Analog IC Design – Xschem and Master Micro Tools

Lab 06

Differential Amplifier

Part 1: Differential Amplifier Design

Parameter	
Supply (V_{DD})	$1.8V$
Bias current (I_{SS})	$40\mu A$
Differential gain	8
CM output level[1]	$V_{DD}/3$
Load capacitance	$1pF$

$$ID = 20\mu A.$$

CM output level1 = $VDD/3$ =1.8/3=0.6 v

$$RD = (2Vout - CM)\ /\text{iss} = 1.2\ /40\text{u} = 30\text{k}$$

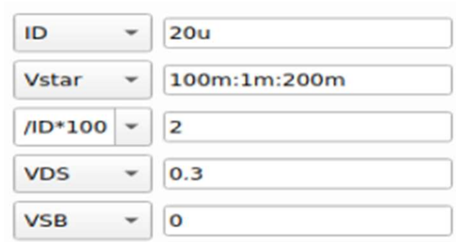
Differential gain = 8

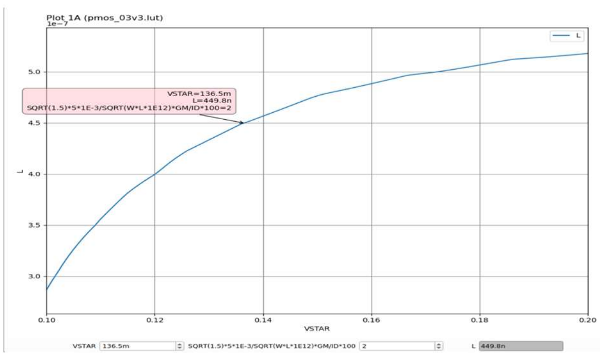
$$V* = 1.82 * \text{ID} * RD /\ |Av| = (1.82*20u*30k)/8 = 136.5\ mv$$

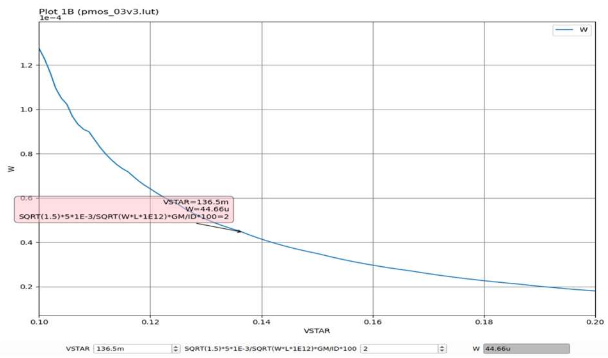
ID	20u
Vstar	136m
ro	30*10k
VDS	0.9
VSB	0.3

3	L	350n
4	W	30.79u
5	VGS	939.3m
6	VDS	900m
7	VSB	300m
8	gm/ID	14.33
9	Vstar	139.5m

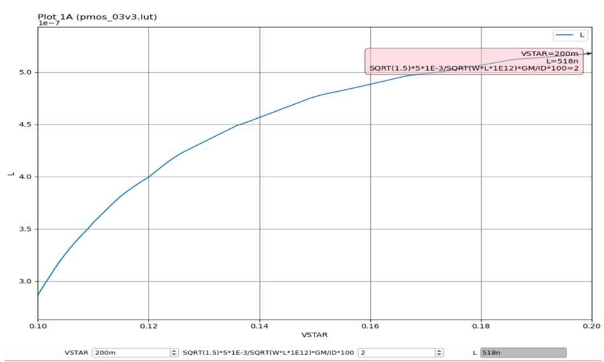
16	gm	286.7u
17	gmb	93.21u
18	gds	3.193u
19	ro	313.2k
20	VTH	870.2m
21	VDSAT	121.4m
22	cgg	41.72f
23	cgs	29.49f
24	cgd	4.667f

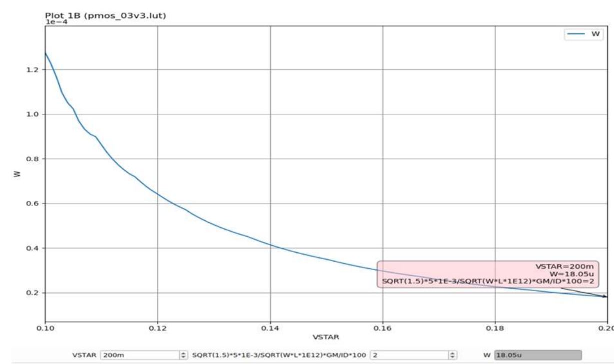






L1= 449.8n W1=44.66u

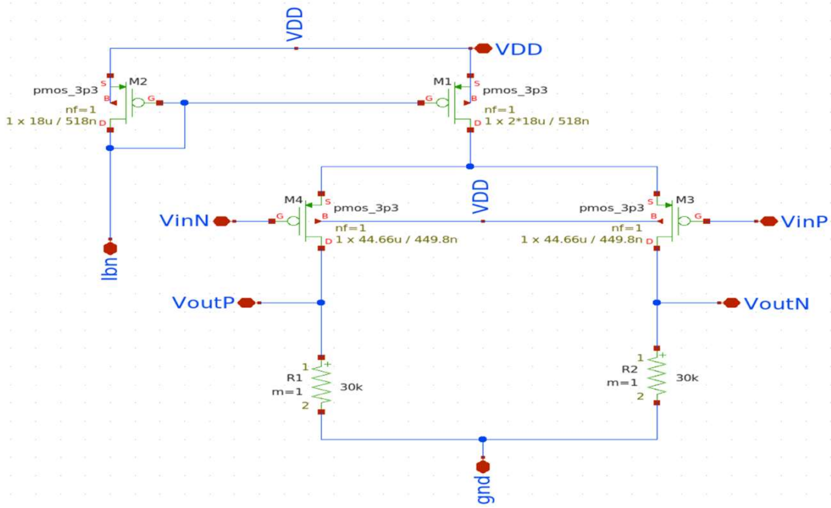


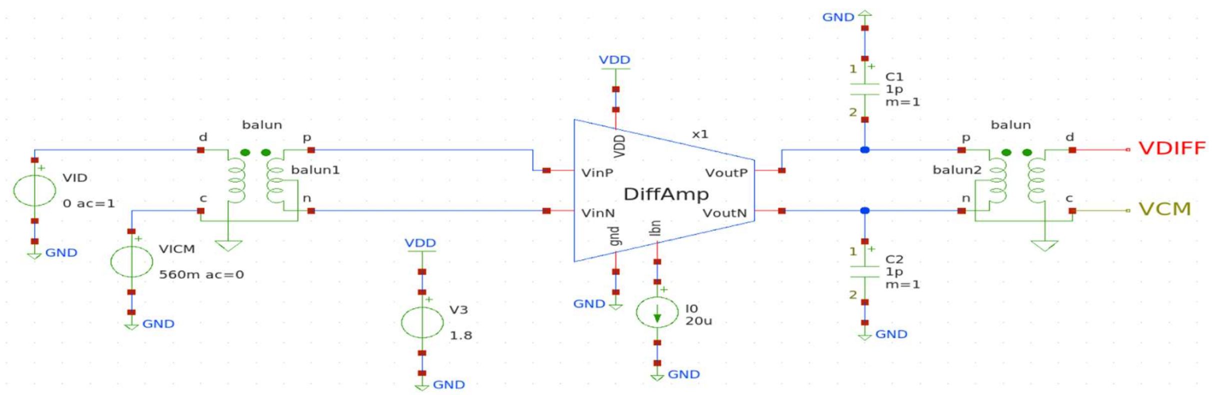


L2= 518n W2=18u

$$VICM = \quad \text{min+max } /2 = = 560\text{mv}$$

Part 2: Differential Amplifier Simulation





1) OP simulation.

```
No. of Data Rows : 1
BSIM4v5: Berkeley Short Channel IGFET Model-4
     device          m.x1.xm3.m0            m.x1.xm4.m0            m.x1.xm2.m0
      model          pmos_3p3.12            pmos_3p3.12            pmos_3p3.13
         id          1.90244e-05            1.97623e-05                  2e-05
        vgs             0.958952               0.958952               0.941906
        vds             0.948218               0.926082               0.941905
      vdsat             0.111061               0.112679               0.166402
        vth             0.899158               0.896616               0.790984
         gm           0.00028764            0.000295671            0.000205003
        gds          1.53187e-06            1.59936e-06            1.01315e-06
       gmbs          0.000106251            0.000109225            9.17836e-05

BSIM4v5: Berkeley Short Channel IGFET Model-4
     device          m.x1.xm1.m0
      model          pmos_3p3.13
         id          3.87867e-05
        vgs             0.941906
        vds             0.281045
      vdsat             0.167548
        vth             0.789436
         gm          0.000392408
        gds          6.97932e-06
       gmbs          0.000175832
```

Check that all transistors operate in saturation.

All Transistors operate in saturation.

2) **Diff small signal ccs:**

```
No. of Data Rows : 101
gain                    =  8.113316e+00 at=  1.000000e+00
bw                      =  5.368121e+06
binary raw file "lab6_ac.raw"
```

Analytical solution:

BW = 1 / (2π $(RD||ro) * CL)$ = 5.81 MHz

Gain = $gm(RD||ro)$ = 7.84 = 17.89 dB

	Analytical	Simulation
BW	**5.81 MHz**	**5.36M**
GAIN	**7.84**	**8.11**

3) **CM small signal ccs:**

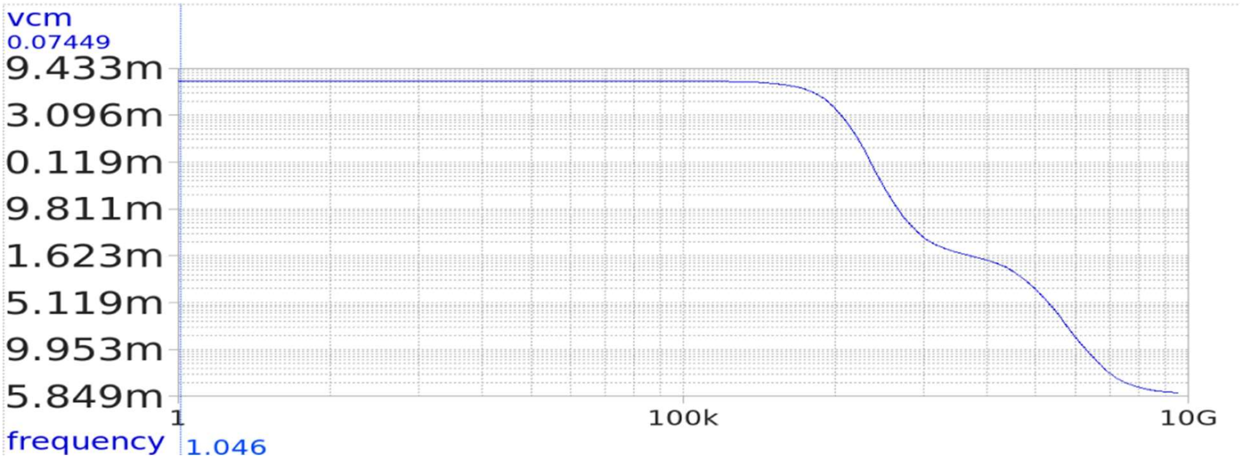
```
No. of Data Rows : 101
cmgain                  =  6.132381e-05 at=  1.258925e+01
binary raw file "lab6_ac.raw"
```

Every time I do a simulation the result changes a lot.

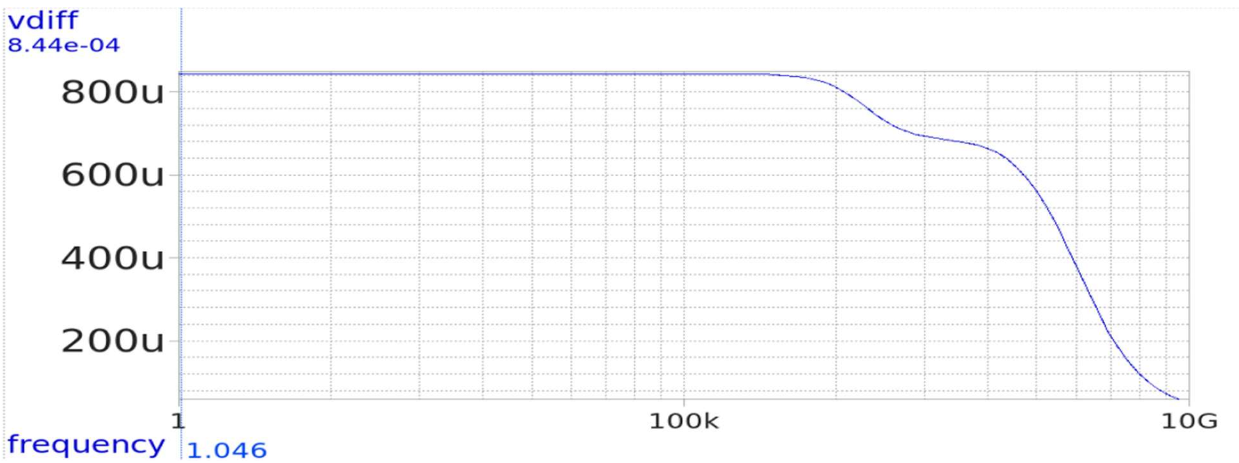
$AVCM = \frac{gm(RD|ro)}{1+2gmRSS}$ **= 0.67**

	Analytical	Simulation
CM, GAIN	**0.67**	**0.613**

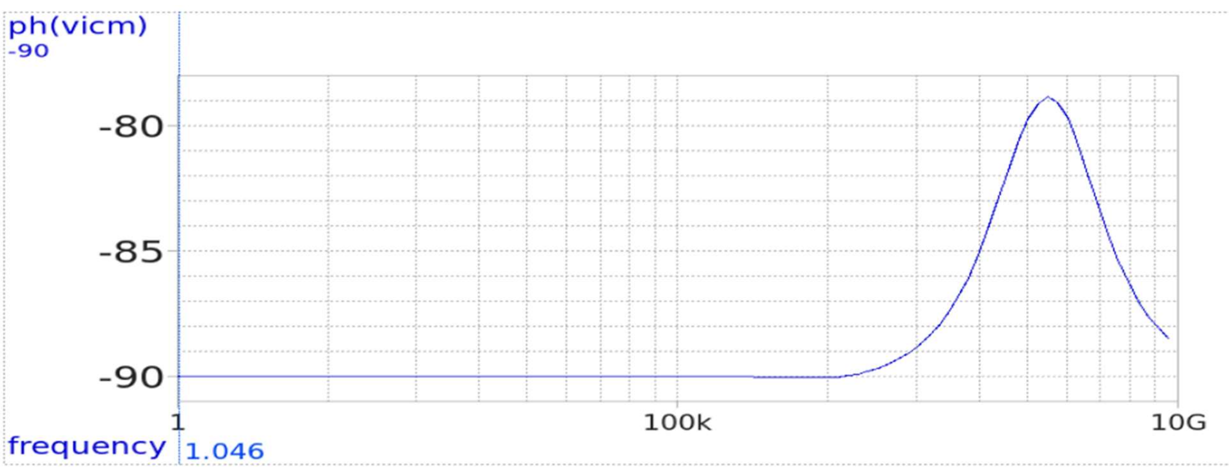
Yes, it is less than 1 because it is degraded by a large resistance 2RSS.



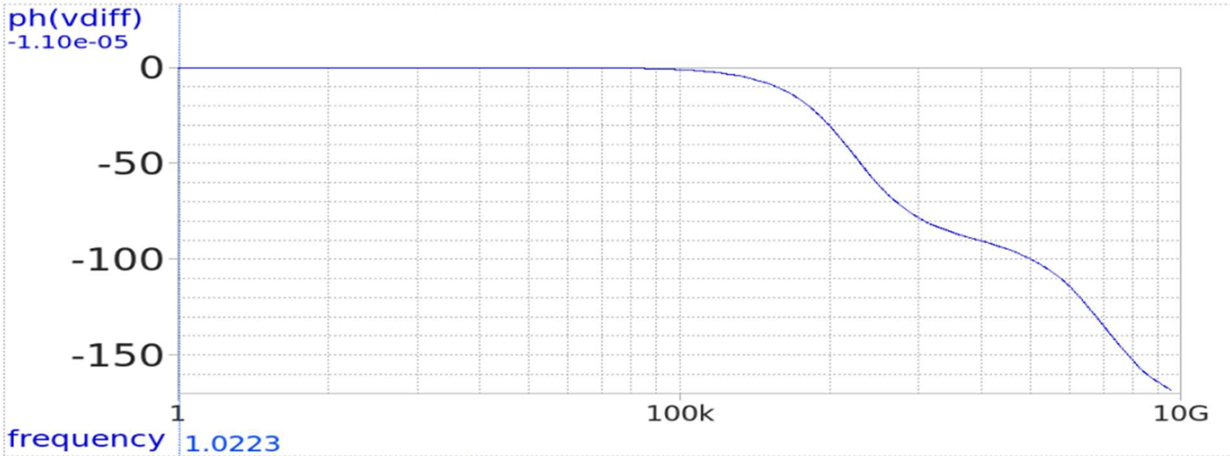
vcm
0.07449
9.433m
3.096m
0.119m
9.811m
1.623m
5.119m
9.953m
5.849m
1
100k
10G
frequency
1.046



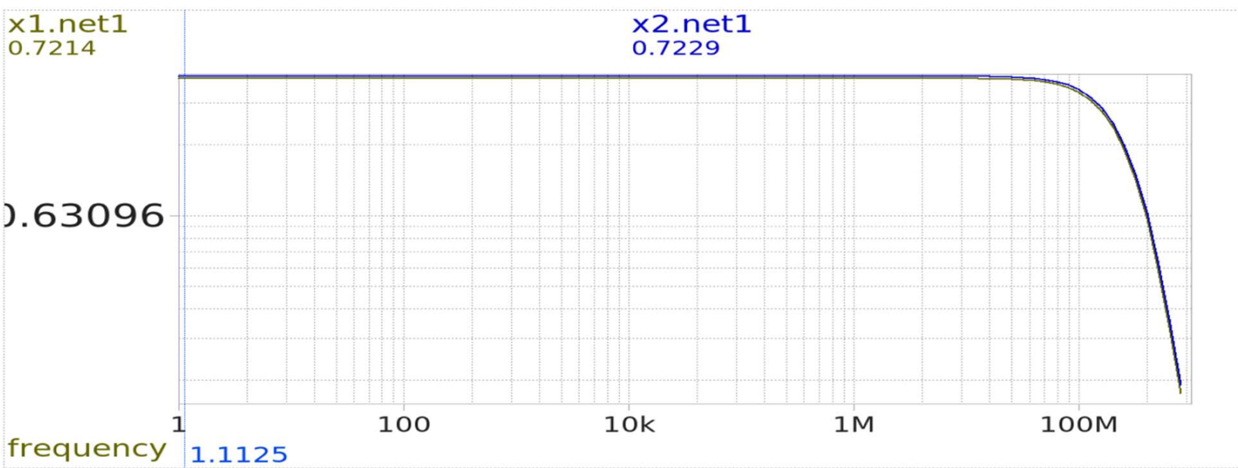
vdiff
8.44e-04
800u
600u
400u
200u
1
100k
10G
frequency
1.046

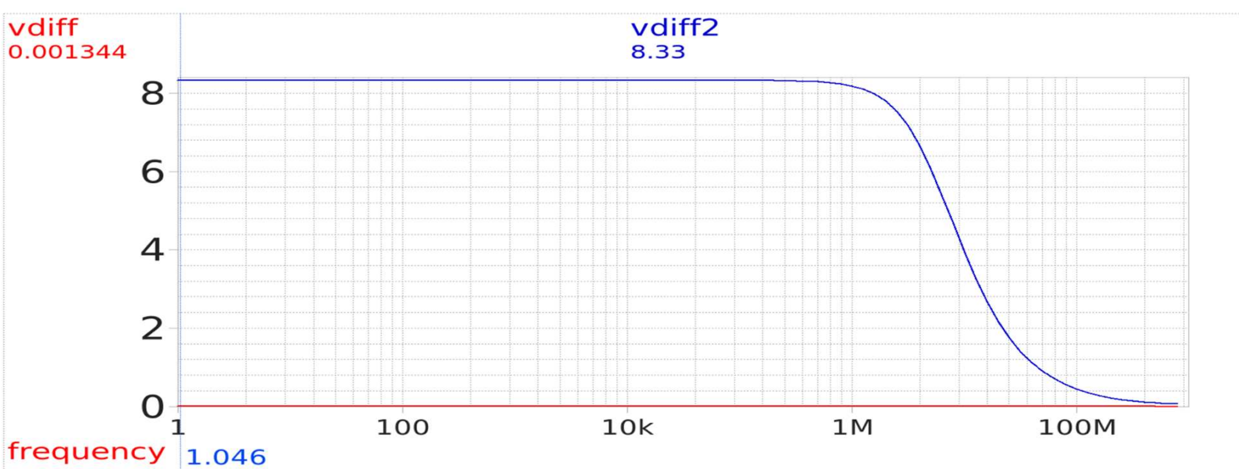


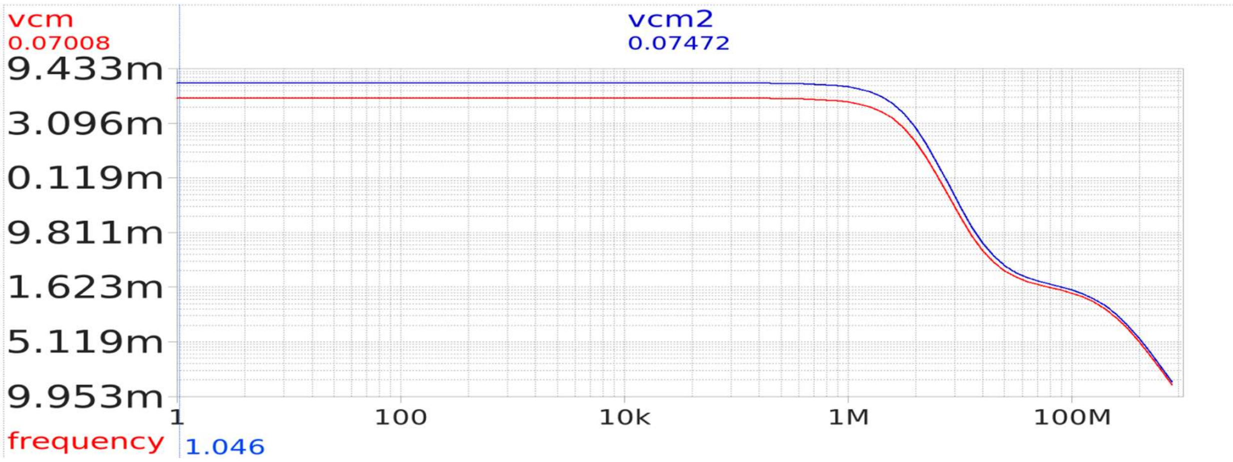
ph(vicm)
-90
-80
-85
-90
1
100k
10G
frequency
1.046

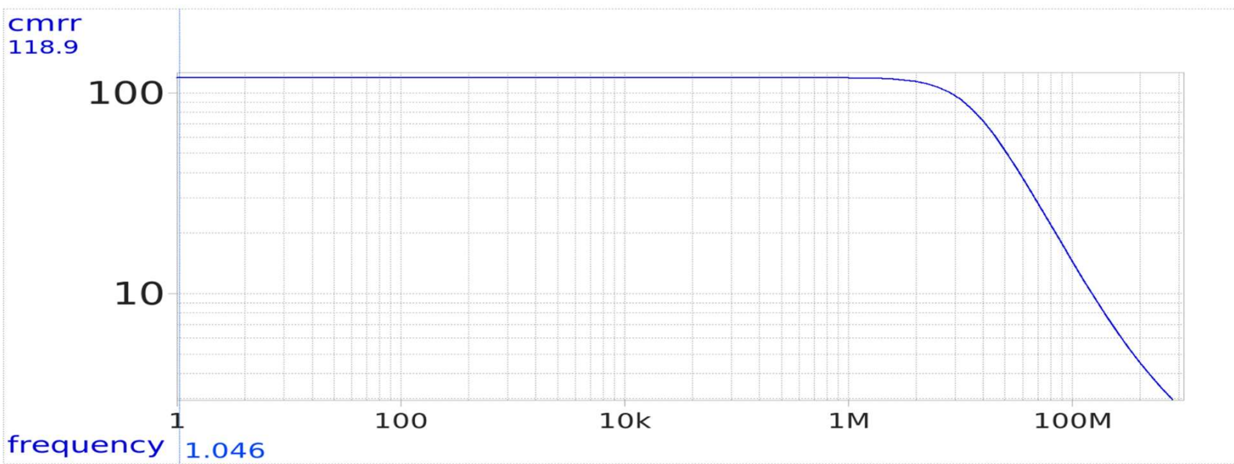



```
No. of Data Rows : 91
cmgain             =  7.008391e-02 at=  1.000000e+00
to=1meg: no such command available in ngspice
diffgain           =  8.329921e+00 at=  1.000000e+00
to=1meg: no such command available in ngspice
cmrr_val = 1.188564e+02
binary raw file "lab6_ac_CM.raw"
```









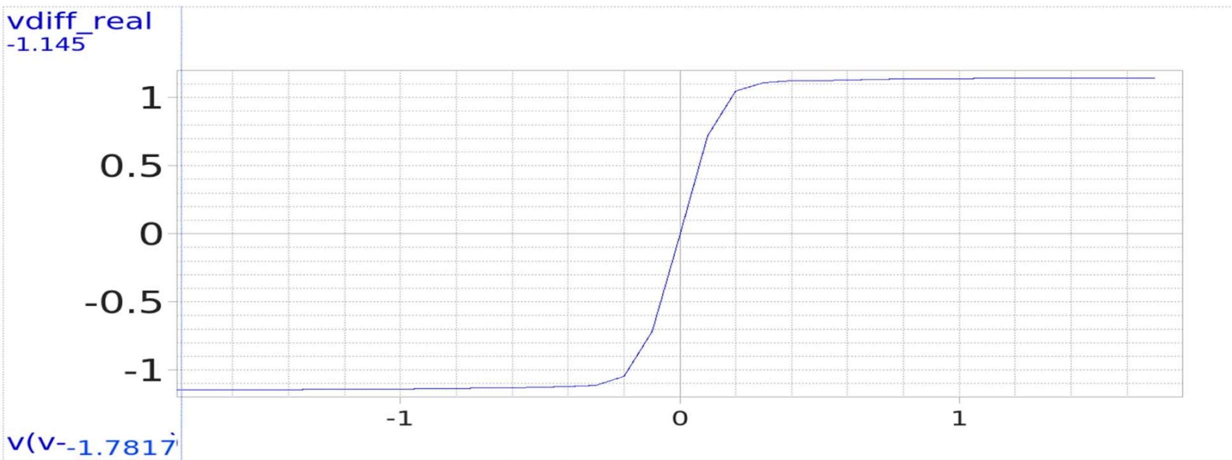
Initially, $AVCM$ decreases because RD is converted with CL which reduces the impedance and gain, at higher frequencies, $AVCM$ increases slightly which means that RSS is converted with the capacitance of $M0$ and $M3$ which reduces the total impedance.

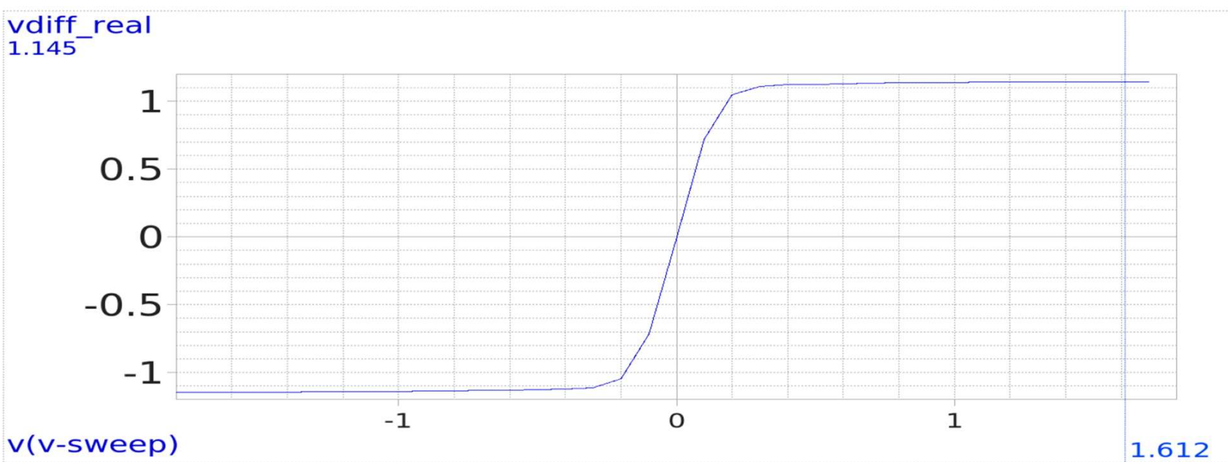
CMRR = Vdiff/vcm

CMRR varies with the variations of VCM at high frequencies.

4) **Diff large signal ccs:**

Report diff large signal ccs (VODIFF vs VIDIFF). Compare the extreme values with hand analysis in a table.



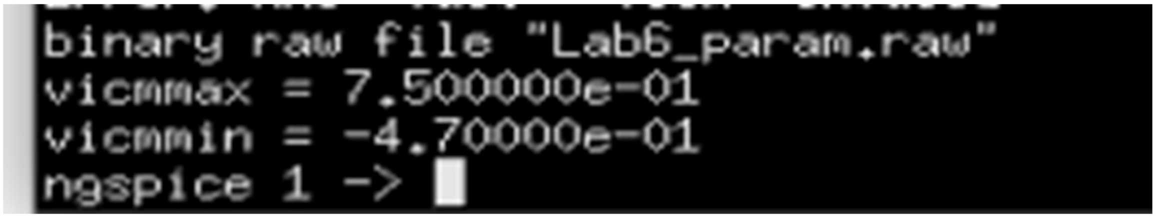


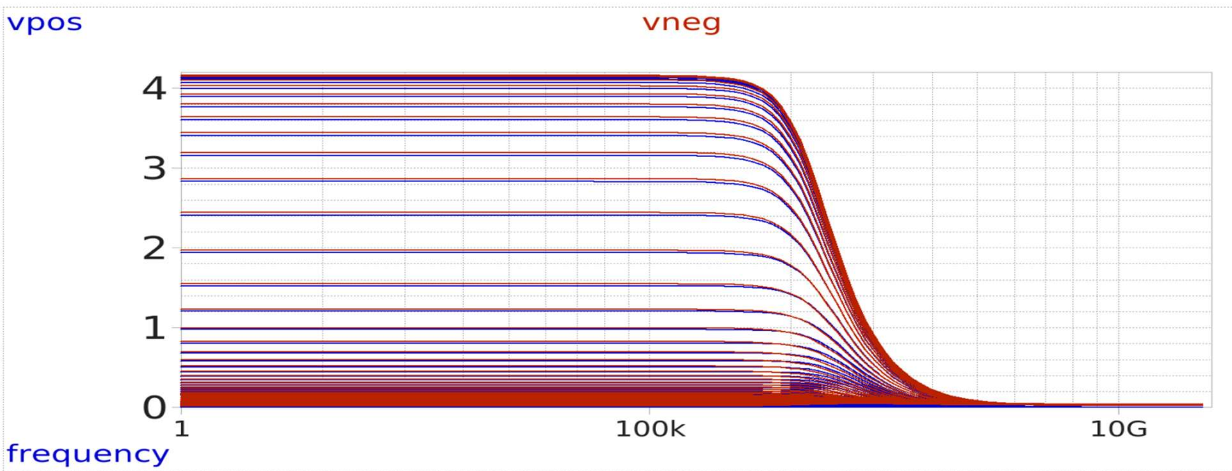
- At $Vdiff \gg 0$, $Vdiff \;\; = ISS * RD = 1.2\text{V}$
- At $Vdiff \ll 0$, $Vdiff = \text{-}ISS * RD = \text{-}1.2\text{V}$

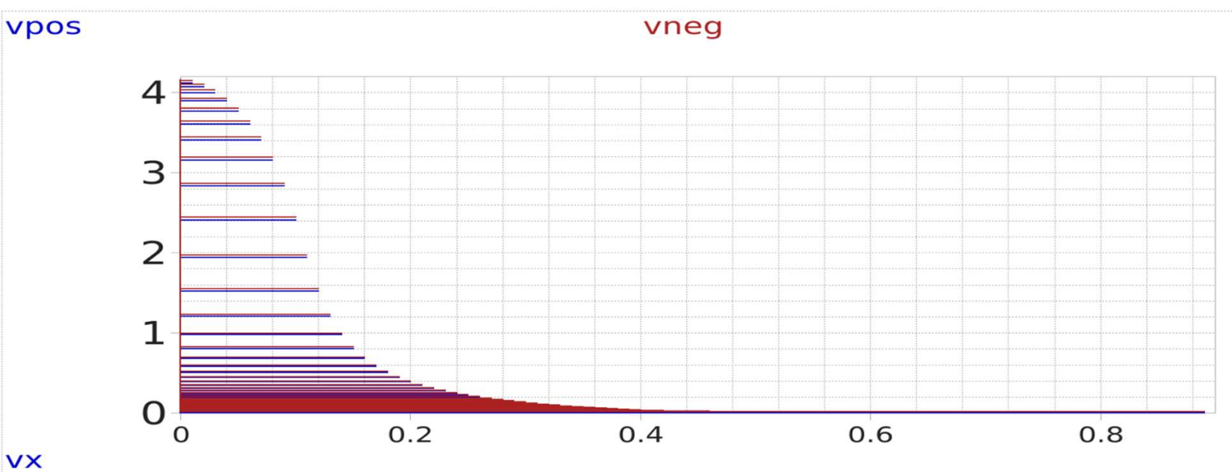
	Analytical	Simulation
$Vdiff \gg 0$	**1.2V**	**1.145V**

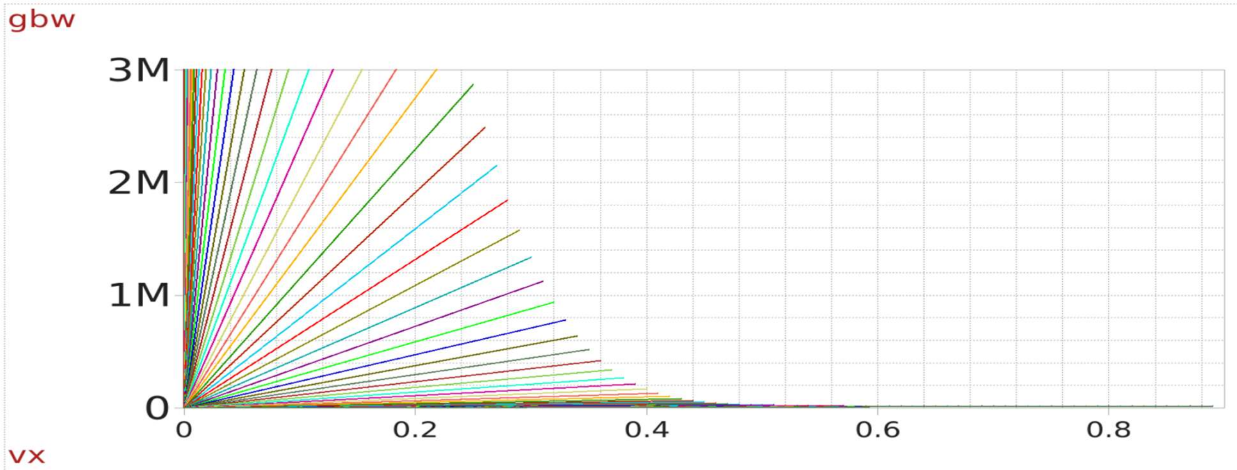
$Vdiff \ll 0$	**-1.2V**	**-1.145V**

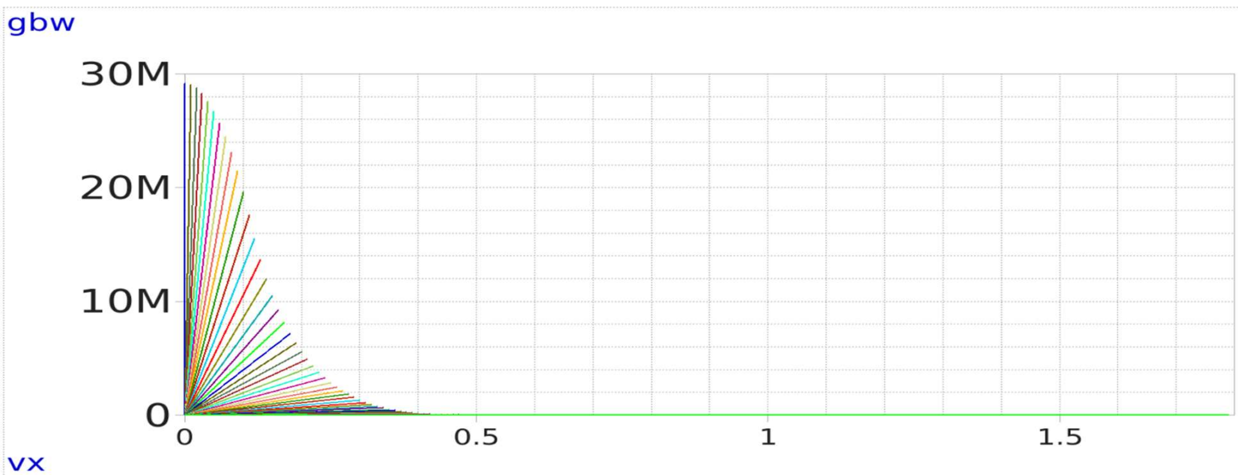
5) CM large signal ccs (GBW vs Vicm):


```
binary raw file "Lab6_param.raw"
vicmmax = 7.500000e-01
vicmmin = -4.70000e-01
ngspice 1 ->
```









CMIR = Vmax - Vmin = (7.5e-1) -(-4.7e-1) = 1.22v

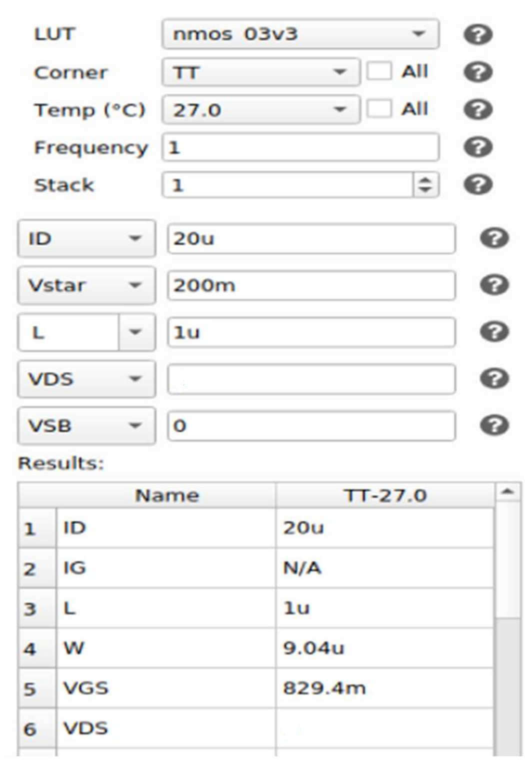
(VDD – Vov - VGS) > $Vicm$ > ([ISS/2] *RD -VTH)

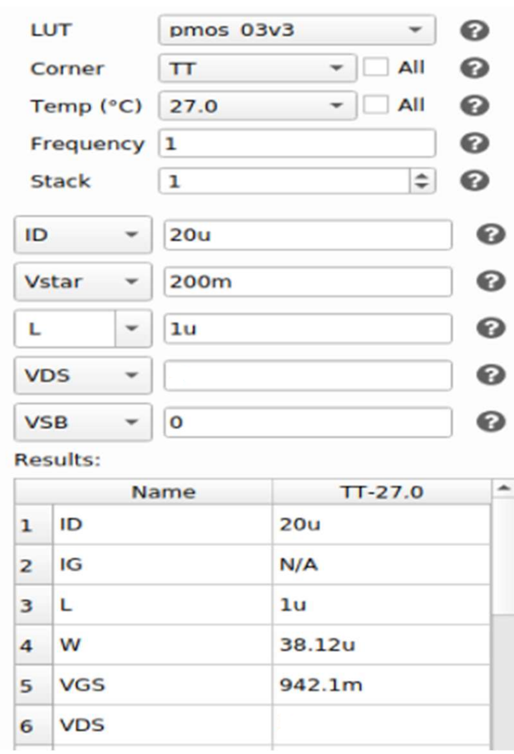
0.808 > $Vicm$ > -0.27

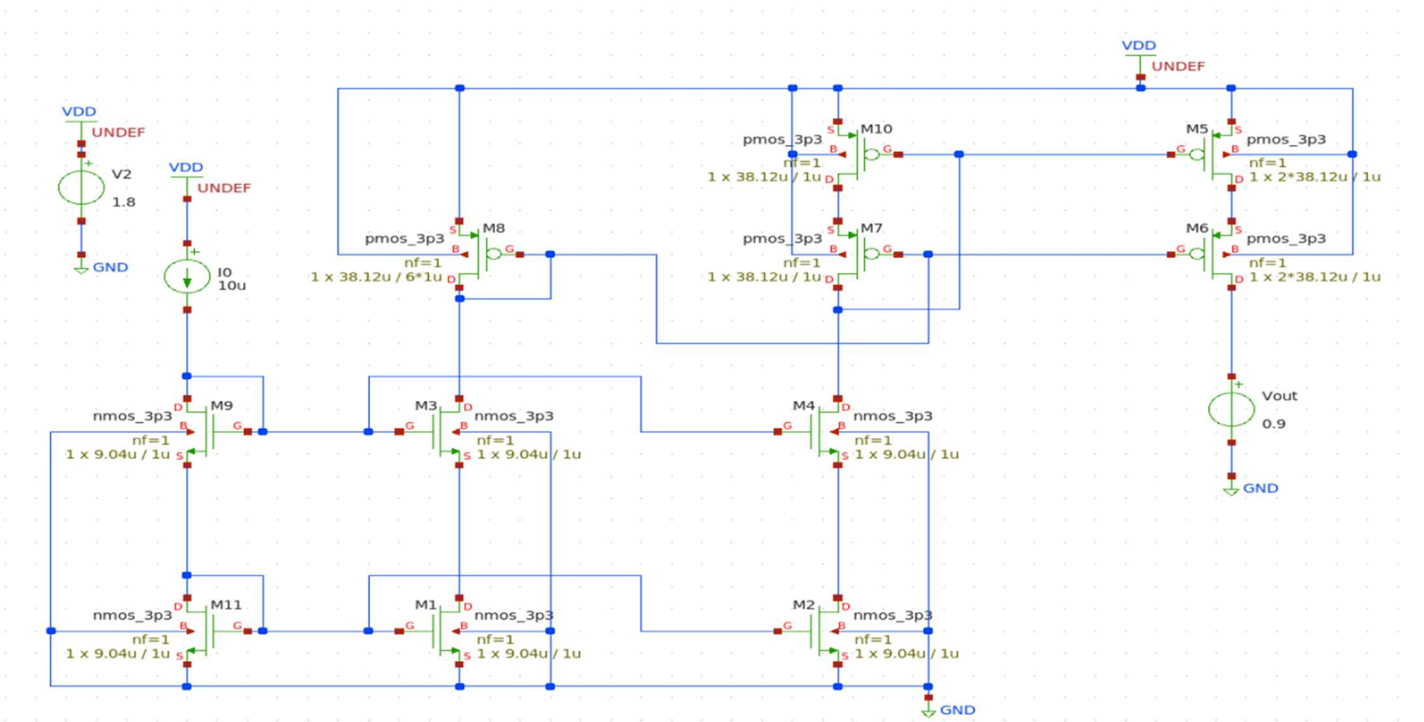
	Analytical	Simulation
VMIR	**1.07V**	**1.22v**

(OPTINAL)

Wide Swing _ Current Mirror







1. OP Analysis

lo. of Data Rows : 1

BSIM4v5: Berkeley Short Channel IGFET Model-4

device	m.xm8.m0	m.xm7.m0	m.xm6.m0
model	pmos_3p3.14	pmos_3p3.13	pmos_3p3.13
id	9.3927e-06	9.38471e-06	1.92893e-05
vgs	1.09229	0.94625	0.946199
vds	1.09229	0.738716	0.753905
vdsat	0.244223	0.116442	0.117704
vth	0.768938	0.852158	0.850091
gm	5.34798e-05	0.000124199	0.000253065
gds	3.47672e-08	2.6492e-07	5.3612e-07
gmbs	2.61796e-05	5.43524e-05	0.000110739

BSIM4v5: Berkeley Short Channel IGFET Model-4

device	m.xm5.m0	m.xm10.m0	m.xm11.m0
model	pmos_3p3.13	pmos_3p3.13	nmos_3p3.9
id	1.92893e-05	9.38471e-06	1e-05
vgs	0.88476	0.88476	0.769232
vds	0.146094	0.146043	0.76923
vdsat	0.117489	0.116163	0.128757
vth	0.783634	0.785783	0.684503
gm	0.000240692	0.000118348	0.000130185
gds	1.57685e-05	7.4542e-06	3.95678e-07
gmbs	0.000114154	5.61279e-05	4.98495e-05

BSIM4v5: Berkeley Short Channel IGFET Model-4

device	m.xm9.m0	m.xm4.m0	m.xm3.m0
model	nmos_3p3.9	nmos_3p3.9	nmos_3p3.9
id	1e-05	9.38471e-06	9.3927e-06
vgs	1.02103	1.02354	1.11827
vds	1.02102	0.148517	0.0357127
vdsat	0.135345	0.135452	0.227753
vth	0.935741	0.938082	0.910949
gm	0.000130652	0.000118647	4.55458e-05
gds	3.25778e-07	8.44878e-06	0.000239683
gmbs	3.67723e-05	3.3431e-05	1.36062e-05

BSIM4v5: Berkeley Short Channel IGFET Model-4

device	m.xm2.m0	m.xm1.m0
model	nmos_3p3.9	nmos_3p3.9
id	9.38471e-06	9.3927e-06
vgs	0.769232	0.769232
vds	0.766717	0.671988
vdsat	0.12562	0.125851
vth	0.689268	0.688914
gm	0.000124736	0.000124781
gds	3.78272e-07	3.96337e-07
gmbs	4.77682e-05	4.77808e-05

2. DC Sweep ($I\ out$ vs VOUT)