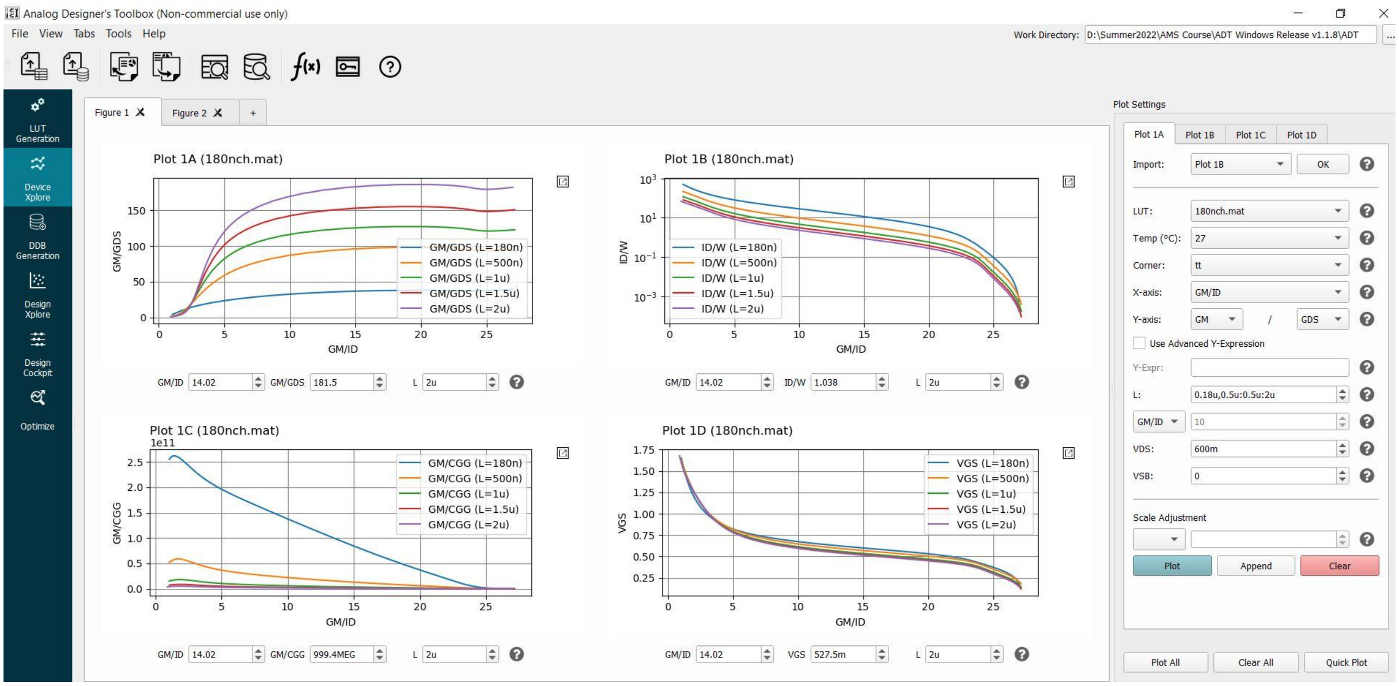
# Lab 04: Analog Design Automation

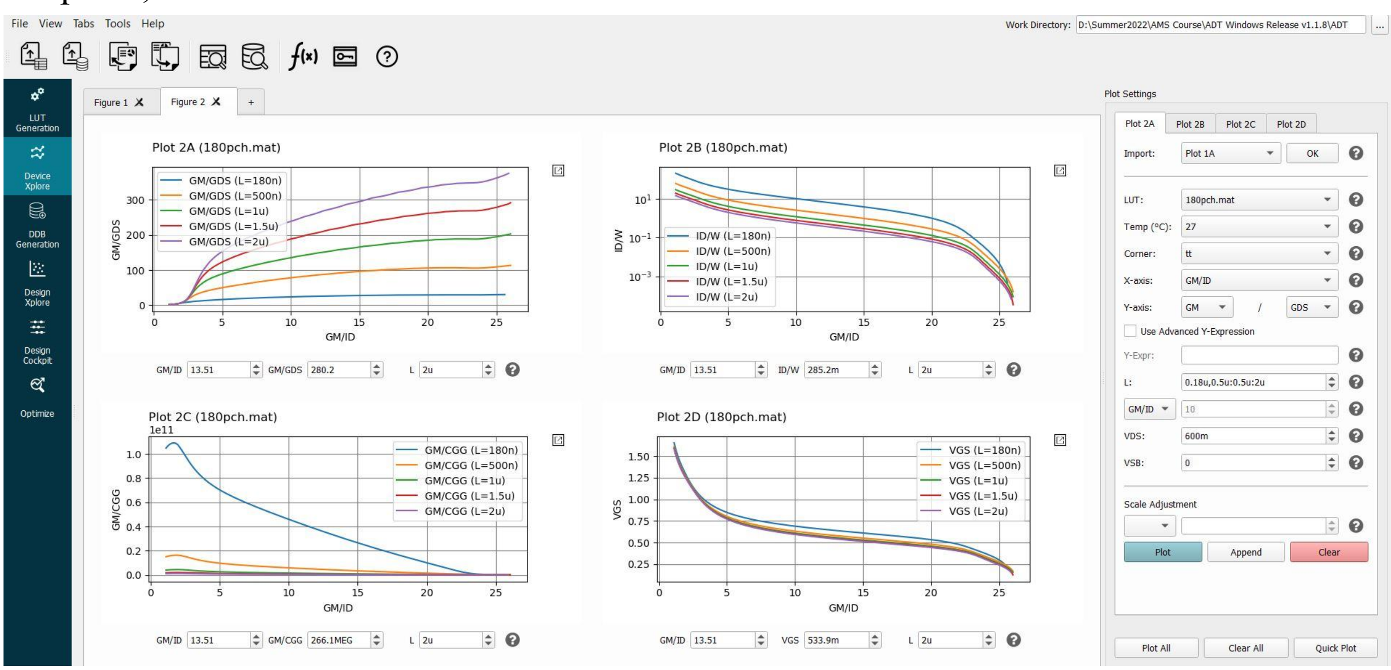
**Part 1:**

**(index 1)**

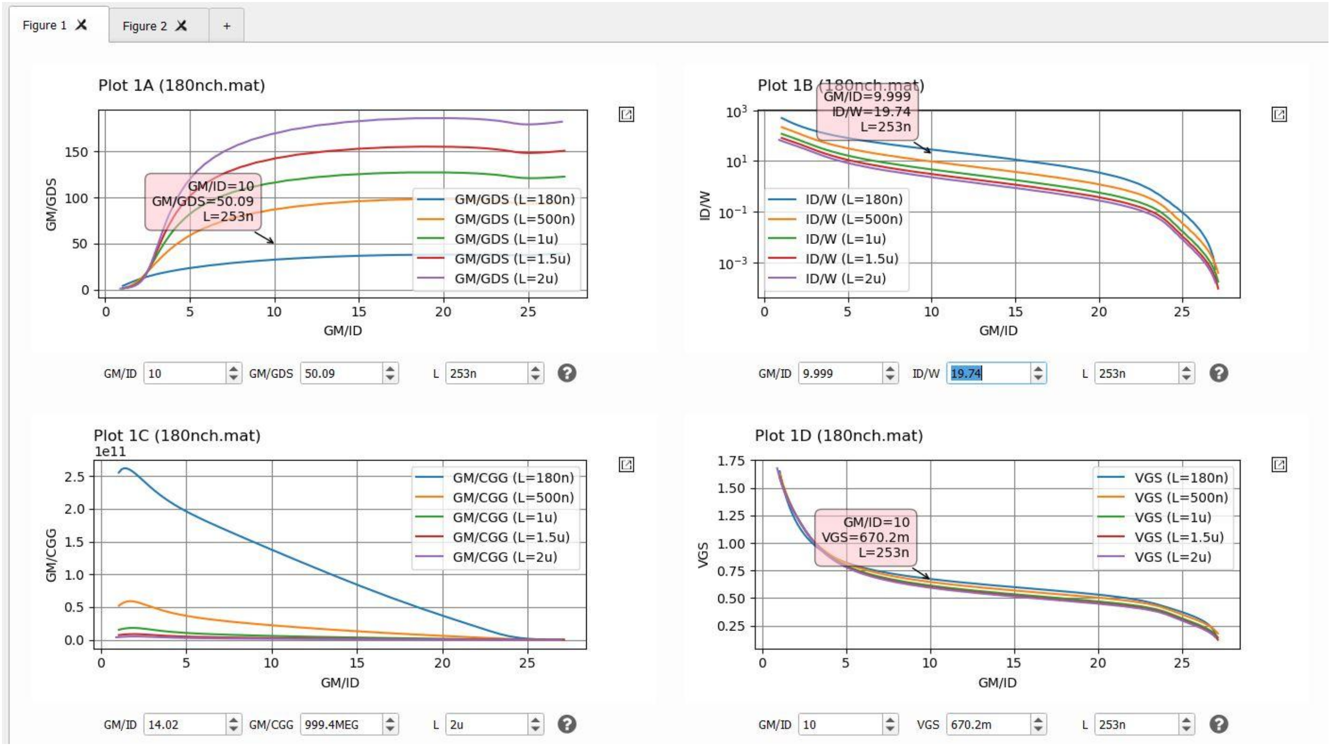
For nmos,




For pmos,




**(index 2)**




L = 253 nm

V_GS = 670.2 mV

I_D/W = 19.74 A/m

I_D = 19.74* (5u) = 98.7 uA

**(index 3)**

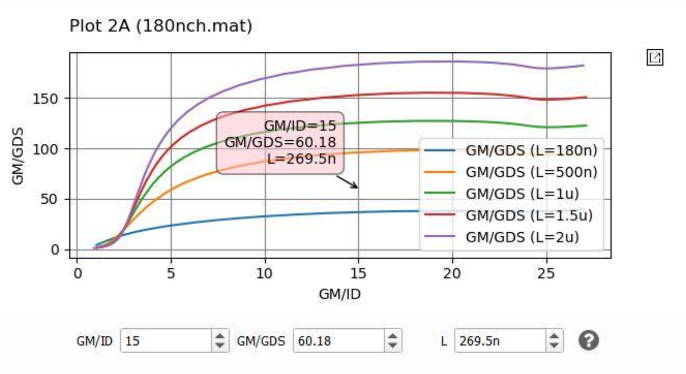
Command Window

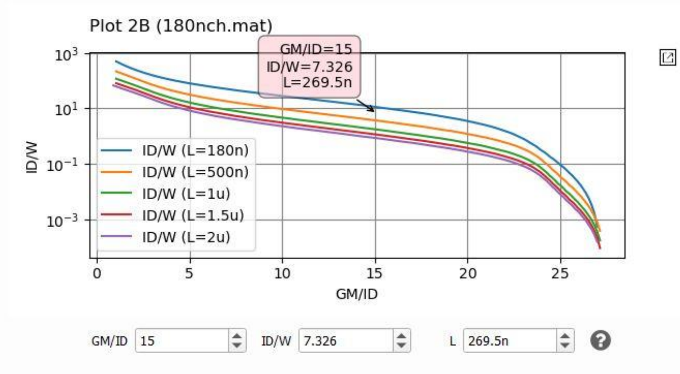
```
VGS = 0.67
ID = 9.52e-05
fx >>
```

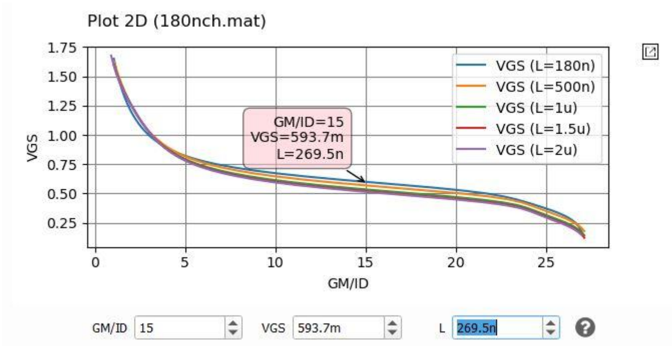
| | ADT | Matlab |
|---|---|---|
| V_GS | 670.2 mV | 670 mV |
| I_D | 98.7 uA | 95.2 uA |

**(index 4)**

For the input pair (nmos),



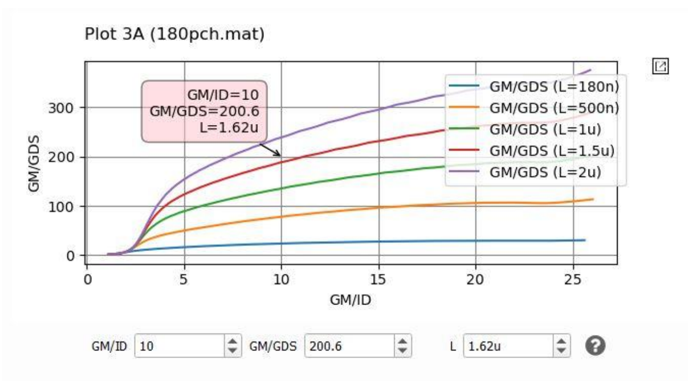



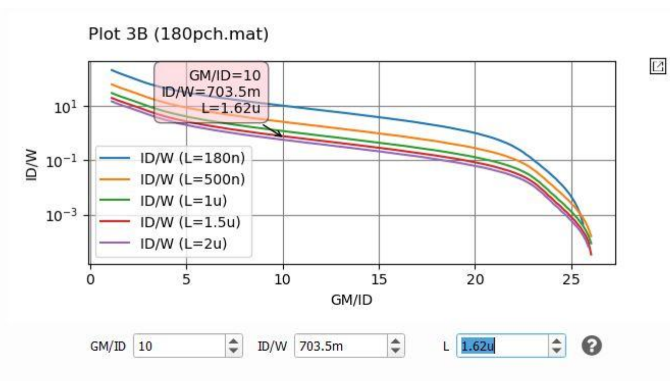




gm1,2 = 314.16 uS, ro1,2= 191.439 kOhm, (gm1,2)(ro1,2) = 60.14244

**L1,2 = 269.5 nm, W1,2 = 2.859 um**

For the current mirror load (pmos),

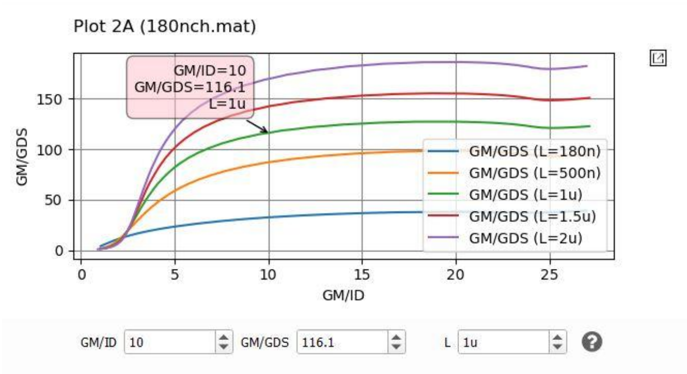


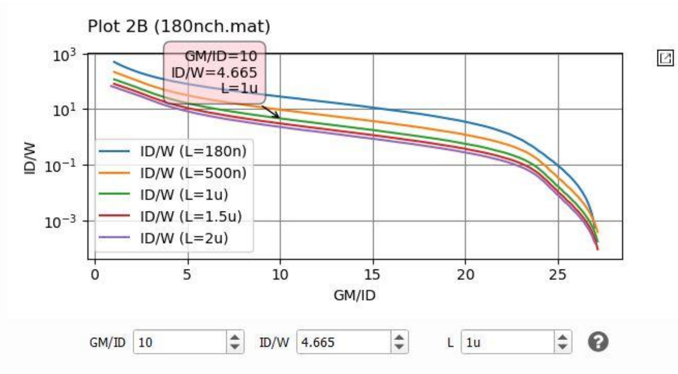




gm3,4 = 209.44 uS, ro3,4= 5*(191.439) kOhm, (gm3,4)(ro3,4) = 200.475

**L3,4 = 1.62 um, W3,4 = 29.77 um**

For the tail current source (nmos),




L5 = 1 um, ID/W = 4.665, W5 = 8.979 um

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

- The input pair is biased in the moderate or weak inversion to maximize efficiency and minimize power consumption.
- The load and tail are biased in the strong inversion to get high output resistance for good mirroring and good gain.

**ro of the load is five times ro of the input pair (why is this reasonable?)**

Because the load are biased in the strong inversion and ro increases as we go deeper into saturation. This improves the output resistance.

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

This is a long-channel device, so ro is large which results in better mirroring.

**(index 5)**

```
%OTA Synthesis Function
function OTA = designOTA(specs)
%Additional Specs
VDD = 1.8;

%load LUTs
load 180nch.mat;
load 180pch.mat;

%Input Pair
OTA.M1.gm = specs.GBW * specs.CL * 2 * pi;
% assume ro(load) = 5 * ro(input) --> ro(input) = 6/5 R_total
DC_Gain_mag = 10^(specs.AVDC / 20); % Convert from dB to mag
Rout = DC_Gain_mag / OTA.M1.gm; % Compute the equivalent output resistance of OTA (Rout)

OTA.M1.ro = (6/5)*Rout; % Complete the line to compute the ro of M1

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; % assumption

OTA.M1.ID = OTA.M1.gm/OTA.M1.gm_ID; % Complete the line to get the current of M1

% Search for the minimum L that gives gm / gds > specified value
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));%Complete the line to get the minimum L that gives gm/gds >= OTA
% Compute ID/W to get the W value
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
OTA.M3.ID = OTA.M1.ID;

OTA.M3.ro = OTA.M1.ro * 5;%Complete the line to get the ro of the CM load

OTA.M3.gds = 1 / OTA.M3.ro;
OTA.M3.VDS = VDD/3;
OTA.M3.gm_ID = 10;
OTA.M3.gm = OTA.M3.gm_ID * OTA.M3.ID;
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));
OTA.M3.ID_W = look_up(pch, 'ID_W', 'GM_ID', OTA.M3.gm_ID, 'VDS', OTA.M3.VDS, 'L', OTA.M3.L); %Complete the line to get the
OTA.M3.W = OTA.M3.ID / OTA.M3.ID_W;

% Tail bias
OTA.M5.L = 1; %assumption
OTA.M5.ID = 2 * OTA.M1.ID;
OTA.M5.VDS = VDD/3;
OTA.M5.gm_ID = 10; %assumption
% Get ID/W to compute W
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;

% get CMIN bias value
OTA.M1.VGS = look_upVGS(nch, 'GM_ID', OTA.M1.gm_ID, 'VDS', OTA.M1.VDS, 'L', OTA.M1.L); %Complete the line to get the VGS of
OTA.M1.VG = OTA.M1.VGS + OTA.M5.VDS; %Complete the line to get the DC CM input of OTA
```

**(index 6)**

```matlab
% OTA Design Script
% Write the SPECS
clear all;
clc;
AVDC = 34; % complete the line to add the gain SPEC
GBW = 100e+6; % complete the line to add the GBW SPEC
CL = 500e-15; % complete the line to add the CL SPEC
specs = struct('AVDC', AVDC,...
'CL', CL,...
'GBW', GBW);
% struct('AVDC', 50.1187,'CL', 500e-15,'GBW', 100e+6)
OTA = designOTA(specs);
% Print the solution
fprintf('**** OTA Design ****\n\n');
fprintf('Input Pair:\n');
fprintf('    L = %.2f um\n    W=%.2f um\n    ViCM=%.4f V\n\n',OTA.M1.L,OTA.M1.W,OTA.M1.VG);
fprintf('CM Load:\n');
fprintf('    L = %.2f um\n    W=%.2f um\n\n',OTA.M3.L,OTA.M3.W);
fprintf('Tail Current Source:\n');
fprintf('    L = %.2f um\n    W=%.2f um\n\n',OTA.M5.L,OTA.M5.W);
```

Command Window

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

Input Pair:
    L = 0.28 um
    W=3.01 um
    ViCM=1.1928 V

CM Load:
    L = 1.70 um
    W=31.44 um

Tail Current Source:
    L = 1.00 um
    W=9.06 um
```

Comparison:

| | ADT | Matlab |
|---|---|---|
| **Input pair** | | |
| L | 269.5 nm | 0.28 um |
| W | 2.859 um | 3.01um |
| ViCM | 1.1937 | 1.1928 |
| **CM load** | | |
| L | 1.62 um | 1.70 um |
| W | 29.77 um | 31.44 um |

| Tail current source | | |
|---|---|---|
| L | 1 um | 1 um |
| W | 8.979 um | 9.06 um |

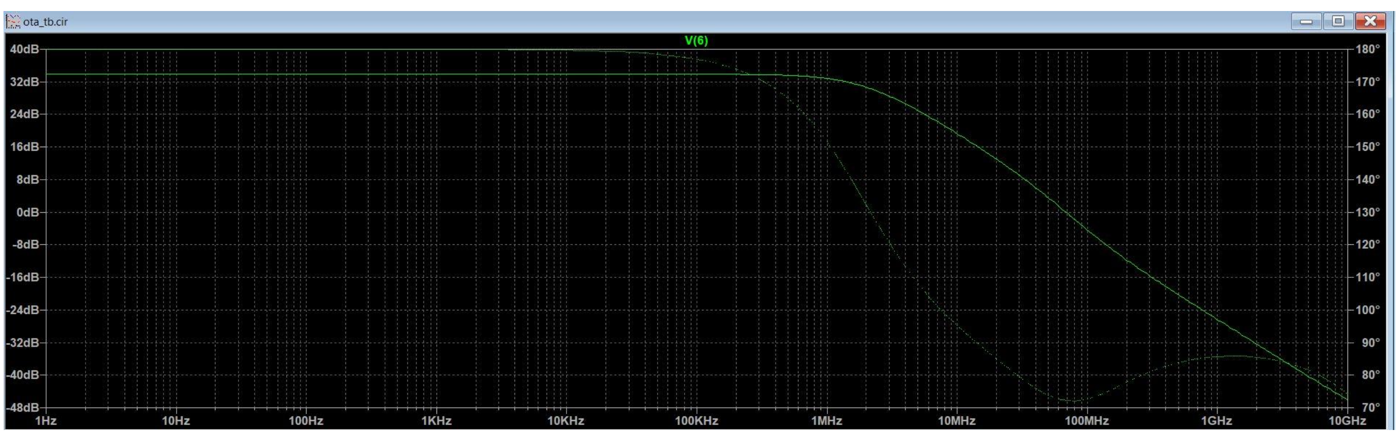
The results are very close to the values obtained from ADT.

**(index 7)**

Netlist:

```
* Add lines here to add the input (voltage)sources
V1 4 0 1.1937 AC 0.5
V2 3 0 1.1937 AC -0.5

* circuit
* 5T OTA
M1 6 4 2 0 nch L=269.5n W=2.859u
M2 5 3 2 0 nch L=269.5n W=2.859u
M3 6 5 7 7 pch L=1.62u W=29.77u
M4 5 5 7 7 pch L=1.62u W=29.77u
M5 2 1 0 0 nch L=1u W=8.979u
CL 6 0 500f
* Current Mirror
M6 1 1 0 0 nch L=1u W=8.979u
Iref 7 1 41.888u

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

.MEAS AC dc_gain max mag(V(6))
.MEAS AC BW WHEN mag(V(6)) = dc_gain/sqrt(2)
** Outputs Requests **
*.PROBE

.END
```

Simulation results:




```
dc_gain: MAX(mag(v(6)))=(33.8855dB,0°) FROM 1 TO 1e+010
bw: mag(v(6))=dc_gain/sqrt(2) AT 1.90255e+006
```

Comparison table:

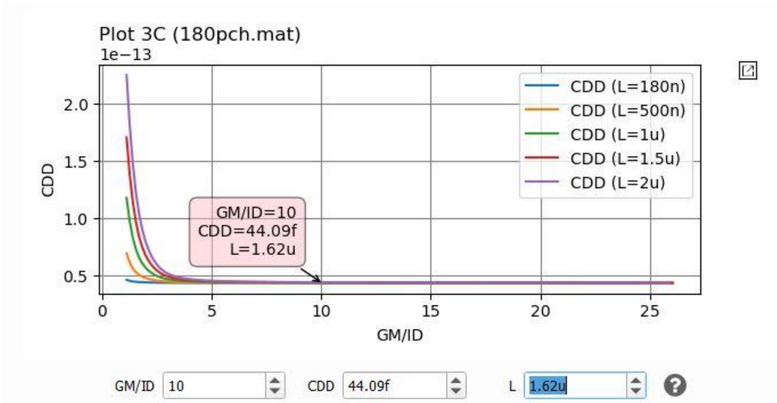
| | Specification | ADT |
|---|---|---|
| AVDC | 34 dB | 33.8855 dB |
| GBW | 100 MHz | 94.105 MHz |

Comment: the GBW spec is not met due to neglecting the parasitic capacitances during the design.

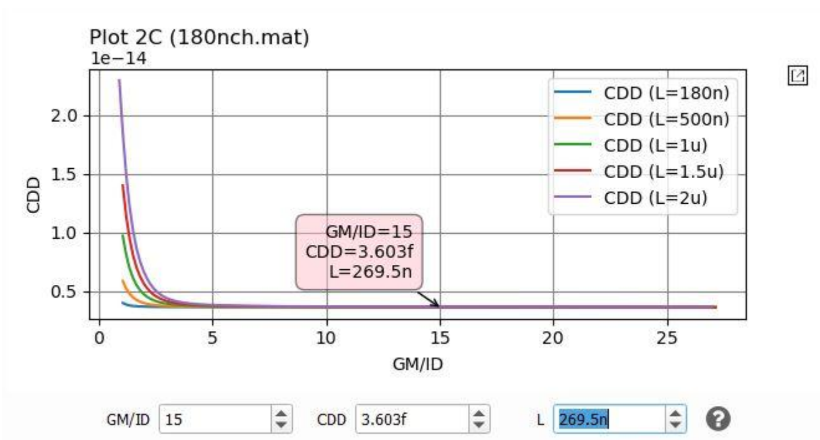
**Part (2):**

**(index 1)**

CDD of the pmos load

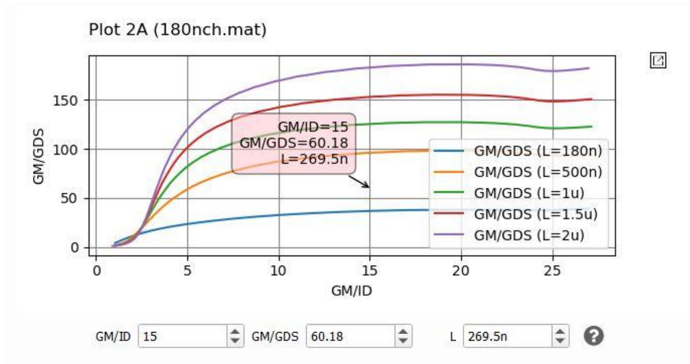


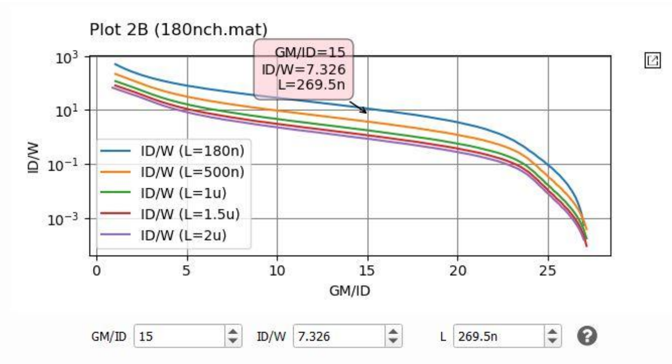

CDD of the nmos load

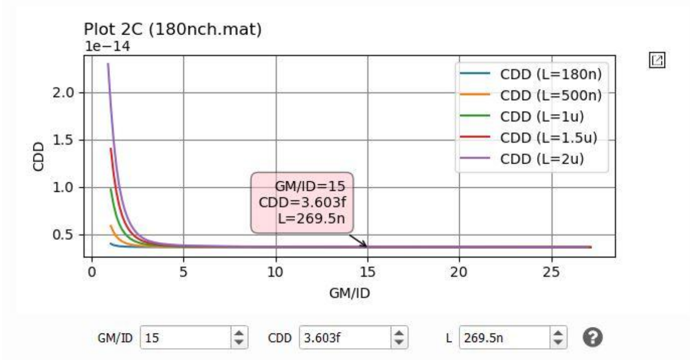


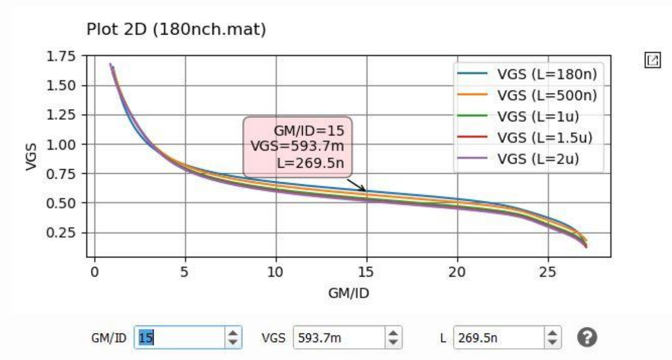

C_tot = 500f + 44.09f + 3.603f = 547.693 fF

For the input pair,

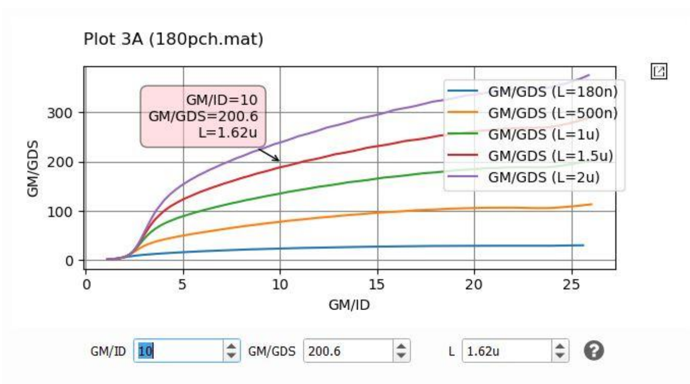


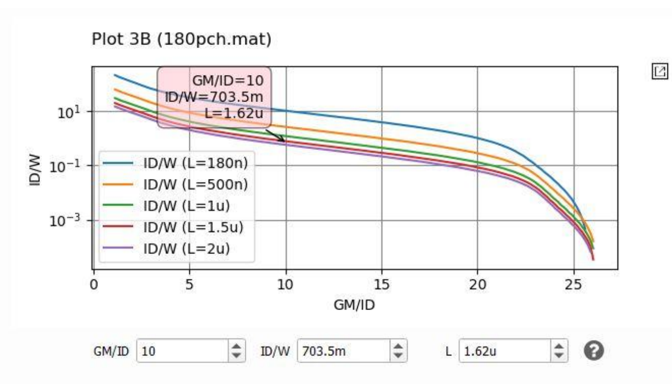



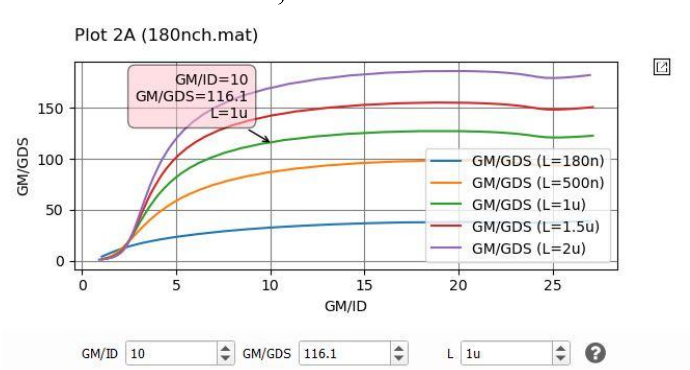



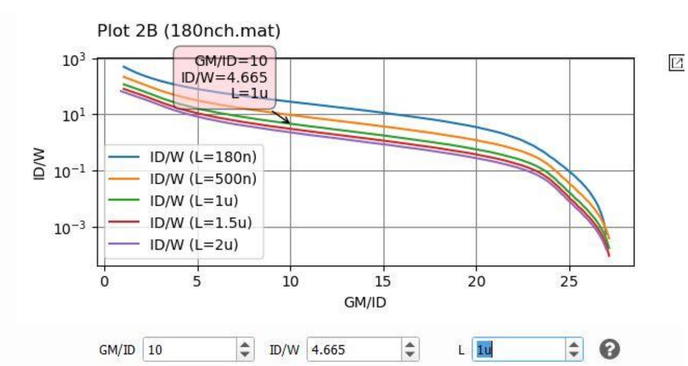

For the load,




For the current tail,




| | Part1 | part2 |
|---|---|---|

| | | |
|---|---|---|
| **Input pair** | | |
| L | 269.5 nm | 269.5 nm |
| W | 2.859 um | 3.1315um |
| ViCM | 1.1937 | 1.1928 |
| **CM load** | | |
| L | 1.62 um | 1.62 um |
| W | 29.77 um | 32.61 um |
| **Tail current source** | | |
| L | 1 um | 1 um |
| W | 8.979 um | 9.836 um |

**(index 2)**

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

Input Pair:
    L = 0.28 um
    W=3.30 um
    ViCM=1.1928 V

CM Load:
    L = 1.70 um
    W=34.44 um

Tail Current Source:
    L = 1.00 um
    W=9.93 um
```

**Compare the results to the results obtained in Part 1.**

| | part2 | part1 |
|---|---|---|
| **Input pair** | | |
| L | 0.28 um | 0.28 um |
| W | 3.3 um | 3.01um |
| ViCM | 1.1928 | 1.1928 |

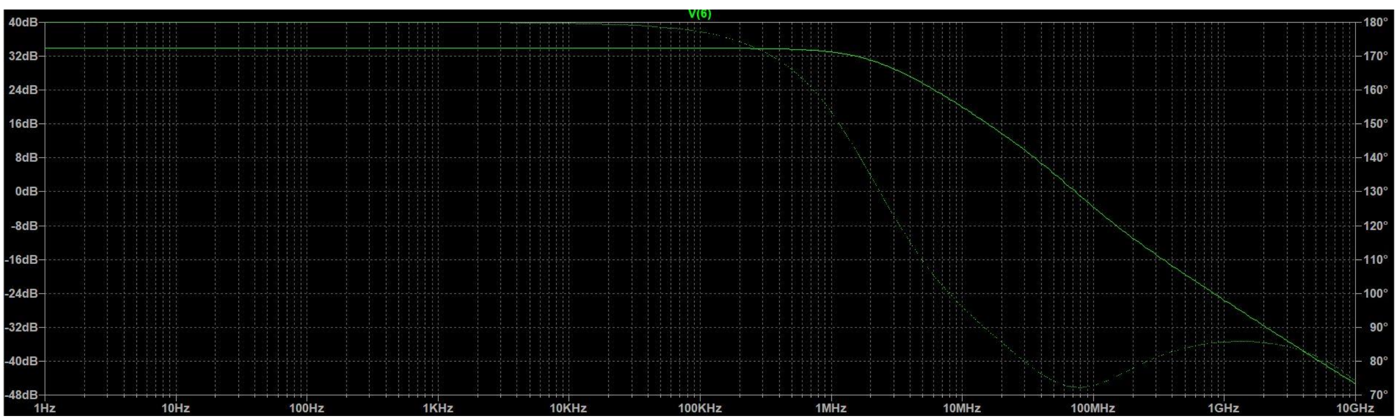
| CM load | | |
|---|---|---|
| L | 1.70 um | 1.70 um |
| W | 34.44 um | 31.44 um |
| **Tail current source** | | |
| L | 1 um | 1 um |
| W | 9.93 um | 9.06 um |

**Compare the results to the results obtained by ADT Device Xplore.**

| | ADT | Matlab |
|---|---|---|
| **Input pair** | | |
| L | 269.5 nm | 0.28 um |
| W | 3.1315um | 3.3 um |
| ViCM | 1.1928 | 1.1928 |
| **CM load** | | |
| L | 1.62 um | 1.70 um |
| W | 32.61 um | 34.44 um |
| **Tail current source** | | |
| L | 1 um | 1 um |
| W | 9.836 um | 9.93 um |

**(index 3)**

```
5T OTA

* Include external file that contains MOSFET Model
.INCLUDE ee214b_hspice.sp
** Circuit Description **

* power supply
VDD 7 0 DC 1.8
* input

* Add lines here to add the input (voltage)sources
V1 4 0 1.1937 AC 0.5
V2 3 0 1.1937 AC -0.5

* circuit
* 5T OTA
M1 6 4 2 0 nch L=269.5n W=3.1315u
M2 5 3 2 0 nch L=269.5n W=3.1315u
M3 6 5 7 7 pch L=1.62u W=32.61u
M4 5 5 7 7 pch L=1.62u W=32.61u
M5 2 1 0 0 nch L=1u W=9.836u
CL 6 0 500f
* Current Mirror
M6 1 1 0 0 nch L=1u W=9.836u
Iref 7 1 45.8834u

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

.MEAS AC dc_gain max mag(V(6))
.MEAS AC BW WHEN mag(V(6)) = dc_gain/sqrt(2)
** Outputs Requests **
*.PROBE

.END
```




```
dc_gain: MAX(mag(v(6)))=(33.8989dB,0°) FROM 1 TO 1e+010
bw: mag(v(6))=dc_gain/sqrt(2) AT 2.0669e+006
```

Comparison table:

| | Specification | ADT |
|---|---|---|
| AVDC | 34 dB | 33.8989 dB |
| GBW | 100 MHz | 102.39 MHz |

Comment: the GBW spec is met after considering the parasitic capacitances.