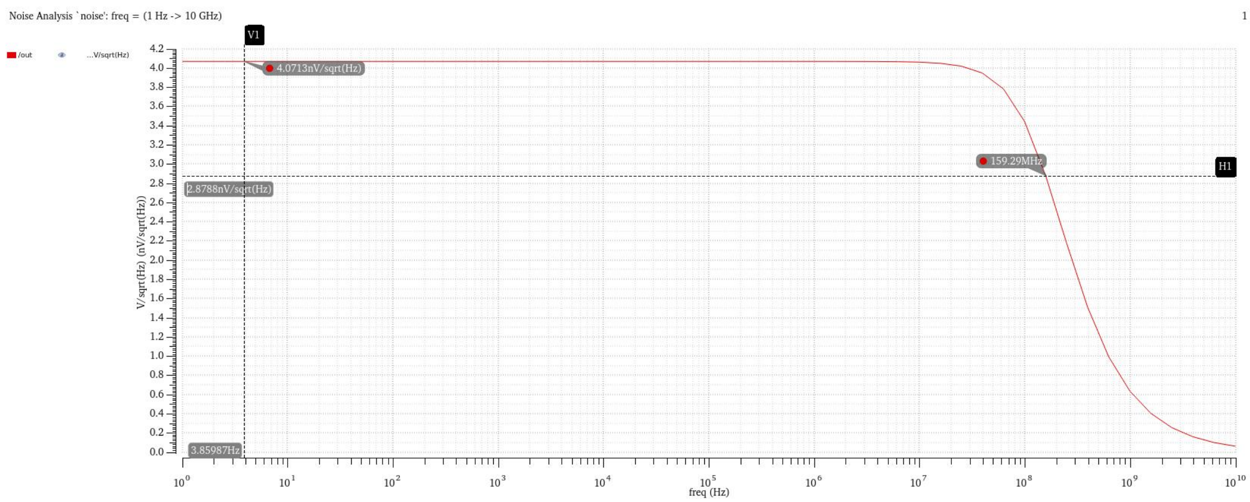
Lab 10

PART 1: LPF AC Noise Analysis:

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



$output\ noise\ denisty = 4.0713nV/\sqrt{HZ}$ and $BW = 159.29MHz$.

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

Test	Output	Nominal	Spec	Weight	Pass/Fail
ITI_labs:Lab_10_Noise_rc:1	rmsNoise(1 1e+10)	65.16u			

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

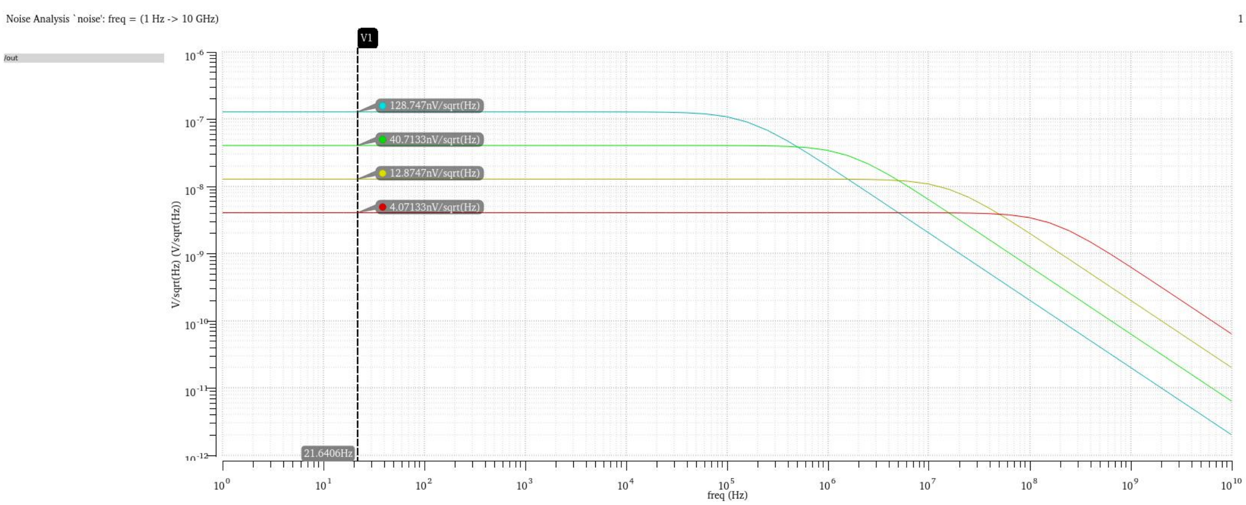
$noise\ denisty = \sqrt{4kTR} = 4.069nV/\sqrt{HZ}$ which is around the value we expected from the lecture.

$$BW = \frac{1}{2\pi RC} = 159.15MHz$$

$$RMS = \sqrt{\frac{KT}{C}} = 64.34\mu Vrms$$

	Hand Analysis	Simulation
Noise density	$4.069nV/\sqrt{HZ}$	$4.0713nV/\sqrt{HZ}$
BW	$159.15MHz$	$159.29MHz$
RMS	$64.34\mu Vrms$	$65.16\mu Vrms$

10) Plot output noise overlaid on the same plot. Using log-scale for y-axis. Comment on the results.



Comment:

As we increase the resistance the noise density increases but the BW decreases with the same ratio which keeps the rms noise constant and depends only on capacitance.

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

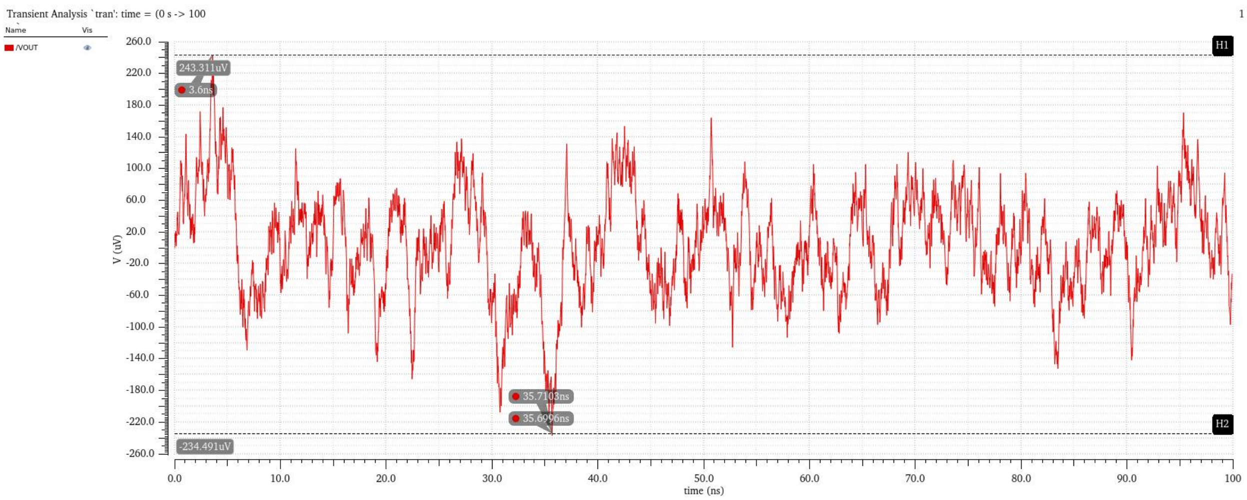
Point	Test	Output	Nominal	Spec	Weight	Pass/Fail
Parameters: RPAR=1k						
1	ITI_labs:Lab_10_Noise_rc:1	rmsNoise(1 1e+10)	65.16u			
Parameters: RPAR=10k						
2	ITI_labs:Lab_10_Noise_rc:1	rmsNoise(1 1e+10)	65.48u			
Parameters: RPAR=100k						
3	ITI_labs:Lab_10_Noise_rc:1	rmsNoise(1 1e+10)	65.51u			
Parameters: RPAR=1M						
4	ITI_labs:Lab_10_Noise_rc:1	rmsNoise(1 1e+10)	65.51u			

Comment:

Rms is almost constant when increasing resistance as it increases noise density but decreases BW which keeps total RMS constant.

PART 2: LPF Transient Noise Analysis:

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



4) 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
ITI_labs:Lab_10_Noise_rc:1	rms(VT("/VOUT"))	63.53u			

	Part 1	Part 2
RMS	$65.16\mu Vrms$	$63.53\mu Vrms$

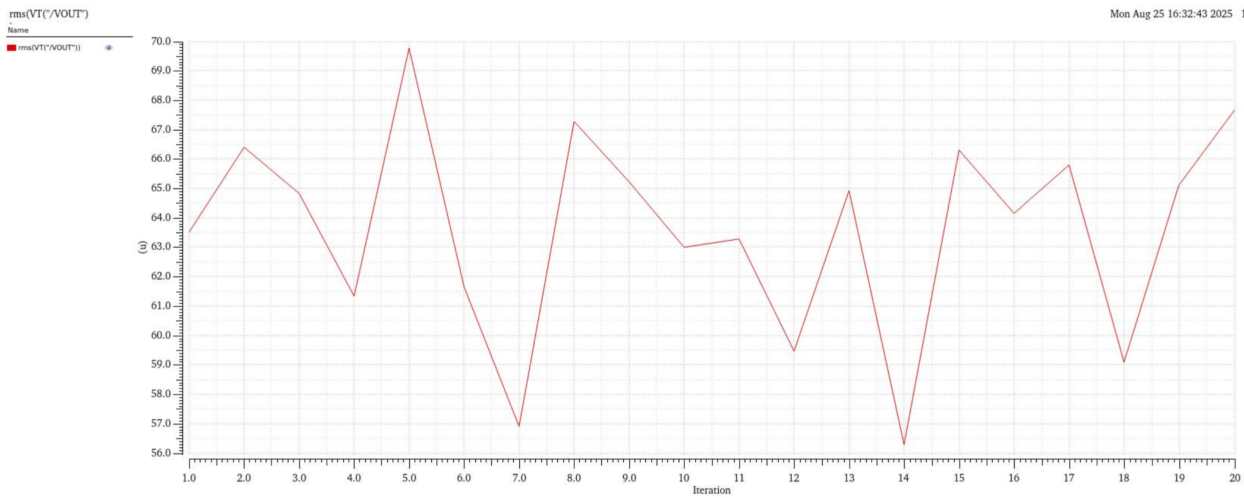
The Rms in both simulations is almost the same but in part 2 is a little less as We use a smaller range of frequencies.

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

Test	Output	Nominal	Spec	Weight	Pass/Fail
ITI_labs:Lab_10_Noise_rc:1	rms(VT("/VOUT"))	66.57u			

When we increase the Tstep the maximum frequency decreases so the total rms should decrease but the simulator has a slight error so it increased.

7) Report the rms noise vs iteration.



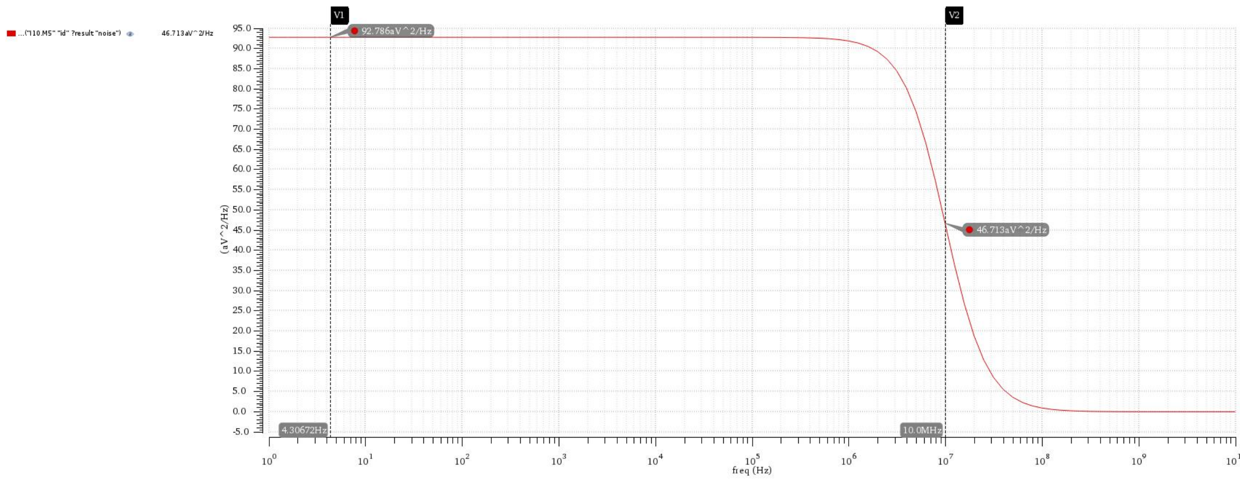
8) Use the calculator to calculate the average rms noise. Compare the calculated value with the rms noise previously obtained in Part 1 and Part 2.

Test	Output	Nominal	Spec	Weight	Pass/Fail
ITI_labs:Lab_10_Noise_rc:1	rms(VT("/VOUT"))				
ITI_labs:Lab_10_Noise_rc:1	average(rms(VT("/VOUT")))	63.51u			

	Part 1	Part 2	Average
RMS	$65.16\mu Vrms$	$63.53\mu Vrms$	$63.51\mu Vrms$

PART 3: 5T OTA AC Noise Analysis:

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



Hand analysis:

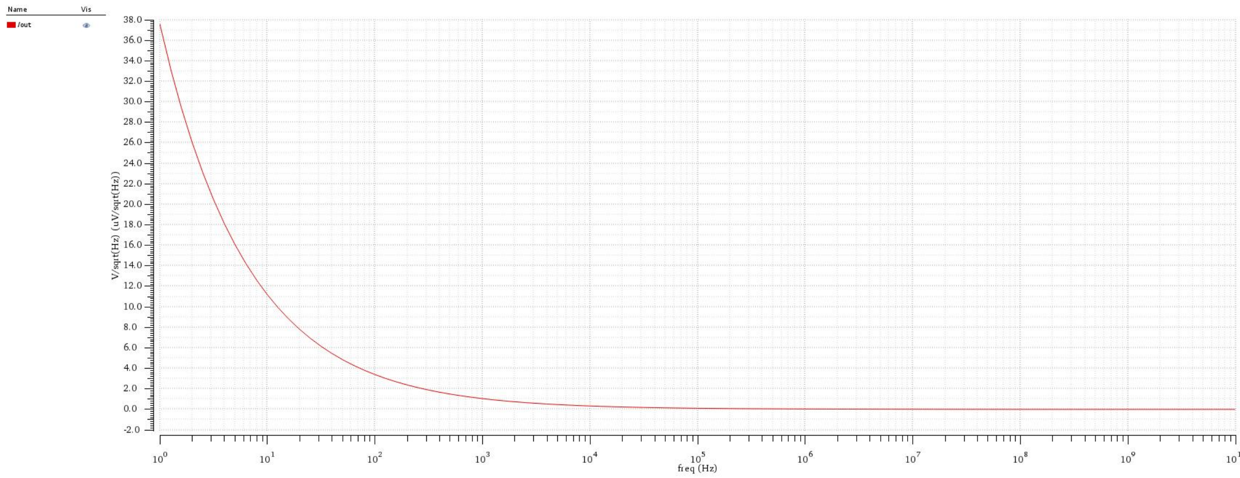
$$v_{nout}^2 = \frac{8kT\gamma}{gm1,2} * \left(1 + \frac{gm3,4}{gm1,2}\right) * A_{CL}^2 = 93.47aV^2/Hz$$

Consider that $gm1,2 = 0.00031354$ *and* $gm3,4 = 0.000102627$ and when we got gamma from ADT it was very near from our assumption that $gamma = \frac{2}{3}$.

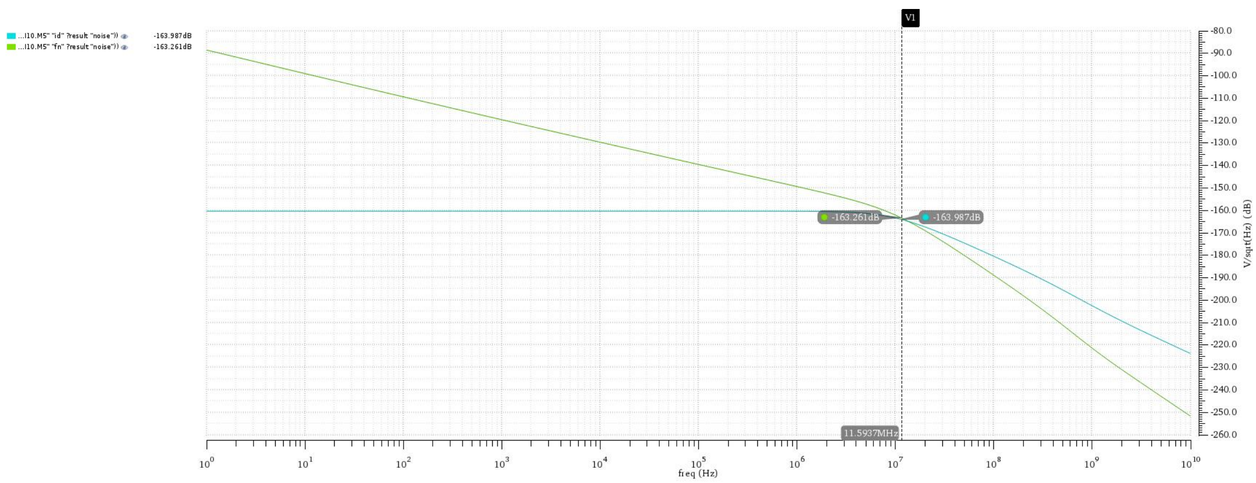
$BW = GBW = 10MHz$ as it is in a unity gain buffer connection.

	Hand Analysis	Simulation
Output Thermal Noise	$93.47aV^2/Hz$	$92.786aV^2/Hz$
BW	$10MHz$	$10MHz$

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



To estimate flicker corner, we will draw flicker and thermal noise overlaid and get the intersection:



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

```
/I10/M0    fn      6.41002e-09          31.08
/I10/M1    fn      6.19933e-09          30.06
/I10/M4    fn      3.41456e-09          16.56
/I10/M3    fn      3.11681e-09          15.11
/I10/M0    id      5.20156e-10          2.52
/I10/M1    id      5.20126e-10          2.52
/I10/M3    id      2.3283e-10           1.13
/I10/M4    id      1.86373e-10          0.90
/I10/M5    fn      8.91713e-12          0.04
/I10/M5    id      5.58173e-12          0.03
/I10/M2    id      4.24459e-12          0.02
/I10/M2    fn      2.16757e-12          0.01

Integrated Noise Summary (in V^2) Sorted By Noise Contributors
Total Summarized Noise = 2.06211e-08
Total Input Referred Noise = 9.27985e-06
The above noise summary info is for noise data
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$RMS\ of\ thermal\ noise = 38.3316\mu V/Hz$

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

$$v_{nout}^2 = \frac{8kT\gamma}{gm1,2} * \left(1 + \frac{gm3,4}{gm1,2}\right) * A_{CL}^2 = 93.47aV^2/Hz$$

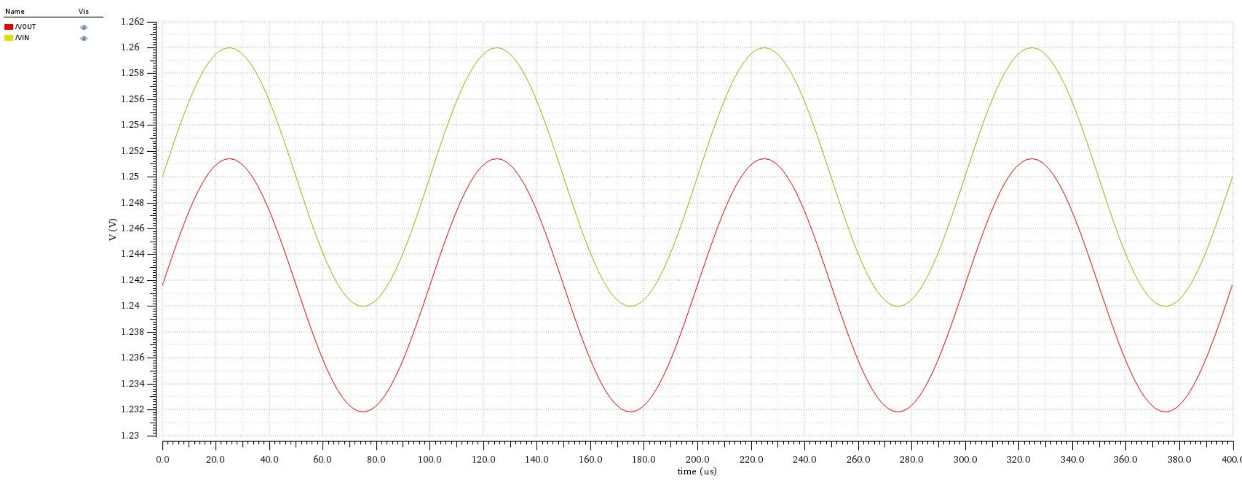
$$BW = GBW = 10MHz$$

$$Rms = \sqrt{v_{nout}^2 * \frac{\pi}{2} * BW} = 38.317\mu V/Hz$$

	Hand Analysis	Simulation
Output Thermal Noise	$93.47aV^2/Hz$	$92.786aV^2/Hz$
BW	$10MHz$	$10MHz$
Rms	$38.317\mu V/Hz$	$38.3316\mu V/Hz$

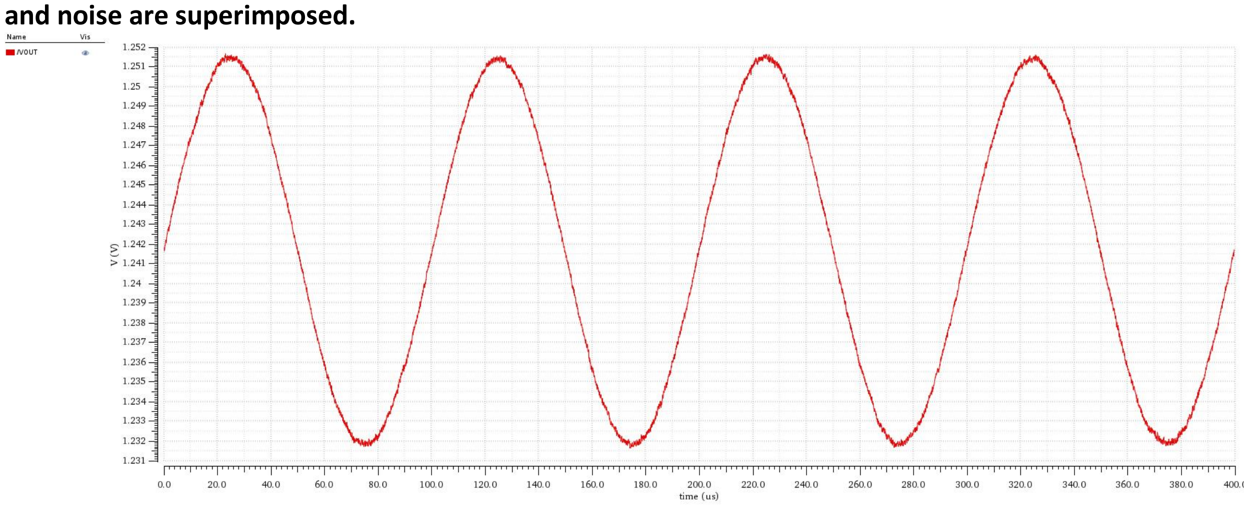
PART 4: 5T OTA Transient Noise Analysis:

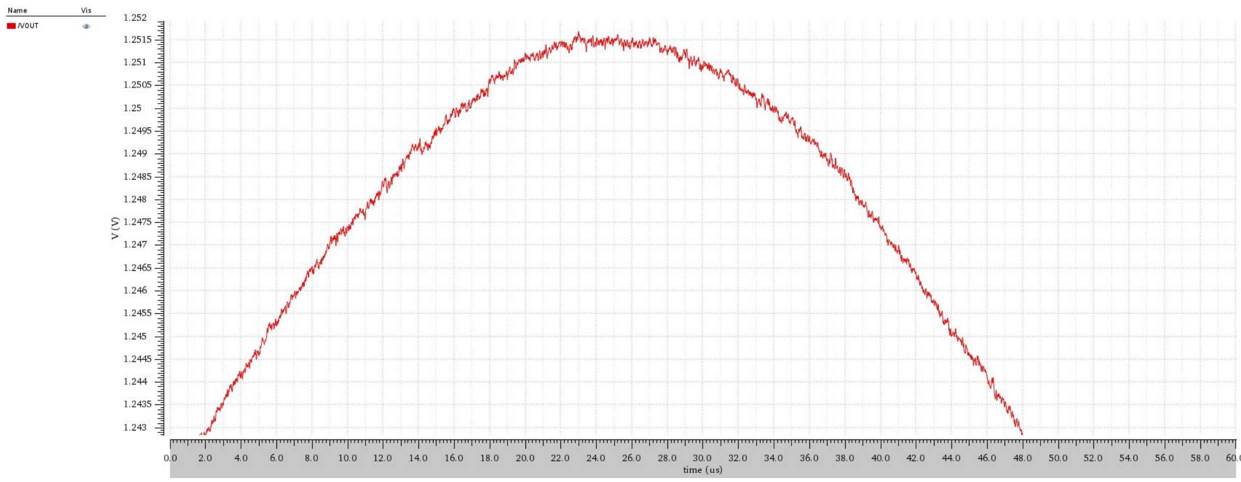
4) Plot input and output overlaid and make sure they match well (verify that the circuit behaves as a buffer).



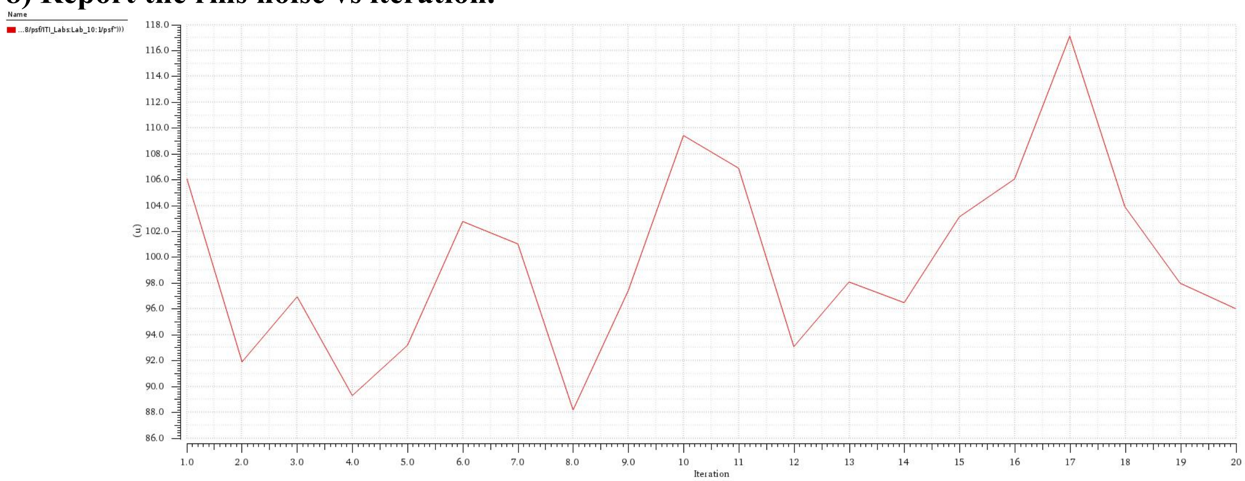
- The circuit behaves as a buffer as Vout is approximately Vin but this difference is due to the existence of Verr between VINP and VINN so the common mode (DC) of the two signals isn't exactly the same also the Acl isn't exactly 1 it is a little less than it so Vptp of Vout isn't exactly 20mV.

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





8) Report the rms noise vs iteration.



9) Use the calculator to calculate the average rms noise. Compare the calculated value with the rms noise previously obtained in Part 3.

	Fin	average...psf")))
1	10.00E3	99.69E-6

	Part 3	Average Part 4
Rms	$143.6\mu V/Hz$	$99.69\mu V/Hz$

- The average total Rms noise in part 4 is less than part 3 as we used fmax in part 4 with 100 MHz which is less than the range we calculated in part 3 which was up to 10 GHz.