Information Technology Institute

CMOS Analog IC Design

Lab 10

Noise Simulation

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PART 1: LPF AC Noise Analysis

Create a new cell. Create a testbench for a simple 1st order LPF as shown below. Set R and C as parameters.

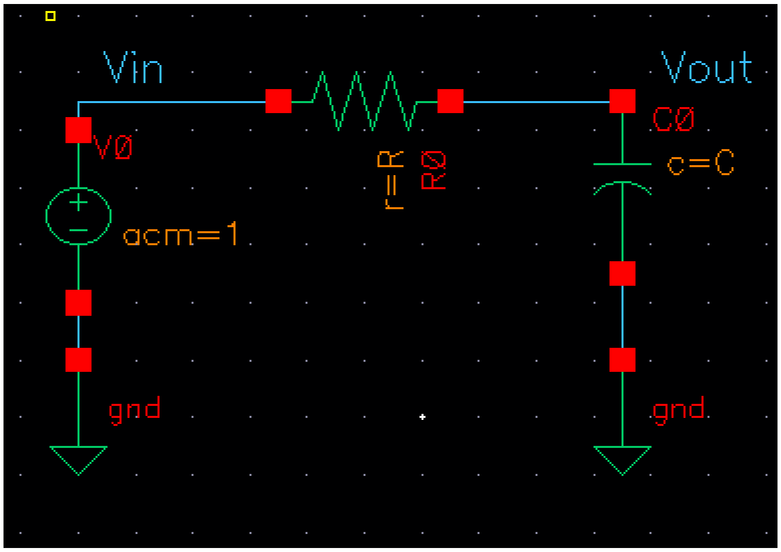

Figure 1 : Schematic of LPF

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

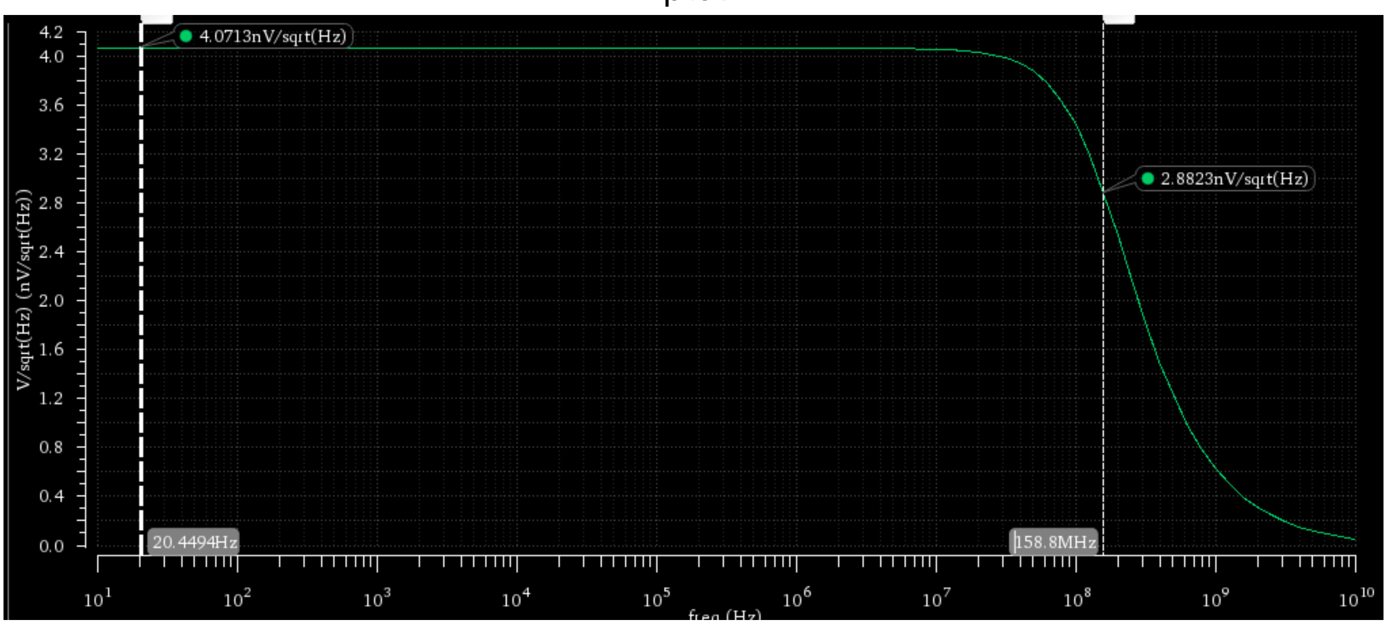

Figure 2 : output noise vs frequency with annotated voltage noise density and bandwidth

	Expression	Value
1	bandwidth(val...	158.8M

Figure 3 : Bw from calculator

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

	Expression	Value
1	rmsNoise(10 1...	64.32E-6

Figure 4 : rms noise from calculator.

hand analysis :

Bw=1/2π*Rc = 159.154MHz

$$V_{n,rms} = \sqrt{\frac{kT}{C}}$$

@ K= 1.38 × 10-23 and T = 300K , Vn,rms = 64.34 μV

$$V_n = \sqrt{4kTR}$$

@ K= 1.38 × 10-23 and T = 300K , Vn = 4.07 nV/sqrt(Hz)

	hand analysis	**Simulation**
Noise density (nV/sqrt(Hz))	**4.07**	**4.07**
rms Noise (μV)	**64.34**	**64.32**
BW (MHz)	**159.154**	**158.8**

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.

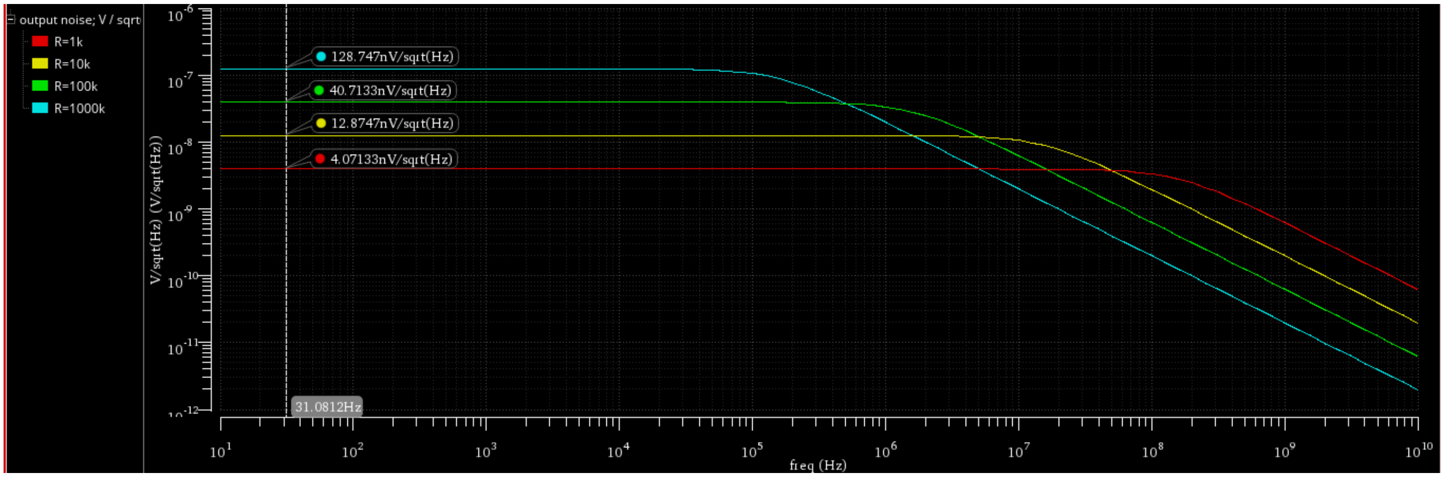

Figure 5 : output noise vs frequency with parametric sweep for resistor

Comment :

Resistor increases; the low-frequency noise density rises while the filter's bandwidth decreases.

	RPAR	rmsNoise(10 10G)
1	1.000k	64.32u
2	10.00k	64.62u
3	100.0k	64.65u
4	1.000M	64.66u

Figure 6 : : rms noise from calculator.

Comment :

The results indicate that the total RMS noise stays nearly constant at about **64 µV**, even when the resistance changes by a factor of 1000.

This agrees with the theoretical prediction:

$$V_{n,rms} = \sqrt{\frac{kT}{C}}$$

which shows that the total noise is independent of the resistance. The increase in noise density from a larger resistor is exactly offset by the reduction in the filter's bandwidth.

PART 2: LPF Transient Noise Analysis

Create a new simulation configuration for transient noise. Define new parameters TAU, TSTOP, and TSTEP

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

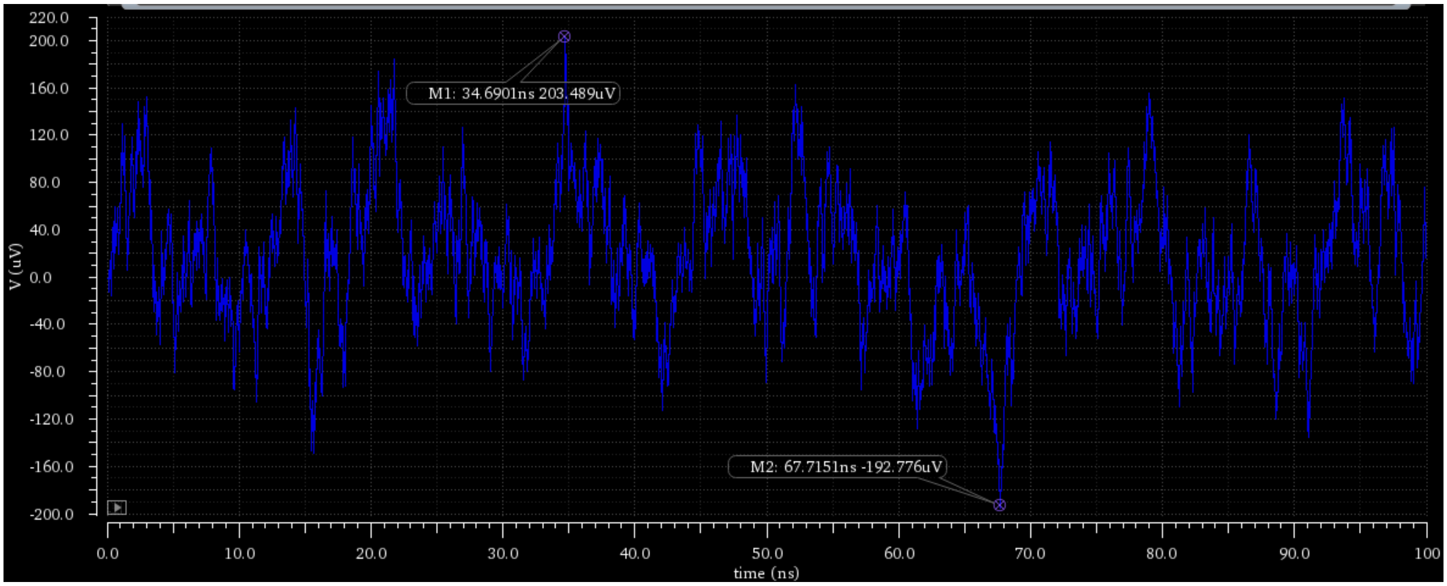

Figure 7 : noise output waveform. Annotate the min and max values

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

	TSTEP	rms(VT("/Vout"))
1	10.00p	60.88u

Figure 8 : rms noise from calculator , Tstep = tau/100

	Part 1	Part 2
rms Noise (µV)	**64. 32**	**60.88**

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

Parameters: TSTEP=100p			
1	Noise:LPF_Noise:1	rms(VT("/Vout"))	61.59u
Parameters: TSTEP=10p			
2	Noise:LPF_Noise:1	rms(VT("/Vout"))	60.88u
Parameters: TSTEP=1p			
3	Noise:LPF_Noise:1	rms(VT("/Vout"))	65.73u

Figure 9 : rms noise from calculator ,@ Tstep = tau/10,tau/100,tau/1000

When changing TSTEP from TAU/100 (10ps) to TAU/10 (100ps), the RMS noise increases from **60.88uV** to **61.59uV**.

In this case the RMS noise increased, but that's actually a simulation artifact. When the timestep is reduced, the simulator struggles to converge accurately since each step relies on the previous point as its initial guess. Ideally, the RMS noise should decrease with a larger timestep, so the observed increase is due to numerical limitations rather than the actual circuit behavior.

Back to TSTEP = TAU/100. Change the transient noise options Multiplier = 20. Now it will run 20 runs of transient noise iterations.

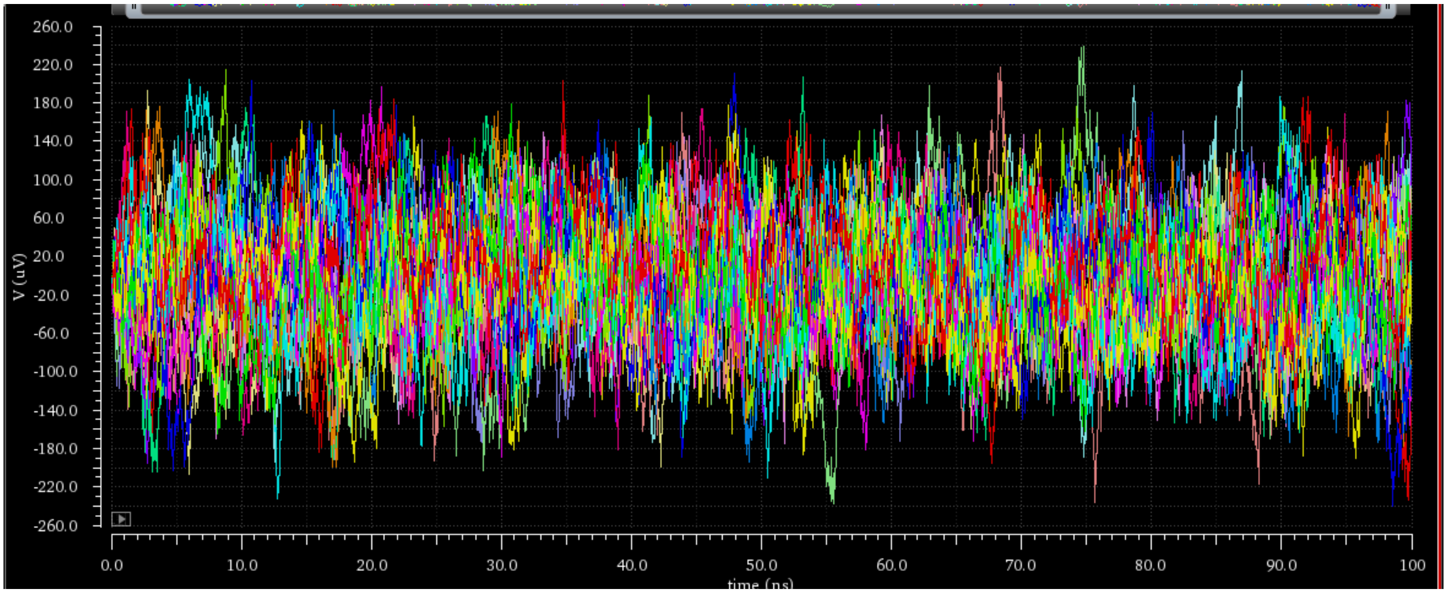

Figure 10 : noise output waveform with 20 runs of transient noise iterations

Report the rms noise vs iteration.

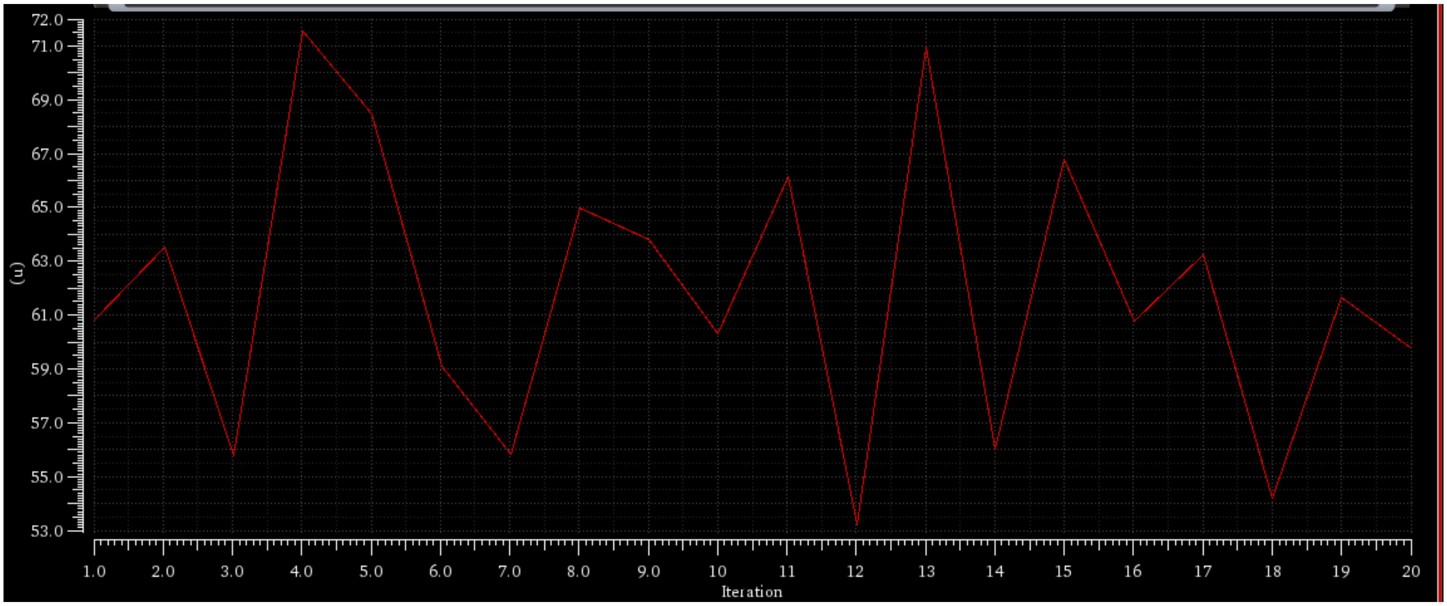

Figure 11 : rms noise vs iteration.

Use the calculator to calculate the average rms noise

	TSTEP	average...out")))
1	10.00E-12	61.97E-6

Figure 12 : average rms noise

	Part 1	Part 2	Part 3
rms Noise (µV)	**64.32**	**60.88**	**61.97**

PART 3: 5T OTA AC Noise Analysis

Create a new testbench. Connect the 5T OTA you designed in Lab 07 in unity-gain buffer configuration. Similar to Part 1, run ac noise analysi

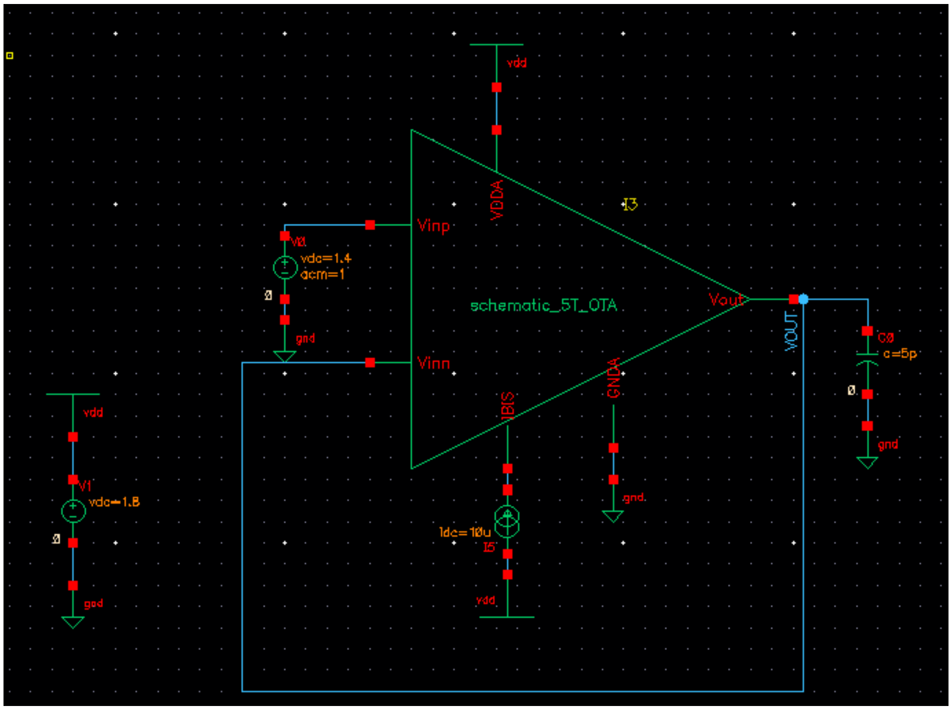

Figure 13 : testbench. Connect the 5T OTA in unity-gain buffer configuration

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

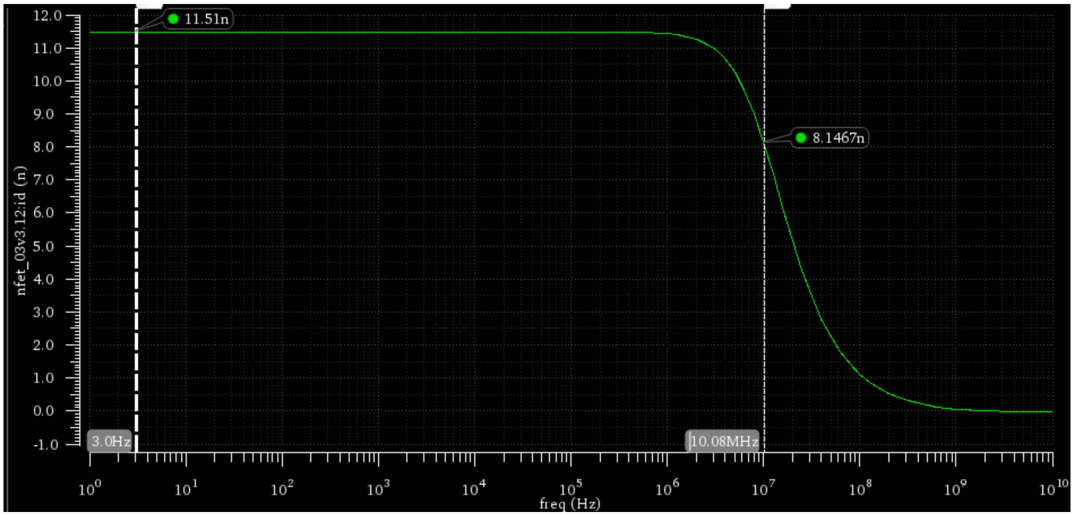

Figure 14 : output thermal noise vs frequency

	Expression	Value
1	bandwidth(sqr...	10.08M

Figure 15 : BW from calculator

Hand analysis :

$$V_{nin}^2(f) = \frac{8kT\gamma}{g_{m1,2}}\left(1 + \frac{g_{m3,4}}{g_{m1,2}}\right)$$

Gamma from SA

Info: [Sizing Assistant] The resultant point 'GAMMA = 709.2m'

gm1 = 0.000328 , gm3 = 0.00028

Vnin^2 = 132.8 aV^2/Hz

Vnin = 11.524 nV

BW = gm1/2*π*Cl = 10.44MHz

Vn(rms) = sqrt(Vnin^2*π/2* Bw) = 46.67 µV

	Simulation	Hand analysis
Noise density (nV/sqrt(Hz))	11.524	11.51
BW (MHz)	10.44	10.08

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

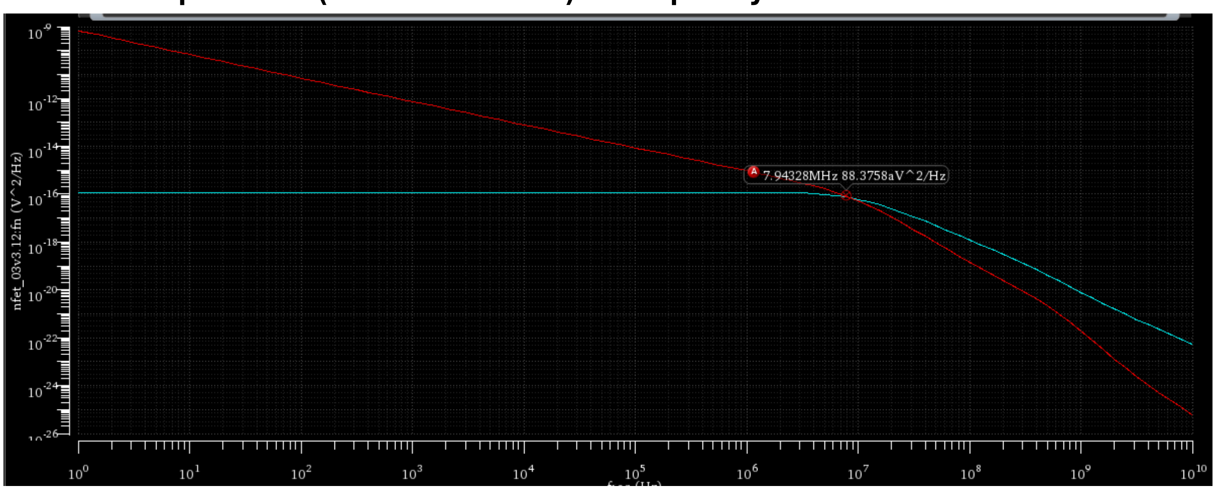

Figure 16 : total output noise (thermal + flicker) vs frequency annotate the Flicker noise corner

the Flicker noise corner = 7.94MHz

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

```
/M0     fn      6.2859e-09      38.63
/M1     fn      6.15489e-09     37.82
/M5     fn      8.52152e-10     5.24
/M4     fn      8.39122e-10     5.16
/M4     id      5.60704e-10     3.45
/M0     id      5.22388e-10     3.21
/M1     id      5.19121e-10     3.19
/M5     id      4.79311e-10     2.95
/M3     fn      2.73247e-11     0.17
/M3     id      1.82887e-11     0.11
/M2     fn      6.79435e-12     0.04
/M2     id      6.31262e-12     0.04

Integrated Noise Summary (in V^2) Sorted By Noise Contributors
Total Summarized Noise = 1.62723e-08
Total Input Referred Noise = 7.49631e-06
```

Figure 17 : rms noise due to thermal noise only using Noise Summary

Vnrms thermal =sqrt((5.6+5.22+5.191+4.79)*1e-10+(18.28+6.31)*1e-11) = 46.5uV

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

	Simulation	Hand analysis
Vn(rms) (uv)	46.5	46.67
Noise density (nV/sqrt(Hz))	11.524	11.51
Bw(MHz)	10.44	10.08

PART 4: 5T OTA Transient Noise Analysis

Create a new simulation configuration. Keep the 5T OTA connected in unity-gain buffer configuration

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

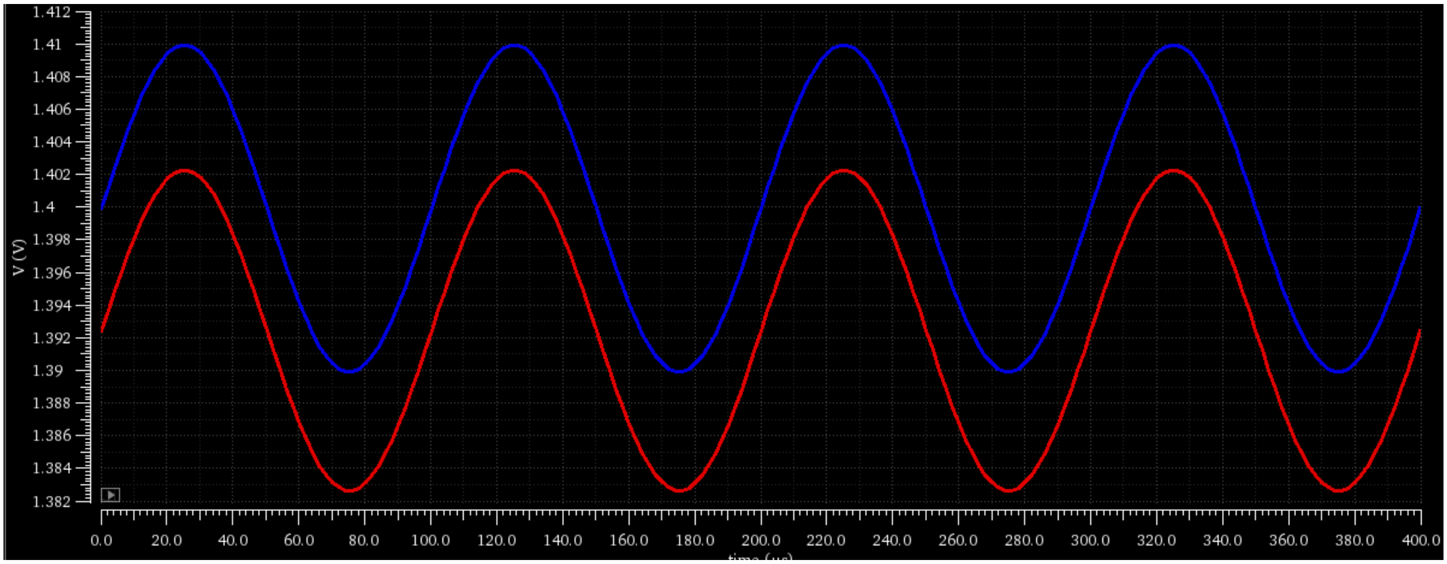

Figure 18 : input and output overlaid

Now we will run transient noise analysis similar to Part 2. Use a single noise simulation run. Set transient noise upper frequency at 10 times the OTA GBW.

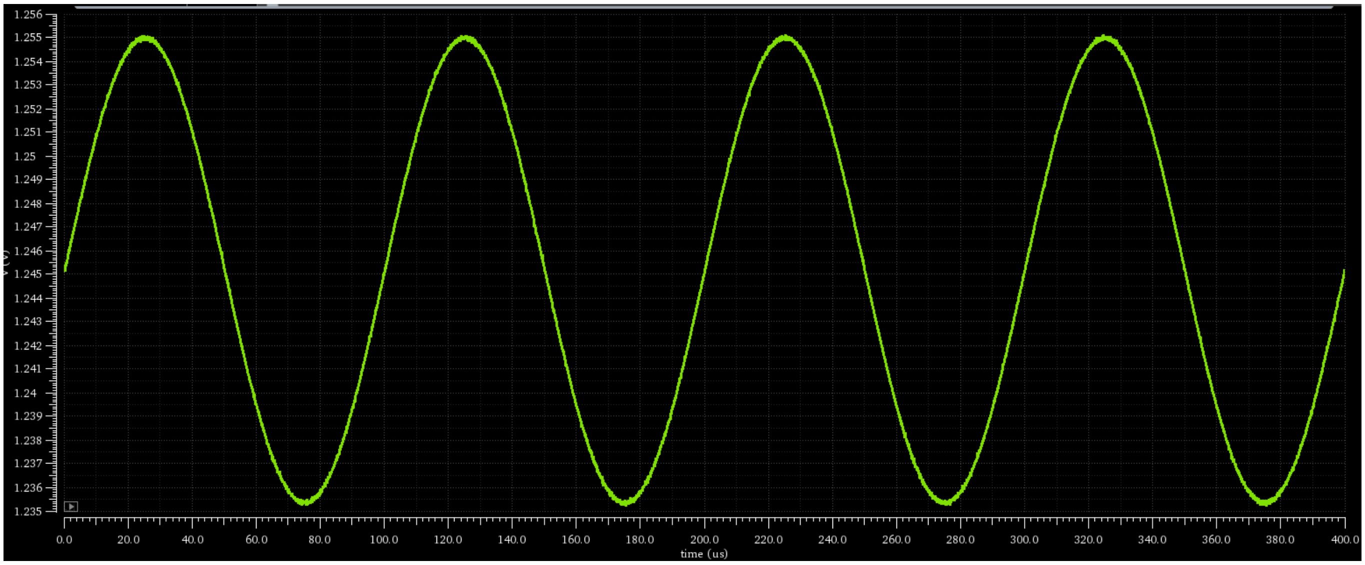

Figure 19 : noisy output waveform

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

Report the rms noise vs iteration.

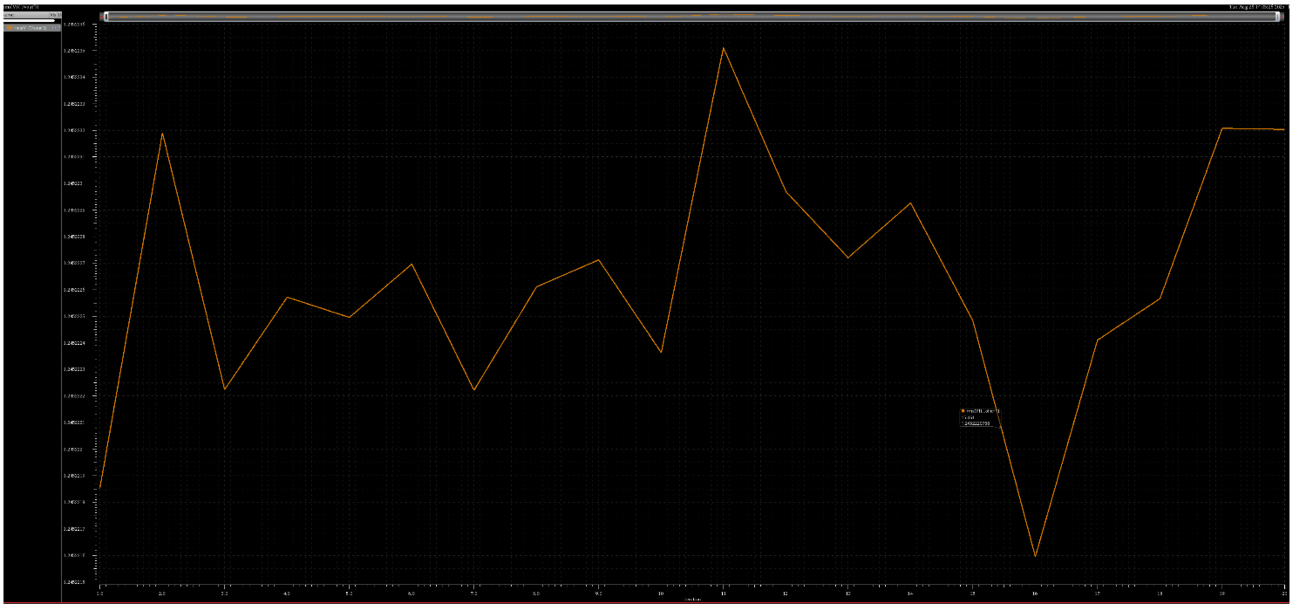

Figure 20 : rms noise vs iteration.

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

	Part 3	Part 4
Vn(rms) (uv)	**46.5**	**47.32**