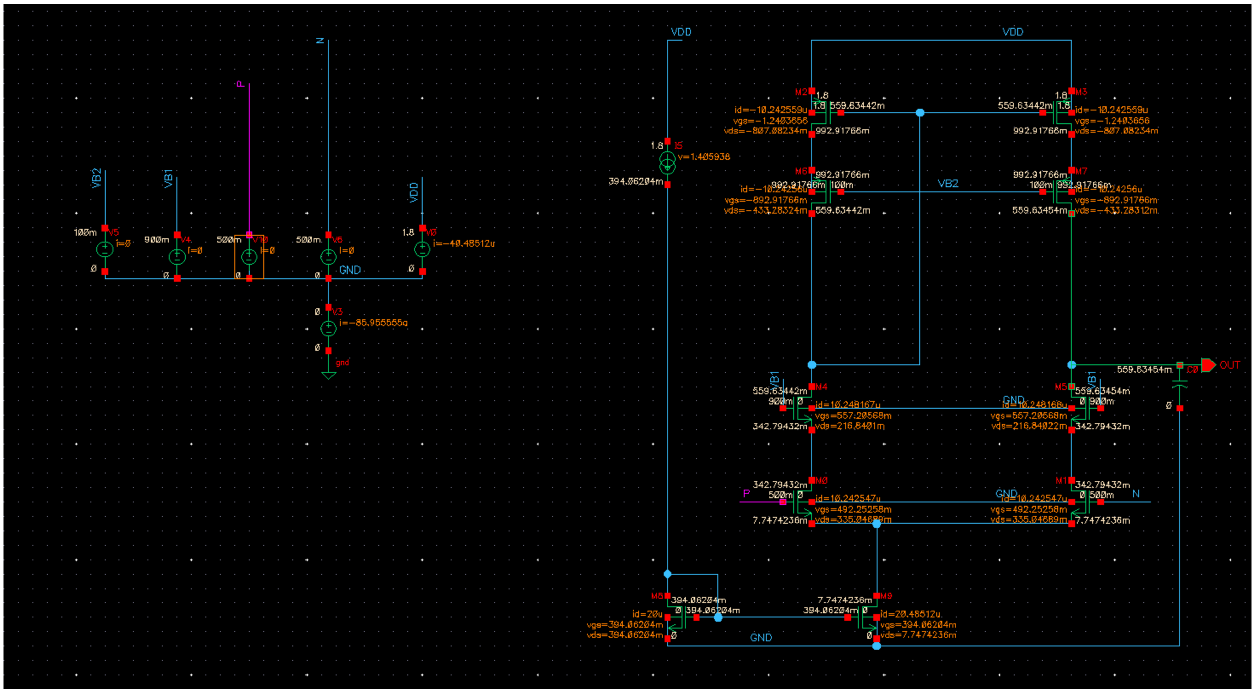
M L SRIHARSHA 2020EEN2501

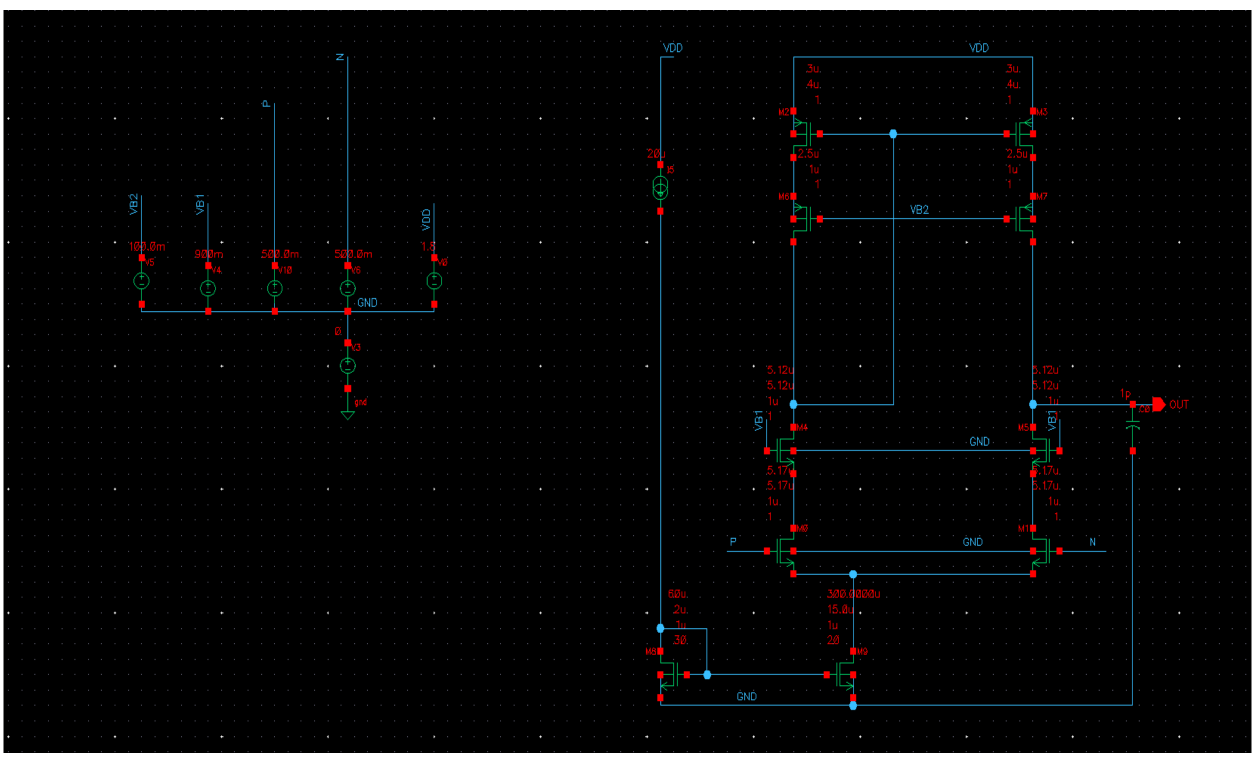
OBJECTIVE:

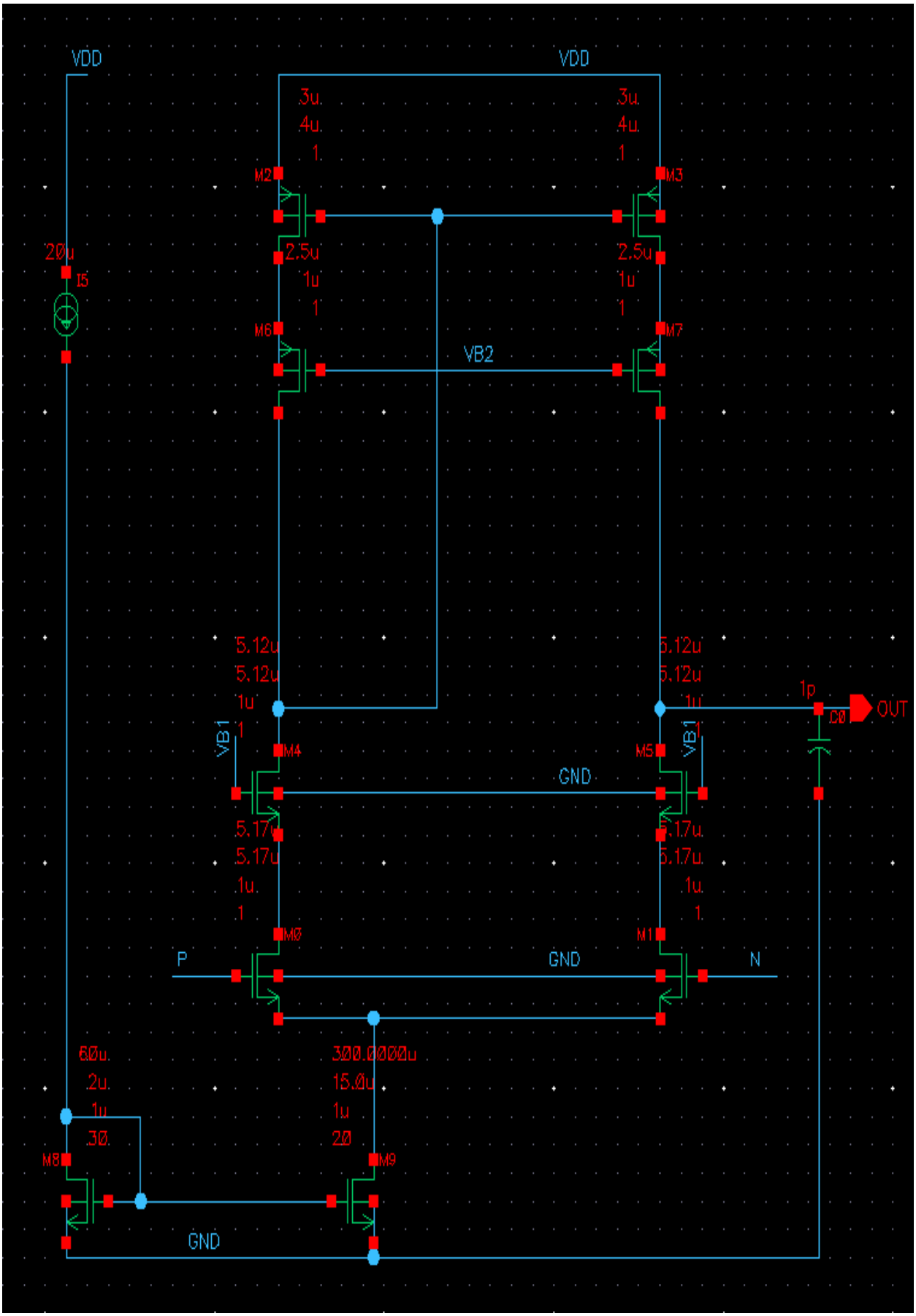
Use 180 nm CMOS process with 1.8V power supply

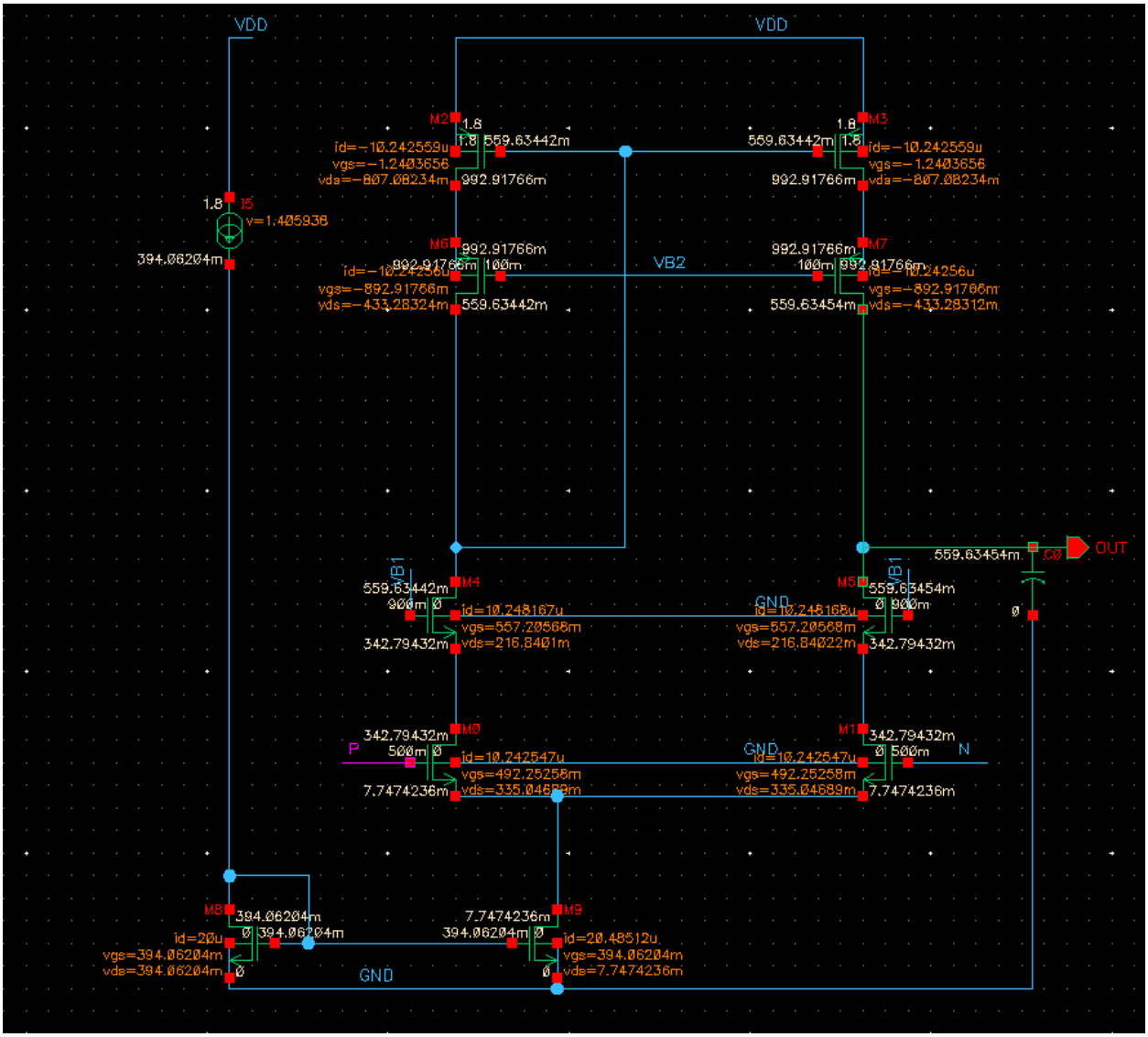
1. 40 dB DC Gain
2. 100 MHz UGB
3. phase Margin should be better than 60°.
4. Output load = 1pF
5. Slew Rate : 10^6 V/s
6. Total current : 20 μA

You should also be able to achieve 84 dB SNR in 24 kHz BW.


VB2
VB1
P
N
VDD
GND
gnd
M0
M1
M2
M3
M4
M5
M6
M7
M8
M9
I5
V3
VB2
VB1
OUT


VB2
VB1
P
N
VDD
GND
gnd
I5
V3
M0
M1
M2
M3
M4
M5
M6
M7
M8
M9
VB2
VB1
OUT
20u
1p


VDD
VDD
3u.
4u.
1.
M2
M3
20u
I5
2.5u
1u
1
M6
M7
VB2
5.12u
5.12u
1u
1
M4
M5
VB1
GND
1p
C0
OUT
5.17u
1u.
M0
M1
P
GND
N
60u.
.2u.
1u
.30
M8
300.0000u
15.0u
1u
20
M9
GND



DC operation points in table for source

signal OP("/V5" "??")	signal OP("/V4" "??")	signal OP("/V10" "??")	signal OP("/V1" "??")	signal OP("/V6" "??")	signal OP("/V3" "??")	signal OP("/V0" "??")	signal OP("/I5" "??")
i 0	i 0	i 0	i 0	i 0	i -86.697608a	i -40.48512u	i 20u
pwr 0	pwr 0	pwr 0	pwr 0	pwr 0	pwr -0	pwr -72.873215u	pwr 28.118759u
v 100m	v 900m	v 500m	v 0	v 500m	v 0	v 1.8	v 1.405938

DC operation points in table for mosfet

signal OP("/M8" "??")	signal OP("/M0" "??")	signal OP("/M4" "??")	signal OP("/M2" "??")	signal OP("/M6" "??")	signal OP("/M9" "??")	signal OP("/M7" "??")	signal OP("/M3" "??")	signal OP("/M1" "??")	signal OP("/M5" "??")	signal OP("/C0" "??")
beff 20.302713	beff 1.9320107m	beff 1.9632637m	beff 34.537545u	beff 131.49723u	beff 994.21028m	beff 131.49724u	beff 34.537545u	beff 1.9320107m	beff 1.9632637m	cap 1p
betaeff 17.7838m	betaeff 1.5414003m	betaeff 1.535164m	betaeff 38.596582u	betaeff 141.95031u	betaeff 89.295248m	betaeff 141.95031u	betaeff 38.596582u	betaeff 1.5414003m	betaeff 1.535164m	
fug 239.93393M	fug 627.31035M	fug 636.42508M	fug 49.224494M	fug 431.05342M	fug 31.39254M	fug 431.05348M	fug 49.224494M	fug 627.31035M	fug 636.42494M	
gbd 0	gbd 0	gbd 0	gbd 0	gbd 0	gbd 0	gbd 0	gbd 0	gbd 0	gbd 0	
gbs 3.2916086n	gbs 0	gbs 0	gbs 26.397284p	gbs 26.626759p	gbs 2.1835416n	gbs 26.626759p	gbs 26.397284p	gbs 0	gbs 0	
gds 4.9299058u	gds 2.0431925u	gds 3.7794728u	gds 396.23793n	gds 1.755531u	gds 2.4677082m	gds 1.755525u	gds 396.23789n	gds 2.0431924u	gds 3.7794831u	
gm 428.08276u	gm 140.42947u	gm 140.32877u	gm 23.937259u	gm 45.106832u	gm 332.66005u	gm 45.106837u	gm 23.937259u	gm 140.42947u	gm 140.32874u	
gmb 89.277278u	gmb 28.446505u	gmb 23.756101u	gmb 8.3300695u	gmb 14.295062u	gmb 71.484779u	gmb 14.295064u	gmb 8.3300695u	gmb 28.446505u	gmb 23.756096u	
gmbs 89.277278u	gmbs 28.446505u	gmbs 23.756101u	gmbs 8.3300695u	gmbs 14.295062u	gmbs 71.484779u	gmbs 14.295064u	gmbs 8.3300695u	gmbs 28.446505u	gmbs 23.756096u	

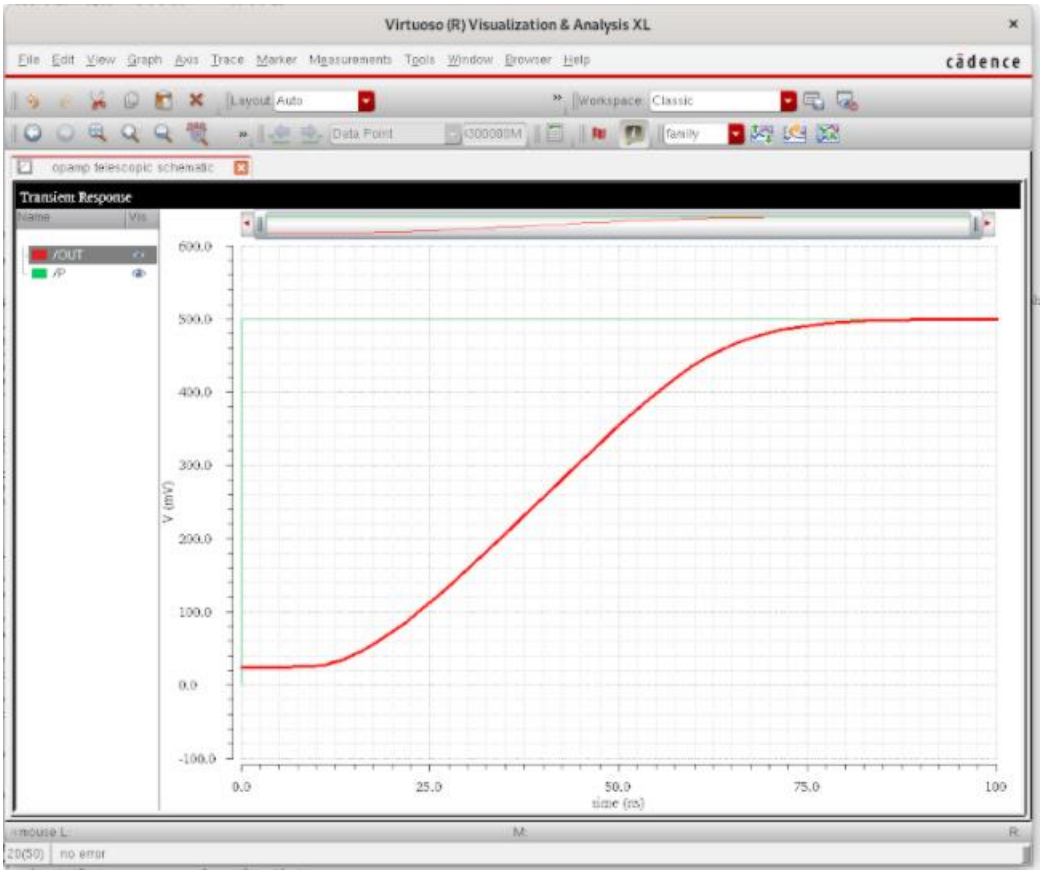
gmoverid 21.404138	gmoverid 13.710406	gmoverid 13.69306	gmoverid 2.337039	gmoverid 4.403863	gmoverid 16.239107	gmoverid 4.4038635	gmoverid 2.337039	gmoverid 13.710406	gmoverid 13.69306
i1 20u	i1 10.242547u	i1 10.248167u	i1 - 10.242559u	i1 - 10.24256u	i1 20.48512u	i1 - 10.24256u	i1 - 10.242559u	i1 10.242547u	i1 10.248166u
i3 -20u	i3 - 10.242547u	i3 - 10.248167u	i3 10.242559u	i3 10.24256u	i3 - 20.485119u	i3 10.24256u	i3 10.242559u	i3 - 10.242547u	i3 - 10.248166u
i4 - 9.7352183f	i4 - 2.2147459f	i4 - 2.1951751f	i4 594.20836a	i4 575.23892a	i4 - 30.729917f	i4 575.23892a	i4 594.20836a	i4 - 2.2147459f	i4 - 2.1951751f
ib NaN	ib NaN	ib NaN	ib NaN	ib NaN	ib NaN	ib NaN	ib NaN	ib NaN	ib NaN
id 20u	id 10.242547u	id 10.248167u	id - 10.242559u	id - 10.24256u	id 20.48512u	id - 10.24256u	id - 10.242559u	id 10.242547u	id 10.248166u
idb 7.4530363f	idb 1.1073729f	idb 1.0975875f	idb 406.74783a	idb 348.33075a	idb 30.419789f	idb 348.33075a	idb 406.74783a	idb 1.1073729f	idb 1.0975875f
ide 20u	ueff 34.906736m	ide 10.248168u	ide - 10.242561u	ide - 10.242561u	ide 20.48512u	ide - 10.242561u	ide - 10.242561u	ide 10.242547u	ide 10.248166u
ids 20u	ids 10.242547u	ids 10.248167u	ids - 10.242559u	ids - 10.24256u	ids 20.485119u	ids - 10.24256u	ids - 10.242559u	ids 10.242547u	ids 10.248166u
is -20u	is - 10.242547u	is - 10.248167u	is 10.242559u	is 10.24256u	is - 20.485119u	is 10.24256u	is 10.242559u	is - 10.242547u	is - 10.248166u
isb 2.282182f	isb 1.1073729f	isb 1.0975875f	isb 187.46053a	isb 226.90817a	isb 310.12876a	isb 226.90817a	isb 187.46053a	isb 1.1073729f	isb 1.0975875f
ise 20u	ise 10.242547u	ise 10.248168u	ise - 10.242559u	ise - 10.24256u	ise 20.48512u	ise - 10.24256u	ise - 10.242559u	ise 10.242547u	ise 10.248166u

isub 0	isub 0	isub 0	isub -0	isub -0	isub 0	isub -0	isub -0	isub 0	isub 0
pwr 7.881 2407u	pwr 3.431 7335u	pwr 2.222 2136u	pwr 8.266 5886u	pwr 4.437 9297u	pwr 158.7 069n	pwr 4.437 9329u	pwr 8.266 5887u	pwr 3.431 7335 u	pwr 2.222 2099u
region 2	region 2	region 2	region 2	region 2	region 2	region 2	region 2	regio n 2	region 2
ron 19.70 3103K	ron 32.71 1288 K	ron 21.15 8915 K	ron 78.79 6943 K	ron 42.30 224K	ron 378.1 9763	ron 42.30 227K	ron 78.79 6944 K	ron 32.71 1288 K	ron 21.15 8886K
rout 202.8 4363K	rout 489.4 3015 K	rout 264.5 8717 K	rout 2.523 7362 M	rout 569.6 2822K	rout 405.2 343	rout 569.6 3017 K	rout 2.523 7364 M	rout 489.4 3016 K	rout 264.5 8645K
self_g ain 86.83 3862	self_g ain 68.73 0419	self_g ain 37.12 9192	self_g ain 60.41 1328	self_g ain 25.69 4124	self_g ain 134.8 0527 m	self_g ain 25.69 4215	self_g ain 60.41 1333	self_g ain 68.73 042	self_g ain 37.12 9084
type 0	type 0	type 0	type 1	type 1	type 0	type 1	type 1	type 0	type 0
ueff 34.86 5931 m	ueff 34.90 6736 m	ueff 35.10 5997 m	ueff 5.718 1809 m	ueff 6.212 4729 m	ueff 34.78 4537 m	ueff 6.212 4729 m	ueff 5.718 1809 m	ueff 34.90 6736 m	ueff 35.10 5997 m
vbs 0	vbs - 7.747 4236 m	vbs - 342.7 9432 m	vbs 0	vbs 0	vbs 0	vbs 0	vbs 0	vbs - 7.747 4236 m	vbs - 342.7 9432 m
vdb 394.0 6204 m	vdb 342.7 9432 m	vdb 559.6 3442 m	vdb - 807.0 8234 m	vdb - 433.2 8324 m	vdb 7.747 4236 m	vdb - 433.2 8355 m	vdb - 807.0 8236 m	vdb 342.7 9432 m	vdb 559.6 3409 m
vds 394.0 6204 m	vds 335.0 4689 m	vds 216.8 401m	vds - 807.0 8234 m	vds - 433.2 8324 m	vds 7.747 4236 m	vds - 433.2 8355 m	vds - 807.0 8236 m	vds 335.0 469m	vds 216.8 3977 m

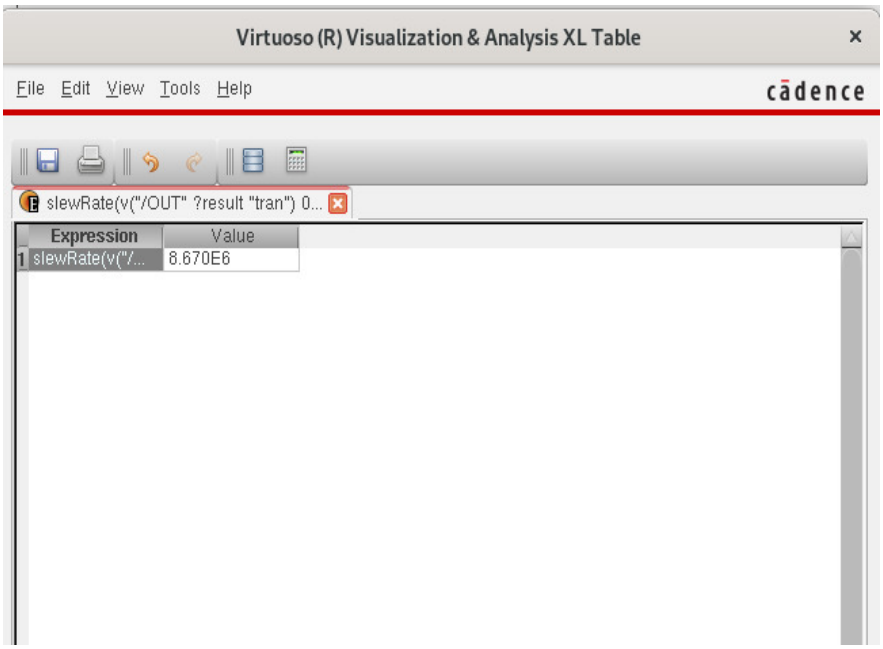
vdsat 64.105226m	vdsat 119.69808m	vdsat 123.41071m	vdsat -656.55699m	vdsat -357.86091m	vdsat 66.565876m	vdsat -357.8609m	vdsat -656.55699m	vdsat 119.69808m	vdsat 123.41071m
vdss 64.105226m	vdss 119.69808m	vdss 123.41071m	vdss -656.55699m	vdss -357.86091m	vdss 66.565876m	vdss -357.8609m	vdss -656.55699m	vdss 119.69808m	vdss 123.41071m
vearly 4.0568727	vearly 5.0130115	vearly 2.7115338	vearly 25.849521	vearly 5.834519	vearly 8.3012731m	vearly 5.8344718	vearly 25.849523	vearly 5.0130116	vearly 2.7115259
vfbeff -934.22806m	vfbeff -938.75343m	vfbeff -935.99979m	vfbeff -993.65101m	vfbeff -967.0875m	vfbeff -942.20662m	vfbeff -967.0875m	vfbeff -993.65101m	vfbeff -938.75343m	vfbeff -935.99979m
vgb 394.06204m	vgb 500m	vgb 900m	vgb -1.2403656	vgb -892.91766m	vgb 394.06204m	vgb -892.91764m	vgb -1.2403656	vgb 500m	vgb 900m
vgd 0	vgd 157.20568m	vgd 340.36558m	vgd -433.28324m	vgd -459.63442m	vgd 386.31462m	vgd -459.63409m	vgd -433.28323m	vgd 157.20568m	vgd 340.36591m
vgs 394.06204m	vgs 492.25258m	vgs 557.20568m	vgs -1.2403656	vgs -892.91766m	vgs 394.06204m	vgs -892.91764m	vgs -1.2403656	vgs 492.25258m	vgs 557.20568m
vgstef f 33.769836m	vgstef f 108.26443m	vgstef f 107.3869m	vgstef f 770.10308m	vgstef f 394.41728m	vgstef f 36.387144m	vgstef f 394.41727m	vgstef f 770.10308m	vgstef f 108.26443m	vgstef f 107.3869m
vgt 1.403631m	vgt 102.97083m	vgt 102.17598m	vgt -770.14684m	vgt -394.69441m	vgt 6.4194102m	vgt -394.6944m	vgt -770.14684m	vgt 102.97083m	vgt 102.17597m

vsat_marg 329.95682m	vsat_marg 215.34882m	vsat_marg 93.429384m	vsat_marg -150.52536m	vsat_marg -75.422334m	vsat_marg -58.818452m	vsat_marg -75.422655m	vsat_marg -150.52537m	vsat_marg 215.34882m	vsat_marg 93.429063m
vth 392.65841m	vth 389.28174m	vth 455.02971m	vth -470.21875m	vth -498.22325m	vth 387.64263m	vth -498.22325m	vth -470.21875m	vth 389.28174m	vth 455.02971m

Q2



Connect negative and output terminal and connect positive terminal to Vpusle

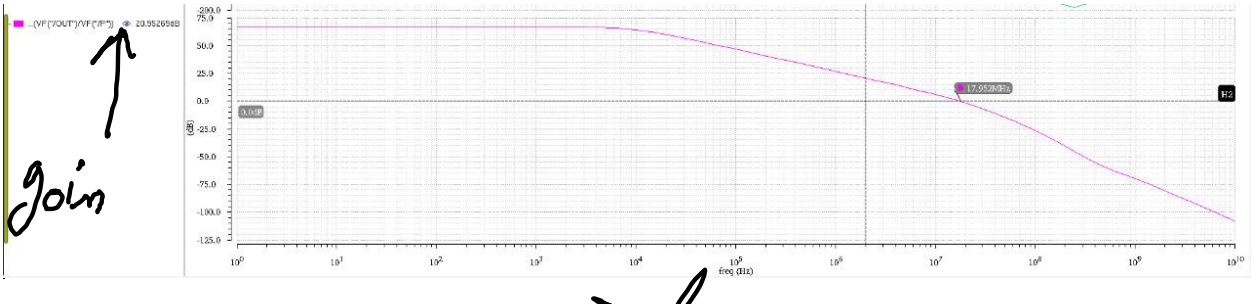


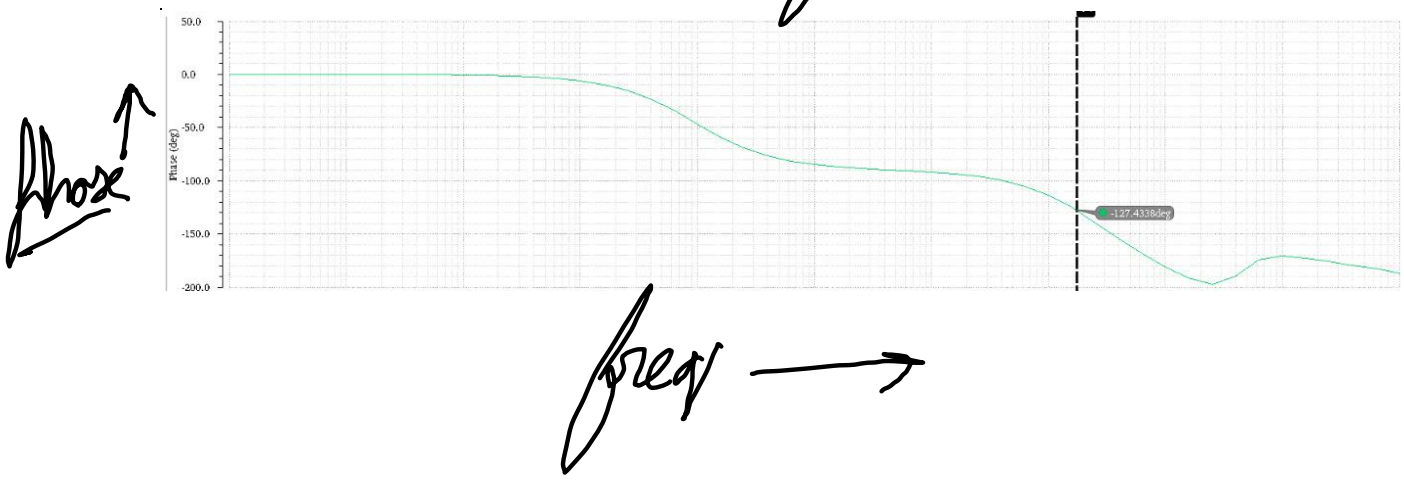
Slew rate is 8.67E6 (V/s)

Q3

So gain is 67.23dB for this telescopic op-amp with phase margin of 53 degree and Unity gain

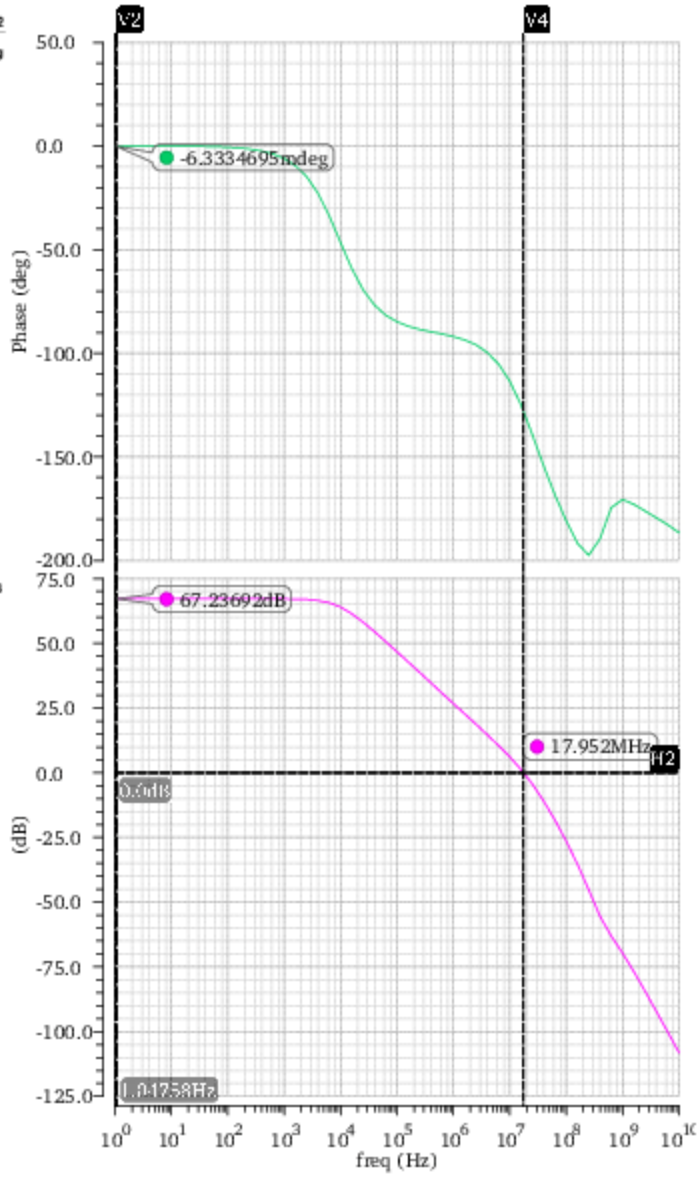
Bandwidth is 18Mhz. Results are displayed at bottom.





AC Response

Name	Vis	V2
...eDegUnwrapped(VF("/OUT")/VF("/P"))		-6.3334695mdeg
dB20(VF("/OUT")/VF("/P"))		67.23692dB



Markers

	V4	V1	V2
x	17.4147MHz	668.119mHz	1.04758Hz
phaseDegUnwrapped(VF("/OUT")/VF("/P"))	-127.4338deg	None	-6.333469mdeg
dB20(VF("/OUT")/VF("/P"))	324.9084mdB	None	67.23692dB

we have

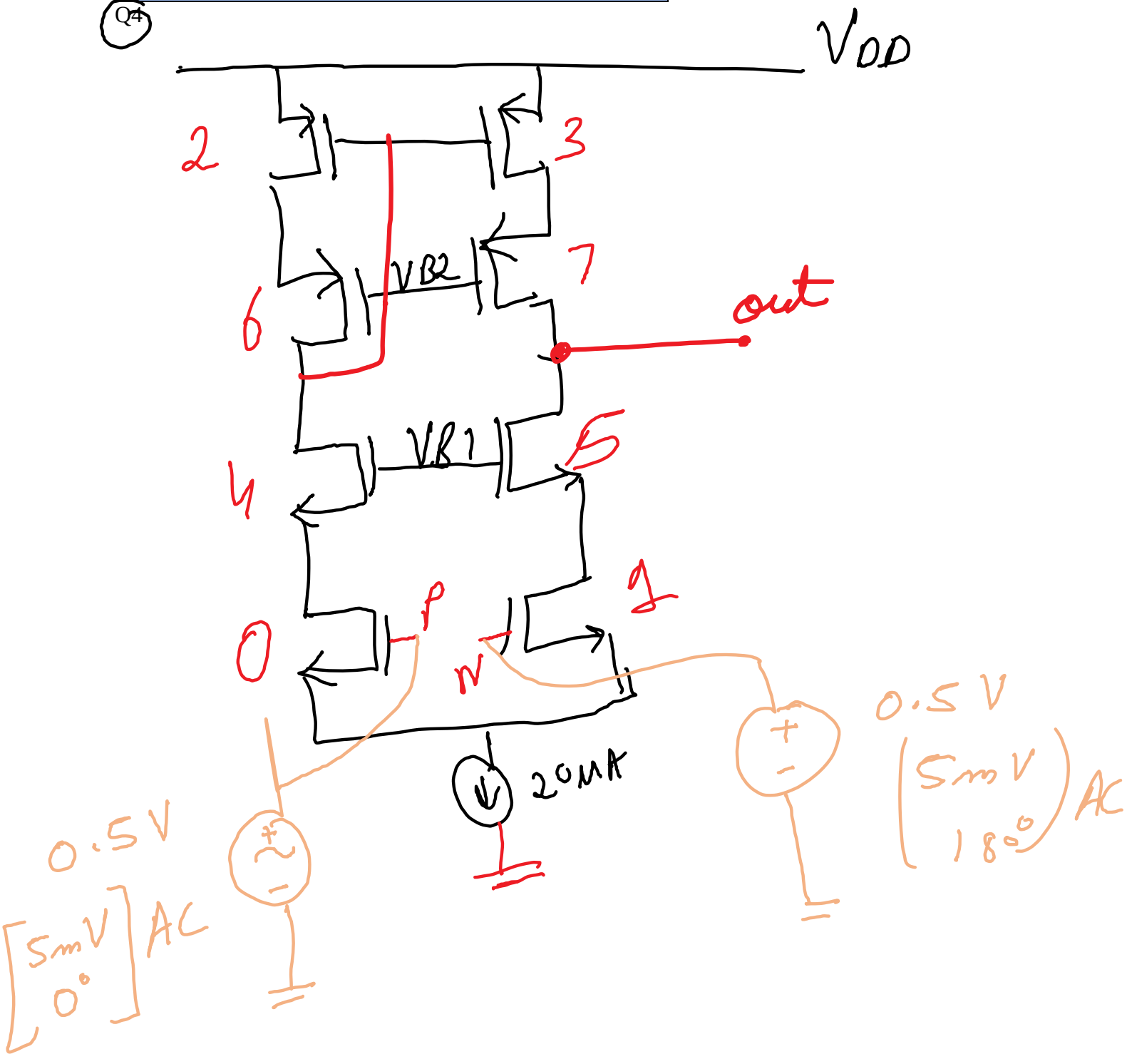
$PM = 180 - 127.43 \approx 53°$

Q5

Device	Param	Noise Contribution	% Of Total
/M1	fn	0.00164795	47.51
/M0	fn	0.00164062	47.30
/M3	fn	8.38505e-05	2.42
/M2	fn	8.3427e-05	2.41
/M1	id	5.32333e-06	0.15
/M0	id	5.29967e-06	0.15
/M3	id	8.97469e-07	0.03
/M2	id	8.92936e-07	0.03
/M5	fn	2.42637e-07	0.01
/M4	fn	2.41558e-07	0.01
/M7	fn	2.84038e-08	0.00
/M6	fn	2.82603e-08	0.00
/M5	id	7.84301e-10	0.00
/M4	id	7.80815e-10	0.00
/M1	rs	5.97298e-10	0.00
/M0	rs	5.94643e-10	0.00
/M7	id	1.10354e-10	0.00
/M6	id	1.09796e-10	0.00
/M3	rs	3.78855e-11	0.00
/M2	rs	3.76942e-11	0.00
/M8	fn	1.03822e-11	0.00
/M9	fn	2.3769e-12	0.00
/M9	id	2.18131e-12	0.00
/M8	id	1.68813e-13	0.00
/M5	rs	8.61884e-14	0.00
/M4	rs	8.58054e-14	0.00
/M1	rd	8.53549e-14	0.00
/M0	rd	8.49755e-14	0.00
/M7	rs	1.13944e-14	0.00
/M6	rs	1.13369e-14	0.00
/M3	rd	5.57521e-15	0.00
/M2	rd	5.54704e-15	0.00
/M9	rs	7.1066e-17	0.00
/M9	rd	5.24717e-17	0.00
/M5	rd	4.36968e-17	0.00
/M4	rd	4.35024e-17	0.00
/M7	rd	9.38938e-18	0.00
/M6	rd	9.34194e-18	0.00

/M8	rs	6.93635e-18	0.00
/M8	rd	6.17996e-22	0.00
Integrated Noise Summary (in V^2) Sorted By Noise Contributors			
Total Summarized Noise = 0.0034688			
Total Input Referred Noise = 7.56386e-10			
The above noise summary info is for noise data			

Q4



for (0 and 1)

$$V_{gs} = 0.5V, \quad V_{th} = 0.392\,V$$

$$Beta_{eff} = \mu_n C_{ox} \frac{W}{L} = 17.78\,m$$

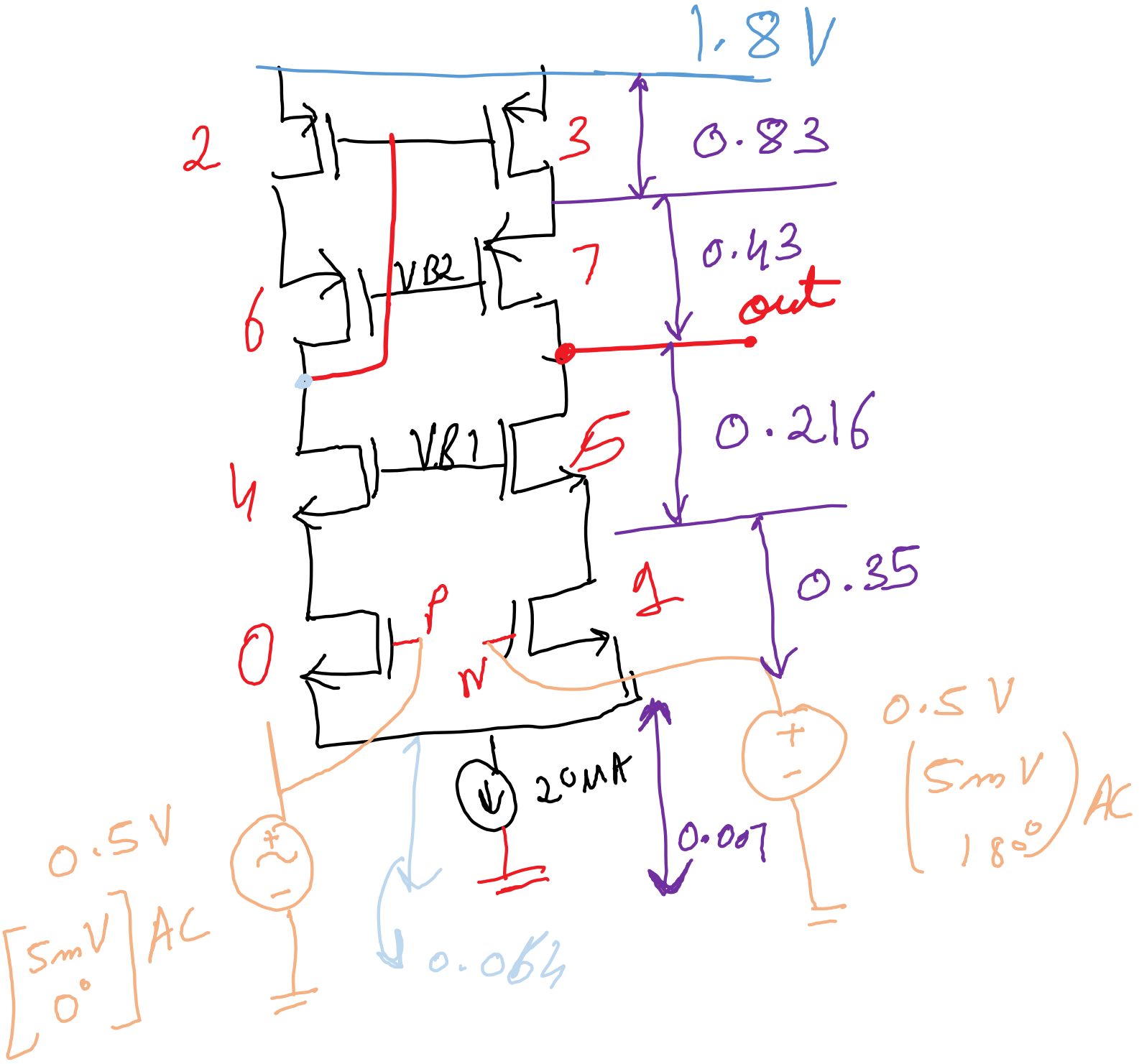
$$\text{So } I_D = \frac{1}{2} \times 17.78m \times (0.5 - 0.392)^2$$

$$= 10.38\,\mu$$

(1) $$g_{oh} = g_{m0}\left[g_{m5} r_{ds5} r_{ds1}\right] \times \left[g_{m7} r_{ds7} r_{ds}\right]$$

(1) $$g_{m0} = \frac{2 I_D}{V_{GS} - V_T} = \frac{2 \times 10.38}{0.5 - 0.392}$$

$$= 0.2\,ms$$


1.8V
0.83
0.43
0.216
0.35
0.007
2
3
7
6
VB2
out
VB1
5
4
1
0
P
N
20MA
0.5V
[5mV 0°] AC
0.5V
(5mV 180°) AC
0.06V

① Assumed Values of V_{DS} for all MOS (Satd)

①	0	&	1	$V_{DS} = 0.4$
②	4	&	5	$V_{DS} = 0.2$
③	6	&	7	$\lvert V_{DS}\rvert = 0.5$
④	2	&	③	$\lvert V_{DS}\rvert = 0.7$

$$(V_{DS})_{sat} = (V_{GS} - V_{th})$$

As I = fixed, $(V_{GS} - V_{th}) \Rightarrow$ Assumed

and for fixed $L = 1\,\mu m$, $V_{th} = 0.4\,V$

So $\left(\frac{W}{L}\right)$ is calculated for all of the MOS

① Slew rate

$$= \frac{2I_o}{C_L} = \frac{2\times 20}{1p} = 40\times 10^{+12}\times 10^{6}$$

$$= 40\times 10^{6}\ V/s$$

Simulated result $= 8.67\times 10^{6}\ V/s$

reason :- more MOS so more junction Cap C ↑ slew rate ↓

② UGB = 16 MHz — 17 MHz

reason $UGB = \frac{1}{r_{out}\times C_L}$

$\Rightarrow r_{out} = g_{m3}r_{d3}\,r_{ds7} \parallel g_{m5}r_{d5}\,r_{ds1}$

$= 1.4\ M\Omega$

$\Rightarrow$

$$UGB = \frac{1}{1.4\,M \times 10^{-12}}$$

$$= \boxed{7.1\,MHz}$$

Calculated

(3) gain $= 0.2m \times 1.4\,M$

$$= \boxed{48.94\,dB}$$

(4) input reffered noise

$$\Rightarrow \frac{16KT}{3g_{mo}} + \frac{16KT}{3g_{mo}^2} \times g_{m7}$$

$$= \frac{16}{3}\left[\frac{1.38 \times 10^{-23} \times 300}{3 \times 0.14}\right] + \frac{16 \times 1.38 \times 10^{-23} \times 300}{3 \times (0.14)^2}$$

0.045 $\times$

$$\approx 1.577 \times 10^{-16}\ V^2/Hz$$

Power = $1.577 \times 10^{-16} \times V^2 \times 24K$

$= 3.78 \times 10^{-11} V^2$

So, we can see that from simulation

$7.6 \times 10^{-10} V^2$

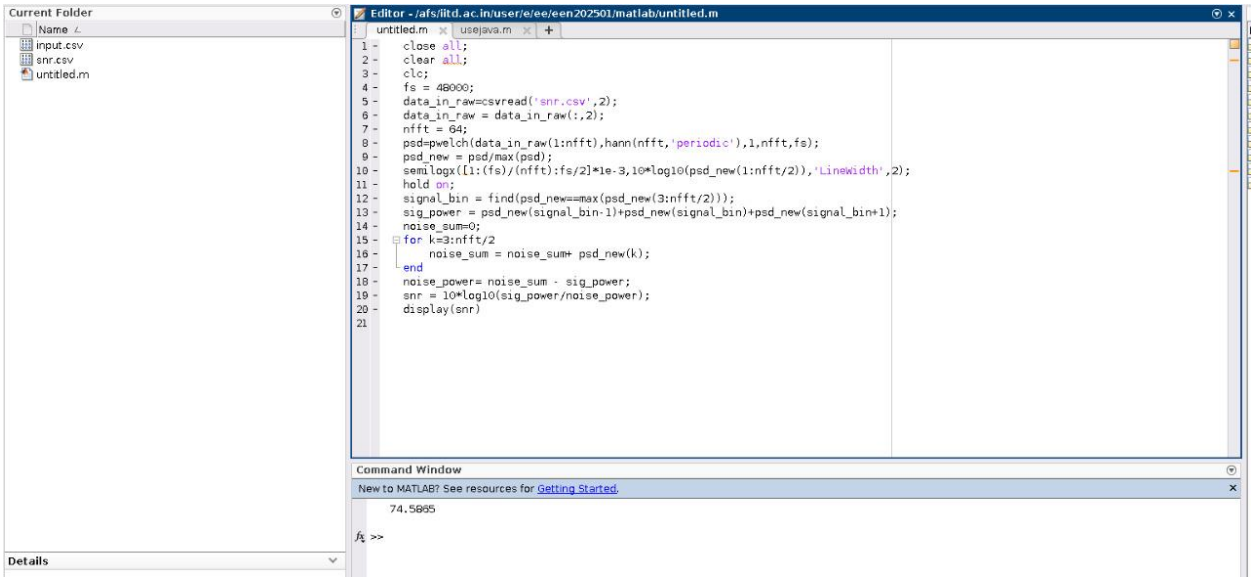
so difference is due to other MOS as C- load make path for other mosfet noise to flow.

So From matlab calculated the SNR

Fr/Fs=M/N

Assuming M=7,N=64 and Fs=24x2=48K so Fr=5.25k

```
close all;
clear all;
clc;
fs = 48000;
data_in_raw=csvread('analogf1m.csv',2);
data_in_raw = data_in_raw(:,2);
nfft = 64;
psd=pwelch(data_in_raw(1:nfft),hann(nfft,'periodic'),1,nfft,fs);
psd_new = psd/max(psd);
semilogx([1:(fs)/(nfft):fs/2]*1e-3,10*log10(psd_new(1:nfft/2)),'LineWidth',2);
hold on;
signal_bin = find(psd_new==max(psd_new(3:nfft/2)));
sig_power = psd_new(signal_bin-1)+psd_new(signal_bin)+psd_new(signal_bin+1);
noise_sum=0;
for k=3:nfft/2
   noise_sum = noise_sum+ psd_new(k);
end
noise_power= noise_sum - sig_power;
snr = 10*log10(sig_power/noise_power);
display(snr);
```


Current Folder
Name
input.csv
snr.csv
untitled.m
Details
Editor - /afs/iitd.ac.in/user/e/ee/een202501/matlab/untitled.m
untitled.m
usejava.m
1 close all;
2 clear all;
3 clc;
4 fs = 48000;
5 data_in_raw=csvread('snr.csv',2);
6 data_in_raw = data_in_raw(:,2);
7 nfft = 64;
8 psd=pwelch(data_in_raw(1:nfft),hann(nfft,'periodic'),1,nfft,fs);
9 psd_new = psd/max(psd);
10 semilogx([1:(fs)/(nfft):fs/2]*1e-3,10*log10(psd_new(1:nfft/2)),'LineWidth',2);
11 hold on;
12 signal_bin = find(psd_new==max(psd_new(3:nfft/2)));
13 sig_power = psd_new(signal_bin-1)+psd_new(signal_bin)+psd_new(signal_bin+1);
14 noise_sum=0;
15 for k=3:nfft/2
16 noise_sum = noise_sum+ psd_new(k);
17 end
18 noise_power= noise_sum - sig_power;
19 snr = 10*log10(sig_power/noise_power);
20 display(snr)
21
Command Window
New to MATLAB? See resources for Getting Started.
74.5885
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