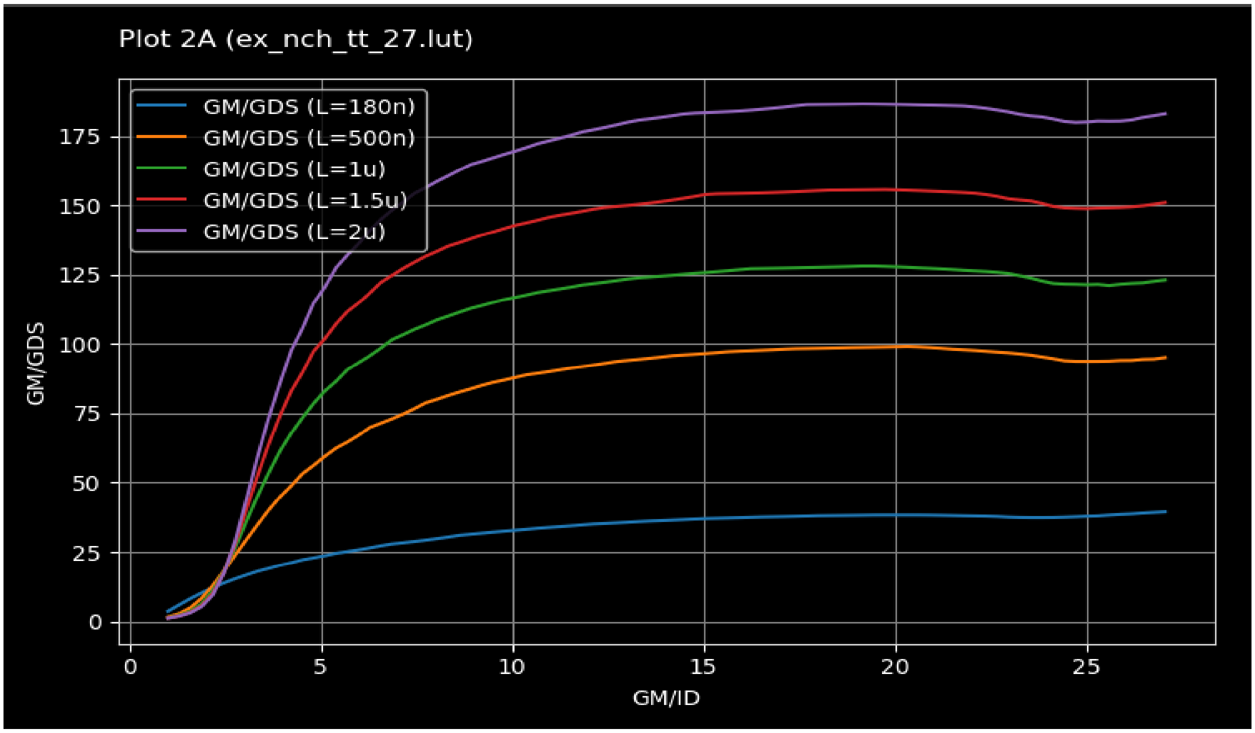
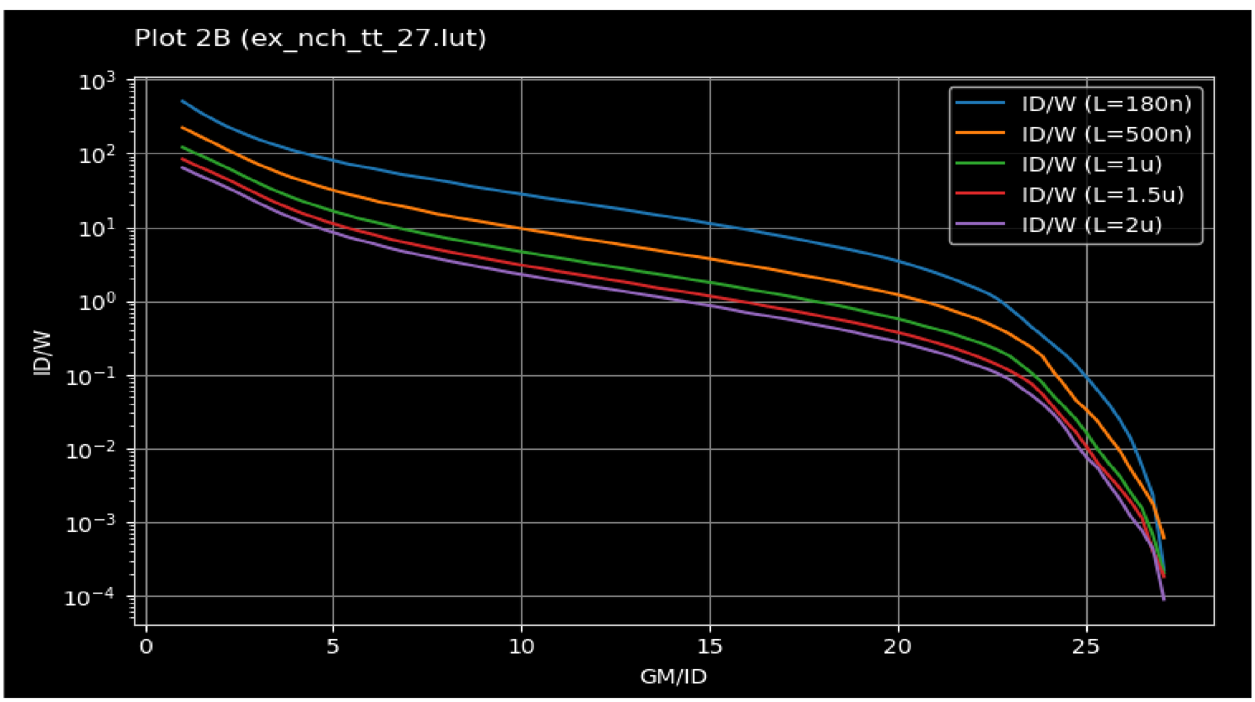
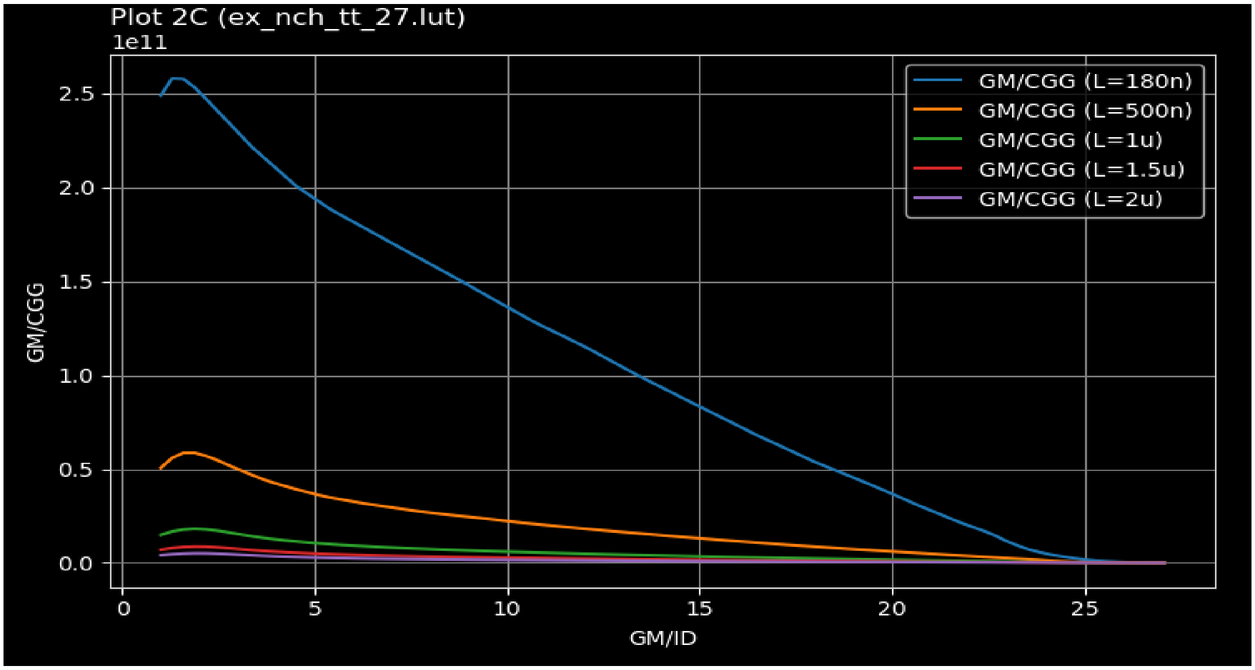
Lab 4

Part 1

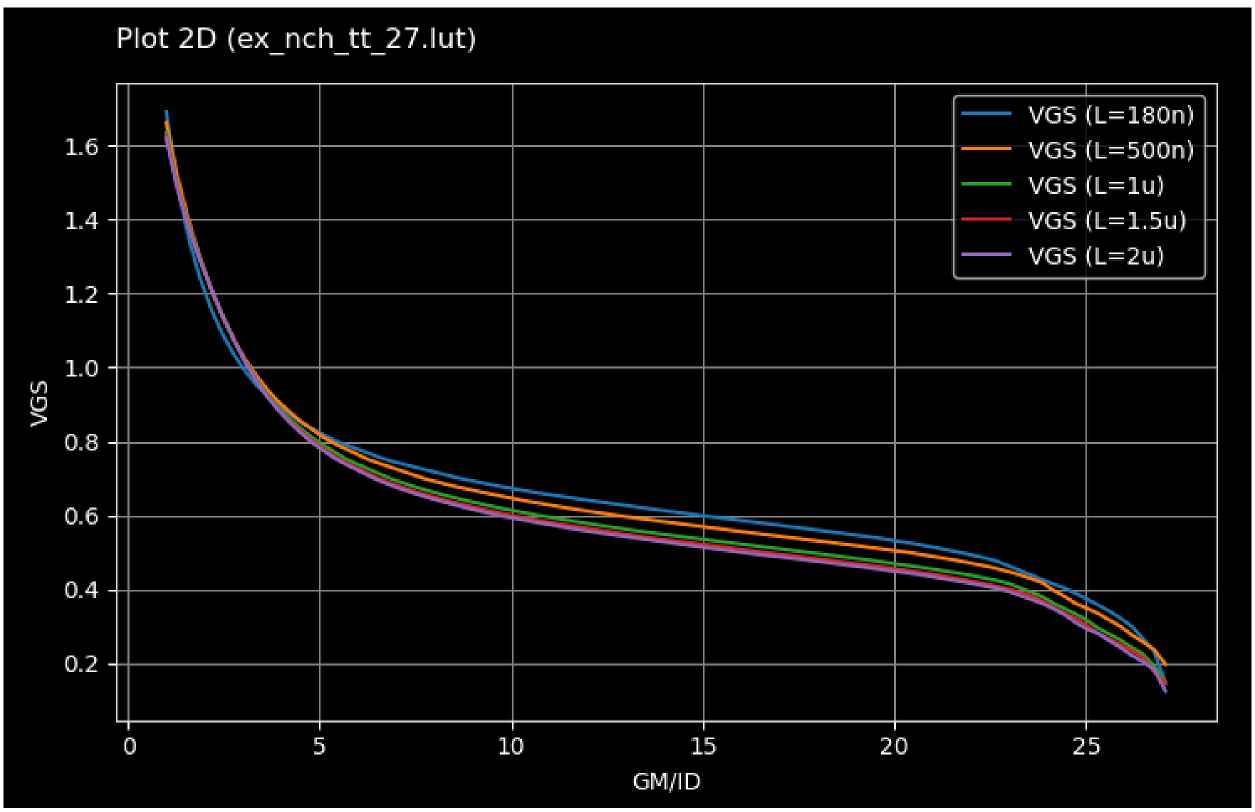
NMOS:





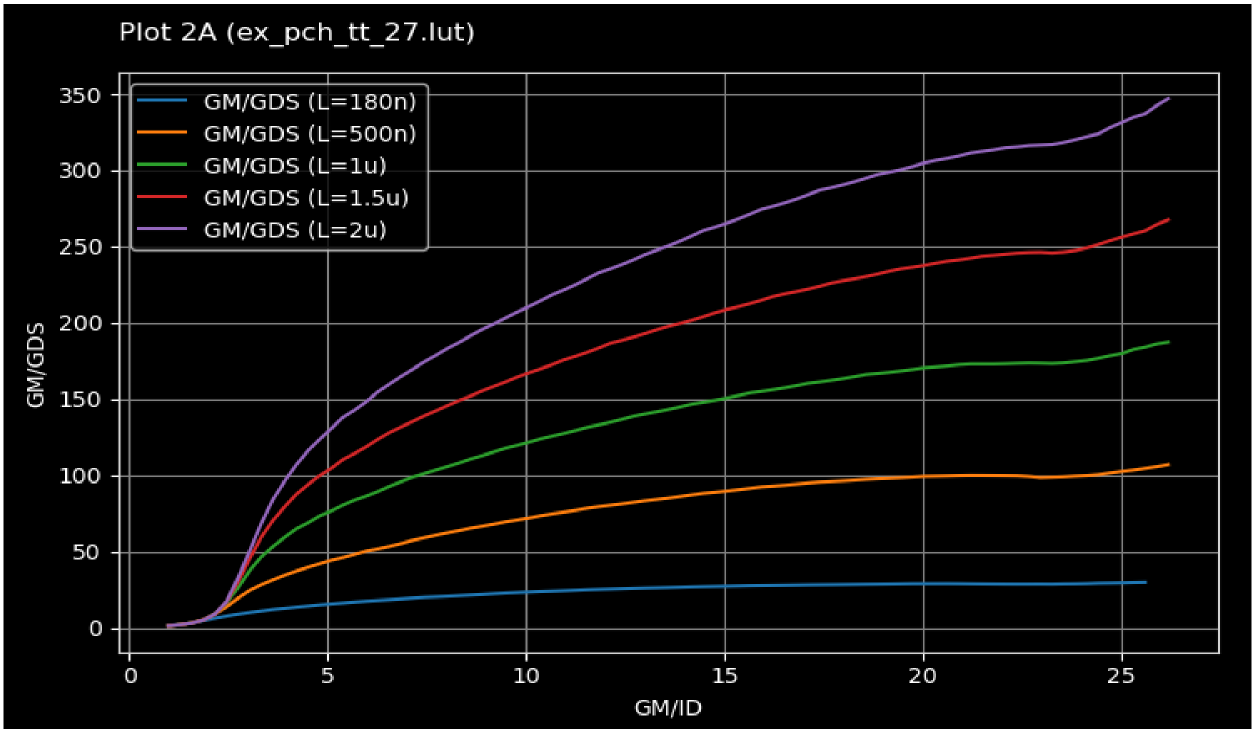


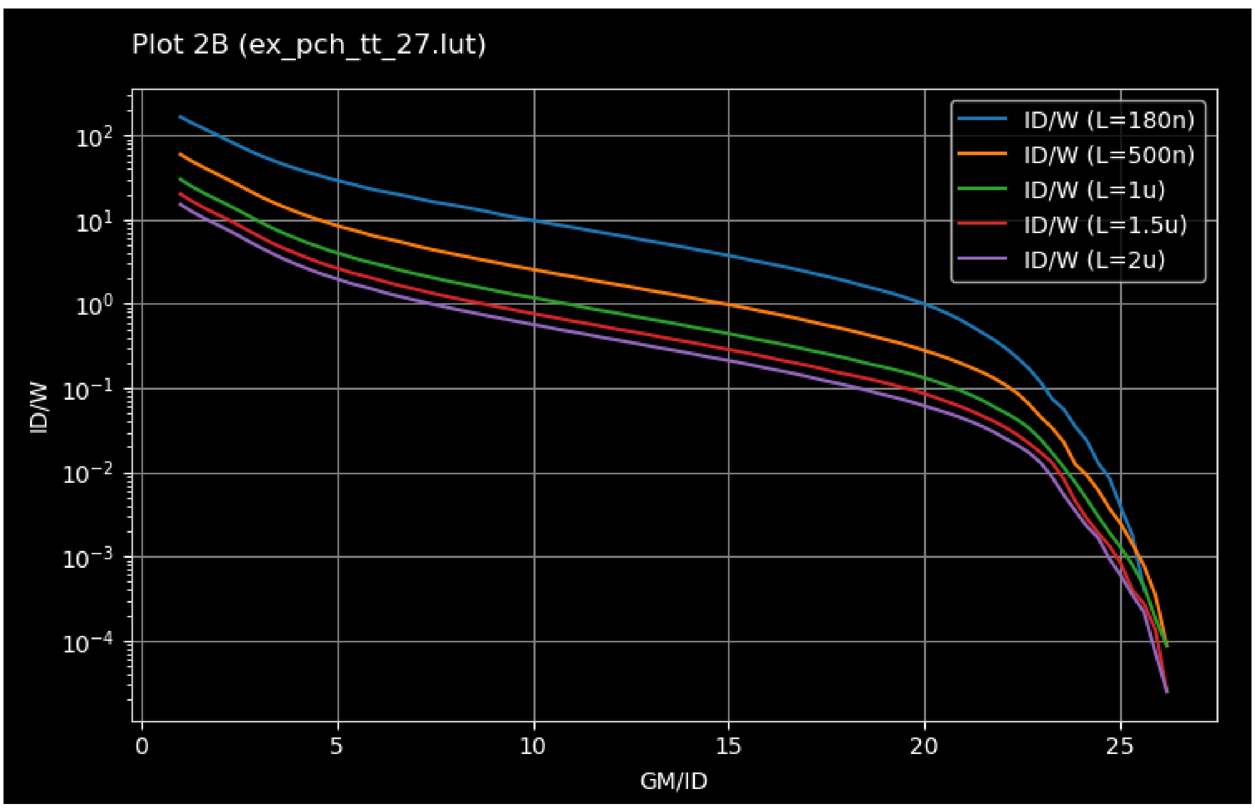
Plot 2C (ex_nch_tt_27.lut)
1e11
GM/CGG (L=180n)
GM/CGG (L=500n)
GM/CGG (L=1u)
GM/CGG (L=1.5u)
GM/CGG (L=2u)
GM/CGG
2.5
2.0
1.5
1.0
0.5
0.0
0
5
10
15
20
25
GM/ID

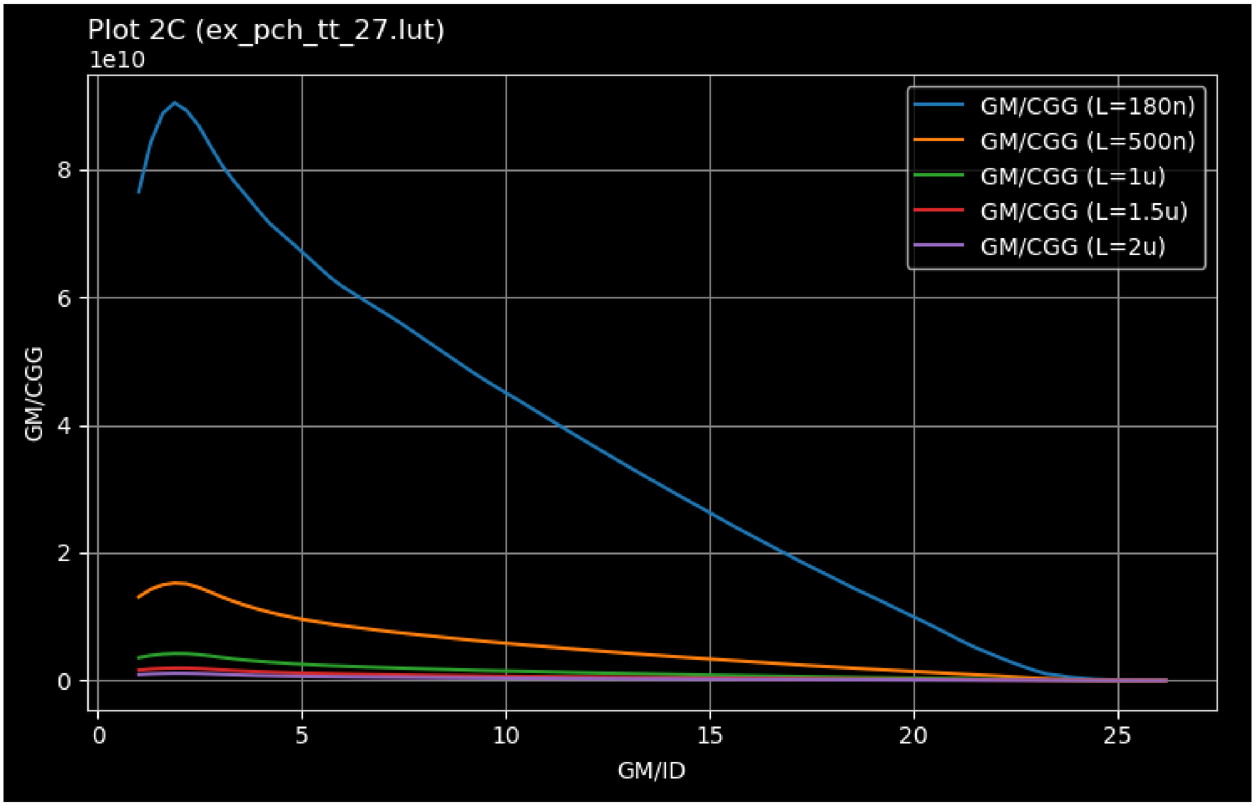


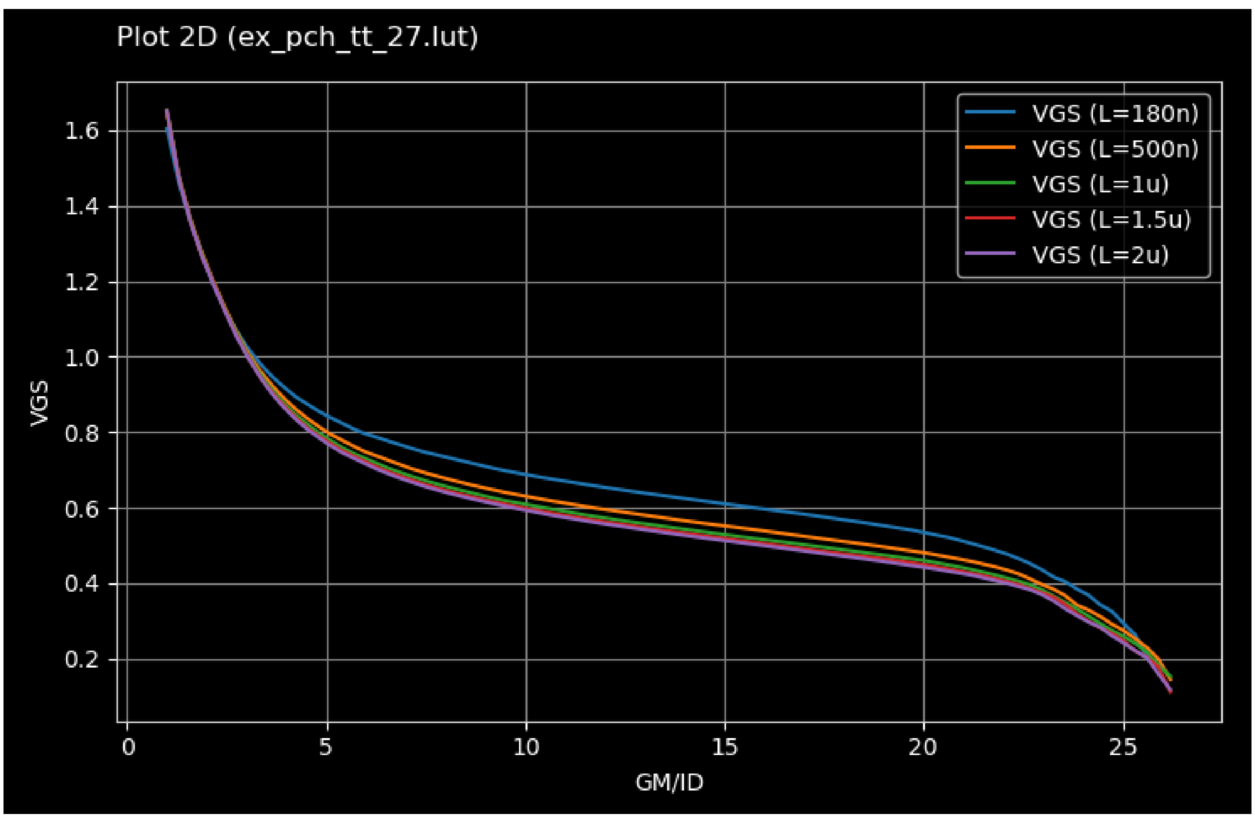
Plot 2D (ex_nch_tt_27.lut)
VGS (L=180n)
VGS (L=500n)
VGS (L=1u)
VGS (L=1.5u)
VGS (L=2u)
VGS
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
5
10
15
20
25
GM/ID

PMOS:


Plot 2A (ex_pch_tt_27.lut)
GM/GDS (L=180n)
GM/GDS (L=500n)
GM/GDS (L=1u)
GM/GDS (L=1.5u)
GM/GDS (L=2u)
GM/GDS
GM/ID
0
50
100
150
200
250
300
350
0
5
10
15
20
25

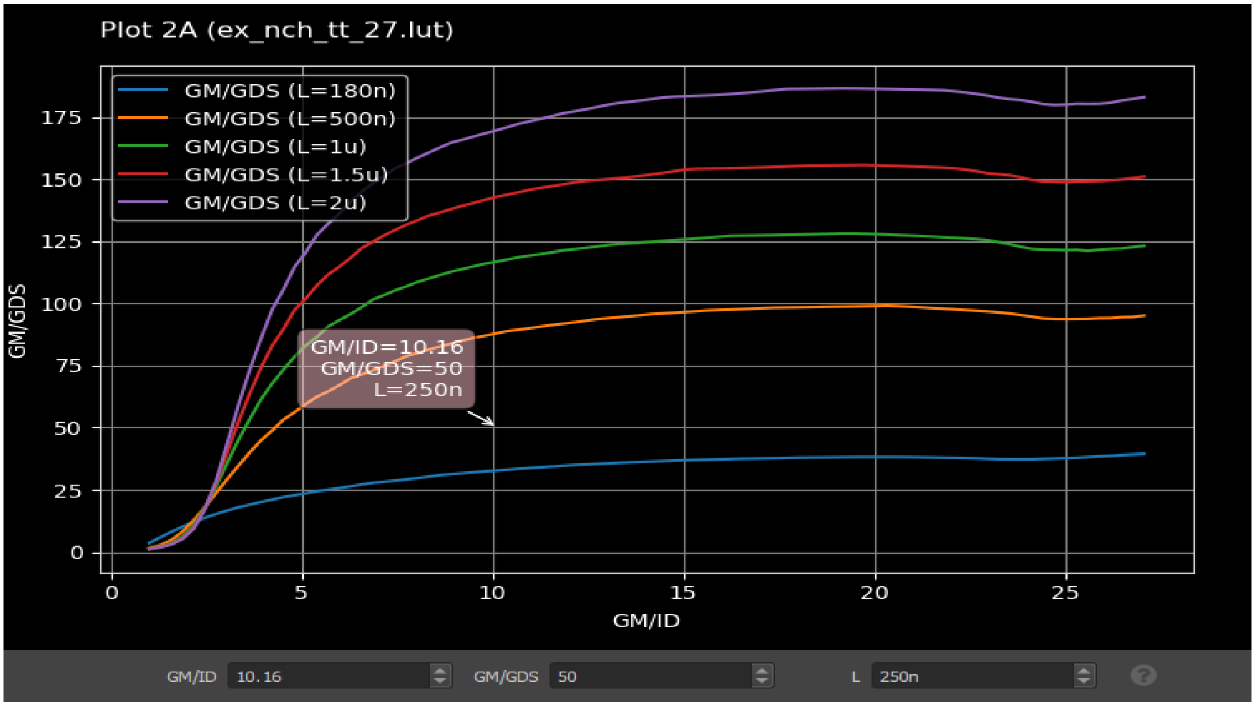

Plot 2B (ex_pch_tt_27.lut)
ID/W (L=180n)
ID/W (L=500n)
ID/W (L=1u)
ID/W (L=1.5u)
ID/W (L=2u)
ID/W
GM/ID
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0
5
10
15
20
25


Plot 2C (ex_pch_tt_27.lut)
1e10
GM/CGG (L=180n)
GM/CGG (L=500n)
GM/CGG (L=1u)
GM/CGG (L=1.5u)
GM/CGG (L=2u)
GM/CGG
GM/ID
0
2
4
6
8
0
5
10
15
20
25

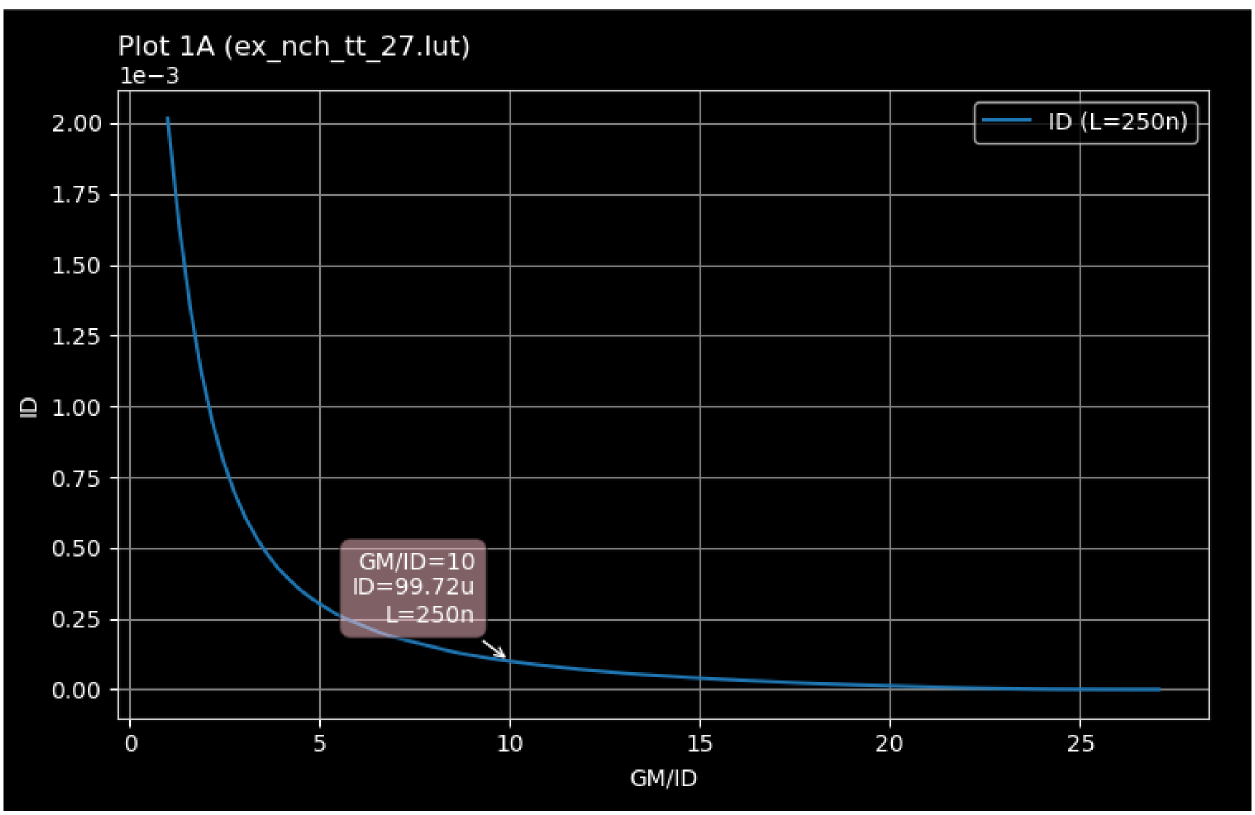

Plot 2D (ex_pch_tt_27.lut)
VGS (L=180n)
VGS (L=500n)
VGS (L=1u)
VGS (L=1.5u)
VGS (L=2u)
VGS
GM/ID
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
0
5
10
15
20
25

2-

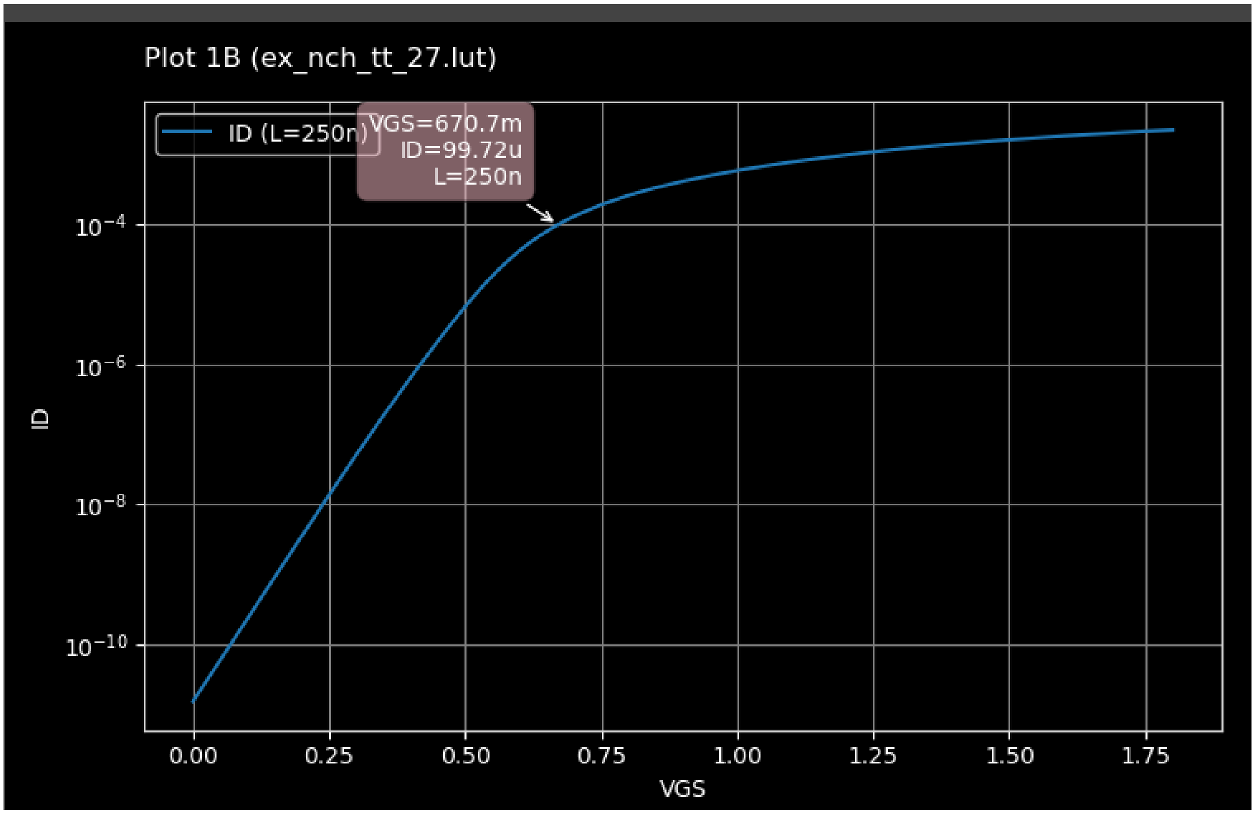
L choice



Plot 2A (ex_nch_tt_27.lut)
GM/GDS (L=180n)
GM/GDS (L=500n)
GM/GDS (L=1u)
GM/GDS (L=1.5u)
GM/GDS (L=2u)
GM/ID=10.16
GM/GDS=50
L=250n
GM/GDS
GM/ID
GM/ID 10.16
GM/GDS 50
L 250n



Plot 1A (ex_nch_tt_27.lut)
1e−3
ID (L=250n)
GM/ID=10
ID=99.72u
L=250n
ID
GM/ID



ID= 99.72 uA

Vgs = 670.7 mV

3- Lookup_Test modifications :

itor - C:\Users\DELL\Desktop\Siemens AMS 2025\lab4\lookup_test.m

```
% Find L that give gm/gds > given value
L_vector = nch.L; % Get the L vector from LUT structure
%Get the gm/gds values vector corresponding to the L_vector
gm_gds_vector = look_up(nch, 'GM_GDS', 'GM_ID', M1.gm_ID, 'VDS', M1.VDS, 'L', L_vector);
% Get the minimum L that gives gm/gds > the given value
% add line to get the minimum L for M1 that gives gm/gds >= M1.gm_gds
valid_indices = find(gm_gds_vector >= M1.gm_gds);
M1.L = L_vector(valid_indices(1));
% Get the current by computing the ID/W and then multiply it by W
M1.ID_W = look_up(nch, 'ID_W', 'GM_ID', M1.gm_ID, 'VDS', M1.VDS, 'L', M1.L);
% add line to get the current of M1
M1.ID = M1.ID_W * M1.W;

% Get the VGS value
% add line to get the VGS value of M1
vgs_vec = nch.VGS;
gm_id_vec = look_up(nch, 'GM_ID', 'VGS', vgs_vec, ...
                    'VDS', M1.VDS, 'L', M1.L);
[~, idx] = min(abs(gm_id_vec - M1.gm_ID));
M1.VGS = vgs_vec(idx);

% Print the solution
fprintf('Minimum L = %.2g µm\n', M1.L);
fprintf('VGS = %.2f\n',M1.VGS);
fprintf('ID = %.2d\n',M1.ID);
```

```
>> lookup_test
Minimum L = 0.26 µm
VGS = 0.68
ID = 9.52e-05
>>
```

Parameter	Matlab	ADT
L min	0.26 um	0.25 um
VGS	0.68 V	0.6707 V
Id	95.2 uA	99.72 uA

4-

<u>Input pair design</u>

23 Rajab 1445 H ٢٣ رجب ١٤٤٥ هـ

Step 1 input Pair design

- $GBW = \frac{g_m}{2\pi C_L}$, $\frac{g_m}{I_D} = 15$

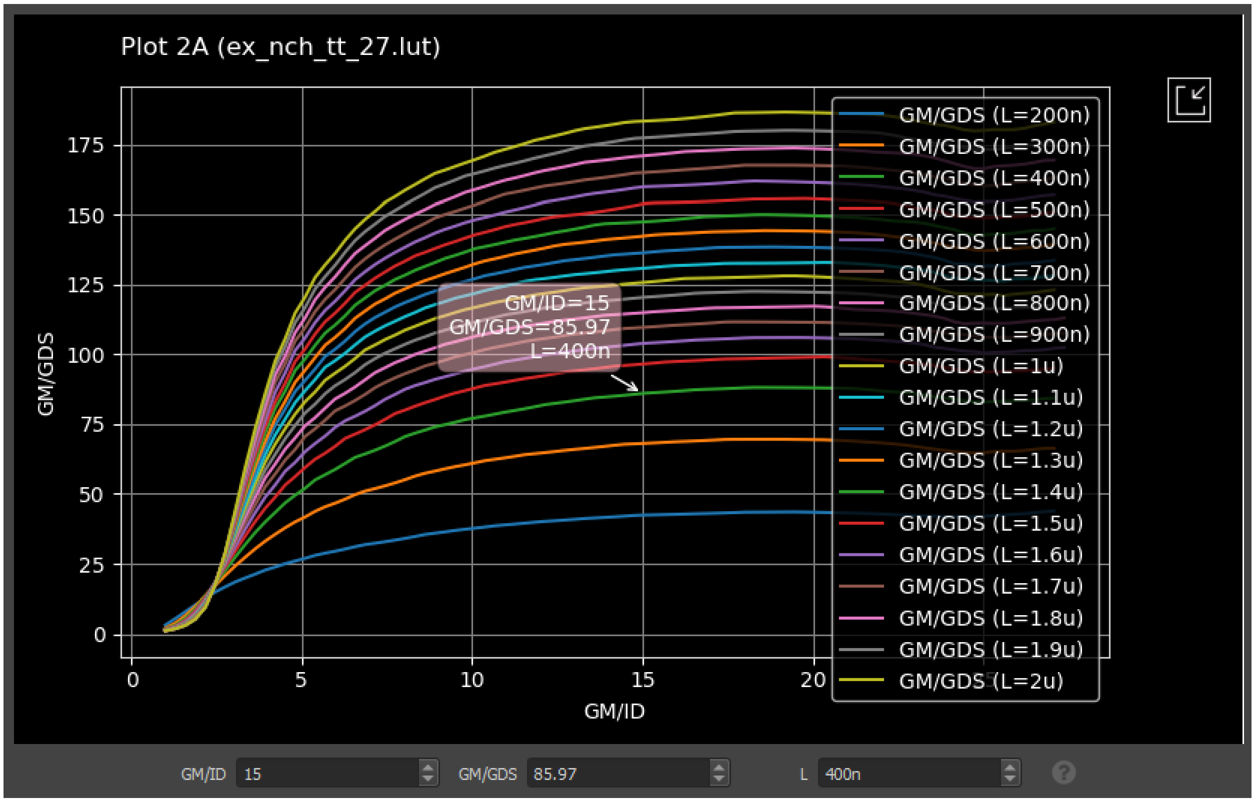
$\therefore g_m = 3{,}14 \times 10^{-4}\ S$, $I_{D_1} = 20{,}9\ \mu A$

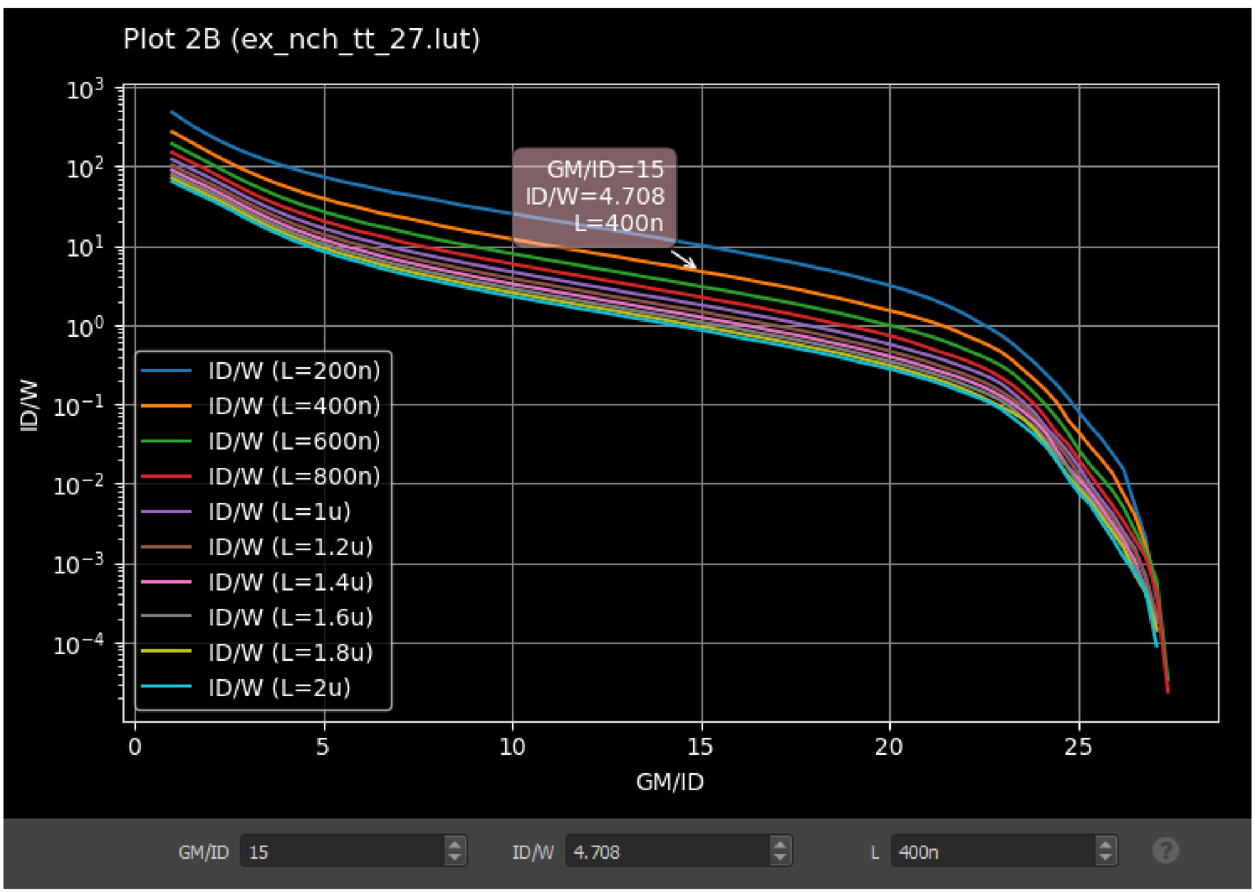
- $r_o = \frac{3}{2} \times \frac{A_V}{g_m} = 238{,}85\ k\Omega$
- $g_{ds} = \frac{1}{r_o} = 4{,}18\ \mu S$

we want $\frac{g_m}{g_{ds}} > \frac{3}{2} \times 50 > 75$

from charts:-

- $L = 0{,}4\ \mu m$ $\frac{I_D}{W} = 4{,}7$
- $W = 4{,}3\ \mu m$


Plot 2A (ex_nch_tt_27.lut)
GM/GDS
GM/ID
0
5
10
15
20
0
25
50
75
100
125
150
175
GM/ID=15
GM/GDS=85.97
L=400n
GM/GDS (L=200n)
GM/GDS (L=300n)
GM/GDS (L=400n)
GM/GDS (L=500n)
GM/GDS (L=600n)
GM/GDS (L=700n)
GM/GDS (L=800n)
GM/GDS (L=900n)
GM/GDS (L=1u)
GM/GDS (L=1.1u)
GM/GDS (L=1.2u)
GM/GDS (L=1.3u)
GM/GDS (L=1.4u)
GM/GDS (L=1.5u)
GM/GDS (L=1.6u)
GM/GDS (L=1.7u)
GM/GDS (L=1.8u)
GM/GDS (L=1.9u)
GM/GDS (L=2u)
GM/ID 15
GM/GDS 85.97
L 400n


Plot 2B (ex_nch_tt_27.lut)
ID/W
GM/ID
0
5
10
15
20
25
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
GM/ID=15
ID/W=4.708
L=400n
ID/W (L=200n)
ID/W (L=400n)
ID/W (L=600n)
ID/W (L=800n)
ID/W (L=1u)
ID/W (L=1.2u)
ID/W (L=1.4u)
ID/W (L=1.6u)
ID/W (L=1.8u)
ID/W (L=2u)
GM/ID 15
ID/W 4.708
L 400n

Load design :

٢٤ رجب ١٤٤٥ هـ

StеP2 (current Mirror Load)

$Id_2 = Id_1$, $\frac{gm}{ID} = 10$

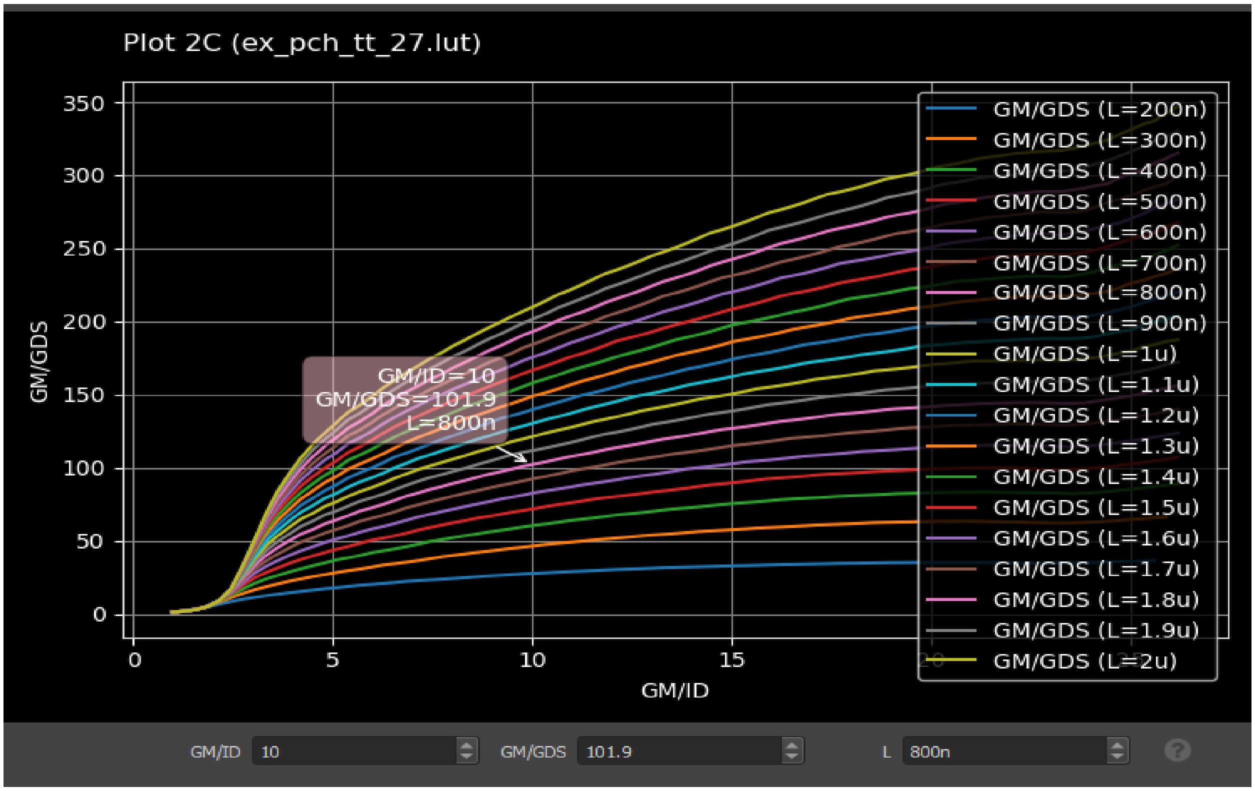
$\therefore gm = 2{,}09 \times 10^{-4}$ S

$gds_2 = \frac{1}{2} gds_1 = 2{,}09\ \mu S$

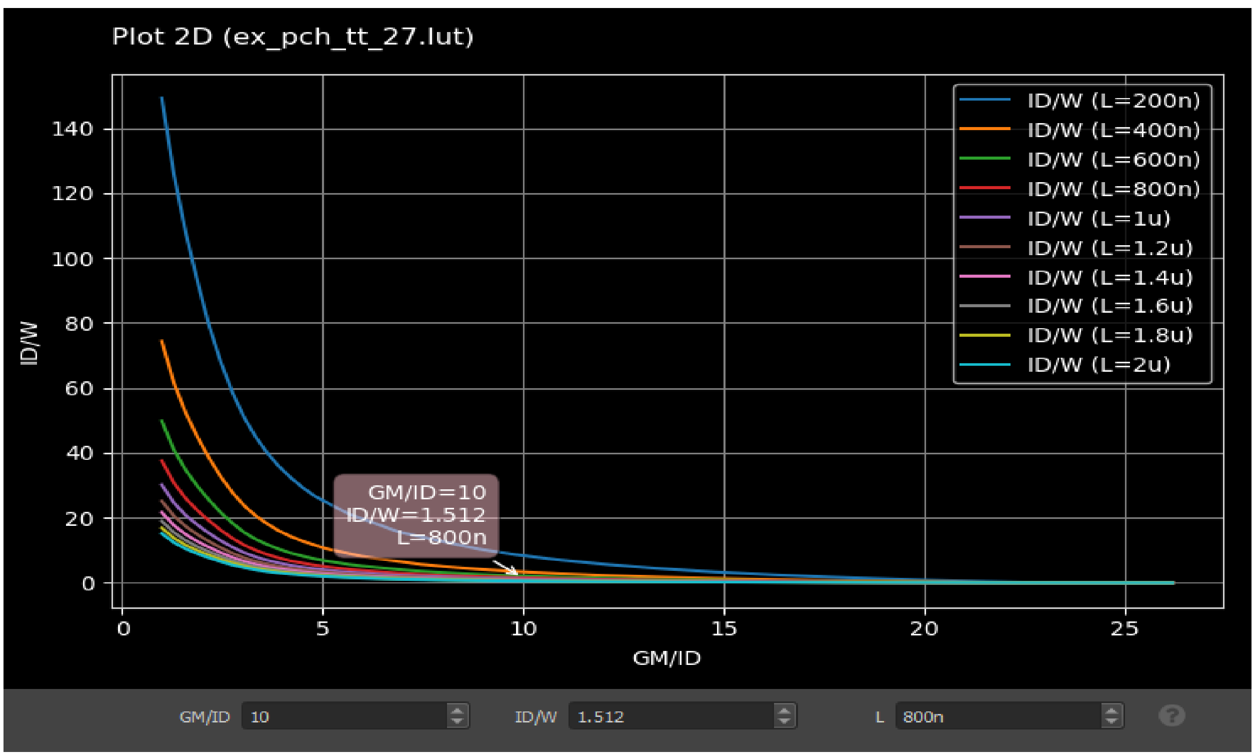
$\therefore \frac{gm}{gds} = 100$

from charts

- $L = 0{,}8\ \mu m$, $\frac{ID}{W} = 1{,}6$
- $W = 13\ \mu m$



Plot 2C (ex_pch_tt_27.lut)
GM/GDS
GM/ID
GM/ID=10
GM/GDS=101.9
L=800n
GM/GDS (L=200n)
GM/GDS (L=300n)
GM/GDS (L=400n)
GM/GDS (L=500n)
GM/GDS (L=600n)
GM/GDS (L=700n)
GM/GDS (L=800n)
GM/GDS (L=900n)
GM/GDS (L=1u)
GM/GDS (L=1.1u)
GM/GDS (L=1.2u)
GM/GDS (L=1.3u)
GM/GDS (L=1.4u)
GM/GDS (L=1.5u)
GM/GDS (L=1.6u)
GM/GDS (L=1.7u)
GM/GDS (L=1.8u)
GM/GDS (L=1.9u)
GM/GDS (L=2u)
GM/ID 10
GM/GDS 101.9
L 800n



Plot 2D (ex_pch_tt_27.lut)
ID/W
GM/ID
GM/ID=10
ID/W=1.512
L=800n
ID/W (L=200n)
ID/W (L=400n)
ID/W (L=600n)
ID/W (L=800n)
ID/W (L=1u)
ID/W (L=1.2u)
ID/W (L=1.4u)
ID/W (L=1.6u)
ID/W (L=1.8u)
ID/W (L=2u)
GM/ID 10
ID/W 1.512
L 800n

Tail design :

17 Rajab 1445 H ... 2024 ... كانون الثاني . يناير ٢٩

١٧ رجب ١٤٤٥ هـ

Step 3

tail design

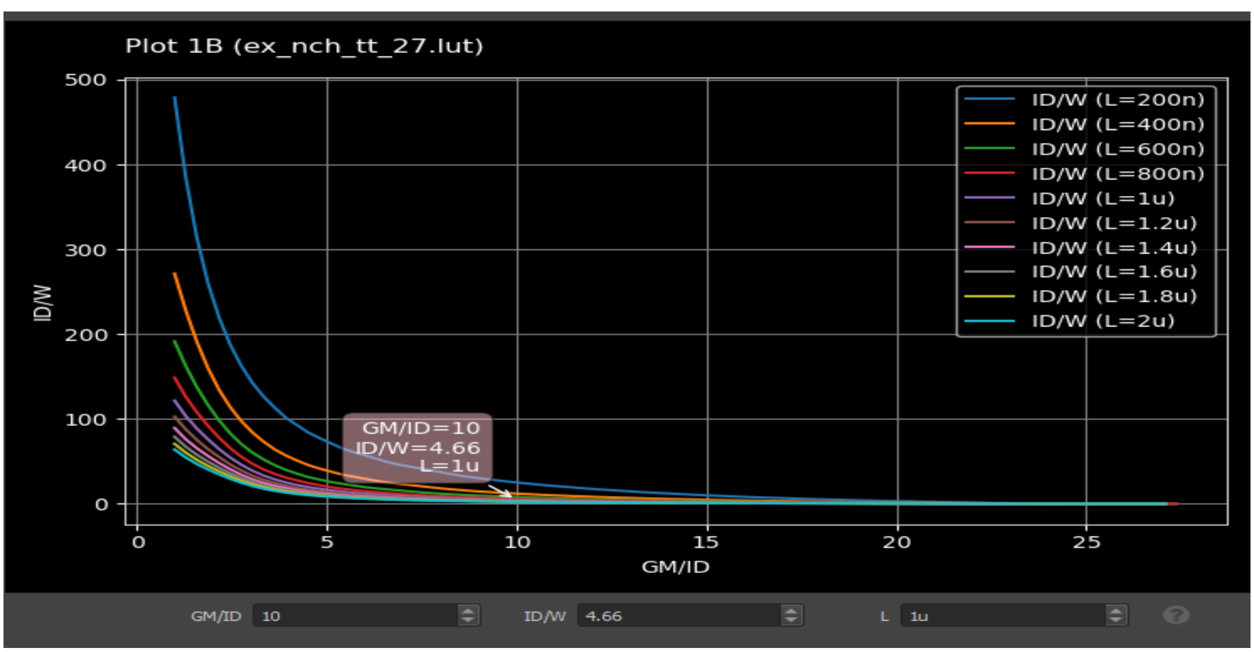
assume $\frac{g_m}{I_d} = 10$, $L = 1\,\mu m$

$I_{tail} = 2 I_d = 4,188 \times 10^{-5}$ A

from chart

$$\frac{I_d}{W} = 4,66$$

$$W = 9\,\mu m$$



gm/ID = 15 for the input pair and gm/ID = 10 for the load and the tail bias (why is this reasonable?)

high gm/Id for the input pair to achieve High gm efficiency, better gain-bandwidth, low power and relatively low gm/Id for load and tail for Smaller area, adequate gm and low channel length modulation , good for current sources

ro of the load is two times ro of the input pair (why is this reasonable?).

PMOS devices have lower mobility, so for the same current, they tend to have wider W, and a longer L . They also tend to have lower λ, so ro is higher.

L= 1um for the tail bias (why is this reasonable?).

High L choice Improves ro and current source quality, helps robustness and matching

<u>DesignOTA.m</u>

```
designOTA.m
function OTA = designOTA(specs)
% OTA Synthesis Function
% Inputs: specs.GBW, specs.CL, specs.AVDC
% Output: OTA structure with sizing and bias info

% Supply voltage
VDD = 1.8;

% Load lookup tables
load 180nch.mat;
load 180pch.mat;

% === Input Pair M1 ===
OTA.M1.gm = specs.GBW * specs.CL * 2 * pi;

% Estimate output resistance from DC gain
DC_Gain_mag = 10^(specs.AVDC / 20); % Convert from dB to magnitude
Rout = DC_Gain_mag / OTA.M1.gm;      % Total output resistance of OTA

% Assume ro(load) = 5 * ro(input), so:
% Rout = (ro_M1 * ro_M3) / (ro_M1 + ro_M3) ≈ ro_M1 * ro_M3 / ro_M3 = ro_M1 / 6
% => ro_M1 = 6 * Rout / 5
OTA.M1.ro = (3 / 2) * Rout;

OTA.M1.gds = 1 / OTA.M1.ro;
OTA.M1.VDS = VDD / 3; % Assume 1/3rd VDD
OTA.M1.gm_gds = OTA.M1.gm / OTA.M1.gds;
OTA.M1.gm_ID = 15; % Assumed gm/ID

% Get drain current from gm and gm/ID
OTA.M1.ID = OTA.M1.gm / OTA.M1.gm_ID;
```

```
% Search for the minimum L that gives gm/gds >= target
L_vector = nch.L;
gm_gds_vector = look_up(nch, 'GM_GDS', 'GM_ID', OTA.M1.gm_ID, ...
                        'VDS', OTA.M1.VDS, 'L', L_vector);
OTA.M1.L = min(L_vector(gm_gds_vector >= OTA.M1.gm_gds));

% Get ID/W for final W sizing
OTA.M1.ID_W = look_up(nch, 'ID_W', 'GM_ID', OTA.M1.gm_ID, ...
                      'VDS', OTA.M1.VDS, 'L', OTA.M1.L);
OTA.M1.W = OTA.M1.ID / OTA.M1.ID_W;

% === CM Load M3 ===
OTA.M3.ID = OTA.M1.ID;
OTA.M3.VDS = VDD / 3;
OTA.M3.gm_ID = 10; % Assumption
OTA.M3.gm = OTA.M3.gm_ID * OTA.M3.ID;

% Use ro = 2 * ro_M1
OTA.M3.ro = 2 * OTA.M1.ro;
OTA.M3.gds = 1 / OTA.M3.ro;
OTA.M3.gm_gds = OTA.M3.gm / OTA.M3.gds;

gm_gds_vector = look_up(pch, 'GM_GDS', 'GM_ID', OTA.M3.gm_ID, ...
                        'VDS', OTA.M3.VDS, 'L', L_vector);
OTA.M3.L = min(L_vector(gm_gds_vector > OTA.M3.gm_gds));

% Final sizing of M3
OTA.M3.ID_W = look_up(pch, 'ID_W', 'GM_ID', OTA.M3.gm_ID, ...
                      'VDS', OTA.M3.VDS, 'L', OTA.M3.L);
OTA.M3.W = OTA.M3.ID / OTA.M3.ID_W;
```

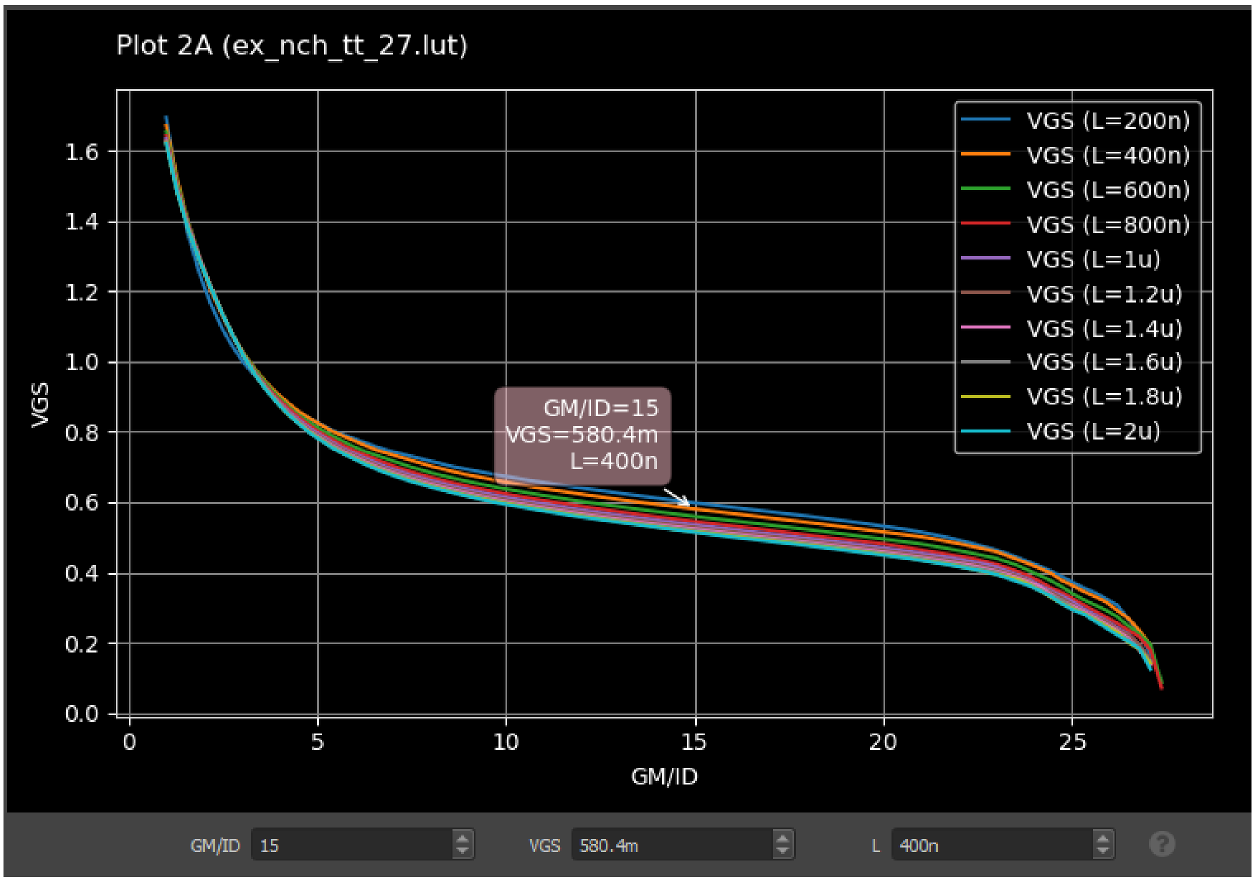
```
% === Tail Transistor M5 ===
OTA.M5.L = 1; % Assumption
OTA.M5.ID = 2 * OTA.M1.ID; % Sinks current from both M1 and M2
OTA.M5.VDS = VDD / 3;
OTA.M5.gm_ID = 10;

OTA.M5.ID_W = look_up(nch, 'ID_W', 'GM_ID', OTA.M5.gm_ID, ...
                      'VDS', OTA.M5.VDS, 'L', OTA.M5.L);
OTA.M5.W = OTA.M5.ID / OTA.M5.ID_W;

% === Common-mode Input Bias ===
% Get VGS from gm/ID
%OTA.M1.VGS = look_up(nch, 'VGS', 'GM_ID', OTA.M1.gm_ID, ...
 %                    'VDS', OTA.M1.VDS, 'L', OTA.M1.L);

vgs_vec = nch.VGS;
gm_id_vec = look_up(nch, 'GM_ID', 'VGS', vgs_vec, ...
                    'VDS', OTA.M1.VDS, 'L',OTA.M1.L);
[~, idx] = min(abs(gm_id_vec -OTA.M1.gm_ID));
M1.VGS = vgs_vec(idx);

OTA.M1.VG = M1.VGS + OTA.M5.VDS; % DC common-mode input voltage

end
```

DesignOTATest.m

```
designOTA_test.m
% === SPECS ===
AVDC = 34;             % DC gain in dB
GBW = 100e6;           % Gain-bandwidth product in Hz
CL = 500e-15;          % Load capacitance in Farads

% Create specs structure
specs = struct('AVDC', AVDC, ...
               'CL', CL, ...
               'GBW', GBW);

% Call the OTA synthesis function
OTA = designOTA(specs);

% === Print the results ===
fprintf('**** OTA Design ****\n\n');

fprintf('Input Differential Pair (M1):\n');
fprintf('    L = %.2f um\n', OTA.M1.L);
fprintf('    W = %.2f um\n', OTA.M1.W);
fprintf('    Bias Current = %.2f uA\n', OTA.M1.ID * 1e6);
fprintf('    ViCM = %.4f V\n\n', OTA.M1.VG);

fprintf('Current Mirror Load (M3):\n');
fprintf('    L = %.2f um\n', OTA.M3.L);
fprintf('    W = %.2f um\n', OTA.M3.W);
fprintf('    Bias Current = %.2f uA\n', OTA.M3.ID * 1e6);


fprintf('Tail Current Source (M5):\n');
fprintf('    L = %.2f um\n', OTA.M5.L);
fprintf('    W = %.2f um\n', OTA.M5.W);
fprintf('    Tail Bias Current = %.2f uA\n', OTA.M5.ID * 1e6);
```

Matlab results :

```
**** OTA Design ****

Input Differential Pair (M1):
    L = 0.34 um
    W = 3.73 um
    Bias Current = 20.94 uA
    ViCM = 1.1750 V

Current Mirror Load (M3):
    L = 0.70 um
    W = 12.09 um
    Bias Current = 20.94 uA
Tail Current Source (M5):
    L = 1.00 um
    W = 9.06 um
    Tail Bias Current = 41.89 uA
>>
```

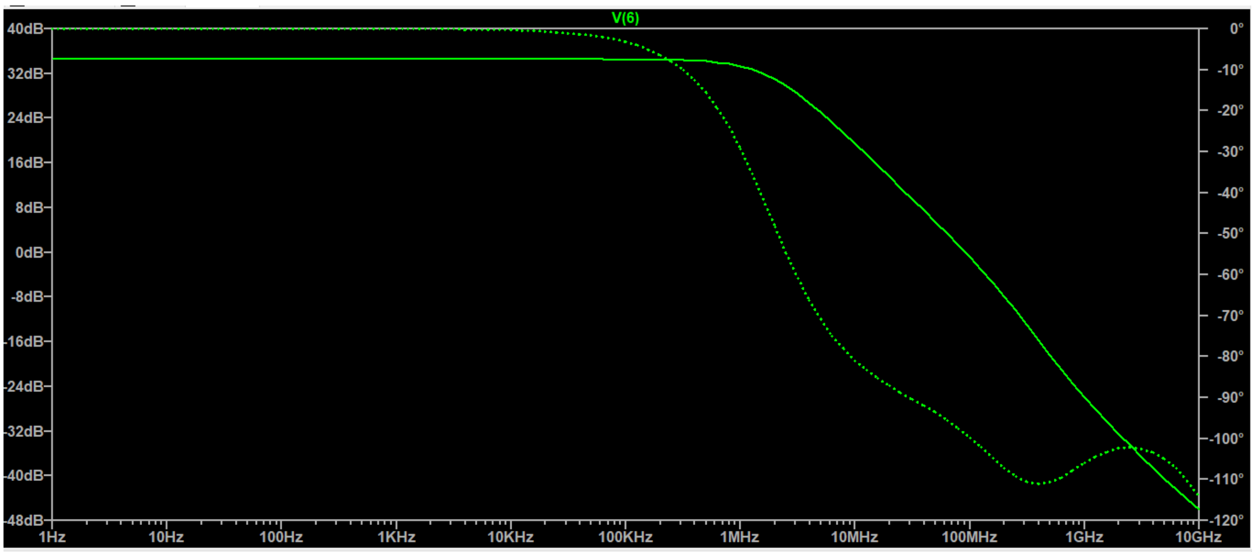


ADT	MATLAB
L1= 0.4 um	L1= 0.34 um
W1= 4.3 um	W1= 3.73 um
L2 = 0.8 um	L2 = 0.7 um
W2 = 13 um	W2 = 12.09 um
W3 = 9 um	W3 = 9.06 um
I bias = 41.8 uA	I bias = 41.8 uA
VGS = 0.58 V	VGS =0.58 V

7-

Netlist

```
** Circuit Description **

* power supply
VDD 7 0 DC 1.8
* input

* Add lines here to add the input (voltage)sources
vin1 3 0 DC 1.2 AC 0.5
vin2 4 0 DC 1.2 AC -0.5
* circuit
* 5T OTA
M1 6 4 2 0 nch L=0.4u W=4.2u
M2 5 3 2 0 nch L=0.4u W=4.2u
M3 6 5 7 7 pch L=0.7u W=12u
M4 5 5 7 7 pch L=0.7u W=12u
M5 2 1 0 0 nch L=1u W=9u
CL 6 0 500f
* Current Mirror
M6 1 1 0 0 nch L=1u W=9u
Iref 7 1 41.8u


** Analysis Requests **
.op
.ac dec 10 1 10e9

** Outputs Requests **
*.PROBE
.MEAS AC dc_gain FIND mag(V(6)) AT=1
.MEAS AC gbw WHEN mag(V(6))=1

.END
```




```
dc_gain: mag(V(6))=(34.5071740082dB,0°) at 1
gbw: mag(V(6))=1 AT 92099007.6439
```

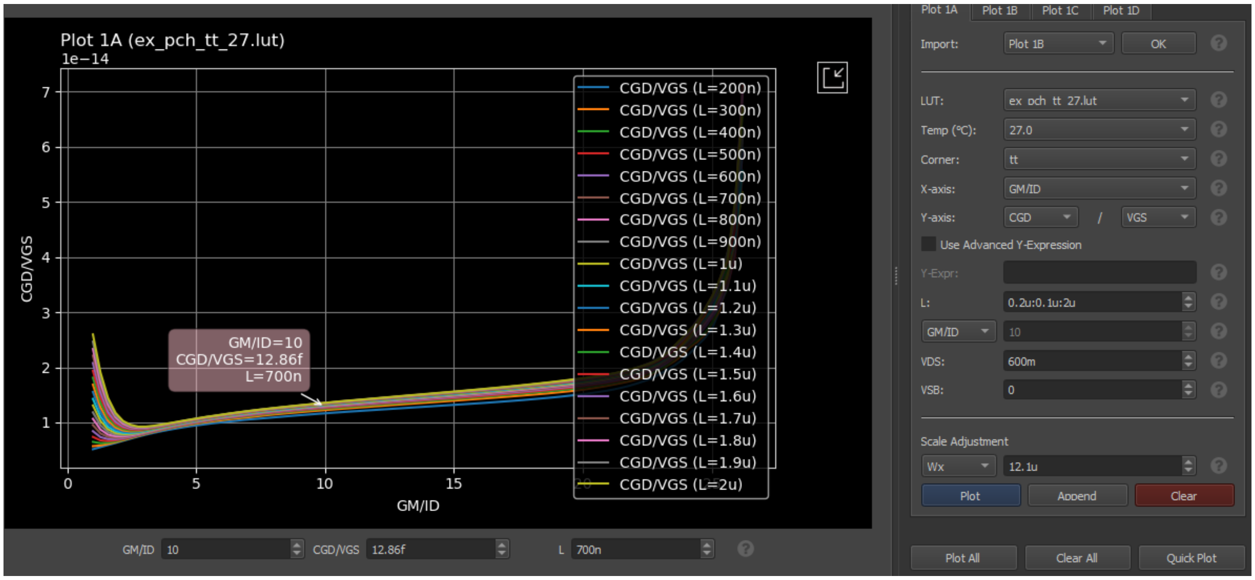
Specs	LTSpice
DC Gain = 34dB	DC Gain = 34.5dB
GBW = 1MHz	GBW = 9.2MHz

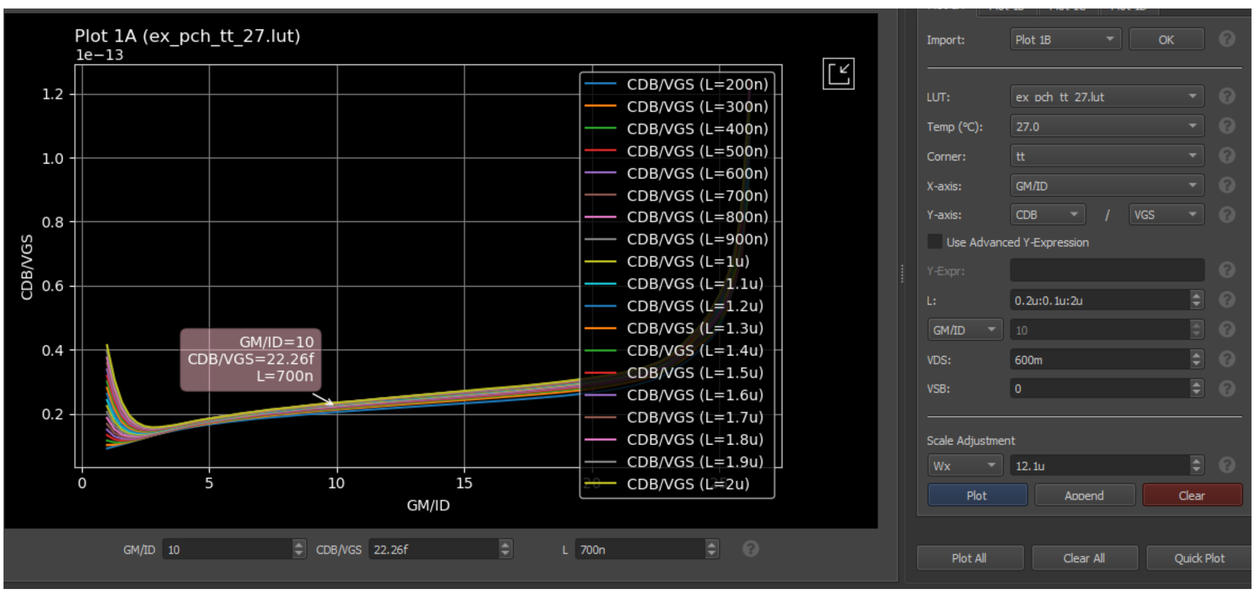
The simulator output of our design is nearly acheiving specs but not so accurate as we are ignoring the effect of VDS , self loading and body effect that can make the design more realistic .

Part 2:

To add self loading effect :

CDD = CGD + CDB





To get CDB and CGD we assume from part 1 that for the load PMOS

VGS= 0.58 V , L = 0.7um , W =12.1 um , VDS=0.6 V , GM/ID =10

We get CGD= 7.5 Ff , CDB = 12.9 fF

So CDD = = 7.5 + 12.9 = 20.4 fF

We add CDD to CL and do the analysis again.

<u>Input pair design:</u>

Step 1

$CL_{total} = Cl + CDD$

$gm = 2\pi * GBW * CL_{total} = 3{,}26 \times 10^{-4}\ S$

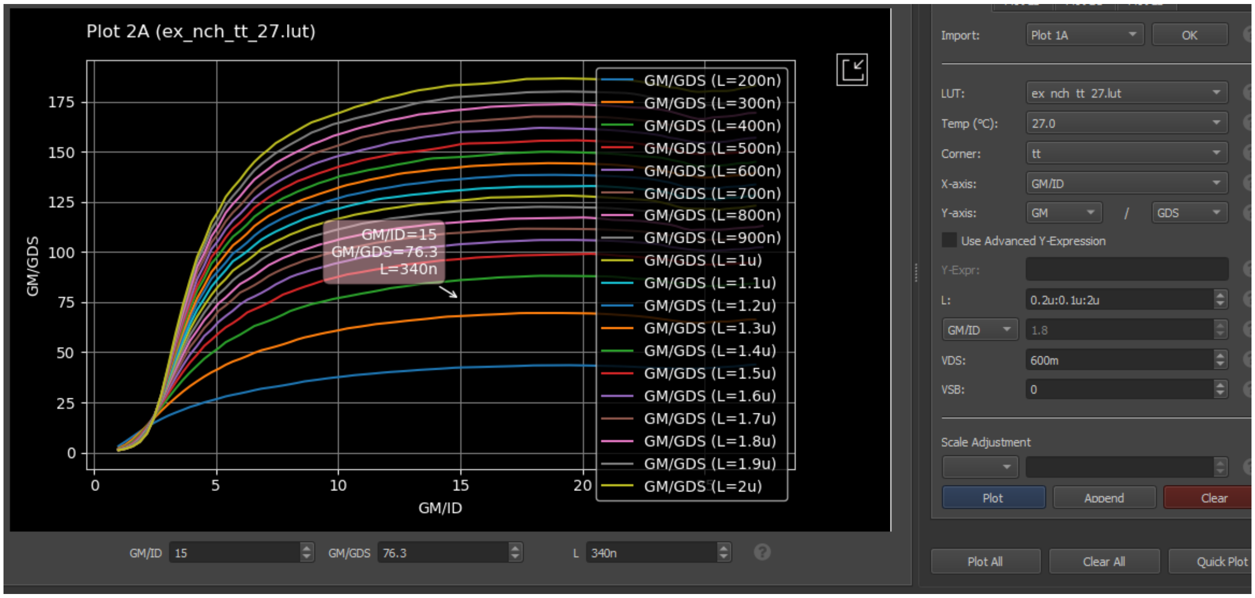
$ID = 21{,}7\ \mu A$

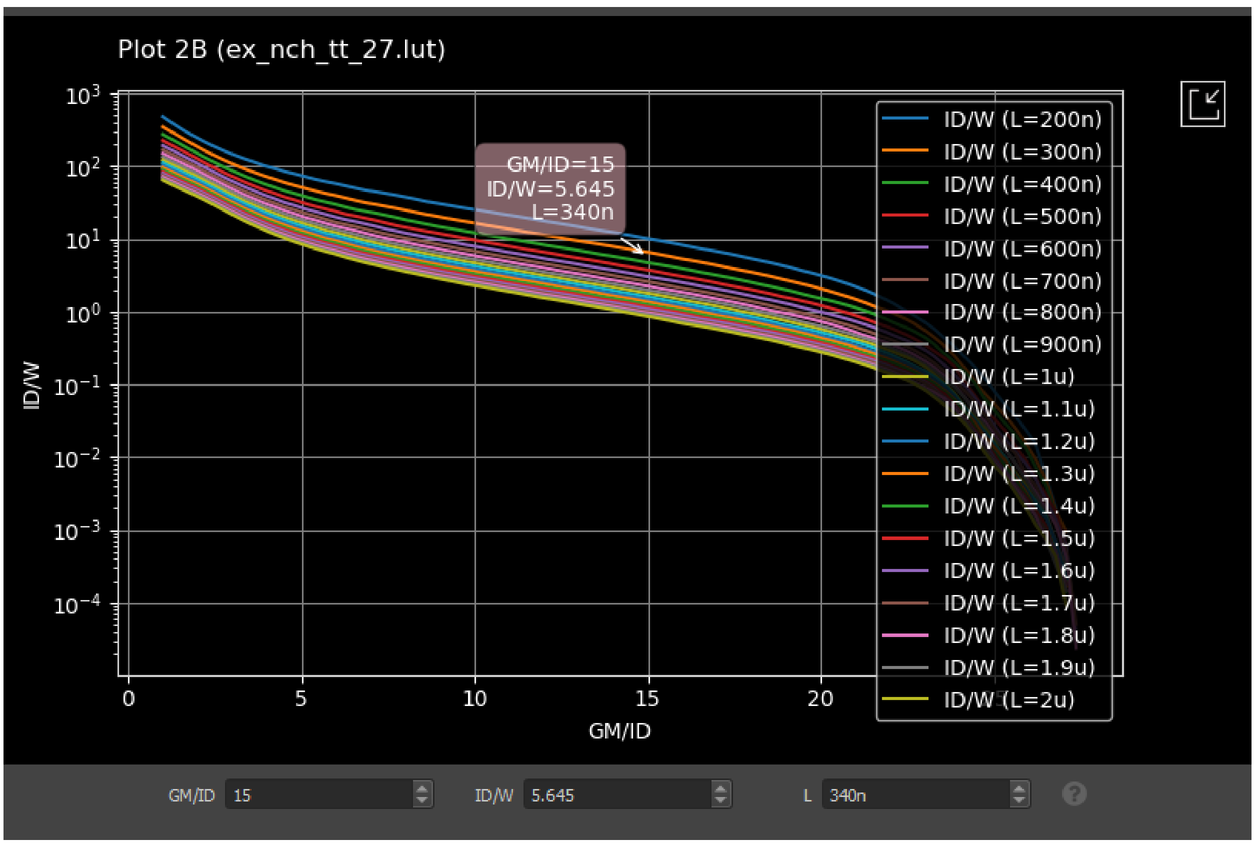
$gds = \frac{1}{r_o} = \frac{2}{3} \times \frac{gm}{AV} = 4{,}346\ \mu S$

$\frac{gm}{gds} = 75$

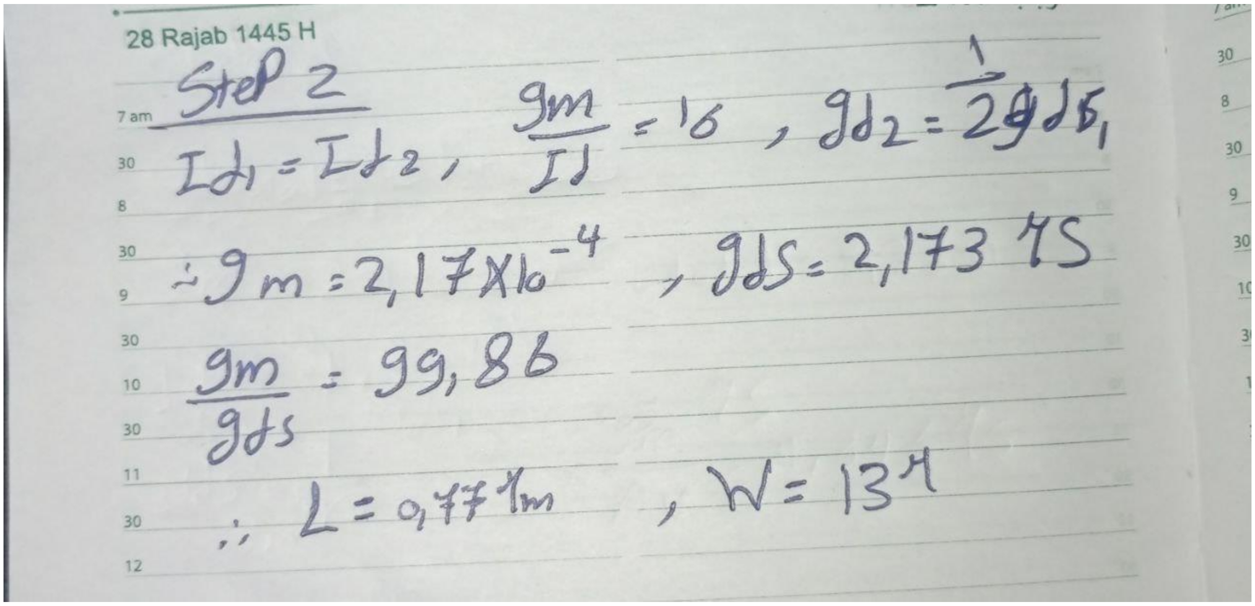
$\therefore$ from charts $L = 0{,}34\ \mu m$

$\frac{ID}{W} = 5{,}645 \quad \therefore W = 3{,}84\ \mu m$


Plot 2A (ex_nch_tt_27.lut)
GM/GDS
GM/ID
GM/ID=15
GM/GDS=76.3
L=340n
GM/GDS (L=200n)
GM/GDS (L=300n)
GM/GDS (L=400n)
GM/GDS (L=500n)
GM/GDS (L=600n)
GM/GDS (L=700n)
GM/GDS (L=800n)
GM/GDS (L=900n)
GM/GDS (L=1u)
GM/GDS (L=1.1u)
GM/GDS (L=1.2u)
GM/GDS (L=1.3u)
GM/GDS (L=1.4u)
GM/GDS (L=1.5u)
GM/GDS (L=1.6u)
GM/GDS (L=1.7u)
GM/GDS (L=1.8u)
GM/GDS (L=1.9u)
GM/GDS (L=2u)
Import: Plot 1A OK
LUT: ex nch tt 27.lut
Temp (°C): 27.0
Corner: tt
X-axis: GM/ID
Y-axis: GM / GDS
Use Advanced Y-Expression
Y-Expr:
L: 0.2u:0.1u:2u
GM/ID 1.8
VDS: 600m
VSB: 0
Scale Adjustment
Plot
Append
Clear
Plot All
Clear All
Quick Plot
GM/ID 15
GM/GDS 76.3
L 340n


Plot 2B (ex_nch_tt_27.lut)
ID/W
GM/ID
GM/ID=15
ID/W=5.645
L=340n
ID/W (L=200n)
ID/W (L=300n)
ID/W (L=400n)
ID/W (L=500n)
ID/W (L=600n)
ID/W (L=700n)
ID/W (L=800n)
ID/W (L=900n)
ID/W (L=1u)
ID/W (L=1.1u)
ID/W (L=1.2u)
ID/W (L=1.3u)
ID/W (L=1.4u)
ID/W (L=1.5u)
ID/W (L=1.6u)
ID/W (L=1.7u)
ID/W (L=1.8u)
ID/W (L=1.9u)
ID/W (L=2u)
GM/ID 15
ID/W 5.645
L 340n

<u>Load design:</u>



28 Rajab 1445 H

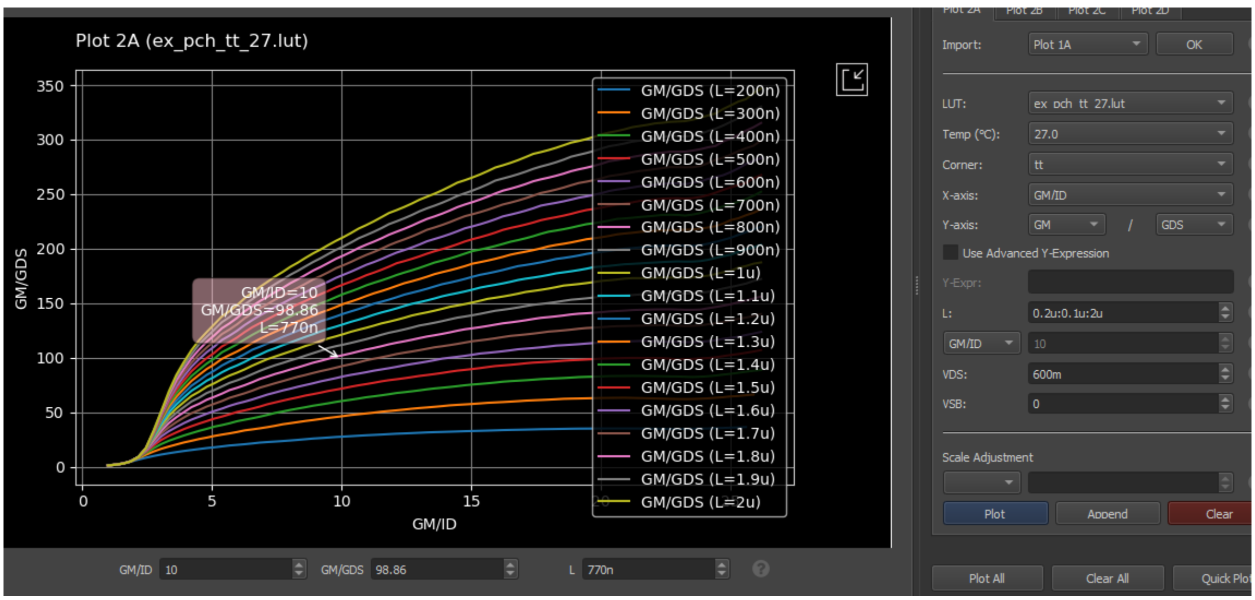
Step 2

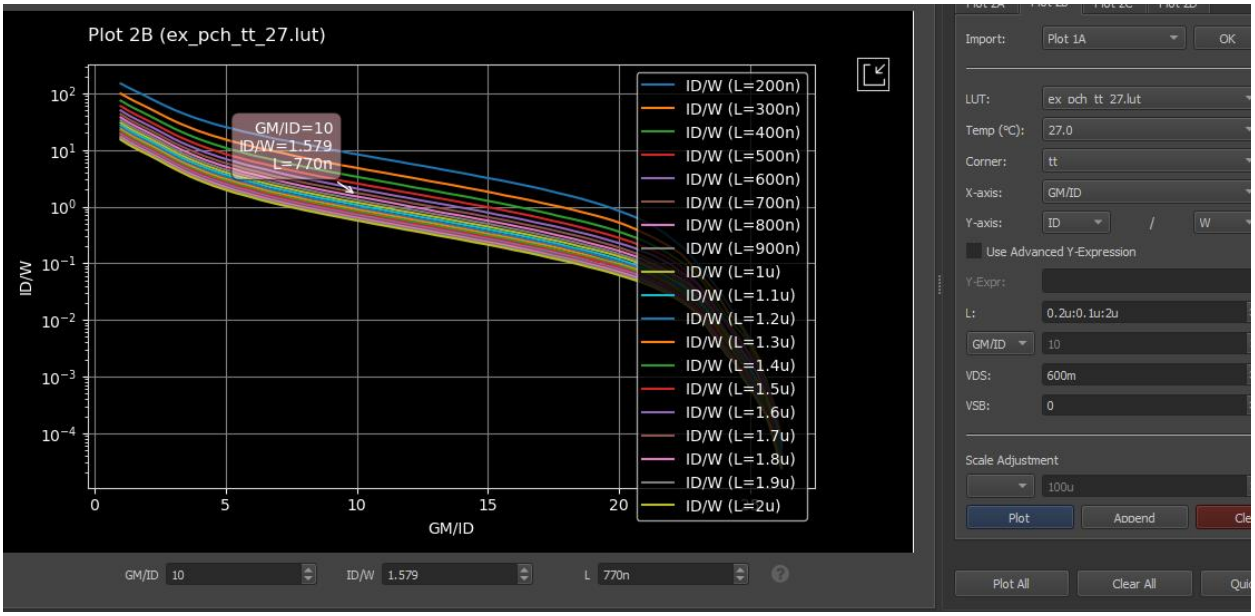
$I_{d1} = I_{d2}$, $\frac{g_m}{I_d} = 10$, $g_{d2} = \frac{1}{2} g_{ds1}$

$\therefore g_m = 2{,}17 \times 10^{-4}$, $g_{ds} = 2{,}173\ \mu S$

$\frac{g_m}{g_{ds}} = 99{,}86$

$\therefore L = 0{,}77\ \mu m$, $W = 134$





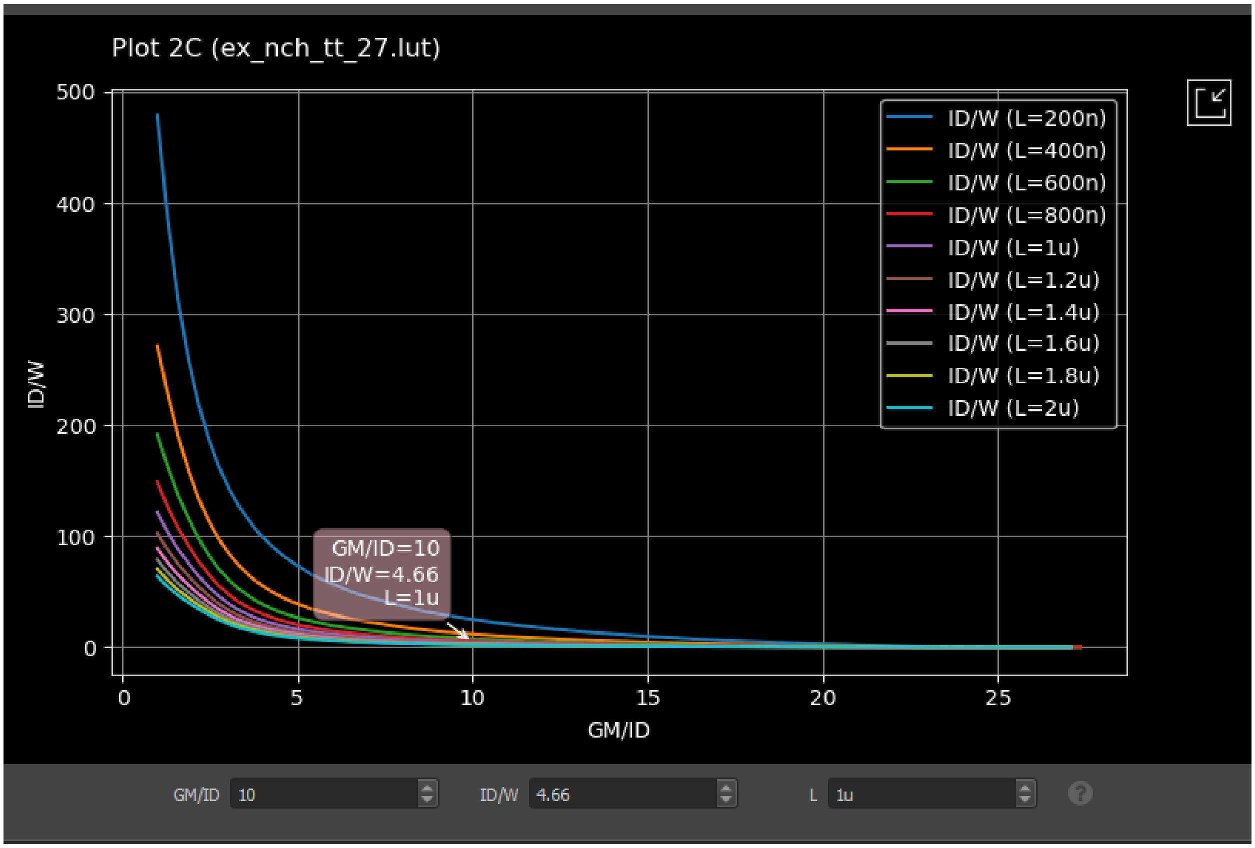
<u>Tail current mirror design:</u>

Step 3

$I_{d3} = 2 I_{d1} = 43{,}5\ \mu A$

$g_m / I_d = 10$, $L = 1\mu$

$W = 9{,}3\ \mu m$



ADT part 1	ADT part 2
L1= 0.4 um	L1= 0.34 um
W1= 4.3 um	W1= 3.89 um
L2 = 0.8 um	L2 = 0.77 um
W2 = 13 um	W2 = 13 um
W3 = 9 um	W3 = 9.3 um
I bias = 41.8 uA	I bias = 43.5 uA
VGS = 0.58 V	VGS =0.58 V

Matlab function:

```
Cdd_M3 = look_up(pch, 'CDD','VGS', 0.58,'VDS', 0.6,'L', 0.8);
Cdd_M1 = look_up(nch, 'CDD','VGS', 0.58,'VDS', 0.6,'L', 0.4);
Cdd_total = Cdd_M3+Cdd_M1;  % One PMOS contributes to output node
CL_total = specs.CL + Cdd_total;
OTA.CL_total = CL_total;
% === Input Pair M1 ===
OTA.M1.gm = specs.GBW * CL_total * 2 * pi;

DC_Gain_mag = 10^(specs.AVDC / 20);
Rout = DC_Gain_mag / OTA.M1.gm;

OTA.M1.ro = (3 / 2) * Rout;
OTA.M1.gds = 1 / OTA.M1.ro;
OTA.M1.VDS = VDD / 3;
OTA.M1.gm_gds = OTA.M1.gm / OTA.M1.gds;
OTA.M1.gm_ID = 15;

OTA.M1.ID = OTA.M1.gm / OTA.M1.gm_ID;
```

```
DC_Gain_mag = 10^(specs.AVDC / 20);
Rout = DC_Gain_mag / OTA.M1.gm;

OTA.M1.ro = (3 / 2) * Rout;
OTA.M1.gds = 1 / OTA.M1.ro;
OTA.M1.VDS = VDD / 3;
OTA.M1.gm_gds = OTA.M1.gm / OTA.M1.gds;
OTA.M1.gm_ID = 15;

OTA.M1.ID = OTA.M1.gm / OTA.M1.gm_ID;

% Find minimum L meeting gm/gds
gm_gds_vector = look_up(nch, 'GM_GDS', 'GM_ID', OTA.M1.gm_ID, ...
                        'VDS', OTA.M1.VDS, 'L', L_vector);
OTA.M1.L = min(L_vector(gm_gds_vector >= OTA.M1.gm_gds));
OTA.M1.ID_W = look_up(nch, 'ID_W', 'GM_ID', OTA.M1.gm_ID, ...
                      'VDS', OTA.M1.VDS, 'L', OTA.M1.L);
OTA.M1.W = OTA.M1.ID / OTA.M1.ID_W;

% === M3 Load (PMOS diode-connected) ===
OTA.M3.ID = OTA.M1.ID;
OTA.M3.VDS = VDS_M3;
OTA.M3.gm_ID = gm_ID_M3;
OTA.M3.gm = OTA.M3.gm_ID * OTA.M3.ID;
OTA.M3.ro = 2 * OTA.M1.ro;
OTA.M3.gds = 1 / OTA.M3.ro;
OTA.M3.gm_gds = OTA.M3.gm / OTA.M3.gds;
```

```matlab
gm_gds_vector = look_up(pch, 'GM_GDS', 'GM_ID', OTA.M3.gm_ID, ...
                        'VDS', OTA.M3.VDS, 'L', L_vector);
OTA.M3.L = min(L_vector(gm_gds_vector > OTA.M3.gm_gds));
OTA.M3.ID_W = look_up(pch, 'ID_W', 'GM_ID', OTA.M3.gm_ID, ...
                      'VDS', OTA.M3.VDS, 'L', OTA.M3.L);
OTA.M3.W = OTA.M3.ID / OTA.M3.ID_W;

% === Tail Transistor M5 ===
OTA.M5.L = 1;
OTA.M5.ID = 2 * OTA.M1.ID;
OTA.M5.VDS = VDD / 3;
OTA.M5.gm_ID = 10;
OTA.M5.ID_W = look_up(nch, 'ID_W', 'GM_ID', OTA.M5.gm_ID, ...
                      'VDS', OTA.M5.VDS, 'L', OTA.M5.L);
OTA.M5.W = OTA.M5.ID / OTA.M5.ID_W;

% === VGS and Common-mode bias ===
vgs_vec = nch.VGS;
gm_id_vec = look_up(nch, 'GM_ID', 'VGS', vgs_vec, ...
                    'VDS', OTA.M1.VDS, 'L', OTA.M1.L);
[~, idx] = min(abs(gm_id_vec - OTA.M1.gm_ID));
OTA.M1.VGS = vgs_vec(idx);
OTA.M1.VG = OTA.M1.VGS + OTA.M5.VDS;
```

results:

```
**** OTA Design ****

Input Differential Pair (M1):
    L = 0.34 um
    W = 3.88 um
    Bias Current = 21.80 uA
    ViCM = 1.1750 V

Current Mirror Load (M3):
    L = 0.70 um
    W = 12.59 um
    Bias Current = 21.80 uA
Tail Current Source (M5):
    L = 1.00 um
    W = 9.43 um
    Tail Bias Current = 43.60 uA
fx >>
```

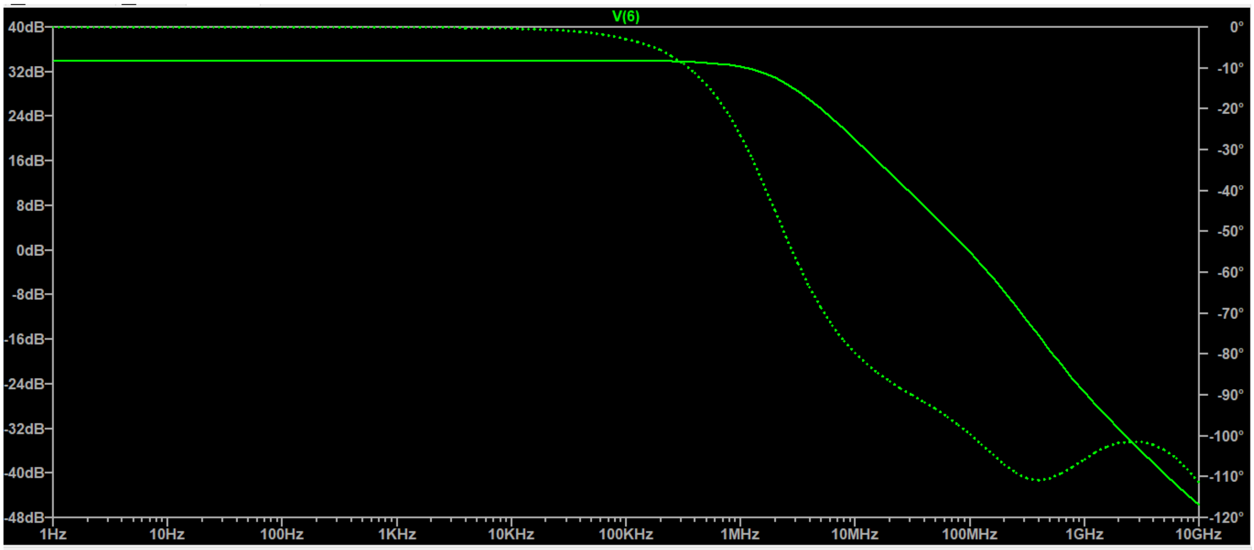
MATLAB part 2	**MATLAB part 1**
L1= 0.34 um	L1= 0.34 um
W1= 3.88 um	W1= 3.73 um

L2 = 0.7 um	L2 = 0.7 um
W2 = 12.59 um	W2 = 12.09 um
W3 = 9.43 um	W3 = 9.06 um
I bias = 43.6 uA	I bias = 41.8 uA
VGS = 0.58 V	VGS =0.58 V

ADT	**MATLAB**
L1= 0.34 um	L1= 0.34 um
W1= 3.89 um	W1= 3.88 um
L2 = 0.77 um	L2 = 0.7 um
W2 = 13 um	W2 = 12.59 um
W3 = 9.3 um	W3 = 9.43 um
I bias = 43.5 uA	I bias = 43.6 uA
VGS =0.58 V	VGS = 0.58 V

<u>LTSpice:</u>

```
* Add lines here to add the input (voltage)sources
vin1 3 0 DC 1.2 AC 0.5
vin2 4 0 DC 1.2 AC -0.5
* circuit
* 5T OTA
M1 6 4 2 0 nch L=0.34u W=3.9u
M2 5 3 2 0 nch L=0.34u W=3.9u
M3 6 5 7 7 pch L=0.77u W=13u
M4 5 5 7 7 pch L=0.77u W=13u
M5 2 1 0 0 nch L=1u W=9.44u
CL 6 0 500f
* Current Mirror
M6 1 1 0 0 nch L=1u W=9.44u
Iref 7 1 43.65u


** Analysis Requests **
.op
.ac dec 10 1 10e9
```




```
dc_gain: mag(V(6))=(34.0972019245dB,0°) at 1
gbw: mag(V(6))=1 AT 96131037.713
```

Specs	LTSpice
DC Gain = 34dB	DC Gain = 34.09dB
GBW = 1MHz	GBW = 9.6MHz

We can see that the obtained design became more accurate and near to the specs after adding effect of self loading and it could be more accurate if we added effect of body effect and VDS