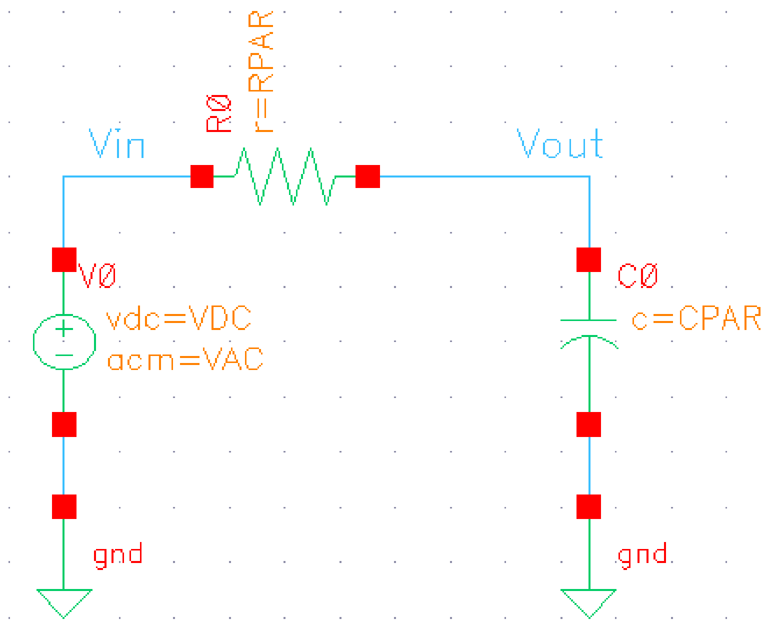
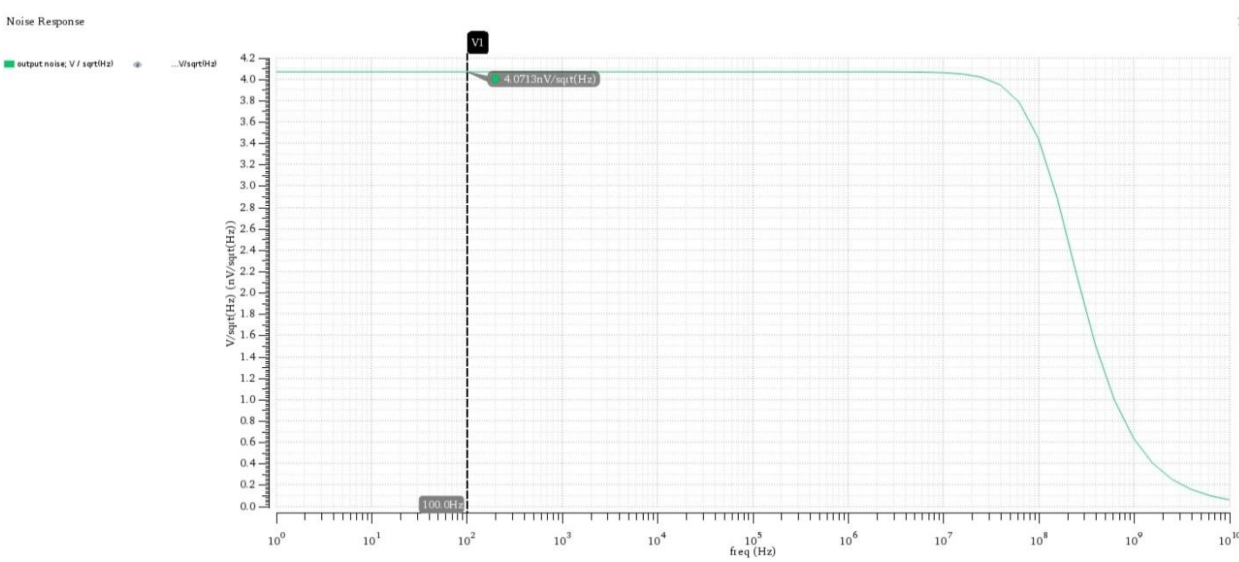
ITI CMOS Analog IC Design 2024
Lab 10
Noise Simulation

PART 1: LPF AC Noise Analysis

1. Schematic



2. Plotting output noise vs frequency.



3. Bandwidth, RMS value, and density from calculator

ITI_Su2024:lab10_LPF:1	density	4.071n
ITI_Su2024:lab10_LPF:1	BW	158.8M
ITI_Su2024:lab10_LPF:1	rms	65.16u

4. Hand analysis for density, bandwidth, and RMS value

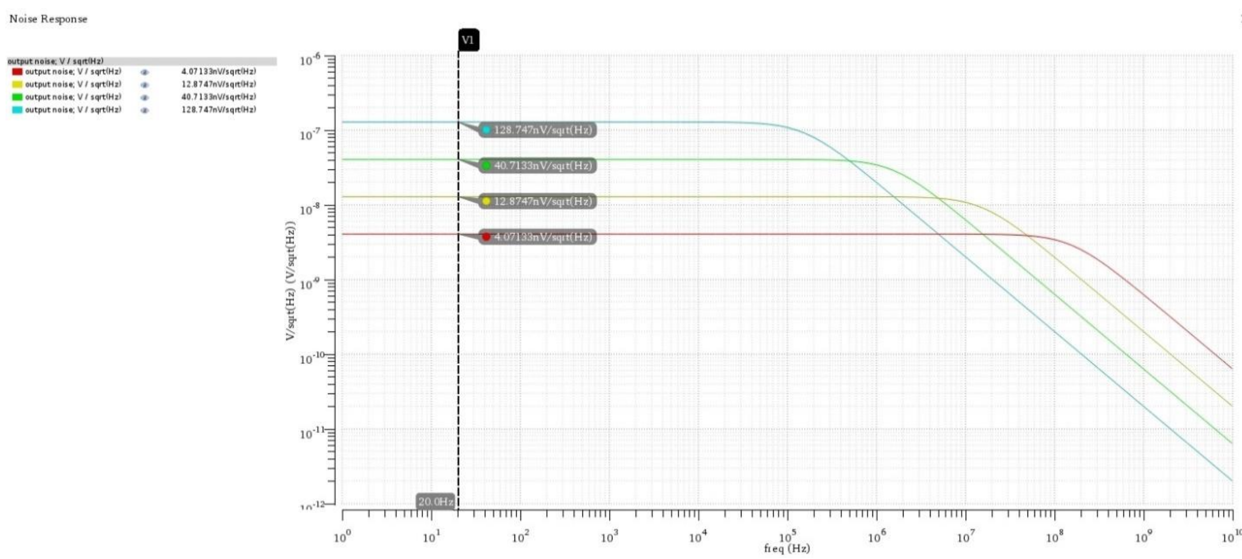
$$V_n = \sqrt{\frac{R}{1k}} * 4\frac{nV}{\sqrt{Hz}} = \sqrt{\frac{1k}{1k}} * 4\frac{nV}{\sqrt{Hz}} = 4\frac{nV}{\sqrt{Hz}}$$

$$BW = \frac{1}{2\pi RC} = \frac{1}{2\pi * 1k\Omega * 1pF} = 159.155MHz$$

$$V_{nrms} = \sqrt{\frac{1pF}{C}} * 64\ \mu V = \sqrt{\frac{1pF}{1pF}} * 64\ \mu V = 64\mu V$$

	Simulation	Analysis
Density V_n	$4.071\frac{nV}{\sqrt{HZ}}$	$4\frac{nV}{\sqrt{Hz}}$
BW	$158.8MHz$	$159.155MHz$
V_{nrms}	$65.16\mu V$	$64\mu V$

5. Plotting output noise for RPAR = 1k, 10k, 100k, 1000k



- Bandwidth decreasing with increasing of resistor
- The density of noise increase with increasing of resistor

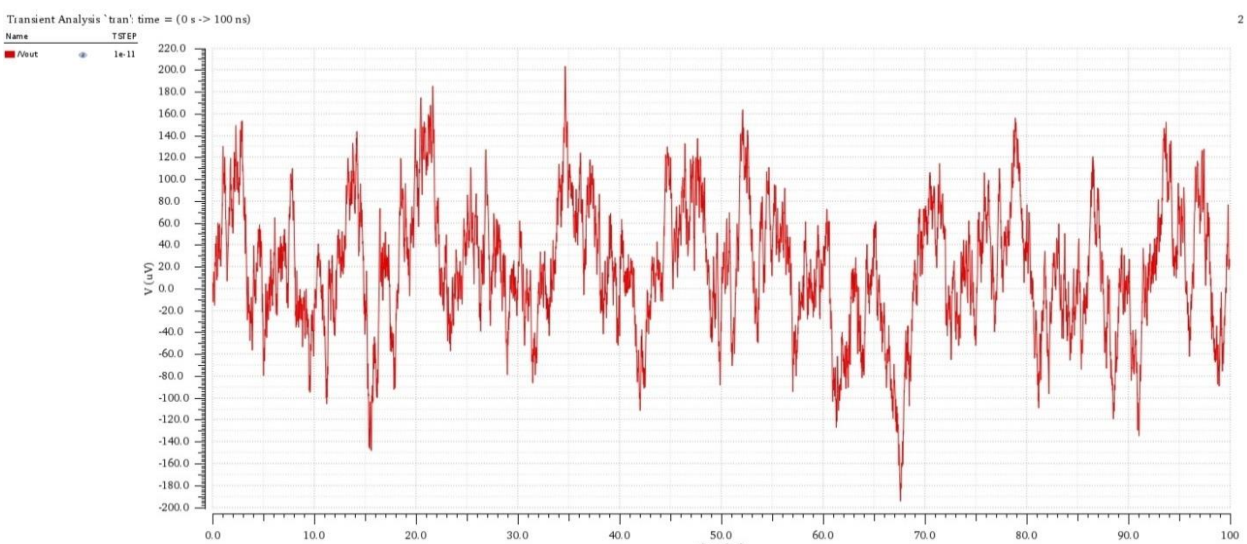
6. Bandwidth, RMS value, and density from calculator

Parameters: RPAR=1k			
1	ITI_Su2024:lab10_LPF:1	Density	4.071n
1	ITI_Su2024:lab10_LPF:1	BW	158.8M
1	ITI_Su2024:lab10_LPF:1	RMS	64.32u
Parameters: RPAR=10k			
2	ITI_Su2024:lab10_LPF:1	Density	12.87n
2	ITI_Su2024:lab10_LPF:1	BW	15.88M
2	ITI_Su2024:lab10_LPF:1	RMS	64.62u
Parameters: RPAR=100k			
3	ITI_Su2024:lab10_LPF:1	Density	40.71n
3	ITI_Su2024:lab10_LPF:1	BW	1.588M
3	ITI_Su2024:lab10_LPF:1	RMS	64.65u
Parameters: RPAR=1M			
4	ITI_Su2024:lab10_LPF:1	Density	128.7n
4	ITI_Su2024:lab10_LPF:1	BW	158.8k
4	ITI_Su2024:lab10_LPF:1	RMS	64.66u

- V_{nrms} doesn't change with change of resistor
- $V_n \propto R,\ and\ BW \propto \frac{1}{R}$ so as R increase V_n increase but BW decrease so V_{nrms} remain constant

PART 2: LPF Transient Noise Analysis

1. Plotting the noise output waveform



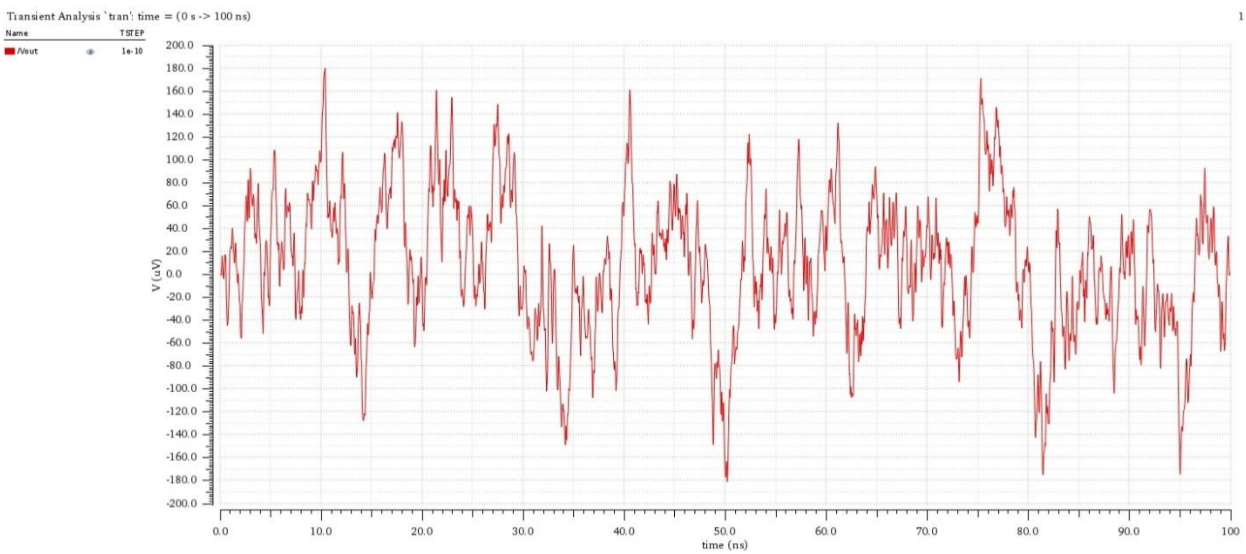
2. Annotate the min, max, and RMS values.

ITI_Su2024:lab10_LPF:1	rms	60.88u
ITI_Su2024:lab10_LPF:1	MAX	203.8u
ITI_Su2024:lab10_LPF:1	MIN	-194.2u

- The RMS value is approximately equal to this of part 1

	Part 1	**Part 2**
V_{nrms}	$65.16\mu V$	$60.88\mu V$

3. Repeat the simulation with TSTEP = TAU/10

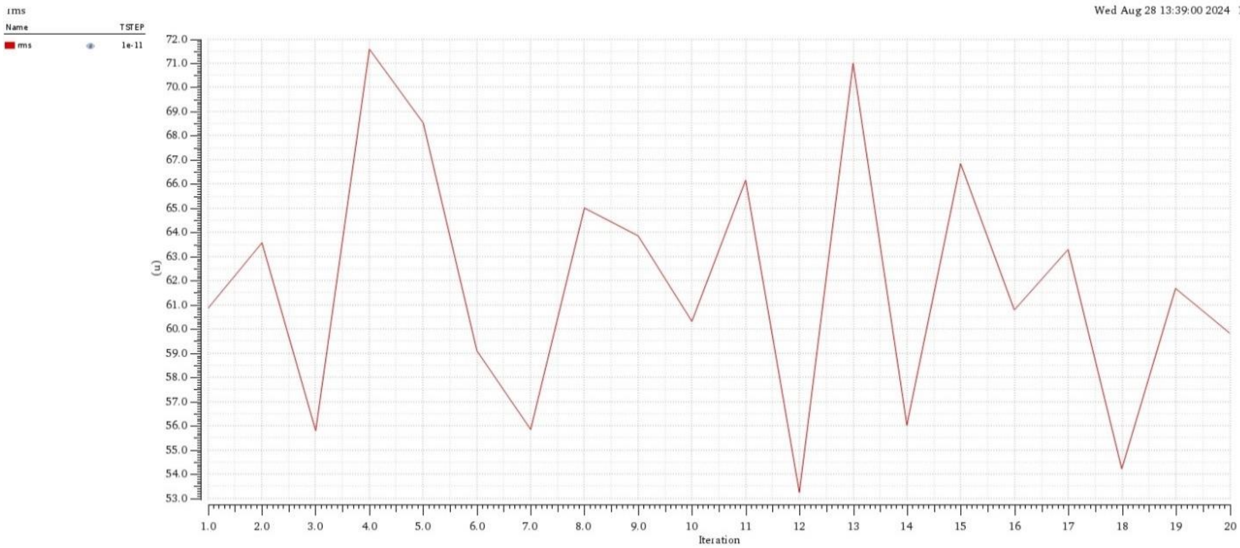


4. Annotate the min, max, and RMS values.

ITI_Su2024:lab10_LPF:1	rms	61.59u
ITI_Su2024:lab10_LPF:1	MAX	180.2u
ITI_Su2024:lab10_LPF:1	MIN	-181u

- There is a bug in simulation as we increase TSTEP it decreases Fmax of noise analysis and step increase so we take less time of samples, and this decrease the accuracy and this should make the result decrease not increase.

5. Plotting the rms noise vs iteration



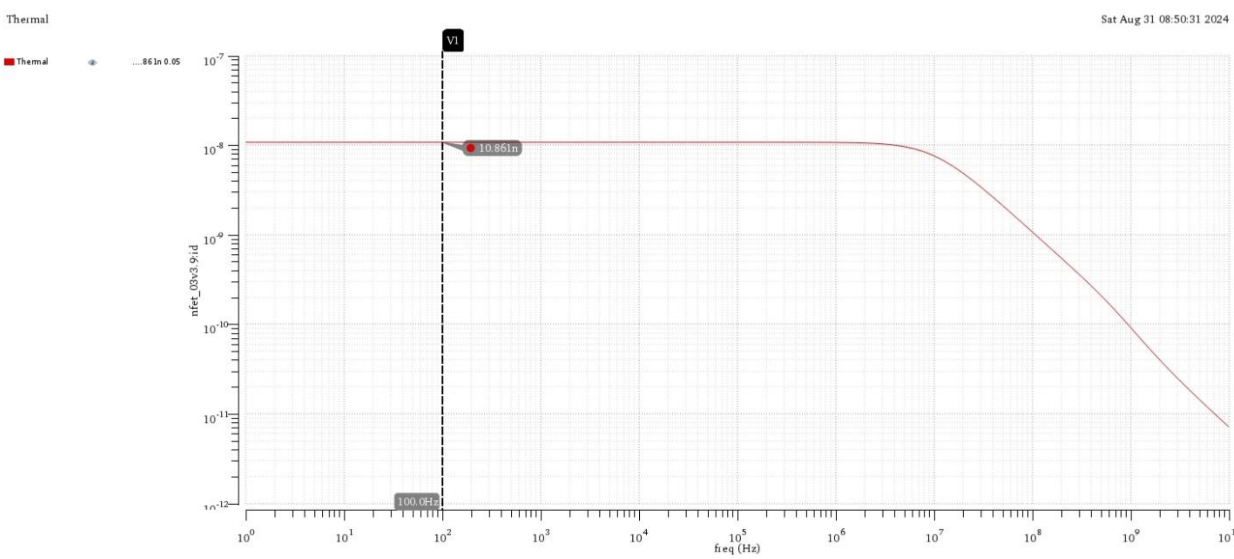
- Calculate the average rms noise

ITI_Su2024:lab10_LPF:1	average	61.97u

	Part 1	Part 2	Average
V_{nrms}	$65.16\mu V$	$60.88\mu V$	$61.97\mu V$

PART 3: 5T OTA AC Noise Analysis

1. Plotting output thermal noise vs frequency



2. Annotate noise density and bandwidth in the plot

ITI_Su2024:5T_OTA_tb:1	density	10.86n
ITI_Su2024:5T_OTA_tb:1	BW	10.11M

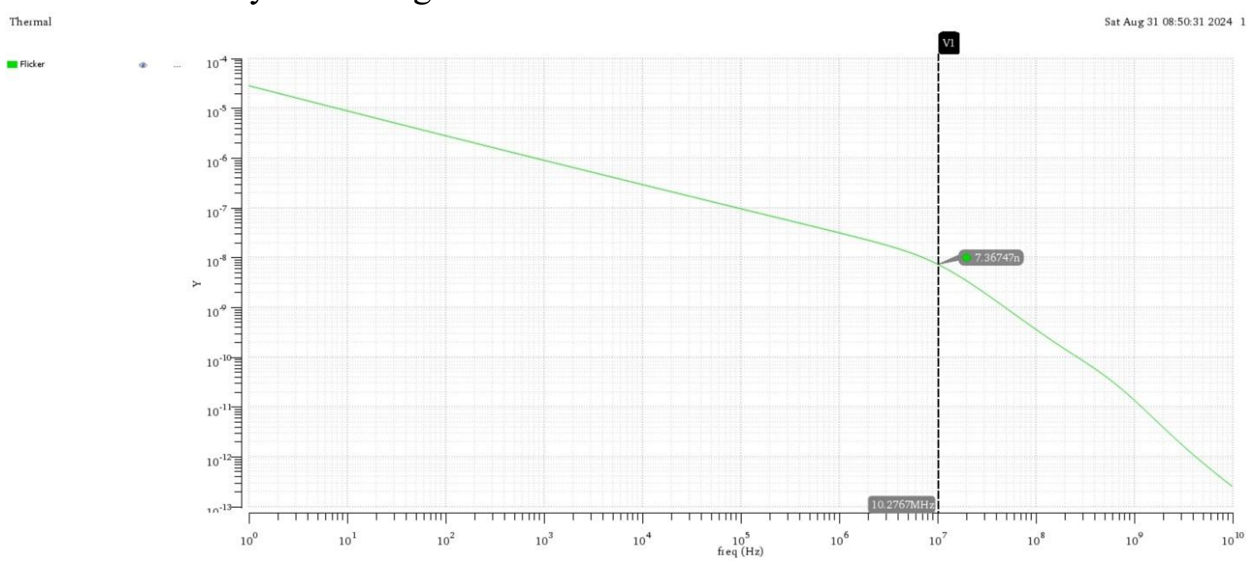
- Hand analysis for density and bandwidth

$$V_{nin} = \sqrt{\frac{8kT\gamma}{g_{m1,2}}\left(1+\frac{g_{m3,4}}{g_{m1,2}}\right)} = \sqrt{\frac{8*4.14*10^{-21}J*\frac{2}{3}}{320\mu S}\left(1+\frac{216.5\mu S}{320\mu S}\right)} = 10.76\frac{nV}{\sqrt{HZ}}$$

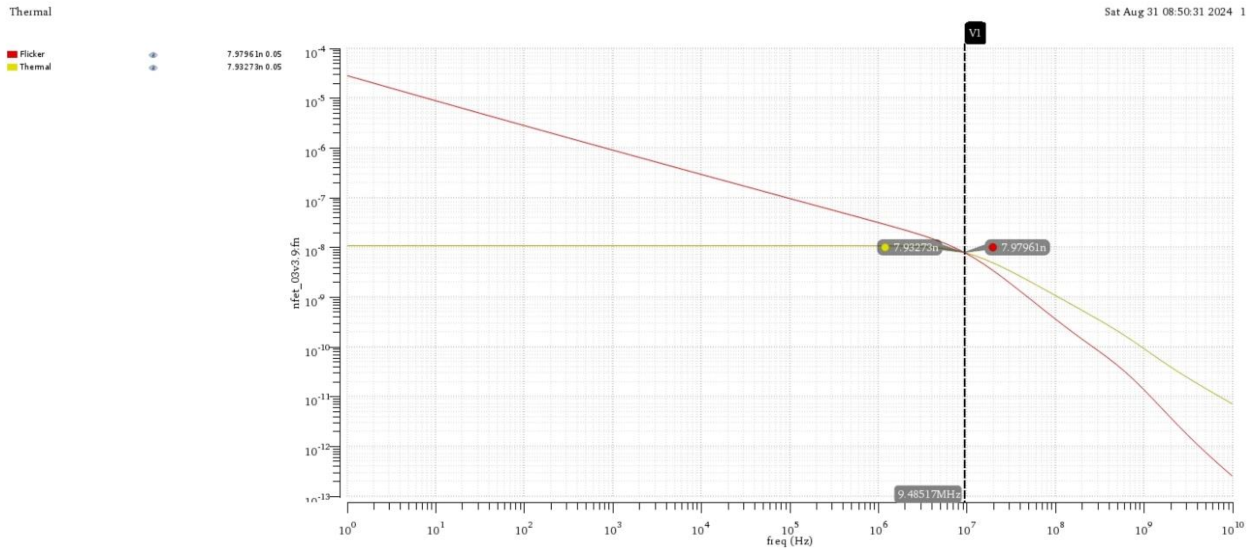
$$BW = GBW_{OL} = \frac{g_{m2}}{2\pi * C_L} = \frac{320.25\mu S}{2\pi * 5pF} = 10.19MHz$$

	Simulation	Analysis
Density V_n	$10.86\frac{nV}{\sqrt{HZ}}$	$10.76\frac{nV}{\sqrt{HZ}}$
BW	$10.11MHz$	$10.19MHz$

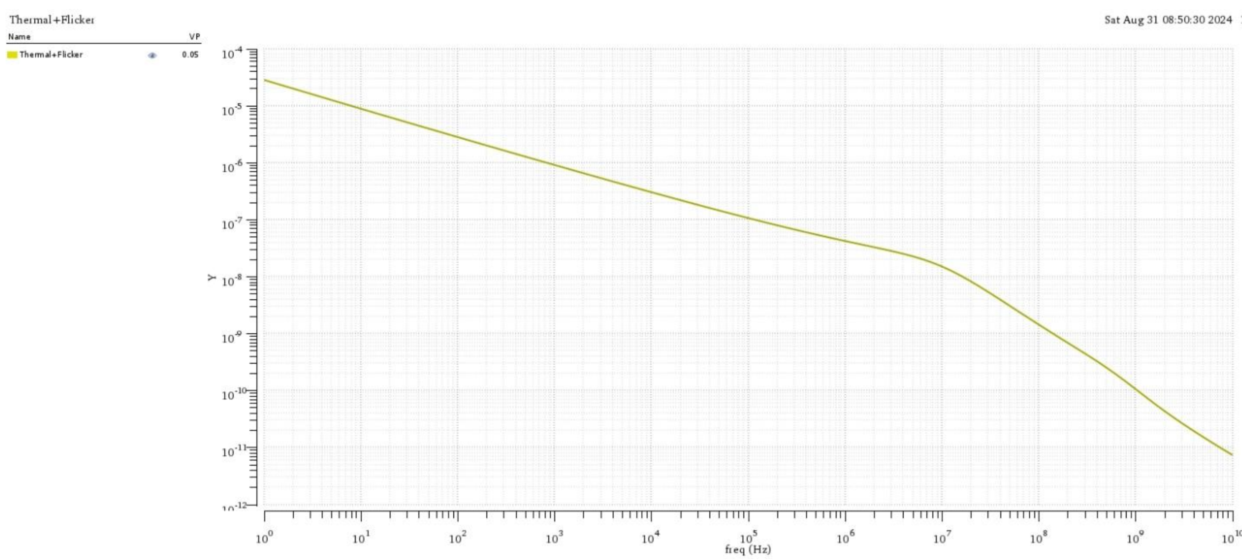
- Flicker noise as y-axis is log scale



3. Plotting thermal and flicker noise overlaid to Estimate the Flicker noise corner as y-axis is log scale



1. Plotting total output noise (thermal + flicker) vs frequency as y-axis is log scale



- The RMS value of total output noise

ITI_Su2024:5T_OTA_tb:1	RMS	127.7u

2. Calculate rms output noise (calculate the rms noise due to thermal noise only)

Device	Param	Noise Contribution	% Of Total
I3.M1.m0	fn	6.04757e-09	37.09
I3.M0.m0	fn	5.95408e-09	36.51
I3.M2.m0	fn	1.20474e-09	7.39
I3.M3.m0	fn	1.1901e-09	7.30
I3.M0.m0	id	5.34127e-10	3.28
I3.M1.m0	id	5.33016e-10	3.27
I3.M3.m0	id	4.24969e-10	2.61
I3.M2.m0	id	3.76821e-10	2.31
I3.M5.m0	fn	1.94387e-11	0.12
I3.M5.m0	id	1.24409e-11	0.08
I3.M4.m0	id	4.99091e-12	0.03
I3.M4.m0	fn	4.73686e-12	0.03

Integrated Noise Summary (in V^2) Sorted By Noise Contributors
Total Summarized Noise = 1.6307e-08
Total Input Referred Noise = 4.4791e-06

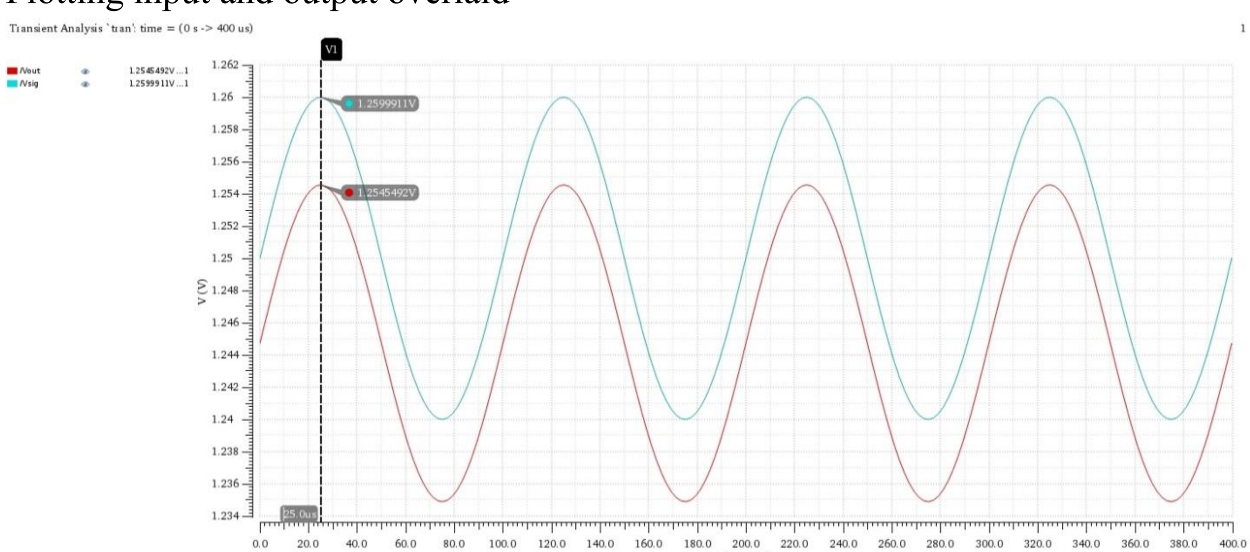
- By take the root aquare of the sum of id the $V_{nrms} = 43.43\mu V$
- By hand analysis

$$V_{nrms} = \sqrt{V_n^2 * BW * \frac{\pi}{2}} = \sqrt{10.76\frac{nV}{\sqrt{Hz}} * 10.19MHz * \frac{\pi}{2}} = 43.049\mu V$$

	Simulation	Analysis
Thermal $\boldsymbol{V_{nrms}}$	$43.43\mu V$	$43.049\mu V$

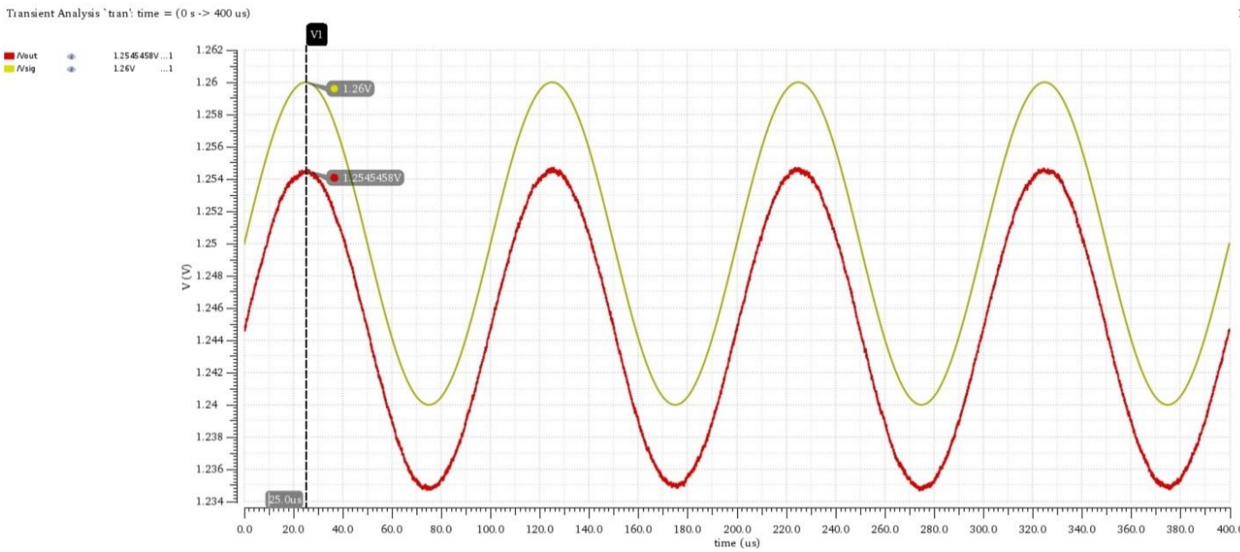
PART 4: 5T OTA Transient Noise Analysis

1. Plotting input and output overlaid

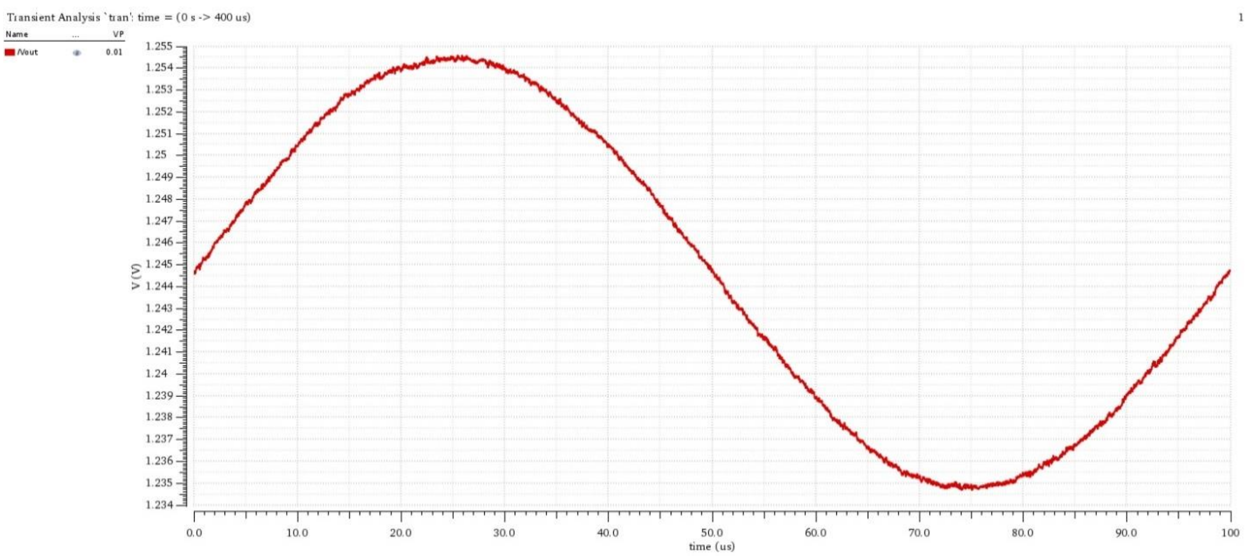


- There is V_{err} between the input and output as the amplifier has a finite gain

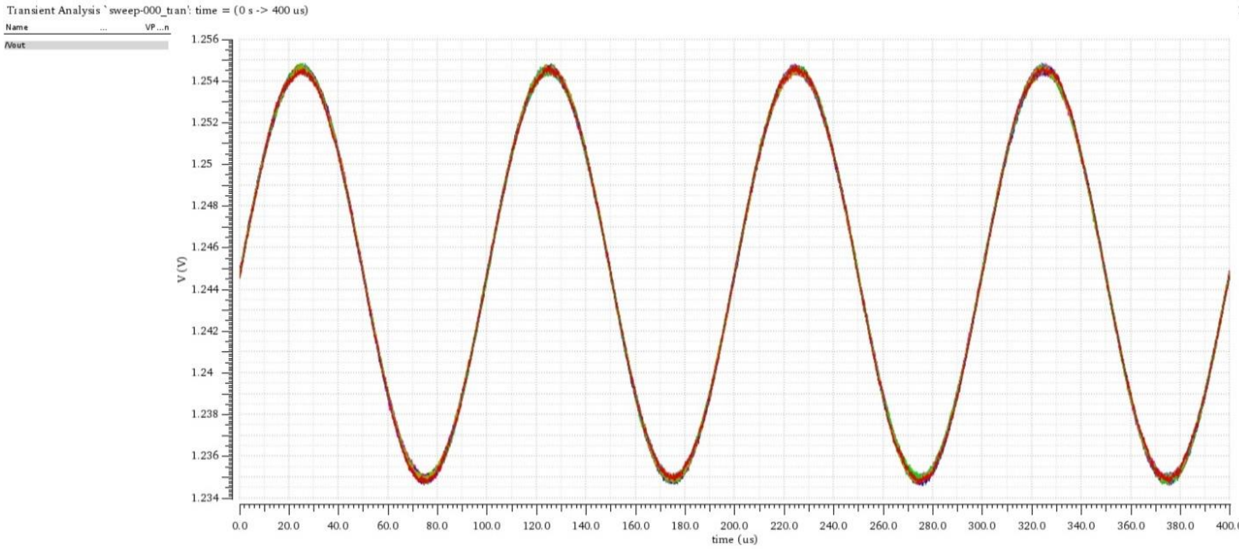
2. Plotting the “noisy” output waveform



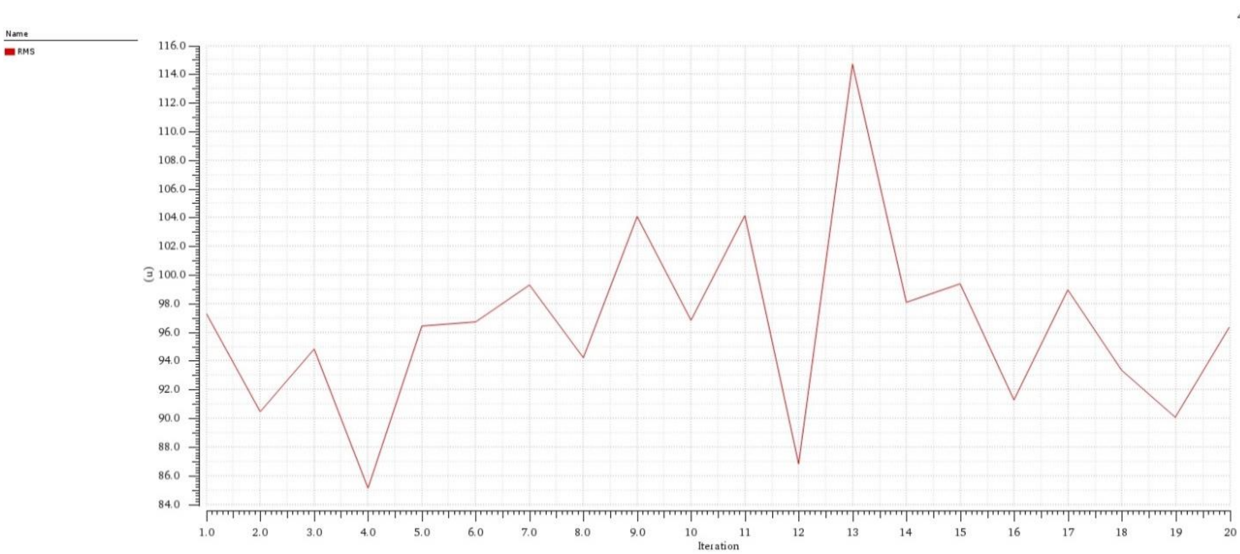
- One cycle of output waveform to highlight the noise



3. plotting the output waveform after 20 simulation runs



4. Reporting the rms noise vs iteration.



- The average value of the total noise

	VP	average...0.01))
1	10.00E-3	96.42E-6

	Part4	**Part3**
$Total\ V_{nrms}$	$96.5\mu V$	$\sqrt{16.3nV} = 127.6\mu V$