dopant [scc]=0
Integral of the second distribution function for scattered well dopant [scb]=0
Integral of the first distribution function for scattered well dopant [sca]=0
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distance between  OD edge to poly of the other side [sb]=0
distance between  OD edge to poly of one side  [sa]=0
Number of fingers [nf]=1
Separate Parallel multiplier [m]=1
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Length [l]=1.5e-07
    @m.xm1.msky130_fd_pr__pfet_01v8: notype, real, 1 long
ngspice 5 ->
```

$V_{thp} = 0.624V$ $\quad g_m = 2.94 \times 10^{-33}$