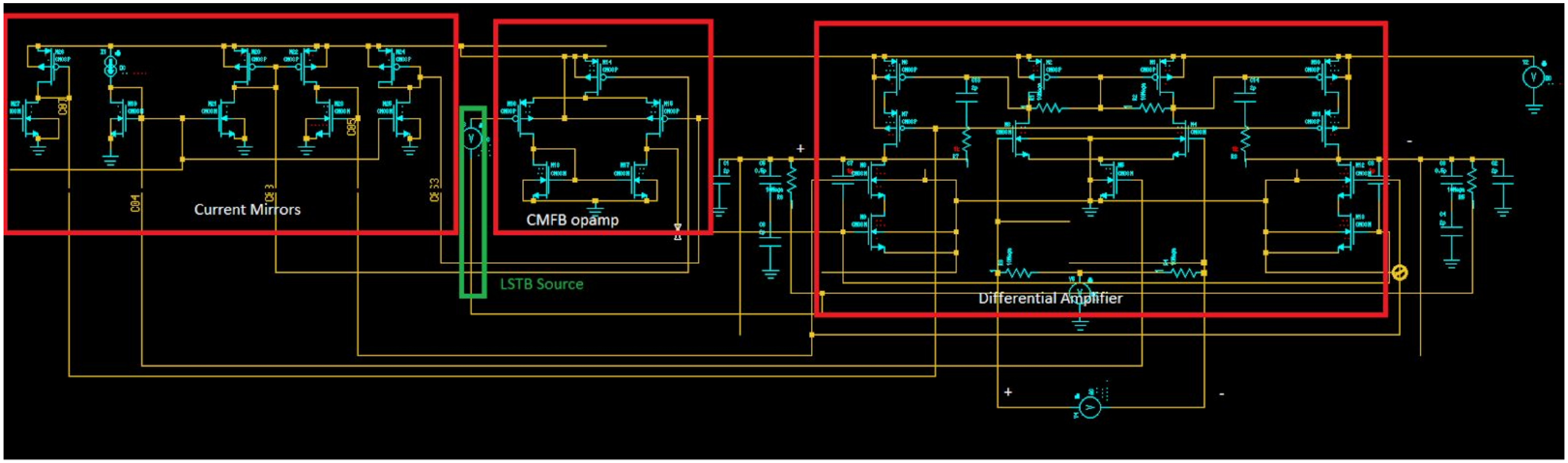
Schematic:



EE17B156
Dhruvjyoti Bagadthey

Performance:

Closed Loop Gain	12.01 db
Settling Time	5.5 ns
Settling Error	690 uV
3-db Bandwidth	232.5 Mega Hz
DC gain of Differential Opamp (A0)	82db
Phase Margin	47^{o}
Quiescent Current	10.828 mA

Devices:

Number	W	L	M	gm	ID(A)	region
1	150u	0.2u	10	64.15m	4.164m	saturation
2	150u	0.2u	10	64.15m	4.164m	saturation
3	150u	0.2u	1	54.68m	4.163m	saturation
4	150u	0.2u	1	54.6m	4.164m	saturation
5	100u	1u	10	94.81m	8.32m	saturation

6	1.4u	0.35u	100	4.54m	0.39m	saturation
7	1.4u	0.35u	1000	8.58m	0.39m	saturation
8	10u	0.35u	1000	10.558m	0.39m	saturation
9	1.5u	0.35u	400	9.3m	0.39m	saturation
10	1.4u	0.35u	100	4.54m	0.39m	saturation
11	1.4u	0.35u	1000	8.58m	0.39m	saturation
12	10u	0.35u	1000	10.55m	0.39m	saturation
13	1.5u	0.35u	400	9.30m	0.39m	saturation
14	1.4u	0.5u	1	45.15m	6.1u	saturation
15	1.4u	0.5u	1	33.65u	2.9u	saturation
16	1.4u	0.5u	1	33.65u	2.9u	saturation
17	1.4u	0.5u	2	68.83u	2.9u	saturation
18	1.4u	0.5u	2	68.83u	2.9u	saturation
19	10u	1u	5	4.956m	0.427m	saturation
20	50u	1u	3	3.167m	0.447m	saturation
21	10u	1u	5	5.19m	0.447m	saturation
22	50u	1u	3	3.2616m	0.47m	saturation
23	10u	1u	2.2	2.91m	0.47m	saturation

24	12u	1u	5	1.85m	0.441m	saturation
25	10u	1u	5	5.06m	0.441m	saturation
26	17u	1u	5	2.66m	0.442m	saturation
27	10u	1u	5	5.088m	0.442m	saturation

.CHI File

	M22	M20	M2	M1	M7	M6	M16	M15
MODEL	CMOSP	CMOSP	CMOSP	CMOSP	CMOSP	CMOSP	CMOSP	CMOSP
MFACTOR	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
ID	-471.7809U	-447.5621U	-4.1653M	-4.1653M	-385.6278U	-385.6271U	-2.9581U	-2.9499U
Ibd	4.7470P	2.9739P	8.7818P	8.7818P	1.3410N	53.8088P	1.9816P	2.0000P
Ibs	0.0000	0.0000	0.0000	0.0000	538.0877P	0.0000	465.5181F	465.5181F
IG	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
IS	-471.7809U	-447.5621U	-4.1653M	-4.1653M	-385.6274U	-385.6271U	-2.9581U	-2.9499U
IB	2.3735P	1.4870P	4.3909P	4.3909P	939.5433P	26.9044P	1.2236P	1.2328P
VGS	-495.6567M	-495.6567M	-439.0893M	-439.0893M	-330.9562M	-439.0893M	-437.7404M	-437.2410M
VDS	-791.1655M	-495.6567M	-439.0893M	-439.0893M	-401.4556M	-269.0438M	-758.0490M	-767.2420M
VBS	0.0000	0.0000	0.0000	0.0000	269.0438M	0.0000	232.7590M	232.7590M
VTH	-234.4861M	-240.4066M	-349.1555M	-349.1555M	-326.9365M	-297.5408M	-290.6300M	-290.4150M
VDSAT	-253.0325M	-248.0380M	-119.5052M	-119.5052M	-62.3778M	-142.0654M	-147.8292M	-147.6194M
GM	3.2616M	3.1678M	64.1476M	64.1476M	8.5805M	4.5435M	33.6488U	33.6009U
GDS	81.6971U	84.1863U	1.6832M	1.6832M	243.4902U	149.6358U	934.0588N	932.4153N
RON	12.2403K	11.8784K	594.0894	594.0894	4.1069K	6.6829K	1.0706MEG	1.0725MEG
GMB	444.5871U	440.8225U	9.0131M	9.0131M	957.9472U	574.0082U	3.6511U	3.6425U
Cdd	47.9296F	49.5720F	563.2525F	563.2525F	521.9699F	52.1851F	487.4672A	487.4418A
Cdg	-590.0118F	-592.0340F	-1.5186P	-1.5186P	-1.4405P	-222.4395F	-2.9608F	-2.9605F
Cds	614.2087F	616.3602F	1.0868P	1.0868P	1.0223P	192.1442F	2.7367F	2.7362F
Cdb	-72.1264F	-73.8981F	-131.4678F	-131.4678F	-103.7959F	-21.8898F	-263.3509A	-263.1021A
Cgd	-33.6990F	-35.8005F	-533.9005F	-533.9005F	-484.5190F	-46.9317F	-406.0375A	-406.0149A
Cgg	1.3838P	1.3864P	3.5390P	3.5390P	3.6295P	533.0073F	7.1209F	7.1203F
Cgs	-1.3040P	-1.3081P	-2.9111P	-2.9111P	-2.7698P	-466.4929F	-6.4110F	-6.4099F
Cgb	-46.0961F	-42.4437F	-93.9956F	-93.9956F	-375.2206F	-19.5828F	-303.7802A	-304.4139A
Csd	-10.2704F	-8.6280F	-18.7475F	-18.7475F	-21.2301F	-2.1349F	-55.7328A	-55.7582A
Csg	-590.0118F	-592.0340F	-1.5186P	-1.5186P	-1.4405P	-222.4395F	-2.9608F	-2.9605F
Css	672.4087F	674.5602F	1.6688P	1.6688P	1.5655P	246.4642F	3.2799F	3.2794F
Csb	-72.1264F	-73.8981F	-131.4678F	-131.4678F	-103.7959F	-21.8898F	-263.3509A	-263.1021A
Cbd	-3.9602F	-5.1435F	-10.6045F	-10.6045F	-16.2209F	-3.1185F	-25.6969A	-25.6686A
Cbg	-203.7858F	-202.3195F	-501.7394F	-501.7394F	-748.4908F	-88.1284F	-1.1992F	-1.1993F
Cbs	17.3972F	17.2230F	155.4128F	155.4128F	181.8994F	27.8845F	394.4553A	394.3482A
Cbb	190.3489F	190.2400F	356.9312F	356.9312F	582.8123F	63.3624F	830.4820A	830.6180A
PHI	888.2684M	888.2684M	888.2684M	888.2684M	888.2684M	888.2684M	888.2684M	888.2684M
VBI	1.0301	1.0301	1.0301	1.0301	1.0301	1.0301	1.0301	1.0301
Region	saturation	saturation	saturation	saturation	saturation	saturation	saturation	saturation
VTH_D	261.1706M	255.2501M	89.9339M	89.9339M	4.0197M	141.5486M	147.1104M	146.8259M

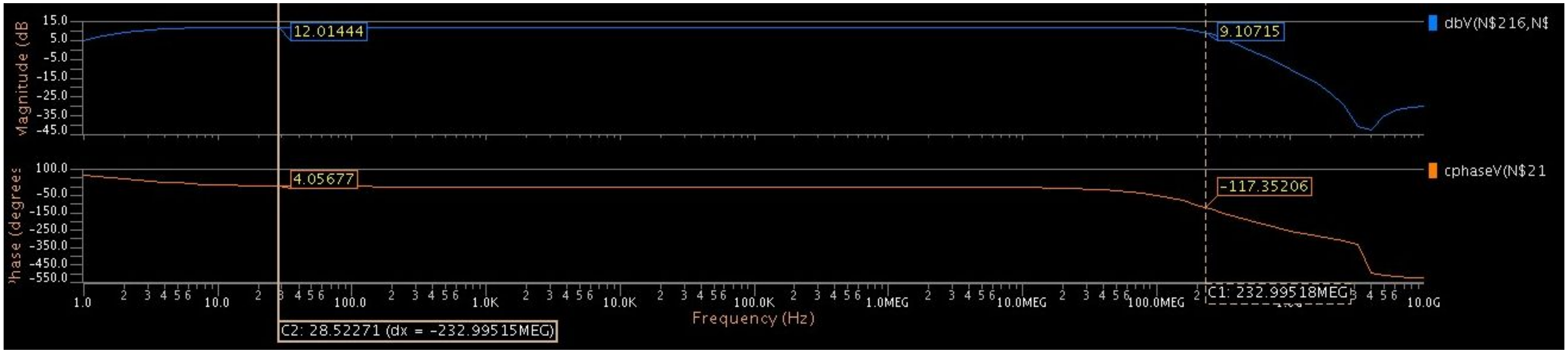
	M23	M21	M19	M4	M18	M17	M5	M8
MODEL	CMOSN	CMOSN	CMOSN	CMOSN	CMOSN	CMOSN	CMOSN	CMOSN
MFACTOR	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
ID	471.7809U	447.5621U	427.0000U	4.1653M	2.9581U	2.9499U	8.3306M	385.6267U
Ibd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ibs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
IG	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
IS	471.7809U	447.5621U	427.0000U	4.1653M	2.9582U	2.9499U	8.3306M	385.6272U
IB	-1.1194P	-4.0217P	-2.0100P	-1.0809P	-618.3839F	-599.9979F	-2.2003P	-1.2824N
VGS	508.8345M	401.9985M	401.9985M	529.9743M	309.1919M	309.1919M	400.0000M	213.5346M
VDS	508.8345M	804.3433M	401.9985M	640.8850M	309.1919M	299.9989M	220.0257M	343.0352M
VBS	0.0000	0.0000	0.0000	-220.0257M	0.0000	0.0000	0.0000	-286.4654M
VTH	168.0287M	167.1318M	168.3529M	344.0158M	226.7369M	226.7687M	168.8925M	296.3472M
VDSAT	268.4723M	177.9317M	176.8292M	120.4859M	59.0377M	59.0256M	182.5552M	40.6336M
GM	2.9162M	5.1196M	4.9568M	54.6863M	68.8391U	68.6731U	94.8104M	10.5585M
GDS	50.2922U	47.4830U	61.6153U	1.1919M	889.6616N	897.3724N	5.5624M	127.8122U
RON	19.8838K	21.0602K	16.2297K	839.0055	1.1240MEG	1.1144MEG	179.7780	7.8240K
GMB	2.8460M	7.1778M	3.7638M	6.9806M	41.6409U	40.5513U	44.7553M	1.4854M
Cdd	9.1170F	19.6925F	20.7679F	60.6449F	1.0995F	1.1007F	651.8554F	5.6364P
Cdg	-86.6163F	-195.6225F	-196.8551F	-157.0237F	-5.4232F	-5.4246F	-4.1434P	-6.9673P
Cds	150.0775F	419.7186F	311.9440F	110.2297F	7.0099F	6.9498F	5.3176P	1.5315P
Cdb	-72.5782F	-243.7887F	-135.8568F	-13.8508F	-2.6863F	-2.6259F	-1.8260P	-200.5677F
Cgd	-8.8980F	-18.9770F	-20.2803F	-60.6252F	-1.0776F	-1.0789F	-707.4711F	-5.6353P
Cgg	205.1292F	465.1444F	466.6346F	362.7925F	13.2843F	13.2854F	9.4986P	20.7410P
Cgs	-331.2209F	-940.1106F	-682.0720F	-293.1108F	-16.4343F	-16.2819F	-11.2305P	-8.7978P
Cgb	134.9897F	493.9432F	235.7177F	-9.0565F	4.2277F	4.0753F	2.4394P	-6.3079P
Csd	260.7333A	-435.4206A	640.0103A	59.2846A	-2.8440A	-1.6806A	247.9995F	534.2815A
Csg	-86.6163F	-195.6225F	-196.8551F	-157.0237F	-5.4232F	-5.4246F	-4.1434P	-6.9673P
Css	158.9338F	439.8466F	332.0719F	170.8153F	8.1123F	8.0521F	5.7215P	7.1674P
Csb	-72.5782F	-243.7887F	-135.8568F	-13.8508F	-2.6863F	-2.6259F	-1.8260P	-200.5677F
Cbd	-479.7220A	-280.0632A	-1.1276F	-78.9915A	-19.0495A	-20.1618A	-192.3838F	-1.5922F
Cbg	-31.8965F	-73.8995F	-72.9244F	-48.7450F	-2.4379F	-2.4362F	-1.2117P	-6.8063P
Cbs	22.2097F	80.5454F	38.0561F	12.0659F	1.3121F	1.2800F	191.4134F	98.8701F
Cbb	10.1666F	-6.3659F	35.9959F	36.7581F	1.1448F	1.1764F	1.2127P	6.7091P
PHI	858.8477M	858.8477M	858.8477M	858.8477M	858.8477M	858.8477M	858.8477M	858.8477M
VBI	1.0154	1.0154	1.0154	1.0154	1.0154	1.0154	1.0154	1.0154
Region	saturation	saturation	saturation	saturation	saturation	saturation	saturation	saturation
VTH_D	340.8058M	234.8667M	233.6456M	185.9586M	82.4550M	82.4232M	231.1075M	-82.8126M

MODEL	CMOSN	CMOSN	CMOSN	CMOSN	CMOSN	CMOSN
MFACTOR	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
ID	439.5431U	385.6267U	4.1653M	385.6266U	443.0937U	385.6266U
Ibd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ibs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
IG	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
IS	439.5431U	385.6272U	4.1653M	385.6267U	443.0937U	385.6267U
IB	-3.1890P	-1.2824N	-1.0809P	-114.5862P	-3.5543P	-114.5862P
VGS	401.9985M	213.5346M	529.9743M	299.9989M	401.9985M	299.9989M
VDS	637.8050M	343.0352M	640.8850M	286.4654M	710.8550M	286.4654M
VBS	0.0000	-286.4654M	-220.0257M	0.0000	0.0000	0.0000
VTH	167.6372M	296.3472M	344.0158M	254.8475M	167.4155M	254.8475M
VDSAT	177.4755M	40.6336M	120.4859M	47.7958M	177.6756M	47.7958M
GM	5.0634M	10.5585M	54.6863M	9.3060M	5.0888M	9.3060M
GDS	49.1090U	127.8122U	1.1919M	151.4161U	48.1779U	151.4161U
RON	20.3629K	7.8240K	839.0055	6.6043K	20.7564K	6.6043K
GMB	5.7514M	1.4854M	6.9806M	5.3551M	6.3742M	5.3551M
Cdd	19.8122F	5.6364P	60.6449F	235.8508F	19.7438F	235.8508F
Cdg	-195.7926F	-6.9673P	-157.0237F	-782.8897F	-195.6985F	-782.8897F
Cds	374.8997F	1.5315P	110.2297F	868.7361F	394.5421F	868.7361F
Cdb	-198.9193F	-200.5677F	-13.8508F	-321.6972F	-218.5875F	-321.6972F
Cgd	-19.1221F	-5.6353P	-60.6252F	-232.6773F	-19.0392F	-232.6773F
Cgg	465.3492F	20.7410P	362.7925F	1.9340P	465.2357F	1.9340P
Cgs	-833.0545F	-8.7978P	-293.1108F	-2.1677P	-879.9931F	-2.1677P
Cgb	386.8274F	-6.3079P	-9.0565F	466.3295F	433.7966F	466.3295F
Csd	-315.7296A	534.2815A	59.2846A	-784.0614A	-384.0958A	-784.0614A
Csg	-195.7926F	-6.9673P	-157.0237F	-782.8897F	-195.6985F	-782.8897F
Css	395.0277F	7.1674P	170.8153F	1.1054P	414.6701F	1.1054P
Csb	-198.9193F	-200.5677F	-13.8508F	-321.6972F	-218.5875F	-321.6972F
Cbd	-374.3863A	-1.5922F	-78.9915A	-2.3895F	-320.5084A	-2.3895F
Cbg	-73.7639F	-6.8063P	-48.7450F	-368.2646F	-73.8387F	-368.2646F
Cbs	63.1271F	98.8701F	12.0659F	193.5892F	70.7809F	193.5892F
Cbb	11.0112F	6.7091P	36.7581F	177.0648F	3.3784F	177.0648F
PHI	858.8477M	858.8477M	858.8477M	858.8477M	858.8477M	858.8477M
VBI	1.0154	1.0154	1.0154	1.0154	1.0154	1.0154
Region	saturation	saturation	saturation	saturation	saturation	saturation
VTH_D	234.3613M	-82.8126M	185.9586M	45.1514M	234.5830M	45.1514M

	M14	M24	M11	M10	M26
MODEL	CMOSP	CMOSP	CMOSP	CMOSP	CMOSP
MFACTOR	1.0000	1.0000	1.0000	1.0000	1.0000
ID	-5.9081U	-439.5431U	-385.6278U	-385.6271U	-443.0937U
Ibd	465.5181F	6.6220P	1.3410N	53.8088P	5.8914P
Ibs	0.0000	0.0000	538.0877P	0.0000	0.0000
IG	0.0000	0.0000	0.0000	0.0000	0.0000
IS	-5.9081U	-439.5431U	-385.6274U	-385.6271U	-443.0937U
IB	232.7590F	3.3110P	939.5433P	26.9044P	2.9457P
VGS	-500.0000M	-662.1950M	-330.9562M	-439.0893M	-589.1450M
VDS	-232.7590M	-662.1950M	-401.4556M	-269.0438M	-589.1450M
VBS	0.0000	0.0000	269.0438M	0.0000	0.0000
VTH	-274.7819M	-237.0700M	-326.9365M	-297.5408M	-238.5346M
VDSAT	-203.6997M	-381.3855M	-62.3778M	-142.0654M	-322.6350M
GM	45.1507U	1.8584M	8.5805M	4.5435M	2.2776M
GDS	4.0717U	53.3927U	243.4902U	149.6358U	63.4643U
RON	245.5961K	18.7292K	4.1069K	6.6829K	15.7569K
GMB	5.7295U	256.0580U	957.9472U	574.0082U	315.2824U
Cdd	591.1016A	19.8244F	521.9699F	52.1851F	28.1087F
Cdg	-3.0674F	-236.7208F	-1.4405P	-222.4395F	-335.4601F
Cds	2.8001F	245.6275F	1.0223P	192.1442F	348.5290F
Cdb	-323.8079A	-28.7312F	-103.7959F	-21.8898F	-41.1775F
Cgd	-524.0940A	-14.2087F	-484.5190F	-46.9317F	-20.2075F
Cgg	7.2894F	557.6098F	3.6295P	533.0073F	788.7255F
Cgs	-6.4975F	-527.9652F	-2.7698P	-466.4929F	-745.7227F
Cgb	-267.7917A	-15.4359F	-375.2206F	-19.5828F	-22.7953F
Csd	47.9016A	-3.4556F	-21.2301F	-2.1349F	-4.8713F
Csg	-3.0674F	-236.7208F	-1.4405P	-222.4395F	-335.4601F
Css	3.3433F	268.9075F	1.5655P	246.4642F	381.5090F
Csb	-323.8079A	-28.7312F	-103.7959F	-21.8898F	-41.1775F
Cbd	-114.9091A	-2.1602F	-16.2209F	-3.1185F	-3.0298F
Cbg	-1.1547F	-84.1683F	-748.4908F	-88.1284F	-117.8053F
Cbs	354.2057A	13.4302F	181.8994F	27.8845F	15.6848F
Cbb	915.4076A	72.8982F	582.8123F	63.3624F	105.1503F
PHI	888.2684M	888.2684M	888.2684M	888.2684M	888.2684M
VBI	1.0301	1.0301	1.0301	1.0301	1.0301
Region	saturation	saturation	saturation	saturation	saturation
VTH_D	225.2181M	425.1251M	4.0197M	141.5486M	350.6104M

1d AC magnitude and phase Vout/Vin:

3db BW = 233 MHz

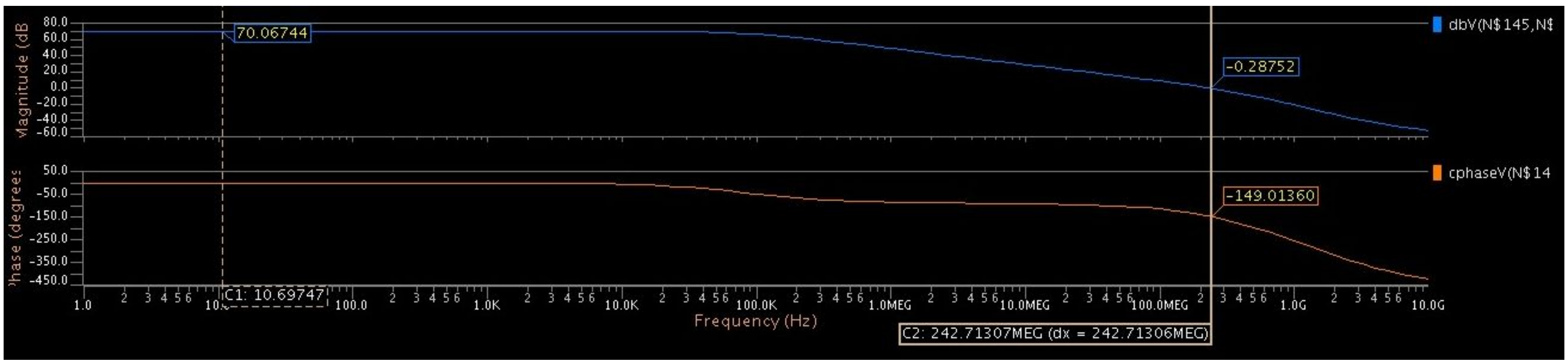


1e Differential Loop Gain :

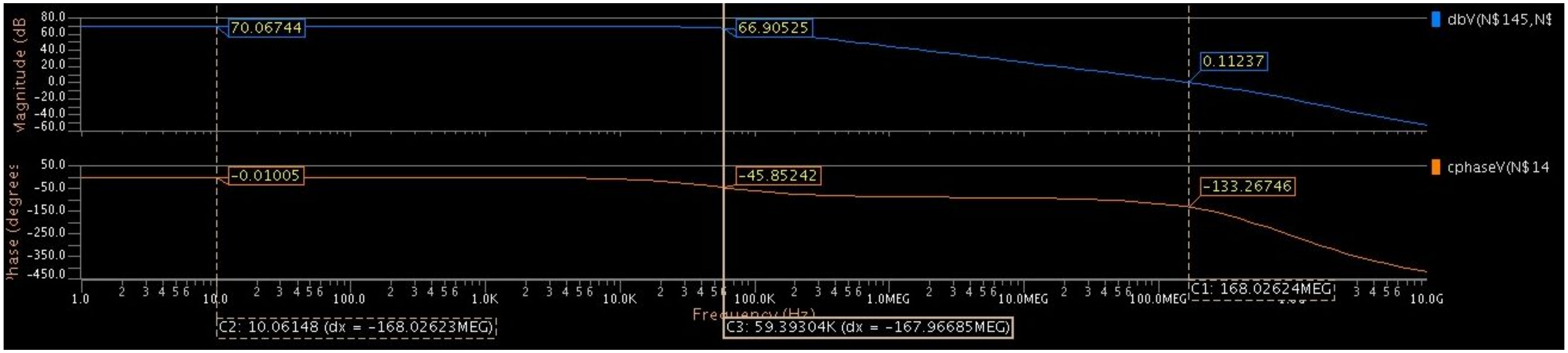
Before Compensation:

PM=31^0

Wu = 242.7 MegaHz



After Compensation:

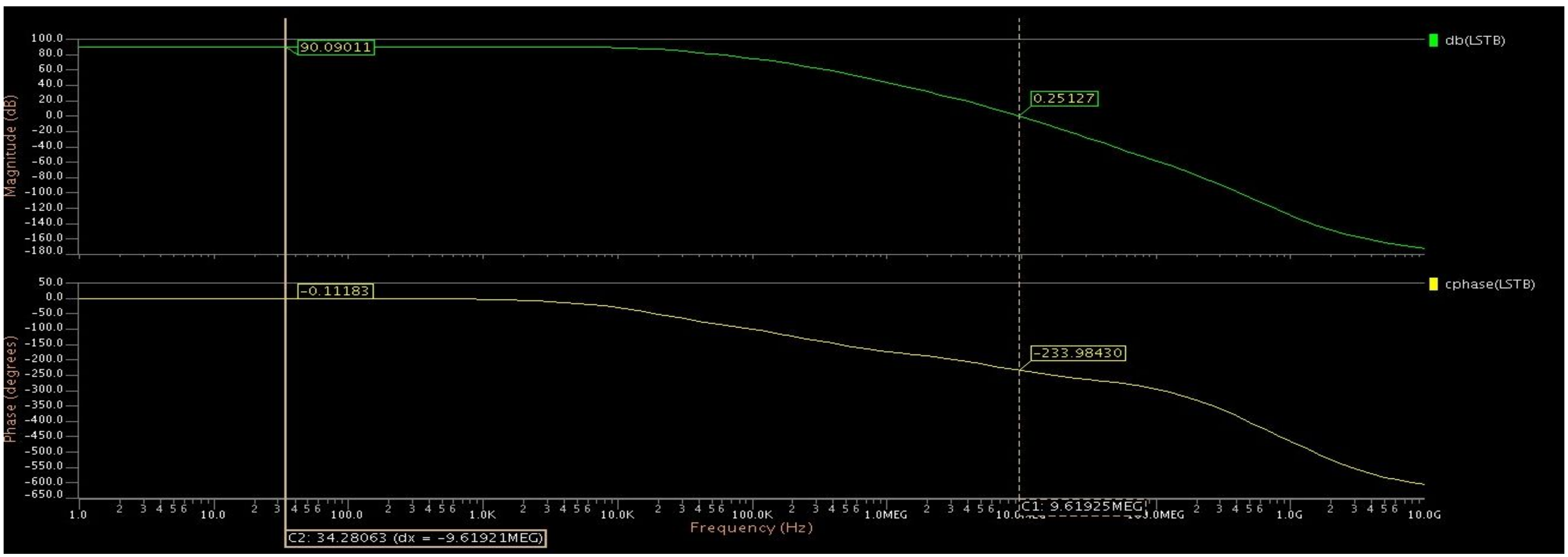


PM=47^0

Wu = 170 MegaHz

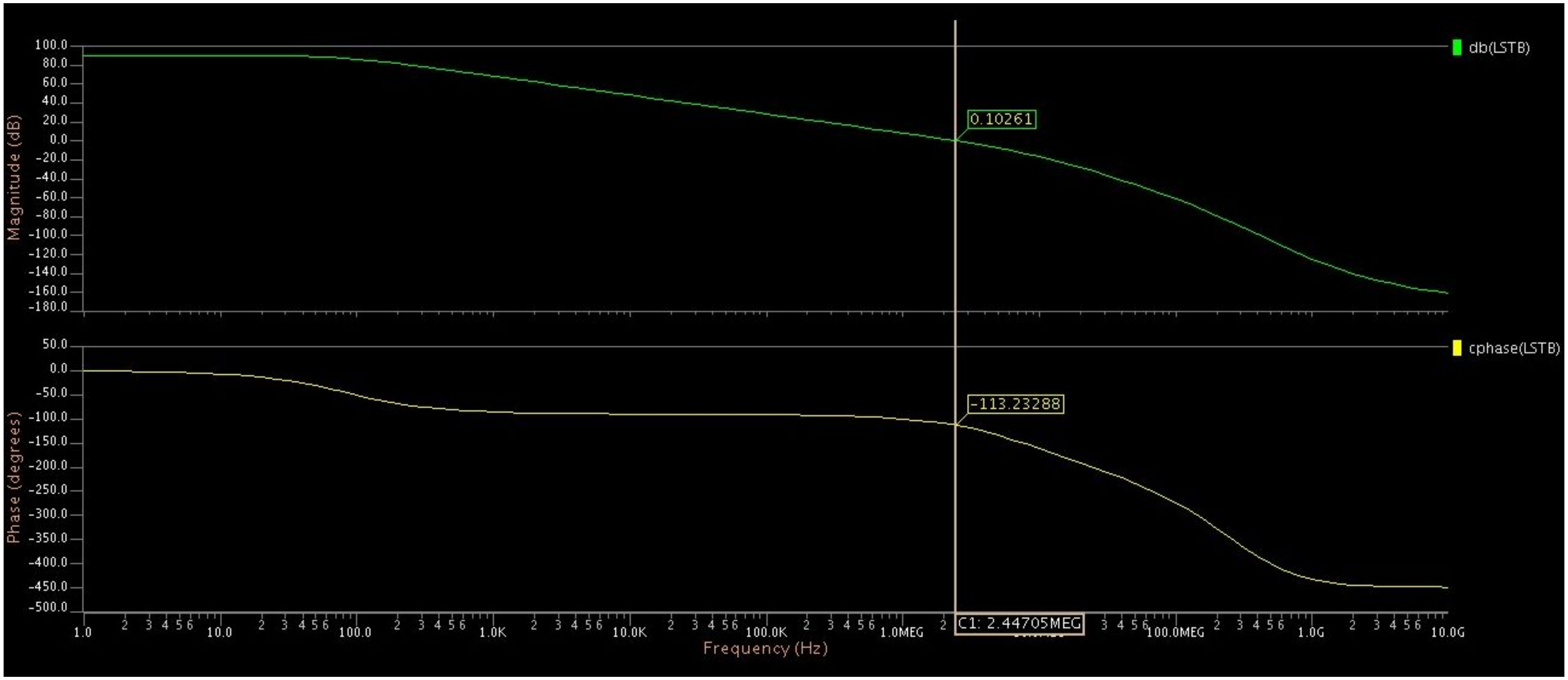
1f CMFB LSTB:

Before Compensation:



-ve PM
Wu = 9.16 MegaHz

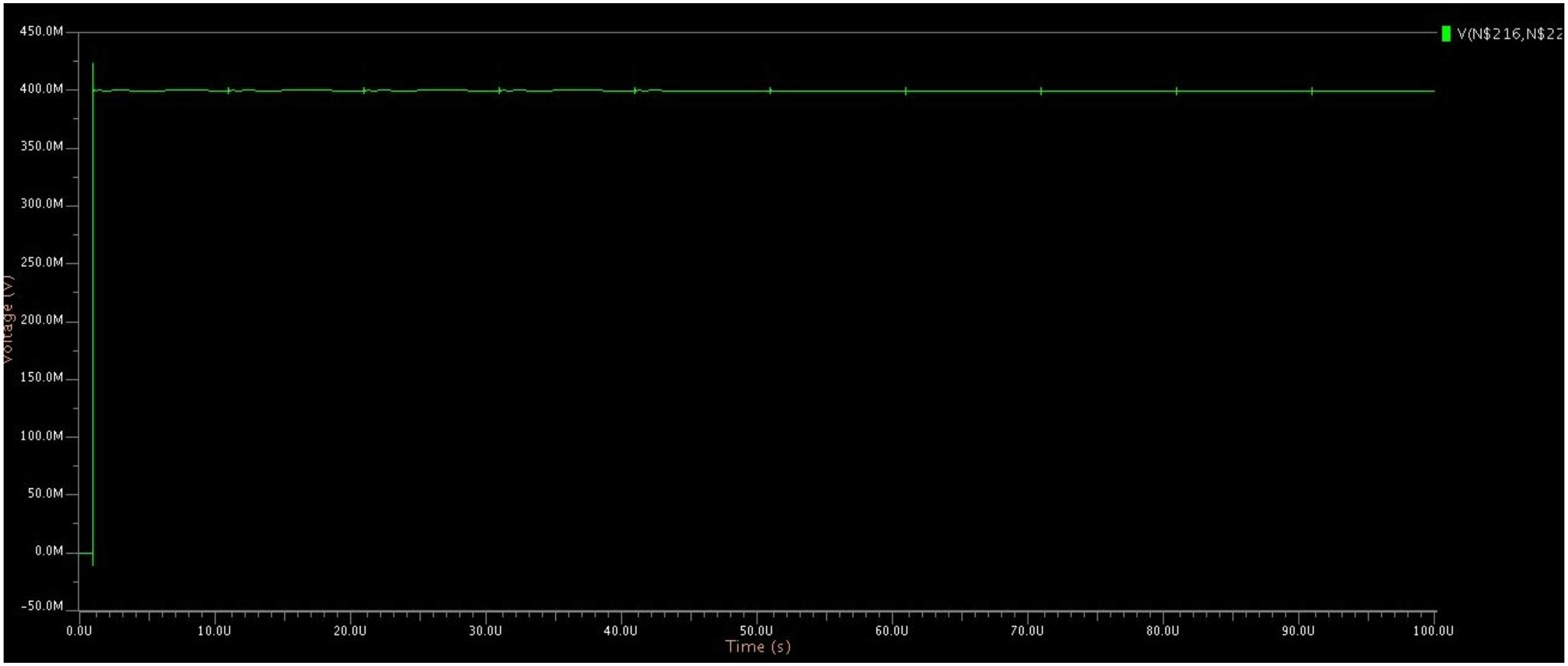
After Compensation:

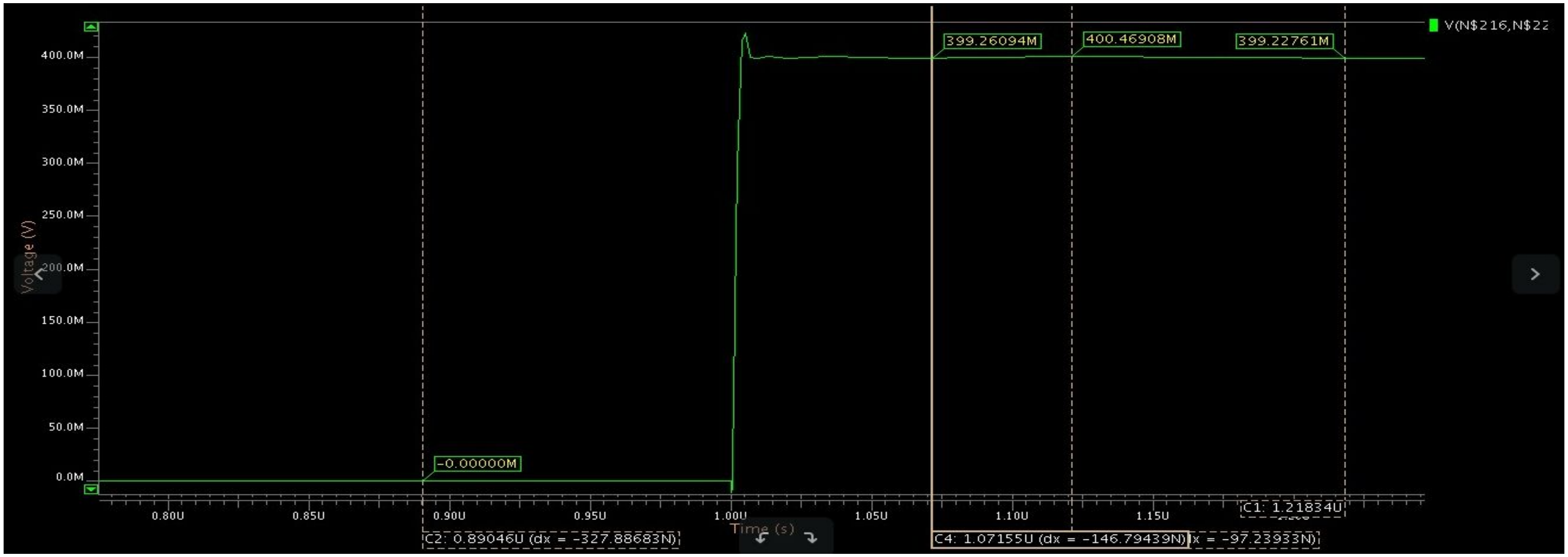


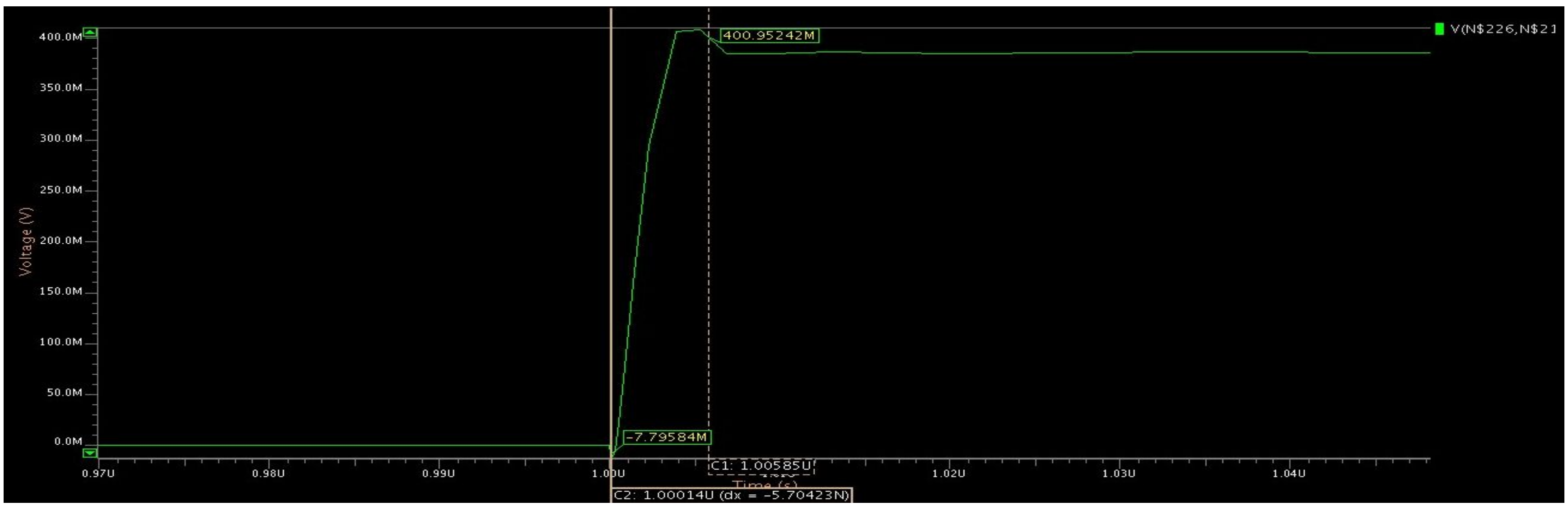
PM=67^0
Wu = 2.44 MegaHz

1g Differential Step Responses:

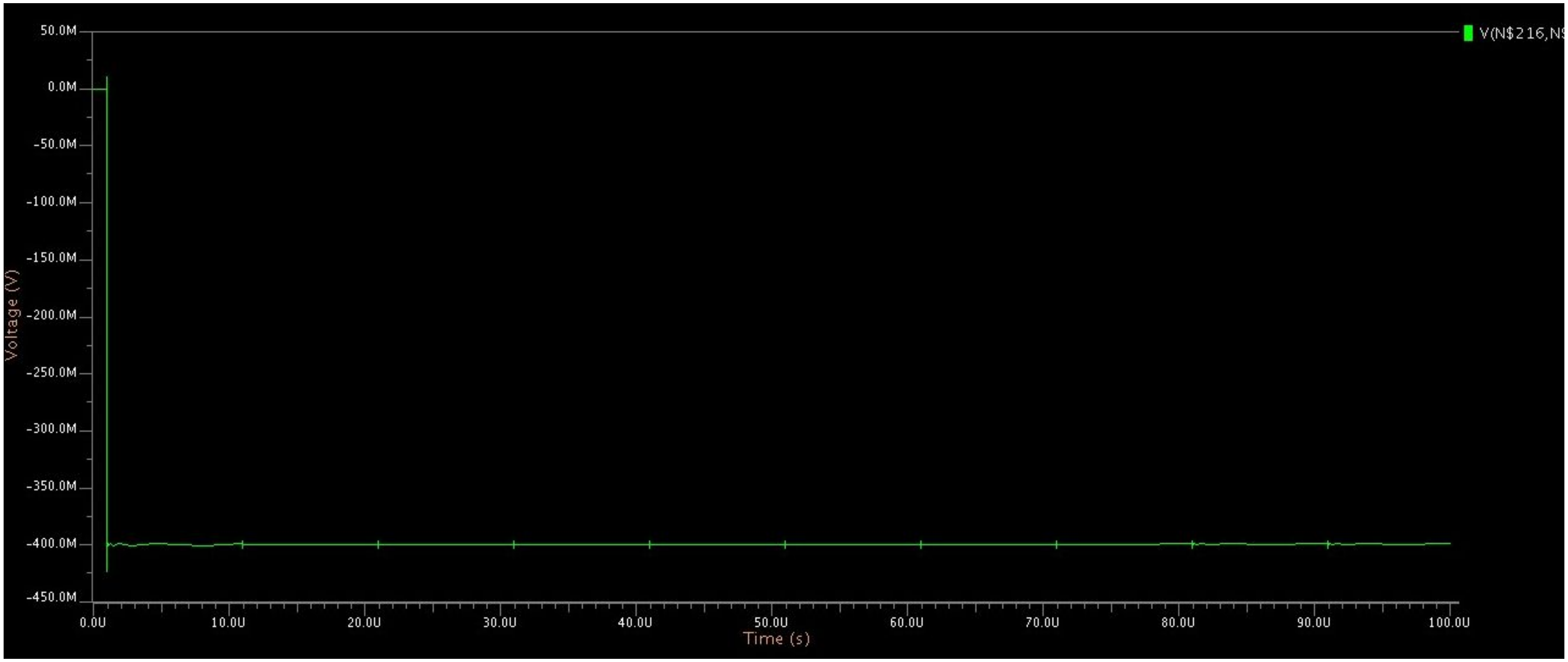
+ve step response:(in order of zoom in)

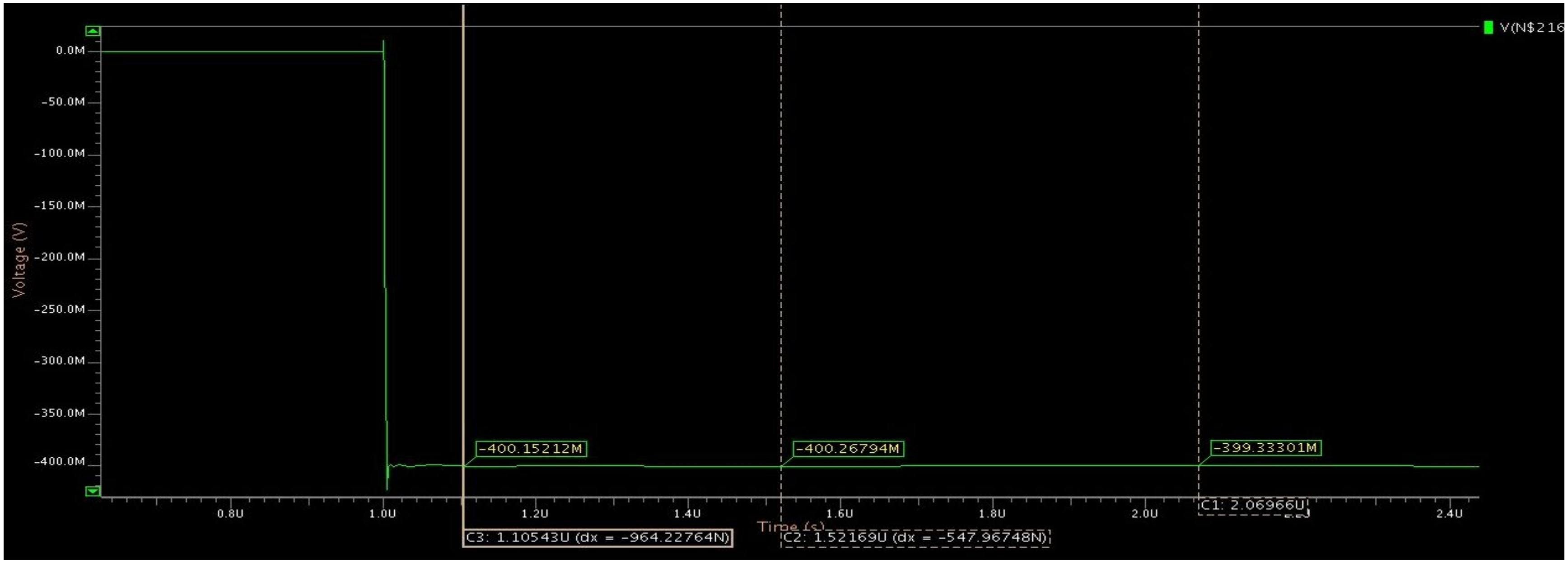


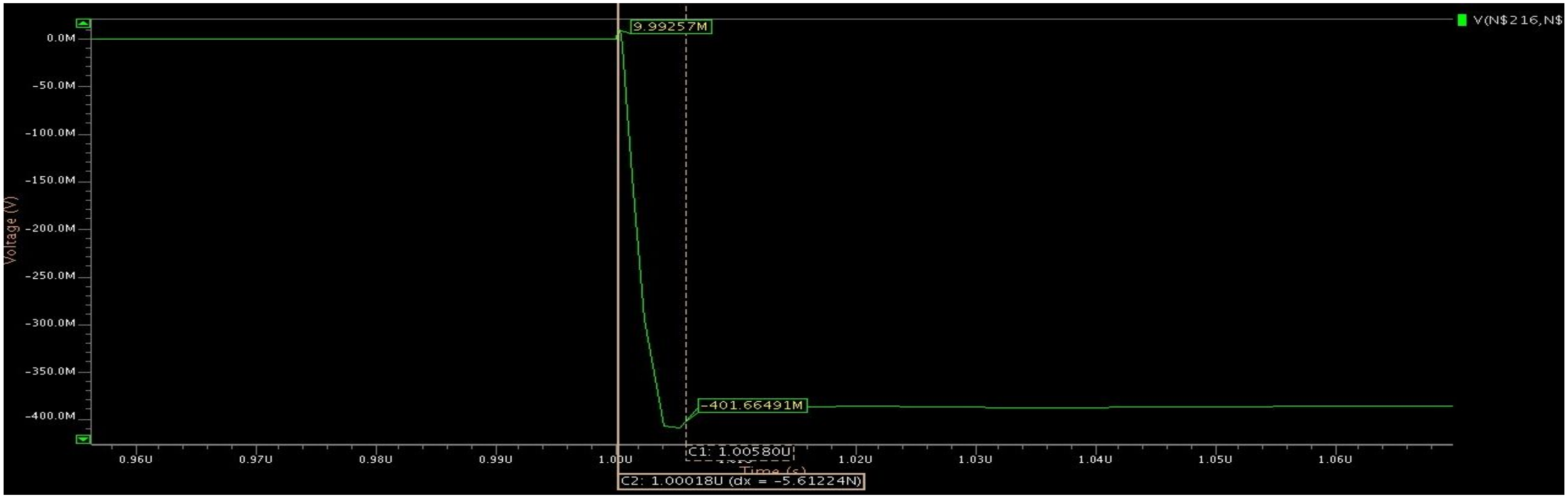

V(N$216,N$22
399.26094M
400.46908M
399.22761M
-0.00000M
Voltage (V)
Time (s)
C2: 0.89046U (dx = -327.88683N)
C4: 1.07155U (dx = -146.79439N)
x = -97.23933N)
C1: 1.21834U


V(N$226,N$21
400.95242M
-7.79584M
Voltage (V)
C1: 1.00585U
C2: 1.00014U (dx = -5.70423N)

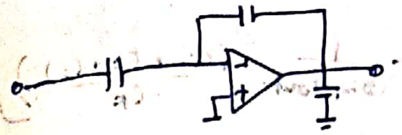
-ve step response:(in order of zoom in)

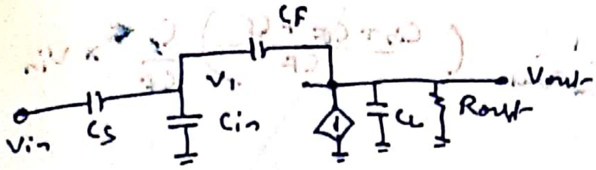



V(N$216
0.0M
-50.0M
-100.0M
-150.0M
-200.0M
-250.0M
-300.0M
-350.0M
-400.0M
Voltage (V)
-400.15212M
-400.26794M
-399.33301M
0.8U
1.0U
1.2U
1.4U
1.6U
1.8U
2.0U
2.4U
C1: 2.06966U
Time (s)
C3: 1.10543U (dx = -964.22764N)
C2: 1.52169U (dx = -547.96748N)


V(N$216,N$
9.99257M
0.0M
-50.0M
-100.0M
-150.0M
-200.0M
-250.0M
-300.0M
-350.0M
-400.0M
Voltage (V)
-401.66491M
C1: 1.00580U
0.96U
0.97U
0.98U
0.99U
1.00U
1.02U
1.03U
1.04U
1.05U
1.06U
Time (s)
C2: 1.00018U (dx = -5.61224N)

1a)





$$(V_{in}-V_1)sC_s = V_1 sC_{in} + (V_1 - V_{out})sC_F$$

$$(V_1 - V_{out})sC_F = V_{out} sC_L + \frac{V_{out}}{R_{out}} + g_m V_1$$

$$\Rightarrow V_1(sC_F - g_m) = V_{out}\left(sC_L + \frac{1}{R_{out}} + sC_F\right)$$

$$\Rightarrow V_{in} sC_s + V_{out} sC_F = V_1(sC_{in} + sC_F + sC_s)$$

$$\Rightarrow V_{in} sC_s + V_{out} sC_F = V_{out}\frac{\left(s(C_L+C_F)+\frac{1}{R_{out}}\right)s(C_{in}+C_F+C_s)}{(sC_F - g_m)}$$

$$\Rightarrow V_{out}\left[\frac{\left(s(C_L+C_F)+\frac{1}{R_{out}}\right)\cancel{s}(C_{in}+C_F+C_s)}{sC_F-g_m} - \cancel{s}C_F\right] = V_{in}\cancel{s}C_s$$

$$\Rightarrow V_{out}\left[\left(\frac{s(C_L+C_F)+\frac{1}{R_{out}}}{sC_F-g_m}\right)(C_{in}+C_F+C_s) - C_F\right] = V_{in}C_s$$

$$\frac{V_{out}}{V_{in}} = \frac{C_s(sC_F-g_m)}{\left(s(C_L+C_F)+\frac{1}{R_{out}}\right)(C_{in}+C_F+C_s) - (sC_F-g_m)C_F}$$

DC gain $\frac{V_{out}}{V_{in}}(0) = -\frac{g_m C_s}{\frac{1}{R_{out}}(C_{in}+C_F+C_s) + g_m C_F}$

$$= -\frac{g_m R_{out} C_s}{(C_{in}+C_F+C_s) + g_m R_{out} C_F}$$

$$= -\frac{C_s}{C_F}\cdot\frac{1}{\frac{(C_{in}+C_F+C_s)}{g_m R_{out} C_F}+1}$$

zero $= +\frac{g_m}{C_F}$, pole $= -\frac{g_m C_F + \frac{1}{R_{out}}(C_{in}+C_F+C_s)}{(C_L+C_F)(C_{in}+C_F+C_s) - C_F^2}$

$$[\text{static error}] = \left[\frac{C_S}{C_F} - \frac{C_S}{C_F}\left(1 - \frac{1}{g_m R_{out}} \left(\frac{C_{in} + C_F + C_S}{C_F} \right)\right)\right] V_{in}$$

$$= \frac{1}{g_m R_{out}} \left(\frac{C_{in} + C_F + C_S}{C_F}\right) \frac{C_S}{C_F} V_{in} \leq 800\mu V$$

$$\Rightarrow \frac{1}{A_0} (1 + 4) 4 \; 100 \;\cancel{m} < 0.8 \;\cancel{m}$$

$$\Rightarrow A_0 > 2500$$

$$\Rightarrow A_0 > 67.95\,dB$$

b) $C_L = 2pF$; $C_S = 2pF$

Open loop DC gain $> 67.95\ dB$

Assuming 2^{nd} order opamp ;

$$A(s) = \frac{A_0}{(1 + \frac{s}{\omega_1})(1 + \frac{s}{\omega_2})}$$

$A\beta = -1$

$$\Rightarrow A_0\beta = -(1 + \frac{s}{\omega_1})(1 + \frac{s}{\omega_2})$$

$$\Rightarrow \frac{s^2}{\omega_1\omega_2} + s\left(\frac{1}{\omega_1} + \frac{1}{\omega_2}\right) + 1 + A_0\beta = 0$$

$$\Rightarrow s^2 + (\omega_1 + \omega_2)s + (1 + A_0\beta)\omega_1\omega_2 = 0$$

$$\Rightarrow s^2 + 2\xi\omega_n s + \omega_n^2 = 0 \Rightarrow \omega_n = \sqrt{(1 + A_0\beta)\omega_1\omega_2}$$

$$\& \; \xi\omega_n = \frac{\omega_1 + \omega_2}{2}$$

for a 2% settling time, for $\omega_n << 1$; T_s = settling time $= \frac{3.9}{\xi\omega_n}$

[assuming zero is very far]

$$\because T_S \leq 5ns \Rightarrow \frac{3.9}{\xi\omega_n} \leq 5n \Rightarrow \xi\omega_n \geq 0.78\,GHz$$

$$\Rightarrow \frac{\omega_1 + \omega_2}{2} \geq 0.78\,GHz$$

$$\Rightarrow \omega_1 + \omega_2 \geq 1.56\,GHz$$

$\because$ min T_s is achieved with PM = 60°; $\Rightarrow$

$\tan^{-1}\left(\frac{\omega_0}{\omega_2}\right) = 60°$

$\therefore$ $\omega_2 \simeq 1.5$ GHz ; $\omega_0 \simeq 0.9$ GHz.

for $\omega_0 < 0.9$ GHz; the PM will decrease

c)

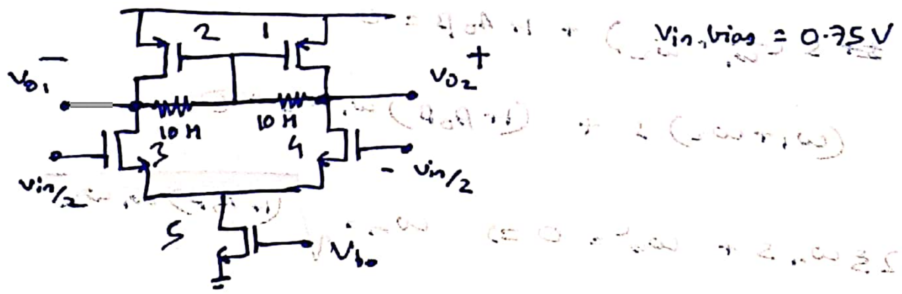
$\because$ $A_0 > 68$ dB ; & ω_0 is in MHz range;

Using a single stage opamp does not work $\because$ it gives a $A_0 \approx 20$ dB (approx).

Hence using a 2 stage opamp is necessary or a telescopic opamp. Due to the swing constraints however biasing a telescopic opamp becomes extremely difficult. Hence we will stick to the 2-stage opamp.

1st stage;

for ease of biasing; we shall consider the configuration of.



We choose device sizes so as to
1) have high bandwidths
2) bias PMOS o/p stage of 2nd stage
3) have optimal gain $\simeq 20$ dB.

$V_{b0} = 0.4$ V

$W_2 = W_1 = 150u$

$L_2 = L_1 = 0.2u$

$M_2 = M_1 = 10$

$W_3 = W_4 = 150u$

$L_3 = L_4 = 0.2u$

$M_3 = M_4 = 1$

$W_5 = 100\mu$

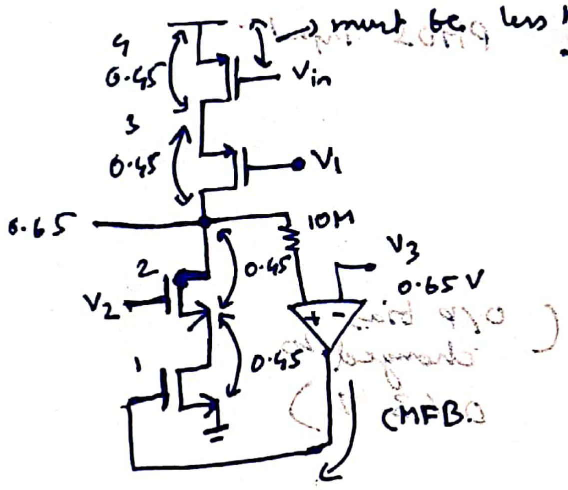
$L_5 = 1\mu$

$M_5 = 10$

low L ensures higher cut off frequency; ∵ current burnt is supposed to be large, it is better to invest in higher W than higher M.

O/P bias is around = 0.862 V

However even after using the 2nd stage gain obtained was ≃ 60dB; hence we use a cascoded 2nd stage for gain.



∵ O/P swing is ± 200mV; it is safer to bias O/P at 0.65 V.

V_{in} is biased at 0.862 V from previous 2nd stage.

Taking $V_1 = 0.7$ V
$V_2 = 0.5$ V

the device sizes were adjusted to keep all in saturation.

$W_4 = W_3 = 1.4\mu$
$L_4 = L_3 = 0.35\mu$
$M_4 = 100$;
$M_3 = 1000$

$W_1 = 1.5\mu$
$W_2 = 10\mu$
$L_1 = 0.35\mu = L_2$
$M_1 = 400$
$M_2 = 1400$

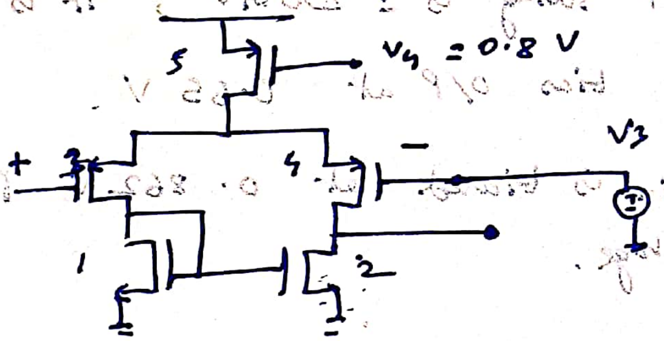
Without compensation;

PM = 31°

gain = 70 dB.

CMFB

∵ an NMOS is driven ; we will use PMOS input pair.



(O/P bias changed to 0.63 V)

$W_1 = W_2 = 1.4u$
$L_1 = L_2 = 0.5u$
$M_1 = M_2 = 2$

$W_3 = W_4 = 1.4\mu$
$L_3 = L_4 = 0.5u$
$M_3 = M_4 = 1$

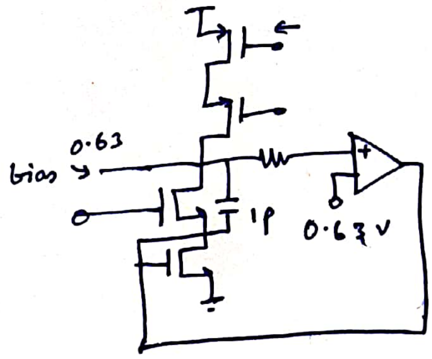
$W_5 = 1.4u$
$M_5 = 1$
$L_5 = 0.5u$

O/P bias is at 300mV.

Without compensation; DC gain = 90 dB &

Phase M = $-53^\circ \rightarrow$ unstable

We use miller compensation.



$\omega_{U_{CMFB}} \simeq$ 3 Meg Hz

DC gain = 90 dB.

& PM = 67°

For the differential circuit

DC gain = 70 dB [Opamp's A_0 = 82 dB]

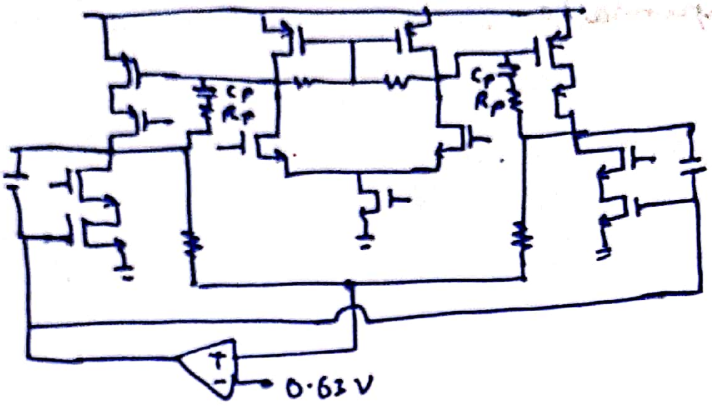
PM = 31°

$\omega_{U_{CMFB}}$ = 242 Meg.

After applying a step however $T_s \simeq 7.9$ nS.

$\therefore$ we shall compensate the differential 2^{nd} stage by using pole-splitting.

$C_p = 2p$
$R_p = 1k$



After compensation;

$T_s = 5.5\,nS$

PM = 47°

DC gain = 70 dB

3dB BW = 232 MHz

CLG = 12 dB

Current Mirrors