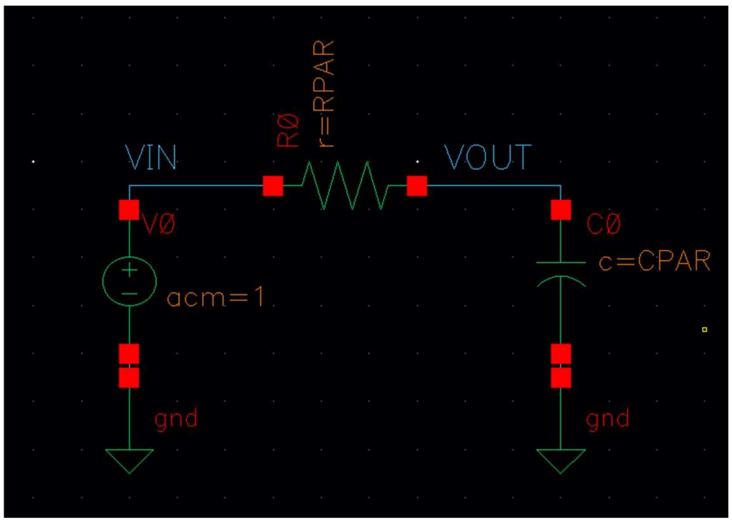
Analog IC Design

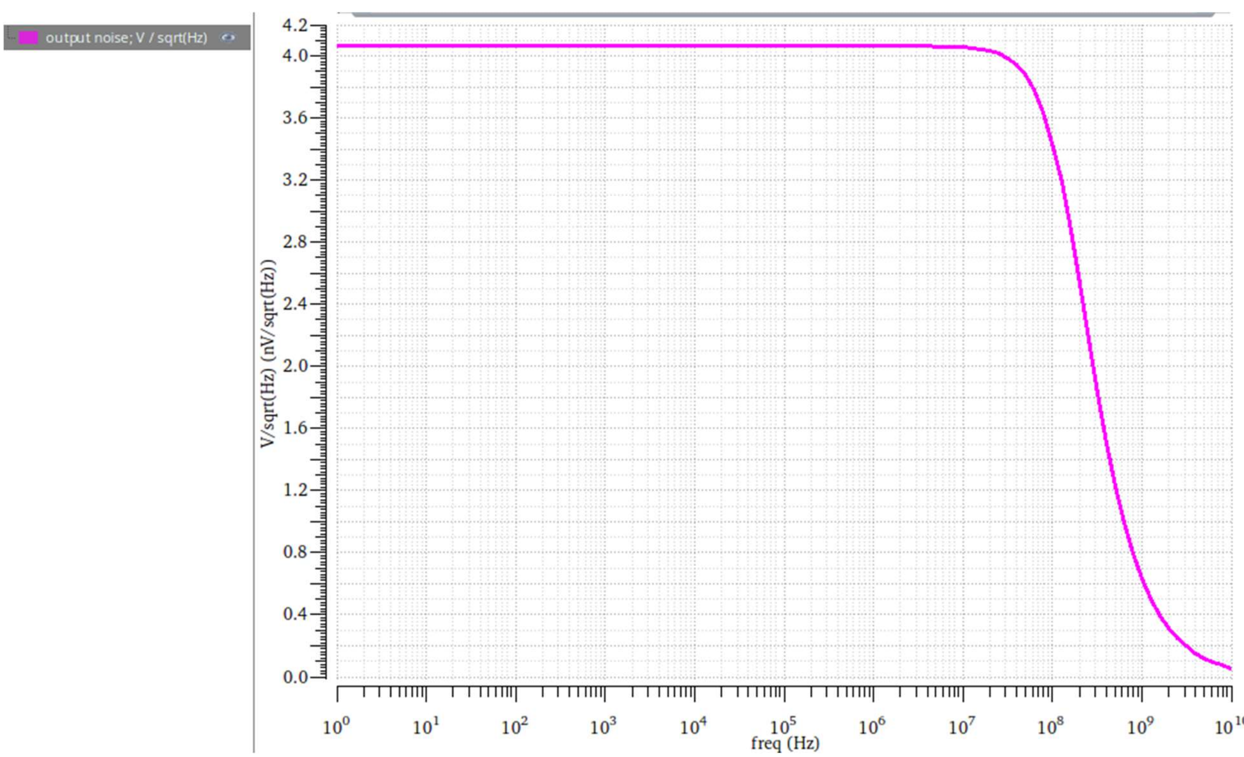
Lab 10

Noise Simulation

PART 1: LPF AC Noise Analysis



Report output noise vs frequency. Annotate voltage noise density and bandwidth in the plot.



Compare the simulation results (noise density, bandwidth, and rms) with hand analysis.

Lab_10:test_Noise:1	Noise_Density	4.071n
Lab_10:test_Noise:1	RMS_Noise	64.32u
Lab_10:test_Noise:1	BW	158.8M

$$\text{Noise\_Density} = \sqrt{\frac{R}{1k}} * 4\frac{nV}{\sqrt{Hz}} = 4\frac{nV}{\sqrt{Hz}}$$

$$\text{RMS\_Noise} = \sqrt{\frac{1p}{C}} * 64\mu Vrms = 64\mu V$$

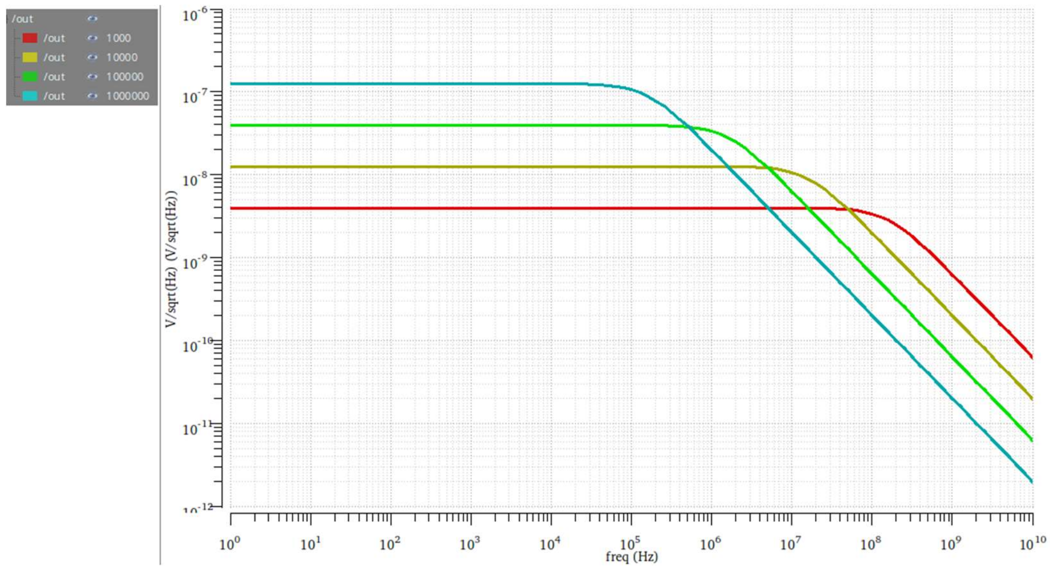
BW = 1/ $2\pi RC$= 159.15 MHz

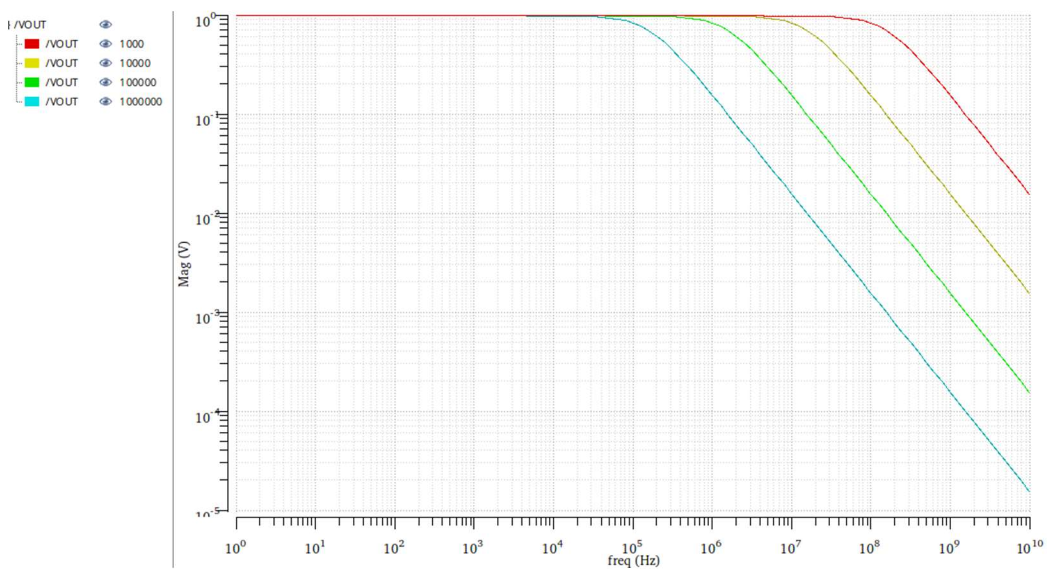
	Analytically	simulation
Noise_Density	$4\frac{nV}{\sqrt{Hz}}$	$4.071\frac{nV}{\sqrt{Hz}}$
RMS_Noise	$64\mu V$	64.32u
BW	159.15M	150.8M

Run parametric sweep for RPAR = 1k, 10k, 100k, 1000k.Plot output noise overlaid on the same plot. Using log-scale for y-axis. Comment on the results.

Parameters: RPAR=1k			
1	Lab_10:test_Noise:1	Noise_Density	4.071n
1	Lab_10:test_Noise:1	RMS_Noise	64.32u
1	Lab_10:test_Noise:1	BW	158.8M
Parameters: RPAR=10k			
2	Lab_10:test_Noise:1	Noise_Density	12.87n
2	Lab_10:test_Noise:1	RMS_Noise	64.62u
2	Lab_10:test_Noise:1	BW	15.88M
Parameters: RPAR=100k			
3	Lab_10:test_Noise:1	Noise_Density	40.71n
3	Lab_10:test_Noise:1	RMS_Noise	64.65u
3	Lab_10:test_Noise:1	BW	1.588M
Parameters: RPAR=1M			
4	Lab_10:test_Noise:1	Noise_Density	128.7n
4	Lab_10:test_Noise:1	RMS_Noise	64.66u
4	Lab_10:test_Noise:1	BW	158.8k

The rms noise value doesn't change as it doesn't depend on R but rather depends on C.

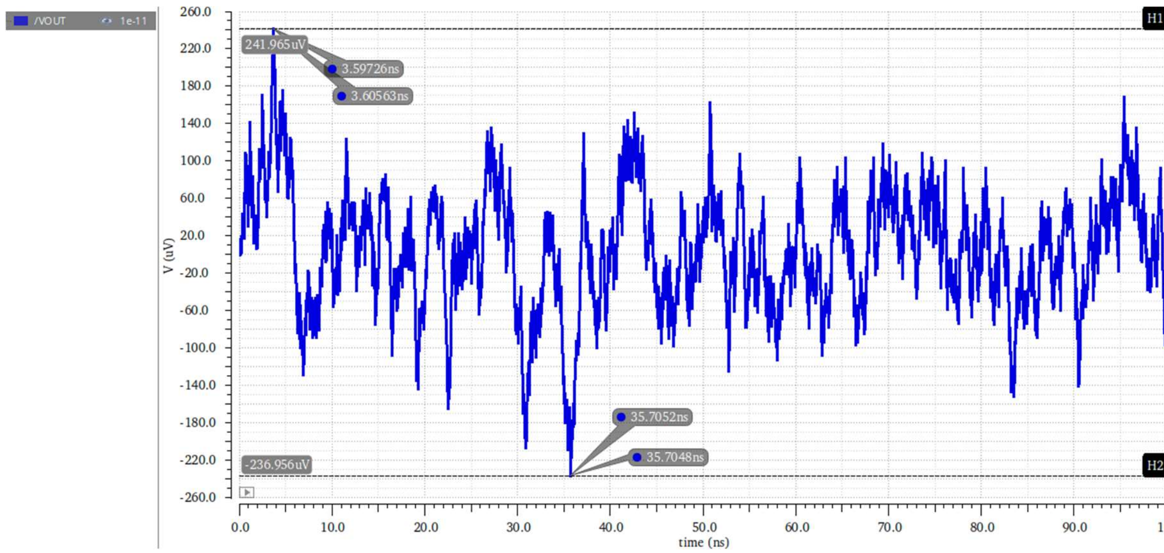




- With R increasing to a factor of 10 we notice the output noise increases as well.
- And the BW decreases

PART 2: LPF Transient Noise Analysis

Report the noise output waveform. Annotate the min and max values.



Use the rms function in the calculator to calculate the rms noise. Compare it to the value calculated in Part 1.

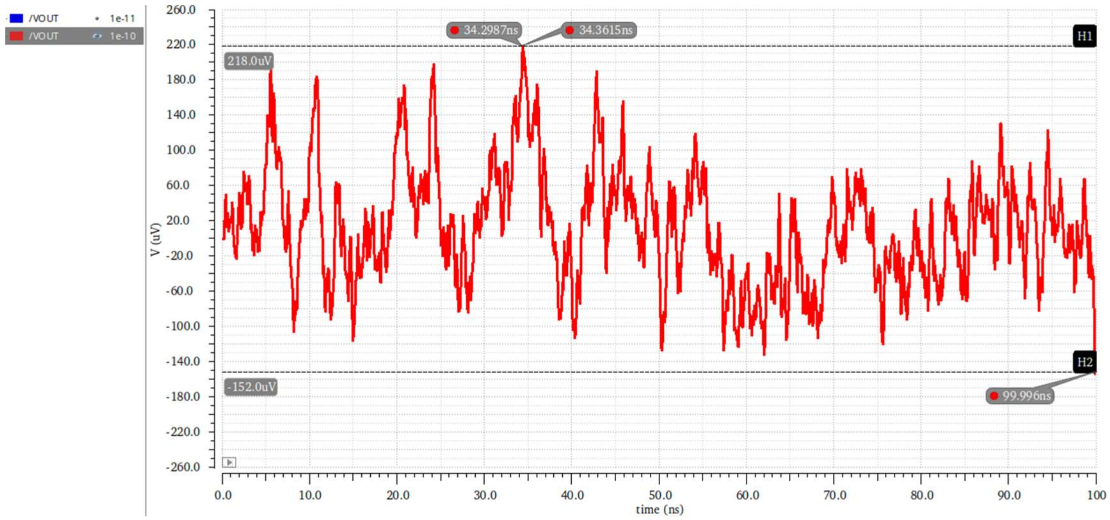
Lab_10:test_Noise:1	/VOUT	
Lab_10:test_Noise:1	RMS	63.53u

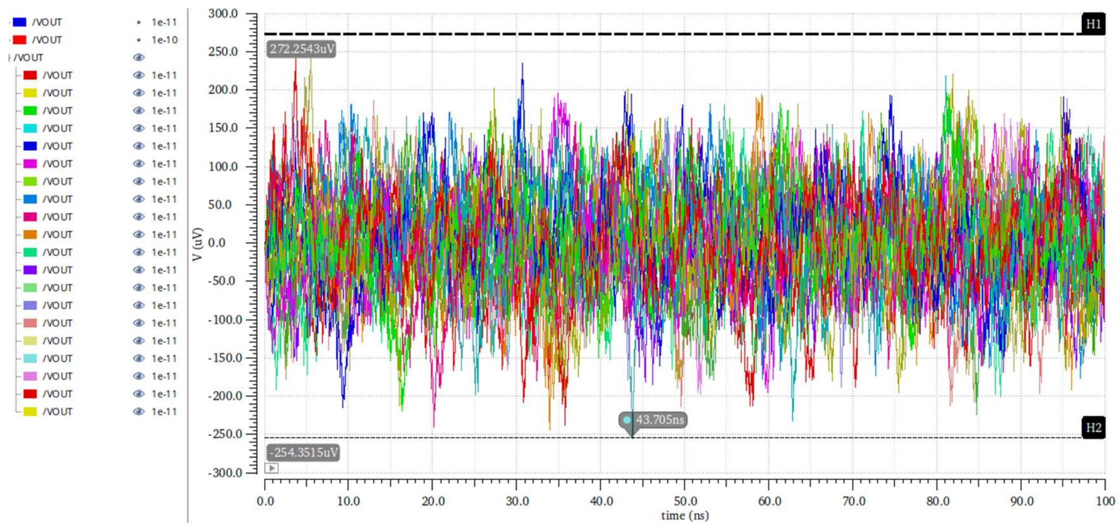
	PART1	PART2
RMS	64.32u	63.53u

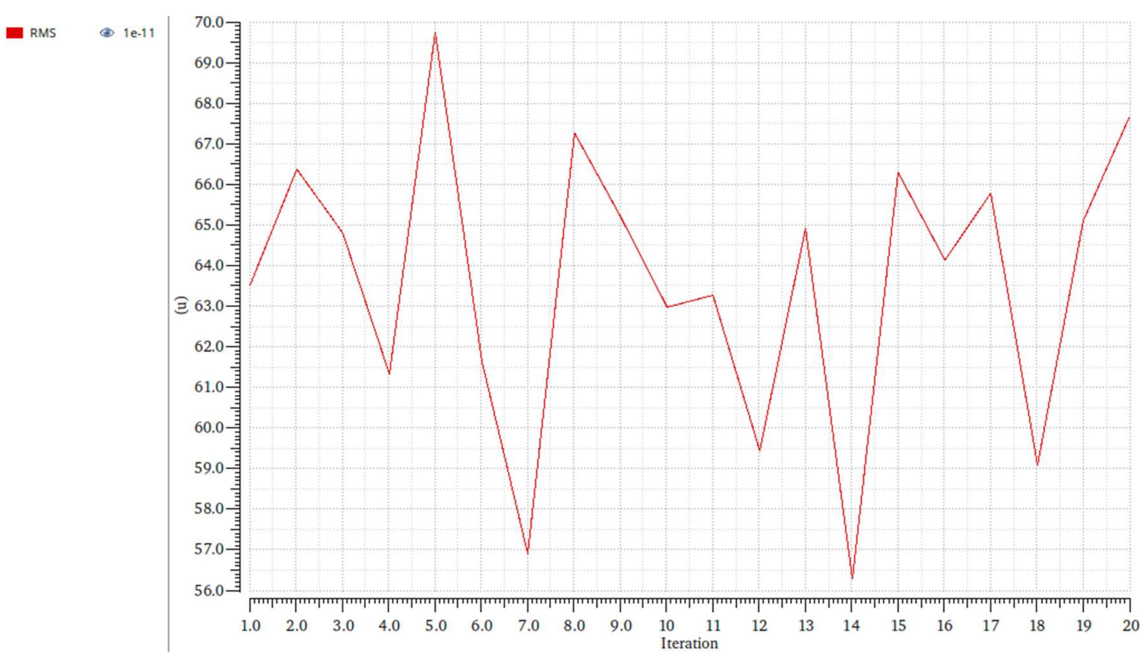
Repeat the simulation with TSTEP = TAU/10. Does the calculated rms noise increase or decrease? Why?

Lab_10:test_Noise:1	/VOUT	
Lab_10:test_Noise:1	RMS	66.57u

It should have decreased as $fmax = 1/\ TSTEP$ and increasing TSTEP means decreasing $fmax$ which means smaller area under the curve, which is by definition the rms noise value, but we notice from simulation that the calculated rms noise increased which is opposite to expected, this might be caused by an accuracy error from spectre.


/VOUT 1e-11
/VOUT 1e-10
34.2987ns
34.3615ns
H1
218.0uV
-152.0uV
H2
99.996ns
V (uV)
time (ns)


/VOUT 1e-11
/VOUT 1e-10
H1
272.2543uV
43.705ns
H2
-254.3515uV
V (uV)
time (ns)


RMS 1e-11
(u)
Iteration

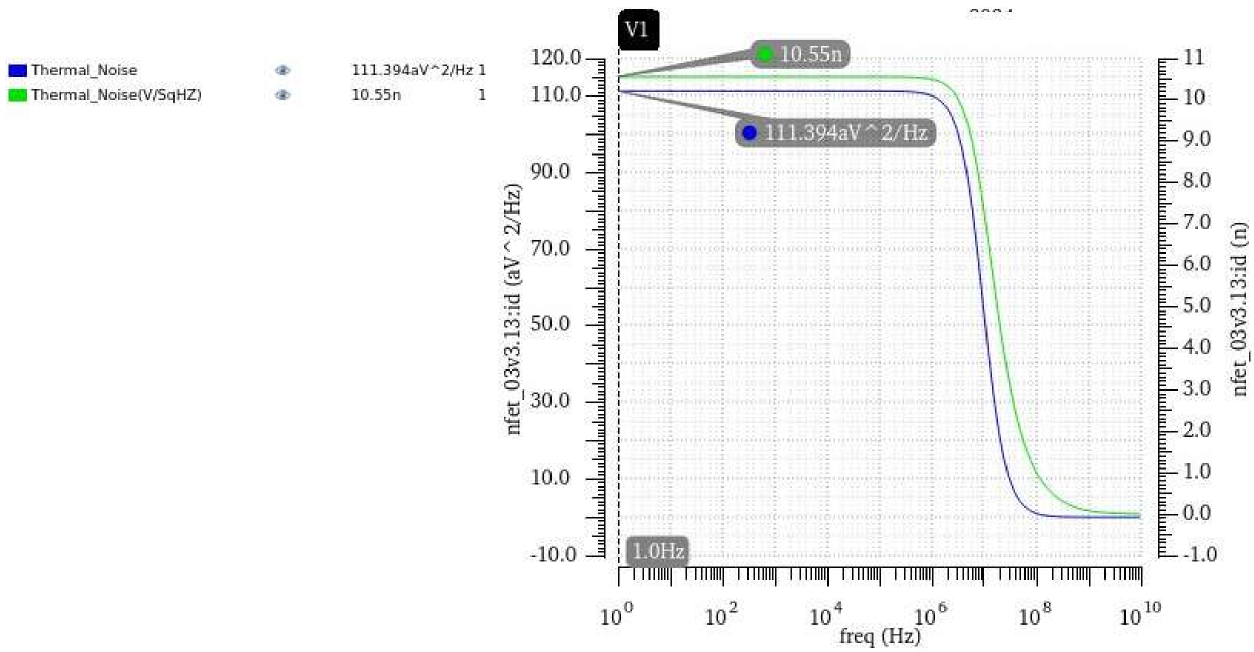
	Iteration	average...VOUT"))
1	1.000	4.853E-6
2	2.000	769.7E-9
3	3.000	11.08E-6
4	4.000	5.750E-6
5	5.000	10.32E-6
6	6.000	2.029E-6
7	7.000	374.9E-9
8	8.000	19.53E-6
9	9.000	2.865E-6
10	10.00	1.024E-6
11	11.00	-996.7E-9
12	12.00	-8.248E-6
13	13.00	-21.58E-6
14	14.00	7.008E-6
15	15.00	-11.86E-6
16	16.00	-7.257E-6
17	17.00	9.165E-6
18	18.00	11.01E-6
19	19.00	-8.242E-6
20	20.00	4.618E-6

Use the calculator to calculate the average rms noise. Compare the calculated value with the rms noise previously obtained in Part 1 and Part 2.

	PART1	PART2	PART3
RMS	64.32u	63.53u	66.57u

PART 3: 5T OTA AC Noise Analysis

Report output thermal noise vs frequency. Annotate noise density and bandwidth in the plot. Compare the simulation results with hand analysis.



Total_Noise	
Thermal_Noise	
RMS_Noise	146.4u
Thermal_Noise(V/SqHZ)	
BW	9.997M
Thermal_Noise(V/SqHZ)_(dB)	

$$V_{nTH}(f) = \sqrt{\frac{8Kt\gamma}{gm1{,}2}\left(1 + \frac{gm\ {,}4}{gm1.2}\right)} = 10.32\ \frac{nV}{\sqrt{Hz}} \quad \rightarrow \gamma = 0.85$$

$$\text{BW} = BW_{CL} = (1 + LG)\ BWOL = \frac{1+LG}{2\pi CL\ (ro\ \ {,}2||ro3{,}4)} = 9.956\text{M}$$

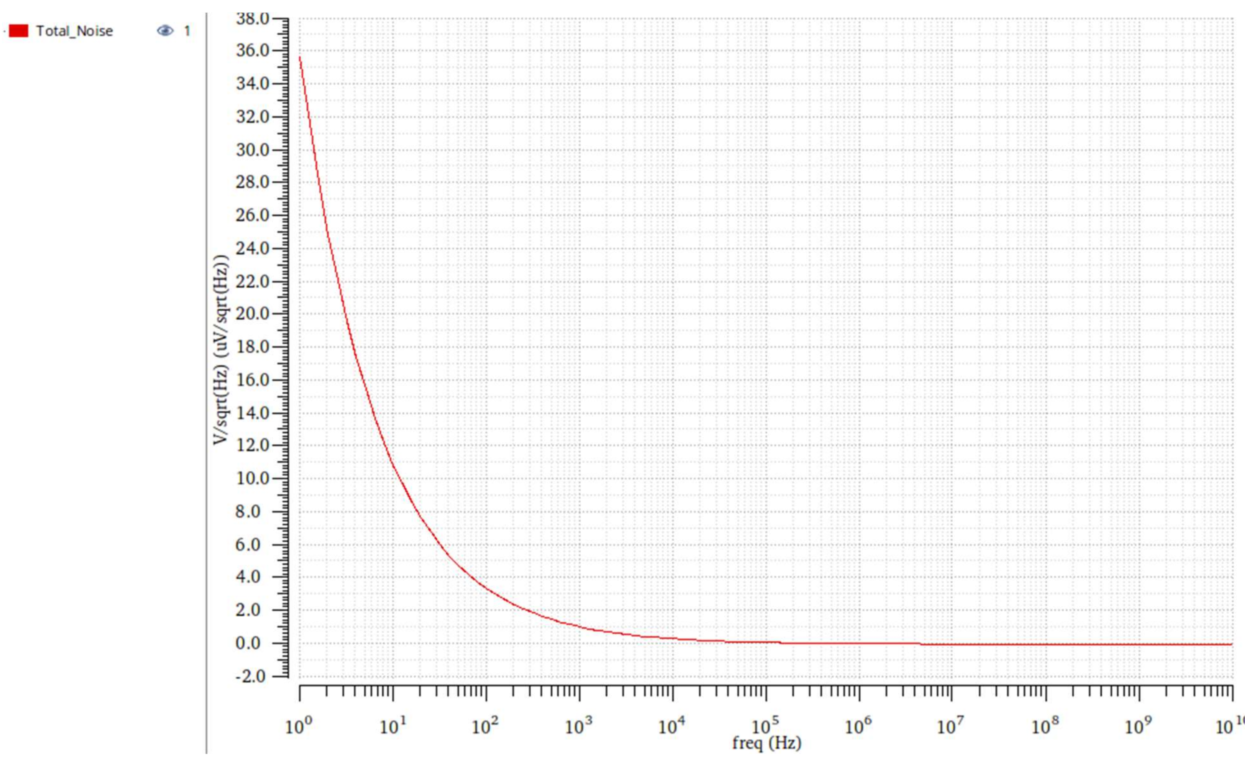
	Analytical	Simulation
Noise	**10.32n**	**10.55n**
BW	**9.956M**	**9.99M**

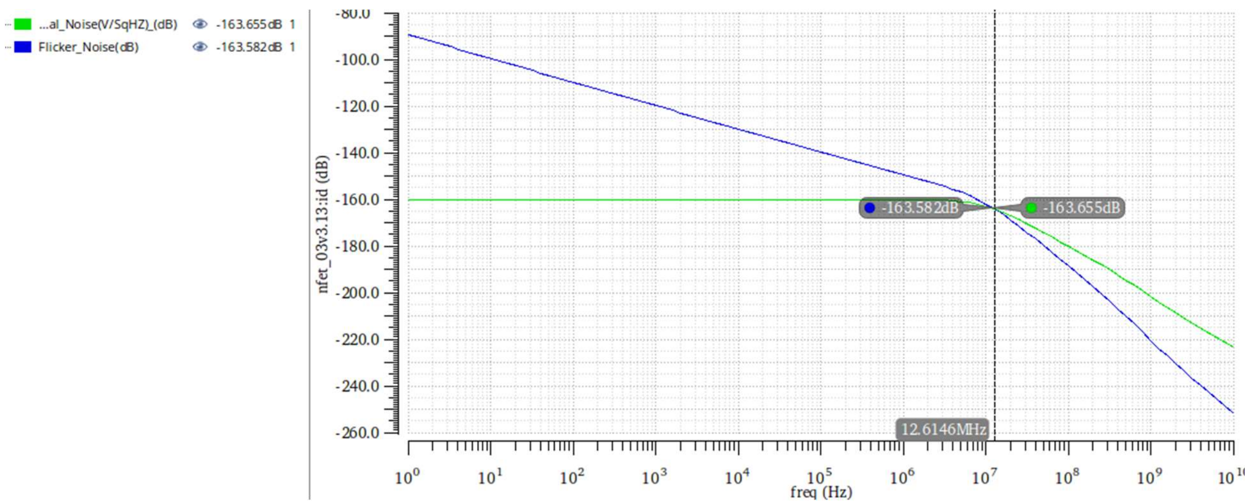
Calculate rms output noise (calculate the rms noise due to thermal noise only using Noise Summary)

Device	Param	Noise Contribution	% Of Total
/I0/M3	fn	4.9531e-09	37.27
/I0/M4	fn	4.88896e-09	36.79
/I0/M2	fn	8.4661e-10	6.37
/I0/M1	fn	8.34261e-10	6.28
/I0/M3	id	5.2054e-10	3.92
/I0/M4	id	5.12534e-10	3.86
/I0/M1	id	3.86906e-10	2.91
/I0/M2	id	3.30466e-10	2.49
/I0/M5	id	5.18228e-12	0.04
/I0/M5	fn	5.08103e-12	0.04
/I0/M6	id	3.45236e-12	0.03
/I0/M6	fn	1.25294e-12	0.01

Integrated Noise Summary (in V^2) Sorted By Noise Contributors
Total Summarized Noise = 1.32883e-08
Total Input Referred Noise = 1.31047e-05
The above noise summary info is for noise data

Report total output noise (thermal + flicker) vs frequency. Estimate the Flicker noise corner.





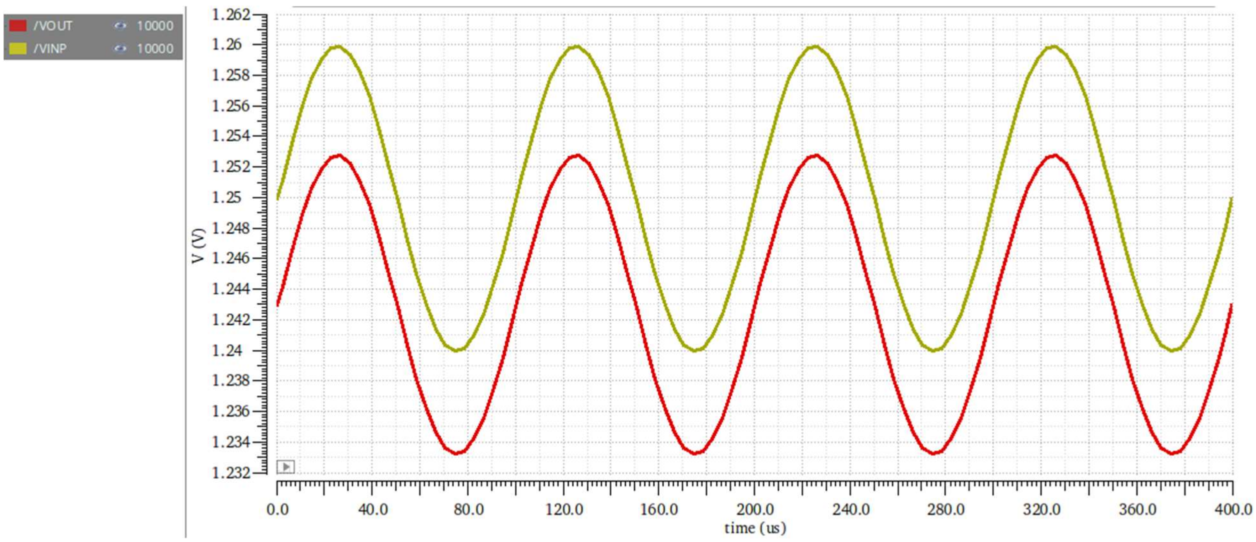
Compare the simulation results (noise density, bandwidth, and rms) with hand analysis.

$$V_{nTH}(f) = \sqrt{\frac{2KT}{BCL}\left(1+\frac{gm3{,}4}{gm1.2}\right)} = 12.76\text{n}V_{rms}$$

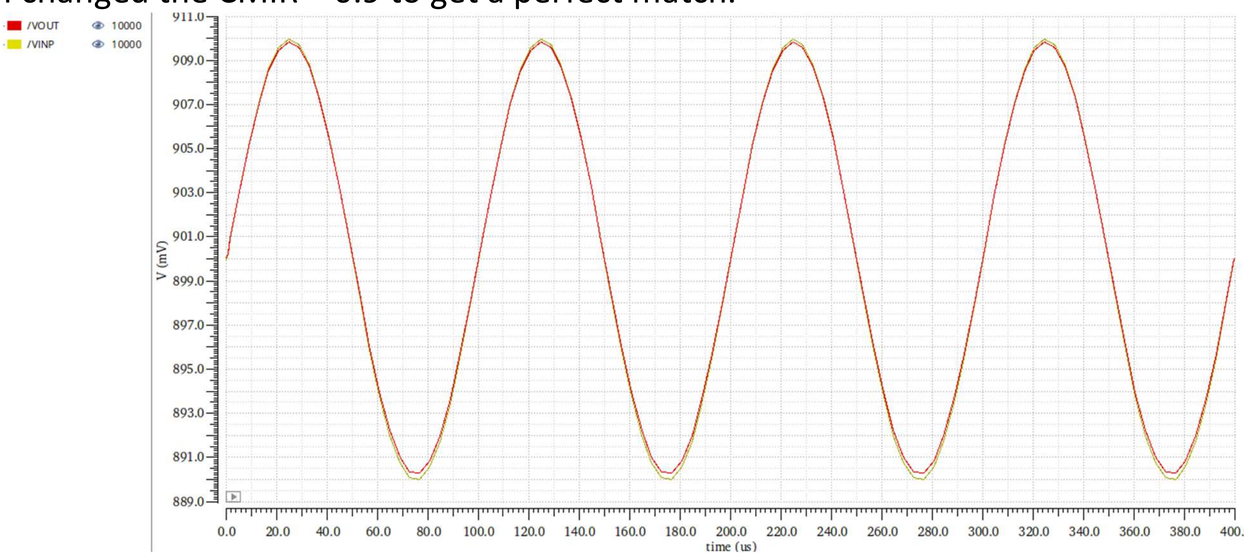
	Analytical	Simulation
Noise	**10.32n**	**10.55n**
BW	**9.956M**	**9.99M**
RMS	**12.76n**	**13.288n**

PART 4: 5T OTA Transient Noise Analysis

Plot input and output overlaid and make sure they match well (verify that the circuit behaves as a buffer).

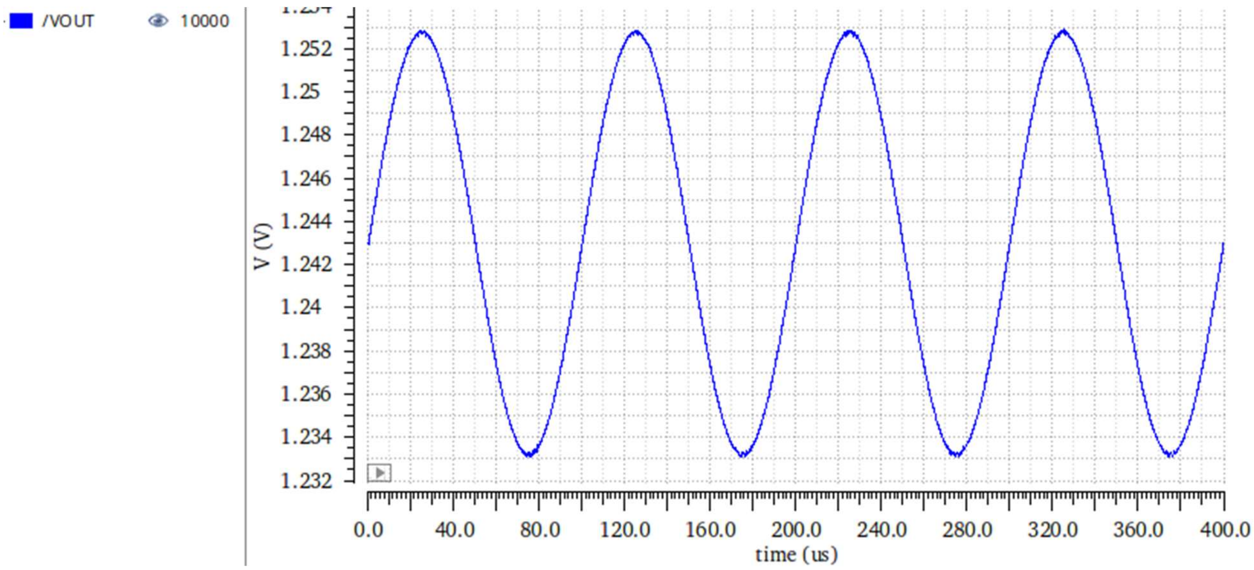


I changed the CMIR = 0.9 to get a perfect match.

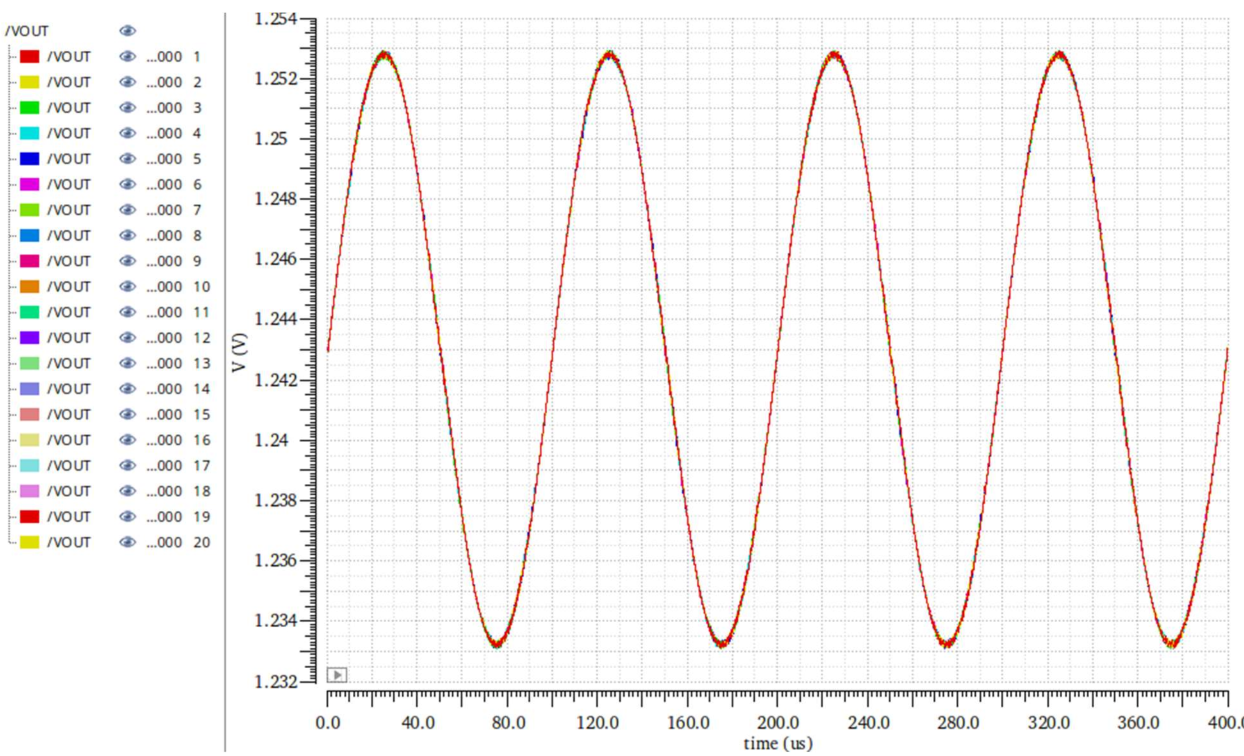


Average_out	1.243
RMS	1.243

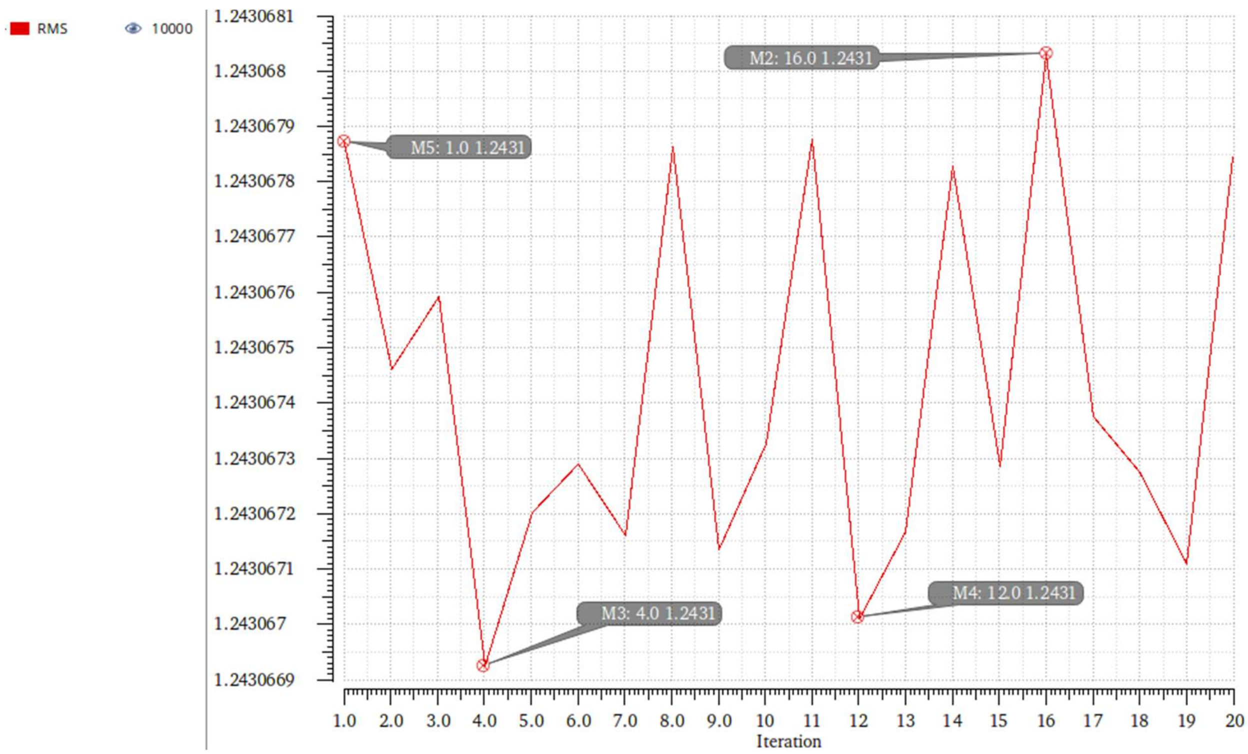
Report the “noisy” output waveform (zoom-in to highlight the noise). Notice that output signal and noise are superimposed.



Change the transient noise options to run 20 simulation runs. Now Specter will run 20 runs of transient noise.



Report the rms noise vs iteration.



Use the calculator to calculate the average rms noise. Compare the calculated value with the rms noise.

Average_out	
Average	1.253
RMS	

	PART3	PART4
RMS	**13.288n**	1.253