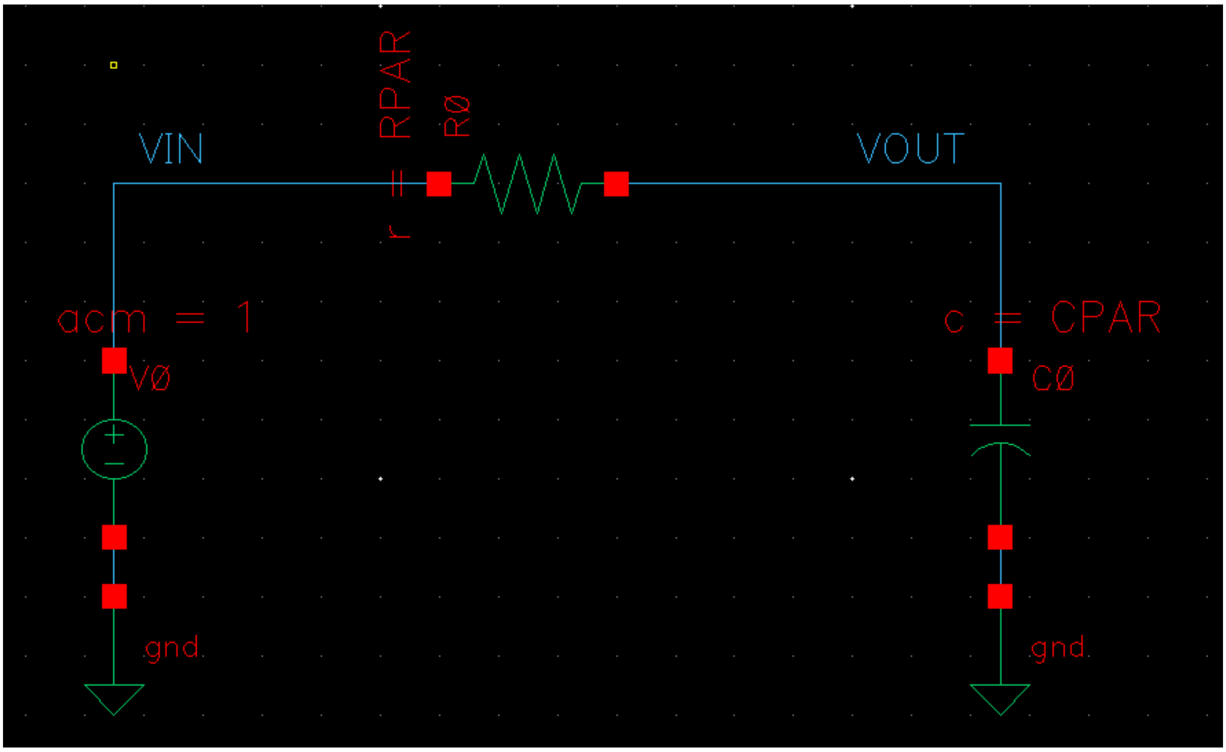
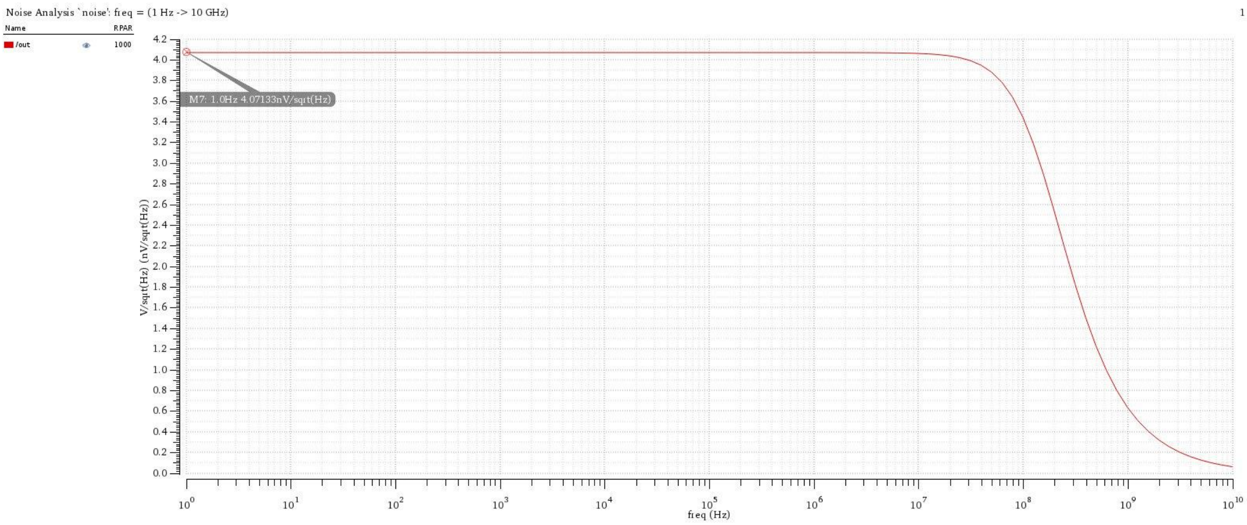
Analog IC Design
Lab 10
Noise Simulation

PART 1: LPF AC Noise Analysis



<u>Report output noise vs frequency. Annotate voltage noise density and bandwidth in the plot.</u>



From the above graph the noise density= 4.07 n

And the bandwidth is 158.8 MHz

Calculate rms output noise using rms noise function in the calculator.

Test	Output	Nominal	Spec	Weight	Pass/Fail
Lab_10:part_1_lpf:1	RMS_Noise	64.32u			
Lab_10:part_1_lpf:1	BW	158.8M			

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

R = 1 K ohm C=1 pF

$$\text{noise density} = \sqrt{\frac{R}{1K}} * 4\frac{nV}{\sqrt{Hz}} = 4\frac{nV}{\sqrt{Hz}}$$

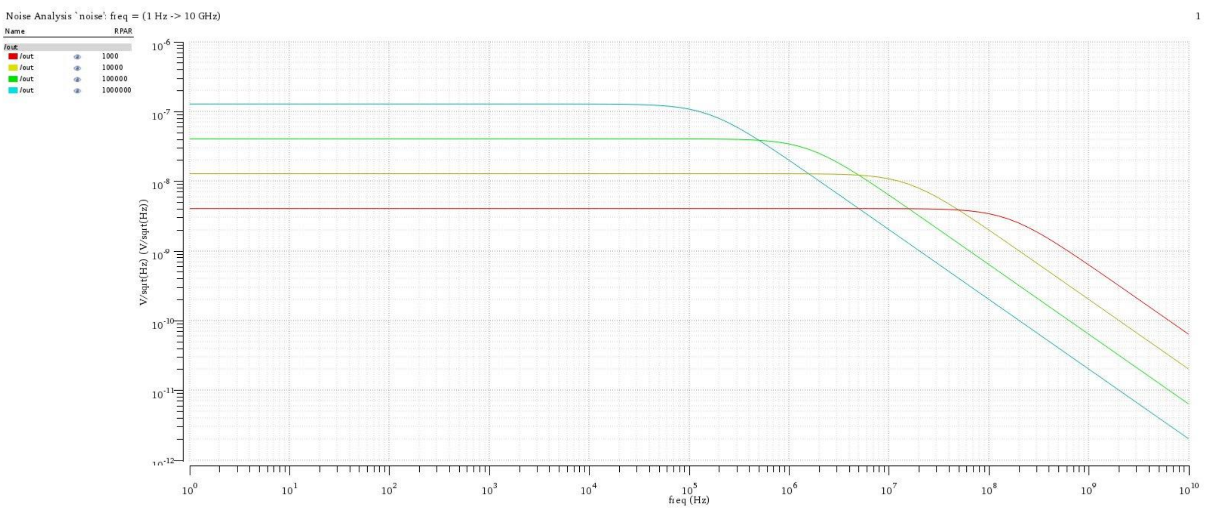
$$\text{BW} = \frac{1}{2 * \text{pi} * \text{R} * \text{C}} = 159.155\ MHz$$

$$RMS_{noise} = \sqrt{\frac{1p}{C}} * 64\ uV_{rms} = 64\ uV_{rms}$$

	Simulation	Analytical
Noise density	4.07 n	4 n
BW	158.8 M	159.155 M
RMS noise	64.32 u	64 u

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.



Comment:

When the resistance is multiplied by 10 the noise density is multiplied by $\sqrt{10}$.

Calculate the rms noise using the calculator. Comment on the results

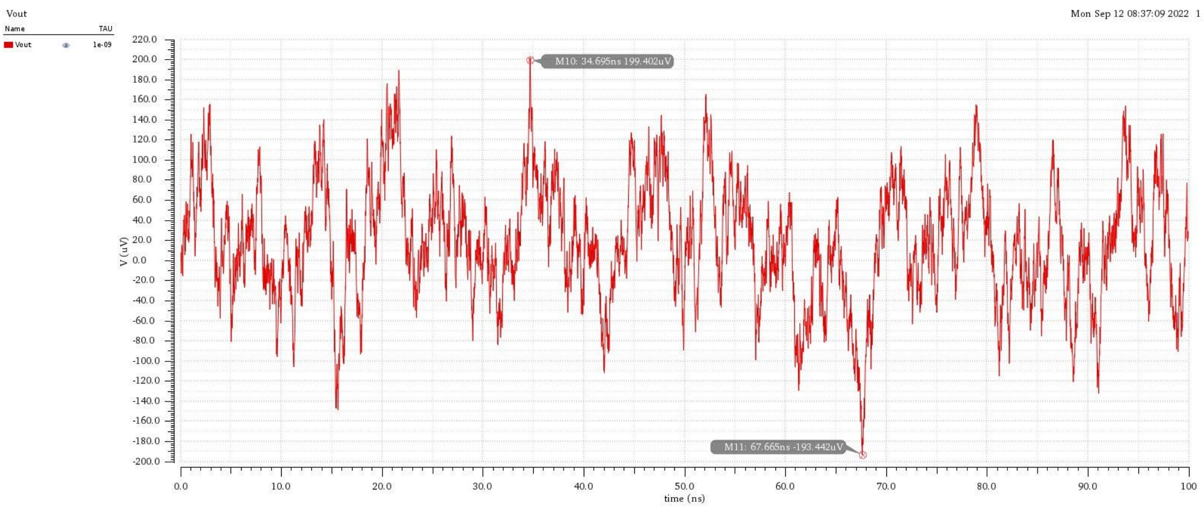
Point	Test	Output	Nominal	Spec	Weight	Pass/Fail
Parameters: RPAR=1k						
1	Lab_10:part_1_lpf:1	RMS_Noise	64.32u			
Parameters: RPAR=10k						
2	Lab_10:part_1_lpf:1	RMS_Noise	64.62u			
Parameters: RPAR=100k						
3	Lab_10:part_1_lpf:1	RMS_Noise	64.65u			
Parameters: RPAR=1M						
4	Lab_10:part_1_lpf:1	RMS_Noise	64.66u			

Comment:

The rms noise is almost the same for all values of R because noise in RC circuits is independent on the value of R

PART 2: LPF Transient Noise Analysis

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



Minimum value = -193.442 uV

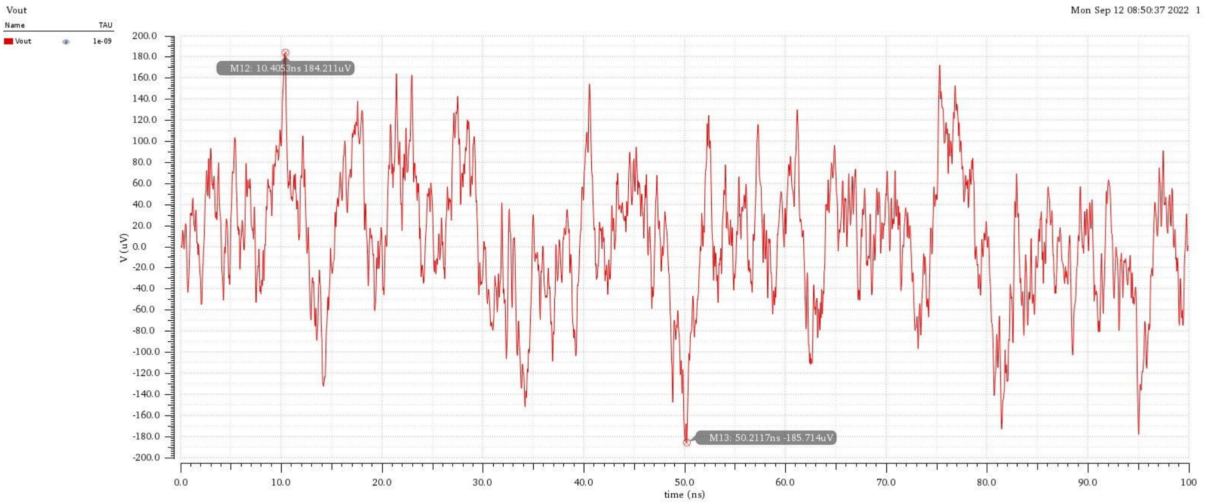
Maximum value= 199.402 uV

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

Test	Output	Nominal	Spec	Weight	Pass/Fail
Lab_10:part_1_lpf:1	Vout				
Lab_10:part_1_lpf:1	rms_noise	61.11u			

The RMS noise decreased as in part 1 was equal to 64.32 u

Repeat the simulation with TSTEP = TAU/10.



Maximum value = 184.211 uV

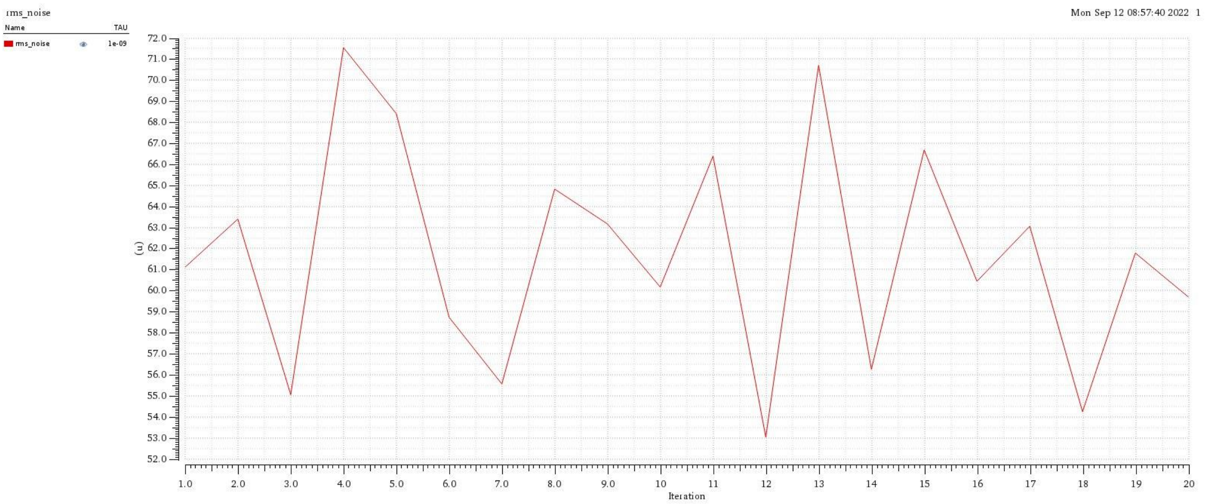
Minimum value = -185.714 uV

Does the calculated rms noise increase or decrease? Why?

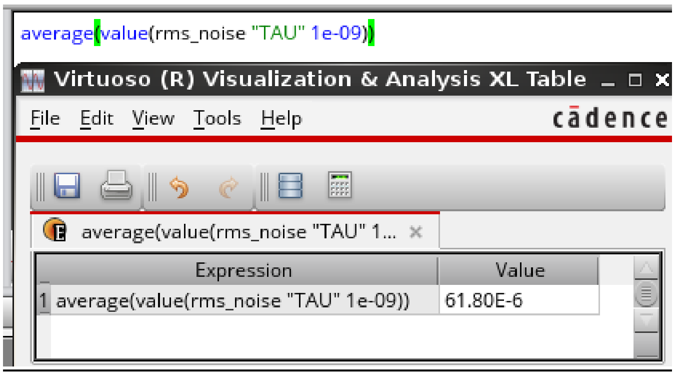
Test	Output	**Nominal**	Spec	Weight	Pass/Fail
Lab_10:part_1_lpf:1	Vout				
Lab_10:part_1_lpf:1	rms_noise	61.65u			

The rms noise increased slightly than that of TAU

Report the rms noise vs iteration.



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.



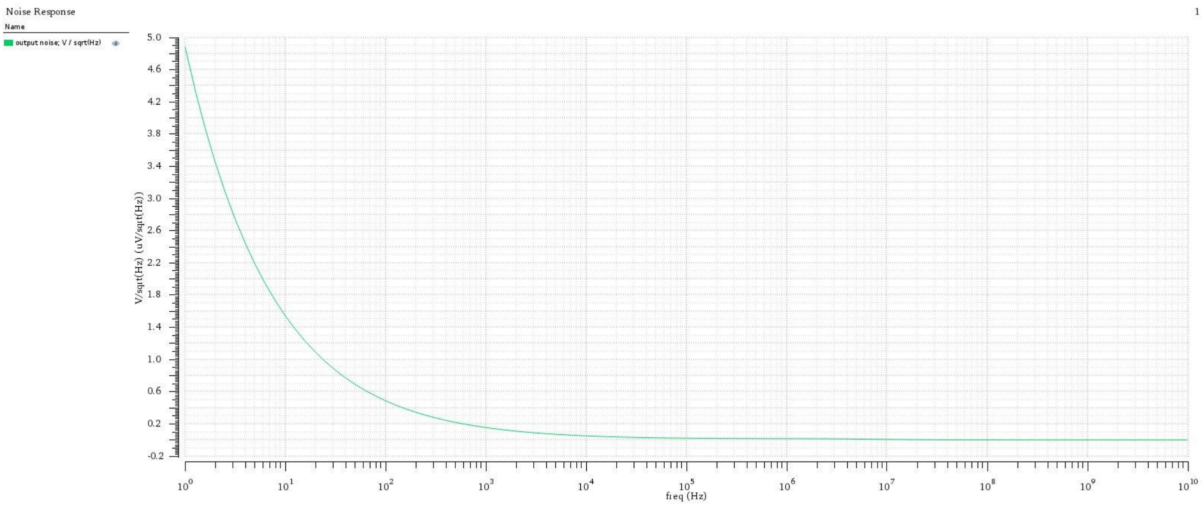
	Part 1	Part 2
Average RMS	64.32 u	61.8 u

PART 3: 5T OTA AC Noise Analysis

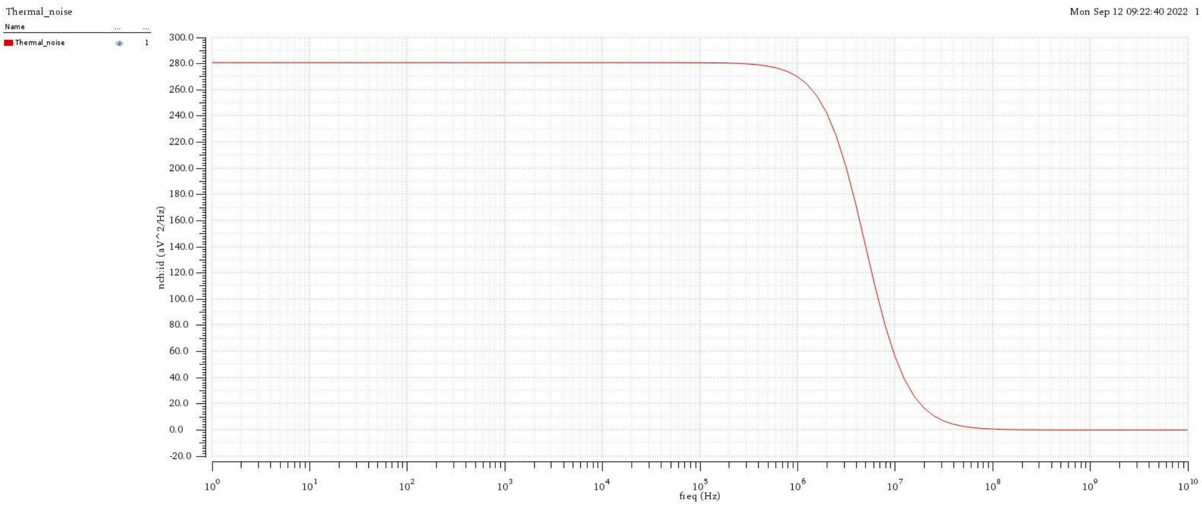
<u>Report output noise vs frequency. Annotate noise density and bandwidth in the plot.Compare the simulation results with hand analysis</u>

This graph shows the total noise which is the flicker noise and thermal noise which is clear that the graph takes the shape of the flicker noise as it decays with frequency and the thermal noise is white noise which here acts as an offset.

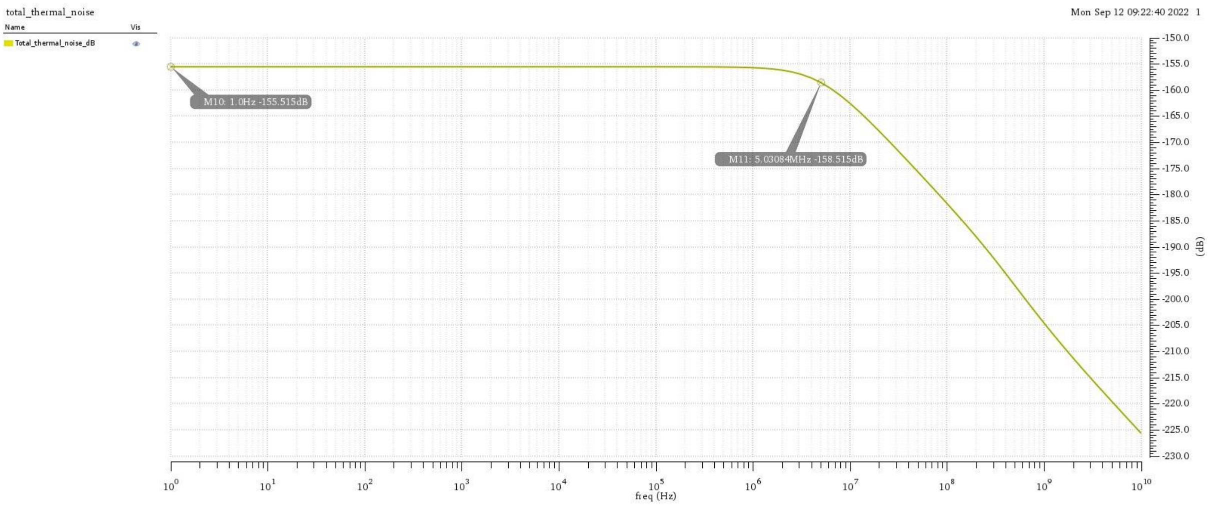
So, I want to get the bandwidth so I got it from the thermal noise.



The thermal noise graph.



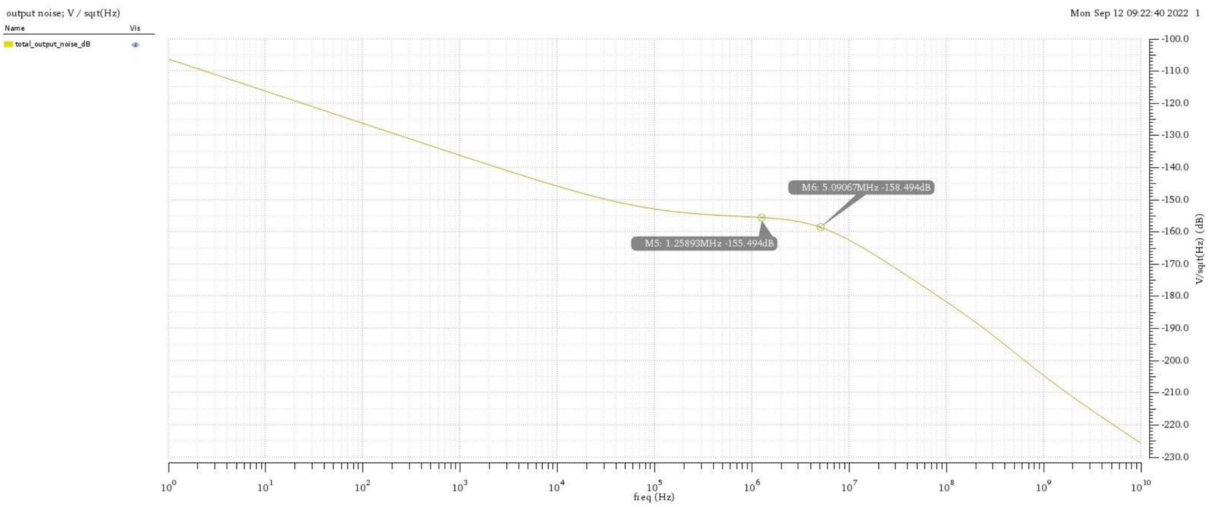
Then the thermal noise in dB.



From this graph thermal noise = 16.759 nV/$\sqrt{Hz}$

Here it’s clear that the bandwidth is equal to 5 MHz

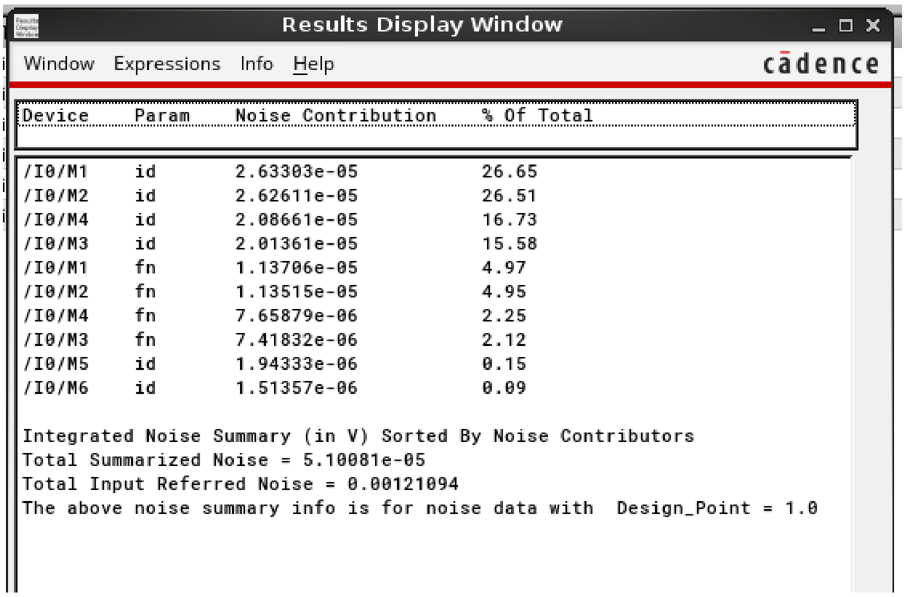
In this graph this is the noise in dB and here is the bandwidth annotated.



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

Test	Output	Nominal	Spec	Weight	Pass/Fail
Lab_10:part3_ota:1	output noise; V / sqrt(Hz)				
Lab_10:part3_ota:1	Thermal_noise				
Lab_10:part3_ota:1	thermal_noise_dB				
Lab_10:part3_ota:1	total_thermal_noise				
Lab_10:part3_ota:1	total_thermal_noise_db				
Lab_10:part3_ota:1	rmsNoise(1 1e+10)	51.01u			

This is the total output rms noise.



The rms noise due to thermal noise only is equal to:

$$100\% - (4.97\% + 4.95\% + 2.25\% + 2.12\%) * TOTAL\ NOISE = 43.72\ u$$

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

$$gamma = \frac{3}{4} \rightarrow g_{m1} = 157.3\ u \rightarrow g_{m3} = 92.54\ u \rightarrow B = 1$$

$$\text{noise density} = \text{Vnoutrms} = \sqrt{\frac{8KT\gamma}{g_{m1}}\left(1 + \frac{gm_3}{g_{m1}}\right)} = 14.93\ \text{nV}/\sqrt{Hz}$$

$$BW = \frac{1}{2 * pi * Rout * C_L} * (1 + BA_{ol}) = 5.09\ MHz$$

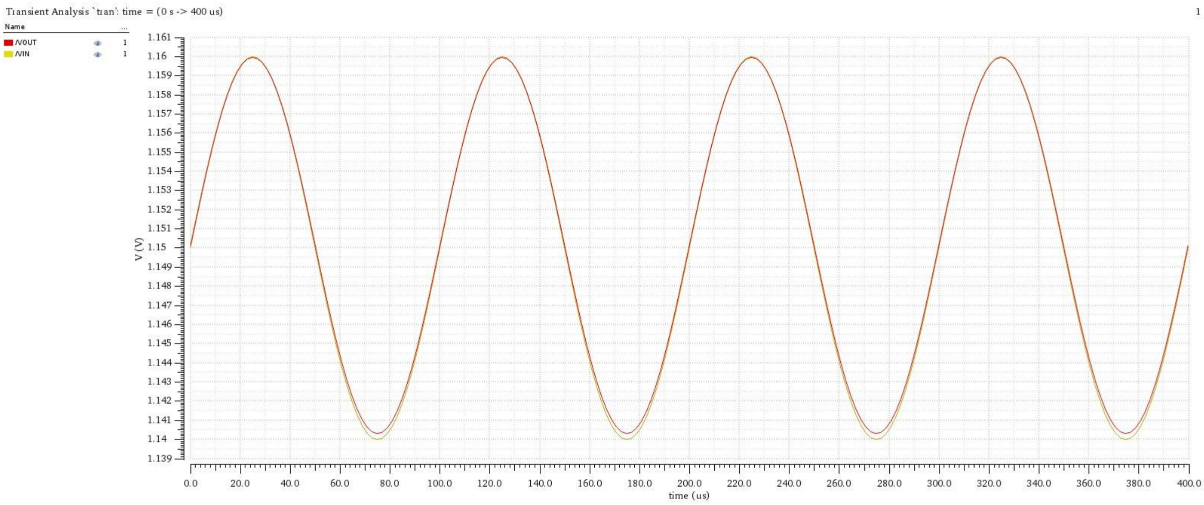
$$rms\ noise = \sqrt{Vnoutrms^2 * BW * \frac{pi}{2}} = 42.216\ u$$

	Simulation	Analytical
BW	5.03 MHz	5.09MHz
Noise density	14.759 n	14.93 n

Rms noise (thermal)	43.72 u	42.216 u

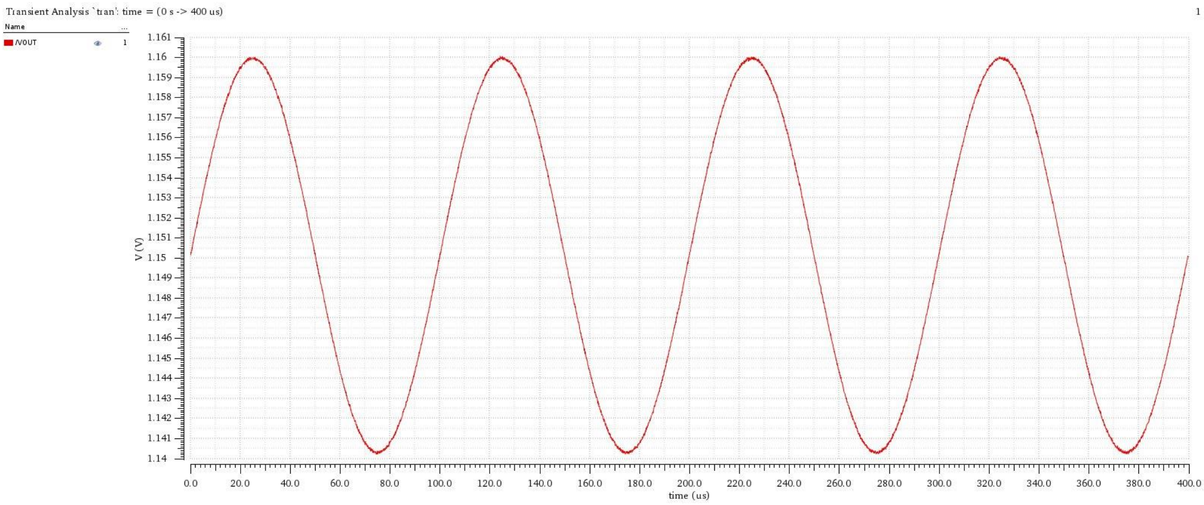
PART 4: 5T OTA Transient Noise Analysis

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

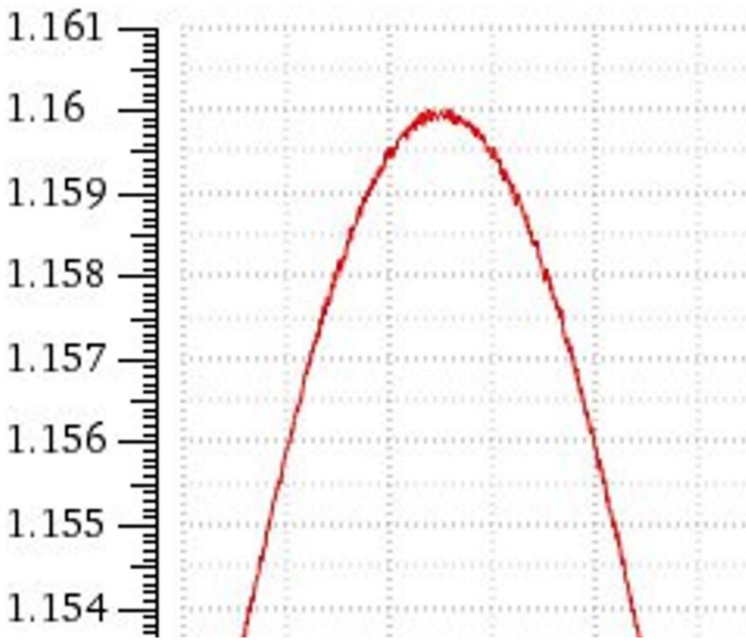


the output signal is almost equal to the input signal but it has some slight errors due to the finite gain of the 5T-OTA.

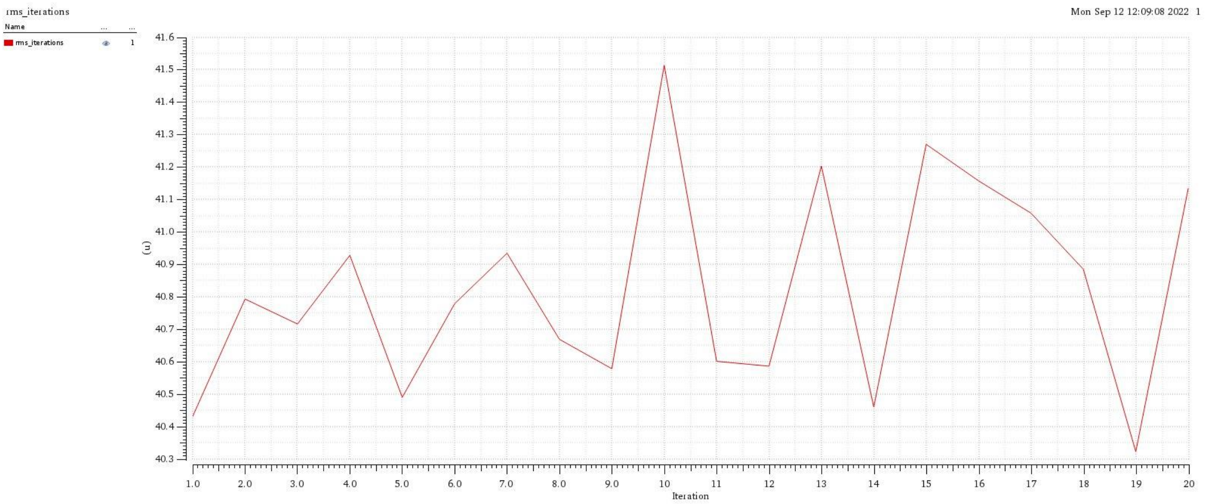
<u>Report the “noisy” output waveform. Notice that output signal and noise are superimposed.</u>



As we can see that the output signal is noisy
here is a closer look.



<u>Report the rms noise vs iteration.</u>



<u>Use the calculator to calculate the average rms noise. Compare the calculated value with the rms noise previously obtained in Part 3.</u>

Test	Output	Nominal	Spec	Weight	Pass/Fail
Lab_10:part3_ota:1	VOUT				
Lab_10:part3_ota:1	VIN				
Lab_10:part3_ota:1	Vdiff				
Lab_10:part3_ota:1	rms_iterations				
Lab_10:part3_ota:1	average(rms(Vdiff))	40.83u			

	Part 3	Part 4
Average rms noise	50.01 u 43.72 u (thermal)	40.83u