Analog IC Design

Lab 10

Noise Simulation

PART 1: LPF AC Noise Analysis

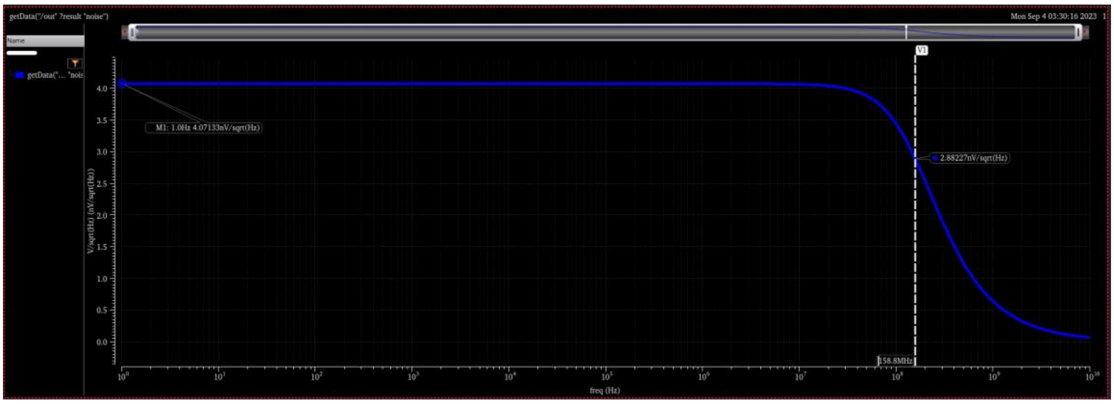

Figure 1 output noise vs frequency

As the source of the noise is a Resistance so it is a White Noise, so This curve follow the equation $V_n = \sqrt{\frac{4kTR}{(1+scR)^2}}$

Parameters: RPAR=1K						
1	Lab_10_lab_10_...	bandwidth(getD...	158.8M			
1	Lab_10_lab_10_...	rmsNoise(1 1e+...	64.32u			
1	Lab_10_lab_10_...	getData("/out" ?...				

$$\text{Noise density} = \sqrt{4kTR} = 4.07n$$

$$\overline{V_{n_{out}}^{\,2}} = \frac{kT}{C}$$

$$V_{n_{rms}} = \sqrt{\frac{kT}{C}} \approx \sqrt{\frac{1p}{C}} * 64\ \mu Vrms = 64\ \mu V$$

$$BW = \frac{1}{2\pi RC} = 159M$$

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

	noise density	bandwidth	rms
simulation results	4.07n	158.8M	64.32µV
hand analysis	4.07n	159M	64µV

Figure 2 output noise

- The curves follow the equation $V_n = \sqrt{\frac{4kTR}{(1+scR)^2}}$, The value of the curve in DC = $\sqrt{4kTR}$, so it is directly proportional with $\sqrt{R}$, but the bandwidth is inversely proportional with R and that appear on the graphs.

Parameters: RPAR=1K			
1	Lab_10_lab_10_...	bandwidth(getD...	158.8M
1	Lab_10_lab_10_...	rmsNoise(1 1e+...	64.32u
1	Lab_10_lab_10_...	getData("/out" ?...	
Parameters: RPAR=10K			
2	Lab_10_lab_10_...	bandwidth(getD...	15.88M
2	Lab_10_lab_10_...	rmsNoise(1 1e+...	64.62u
2	Lab_10_lab_10_...	getData("/out" ?...	
Parameters: RPAR=100K			
3	Lab_10_lab_10_...	bandwidth(getD...	1.588M
3	Lab_10_lab_10_...	rmsNoise(1 1e+...	64.65u
3	Lab_10_lab_10_...	getData("/out" ?...	
Parameters: RPAR=1M			
4	Lab_10_lab_10_...	bandwidth(getD...	158.8K
4	Lab_10_lab_10_...	rmsNoise(1 1e+...	64.66u
4	Lab_10_lab_10_...	getData("/out" ?...	

- The Resistance has no dependence on the rms as we expected from the equation $V_{n_{rms}} = \sqrt{\frac{kT}{C}}$ so it's value just depend on the capacitance and temperature.
- And the band width is inversely proportional with the Resistance ($BW = \frac{1}{2\pi RC}$)so its value decreased by factor of 10 when R increase by the same factor.

PART 2: LPF Transient Noise Analysis

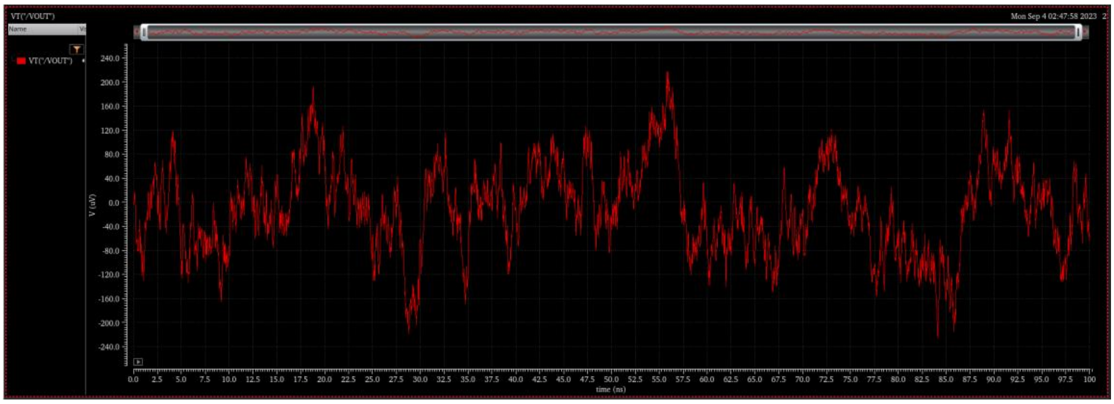

Figure 3 noise output waveform

ymin(VT("/VOUT"))	-226.7u
ymax(VT("/VOUT"))	218u

Figure 4 Min and MAX VALUES

rms(VT("/VOUT"))	73.04u

Figure 5 rms noise

	transient	Part 1
RMS	73.04u	64.32u

rms(VT("/VOUT"))	68.92u

Figure 6 rms noise at TSTEP = TAU/10

the calculated rms noise decreases, because when TSTEP increase then Fmax = 1/TSTEP decrease, so the frequency range we calculate the noise power over (integration boundaries) will decrease and as rms is the square root of the noise power then it will also decrease.

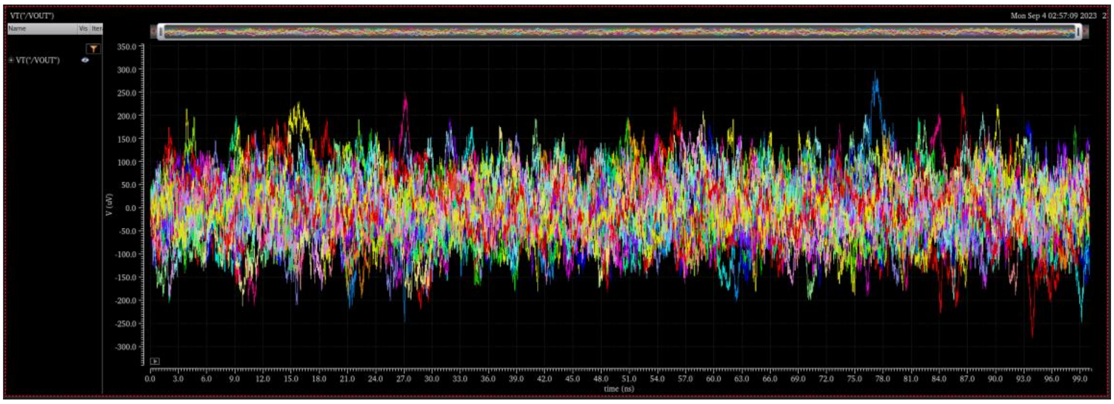

Figure 7 output noise vs time

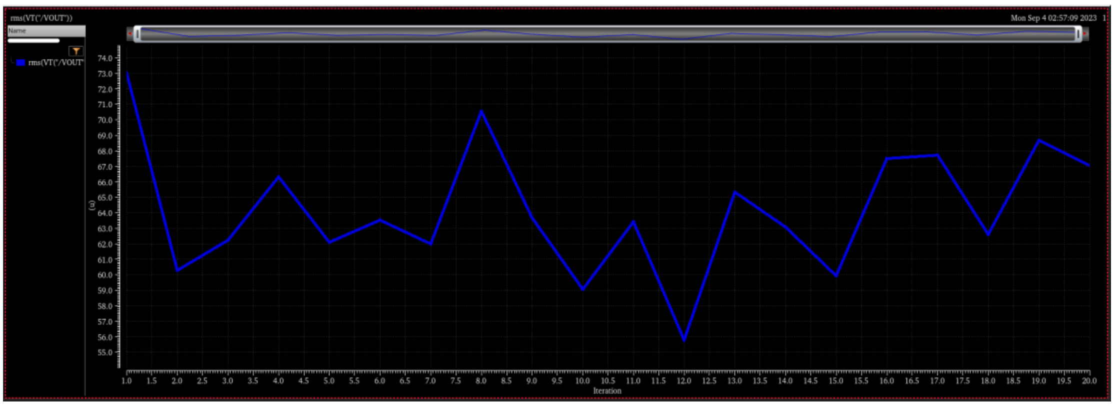

Figure 8 rms noise vs iteration

average(rms(VT("/VOUT")))	63.89u

Figure 9 average rms noise

	Average	Part 2	Part 1
RMS	63.89u	73.04u	64.32u

PART 3: 5T OTA AC Noise Analysis

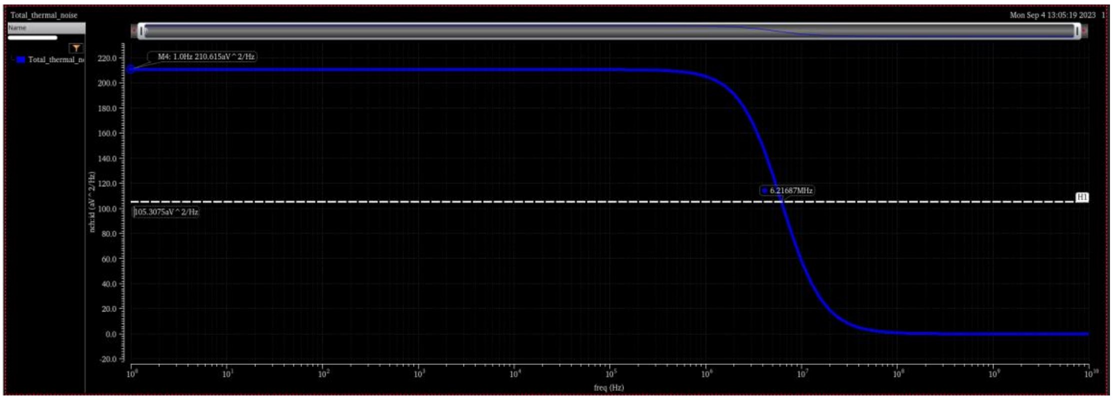

Figure 10 output thermal noise square vs frequency

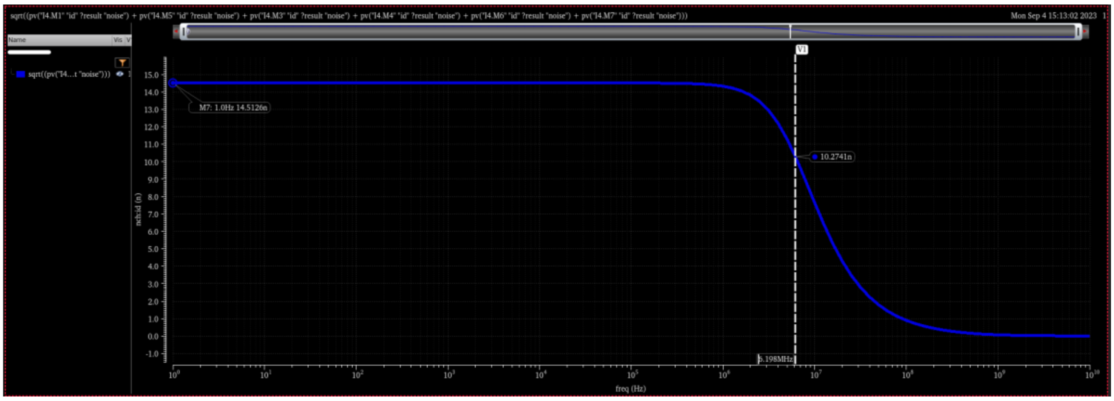

Figure 11 output thermal noise vs frequency

bandwidth(sqrt(Total_thermal_noise) 3 "low")	6.198M

Compare the simulation results with hand analysis.

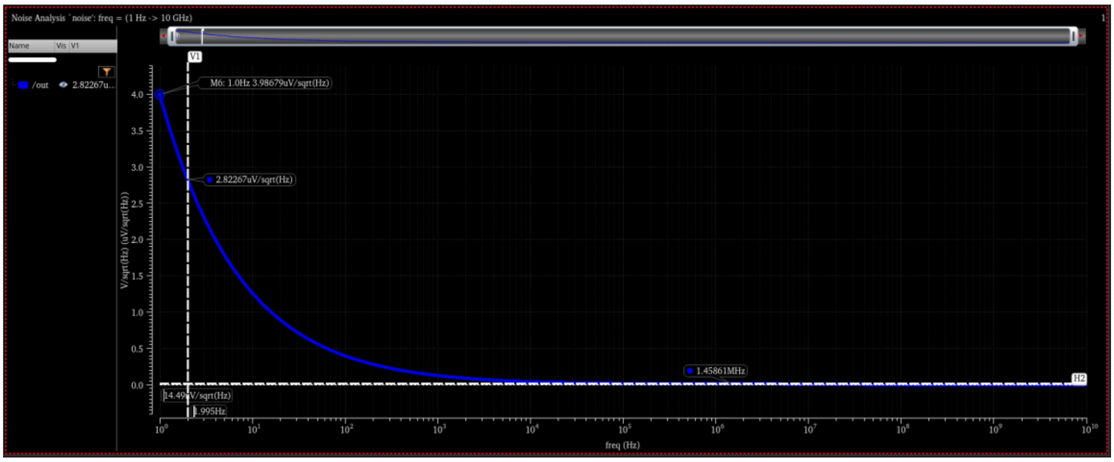

Figure 12 output Total noise vs frequency

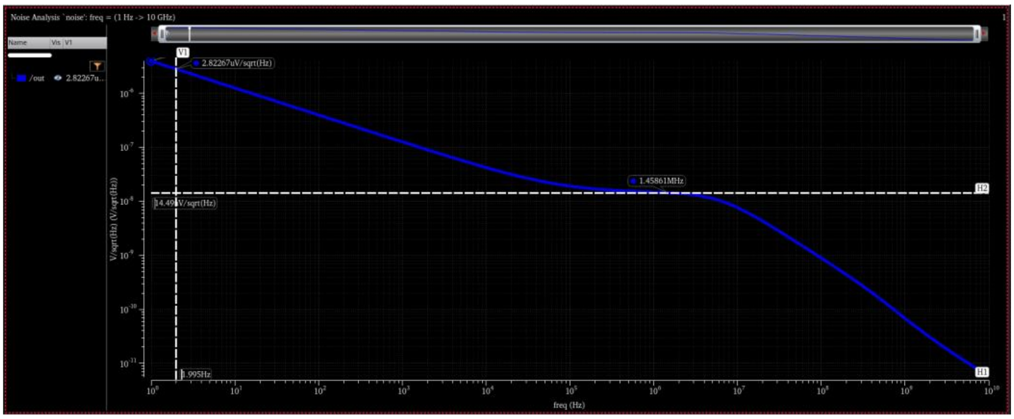

Figure 13 output Total noise in log scale vs frequency

bandwidth(getData("/out" ?result "noise") 3 "low")	1.995
rmsNoise(1 1e+10)	48.09u

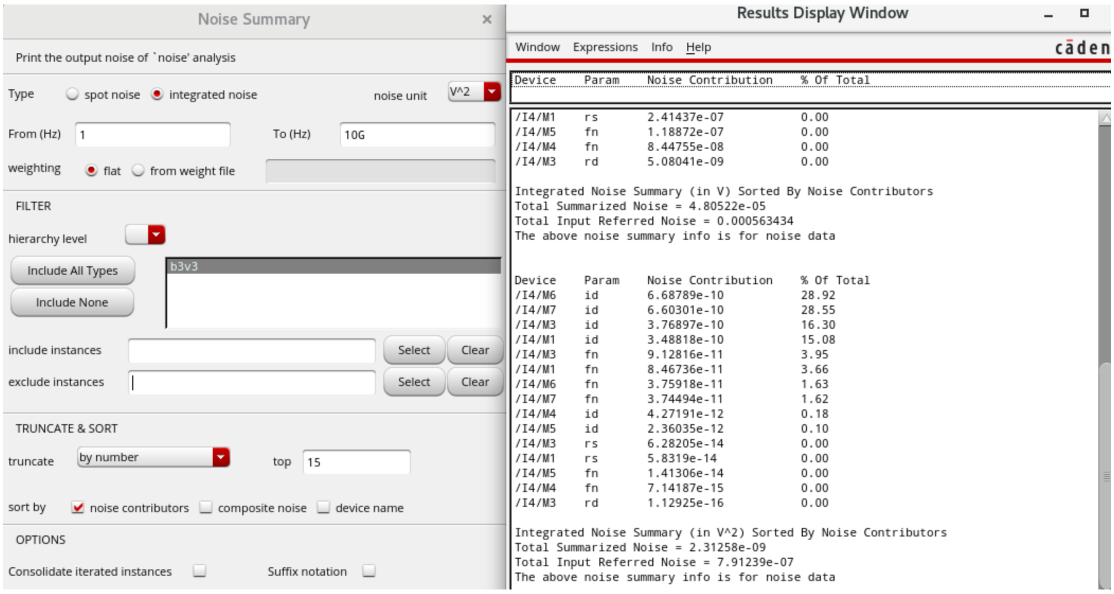

Figure 14 rms noise using noise summary.

sqrt(integ((pv("I4.M1" "id" ?result "noise") + pv("I4.M5" "id" ?result "noise") + pv("I4.M3" "id" ?...	45.4u

RMS Output Noise $=\sqrt{2.052n} = 45.3u$

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

Let $\gamma = 0.9$ & $gm1 = 200\ u$ & $gm3 = 101\ u$ & $B = 1$

Noise Density = $V_{out_{rms}} = \sqrt{\frac{8KT\gamma}{gm1} * \left(1 + \frac{gm3}{gm1}\right)} = 14.98\ \frac{nV}{\sqrt{HZ}}$

$Bandwith = \frac{1}{2*\pi*ROUT*CL} * (1 + \beta AOL) = 6.2\ MHz$

$RMS_{Noise} = V_{out_{rms}} \sqrt{BW * \frac{\pi}{2}} = 46.81\ u$

	Noise Density	Bandwidth	RMS
Simulation results	14.5 n	6.198 M	45.4 u
Hand analysis	14.98 n	6.2 M	46.81 u

PART 4: 5T OTA Transient Noise Analysis

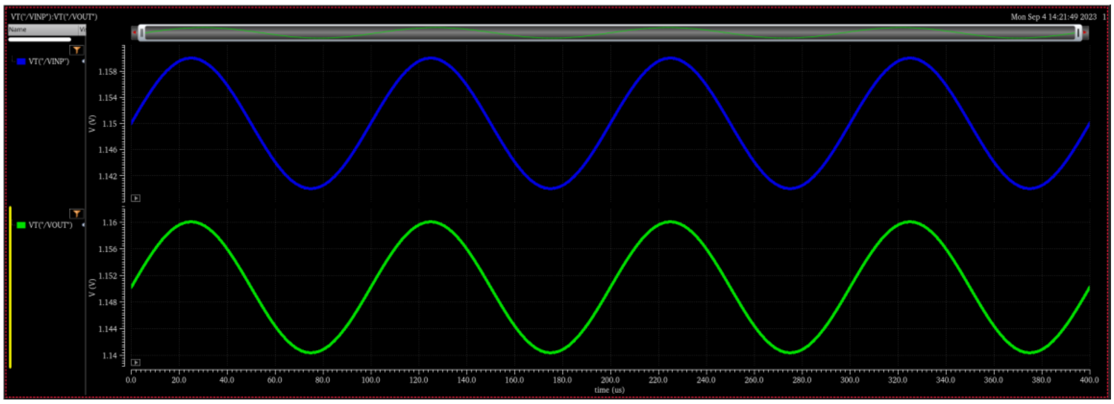

Figure 15 input and output overlaid

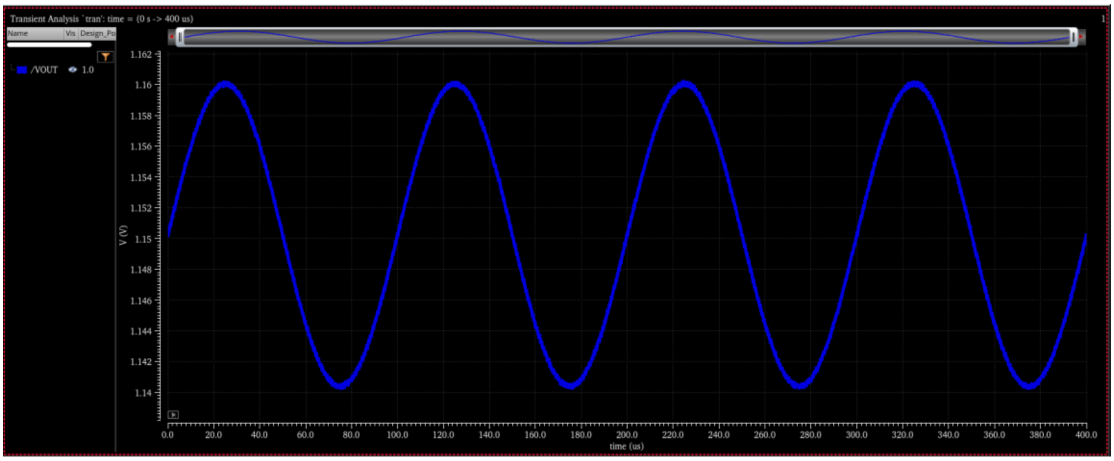

Figure 16 Vout with noise

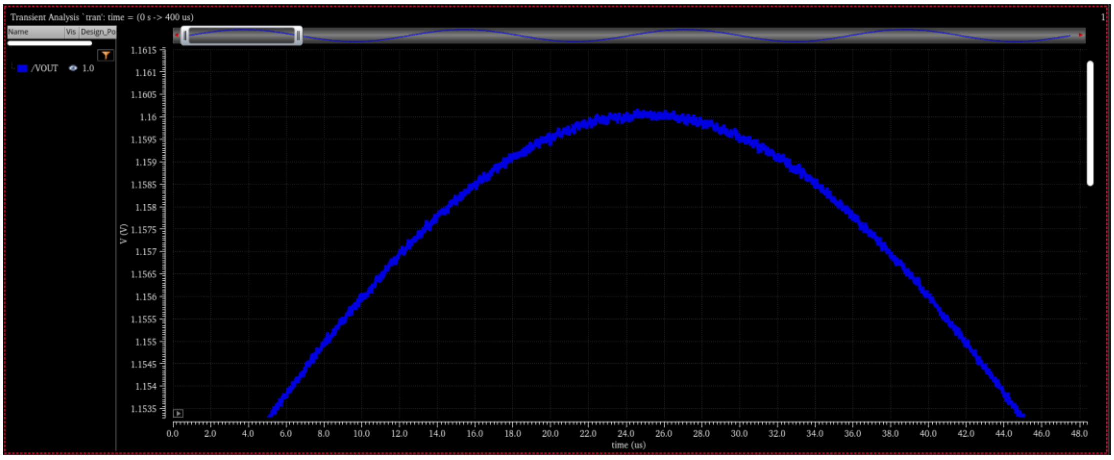

Figure 17 zoom-in

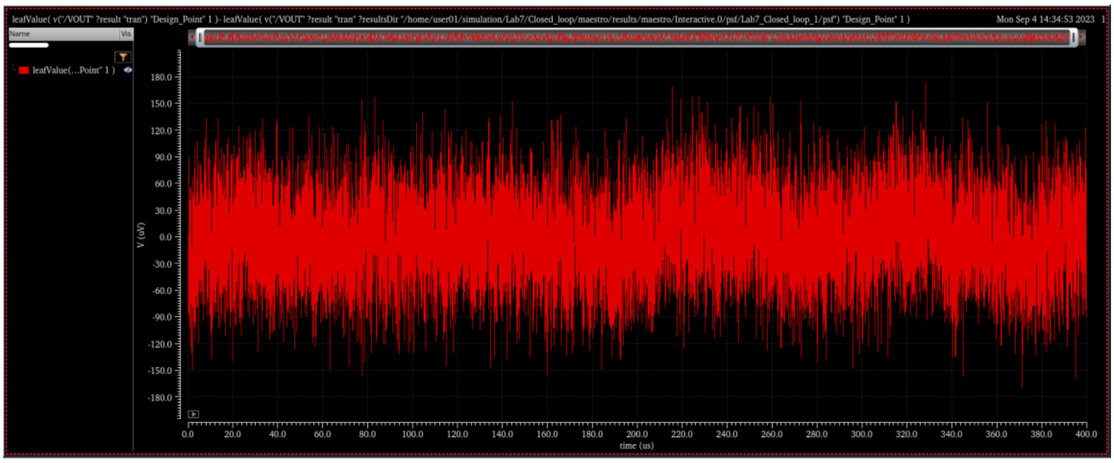

Figure 18 output noise

rms(leafValue(v...	43.63E-6

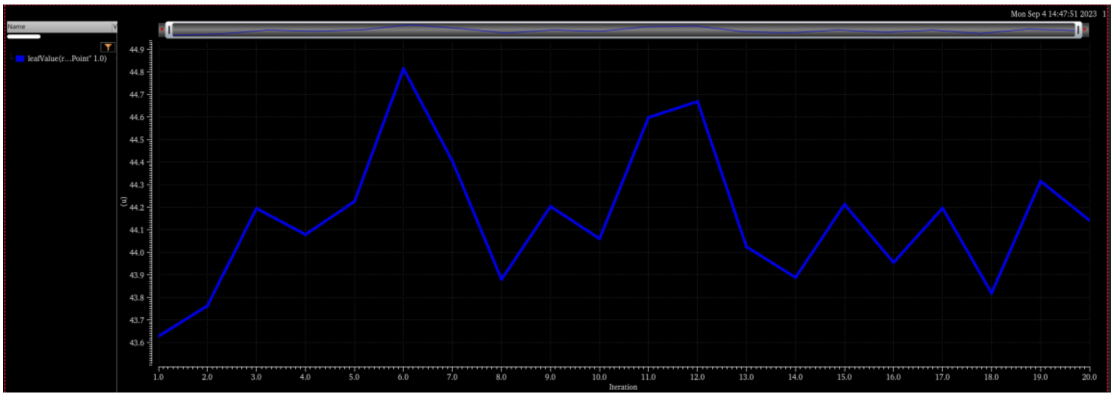

Figure 19 RMS vs iteration

Design_Point	average(r...t" 1))))
1.000	44.17E-6

Compare the calculated value with the rms noise previously obtained in Part 3.

	Part 4	Part 3
rms noise	44.17u	48.09u