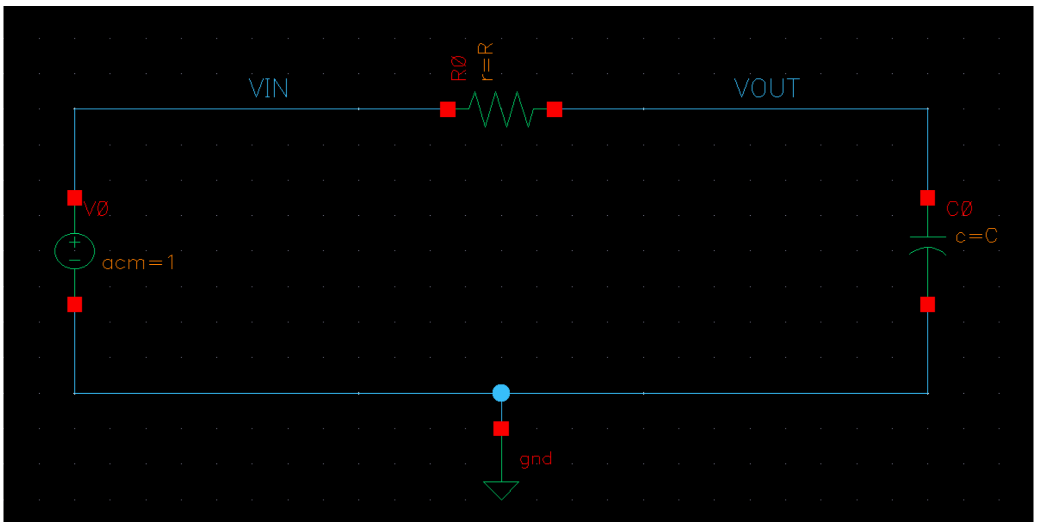
CMOS AIC design - ITI - Lab 10

Part 1: LPF AC Noise Analysis

- Create a new cell “lab_09_noise_rc”. Create a testbench for a simple 1st order LPF as shown below. Set R and C as parameters.



Required testbench

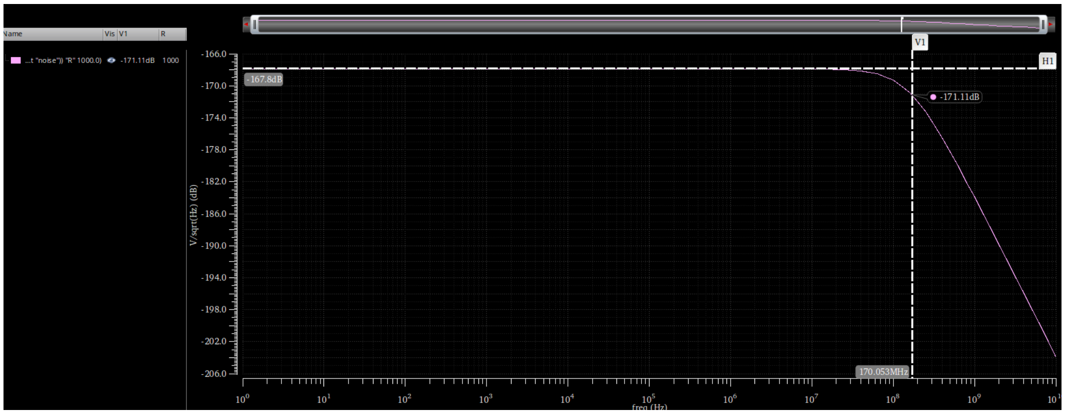
- Set up AC analysis (1Hz:10Gz, logarithmic, 10 points/decade).

  Setup noise analysis as shown below.

  Set RPAR = 1k and CPAR = 1p.

  Run noise analysis.

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



VOUTN in dB vs frequency with voltage noise density and 3dB BW annotated

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

Test	Output	Nominal	Spec	Weight	Pass/Fail
ITI_labs:lab_09_noise_rc:1	rms_out_noise	64.32u			

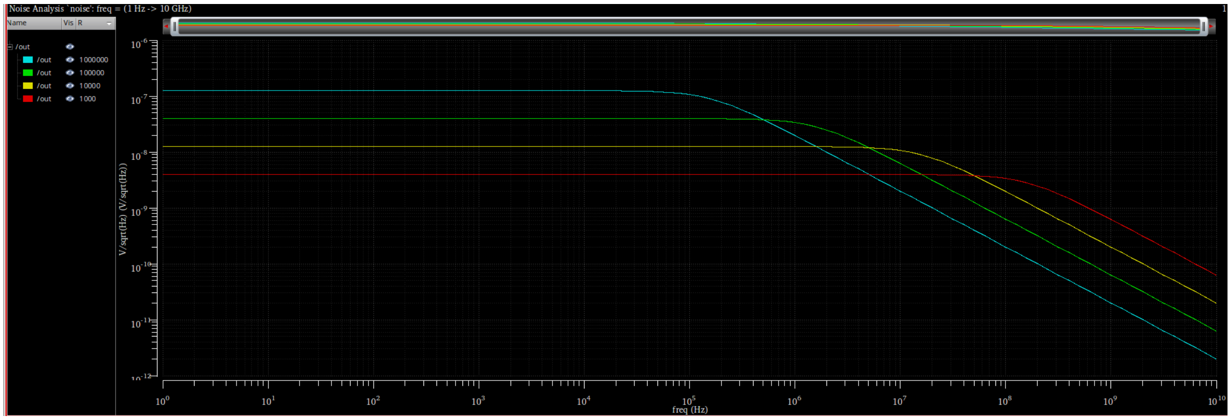
rms o/p noise

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

$Quantity$	$Simulated$	$Calculated$
$noise\ density$	$-167.8dB$	$20log(\frac{KT}{C}) = -167.66dB$
BW	$158.8M$	$BW = \frac{1}{2\pi RC} = 159.15M$
$rms\ noise$	$64.32u$	$V_{noutrms} = sqrt(\frac{KT}{C}) = 64.34uV$

- 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.



Parametric sweep results

- As R increases, the BW decreases and the magnitude of noise increases, this is because a resistance is associated with thermal noise which is directly proportional to the value of the resistor.

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

Point	Test	Output	Nominal	Spec	Weight	Pass/Fail
Parameters: R=1k						
1	ITI_labs:lab_09_noise_rc:1	rms_noise_parametric	64.32u			
Parameters: R=10k						
2	ITI_labs:lab_09_noise_rc:1	rms_noise_parametric	64.62u			
Parameters: R=100k						
3	ITI_labs:lab_09_noise_rc:1	rms_noise_parametric	64.65u			
Parameters: R=1M						
4	ITI_labs:lab_09_noise_rc:1	rms_noise_parametric	64.66u			

Required calculations

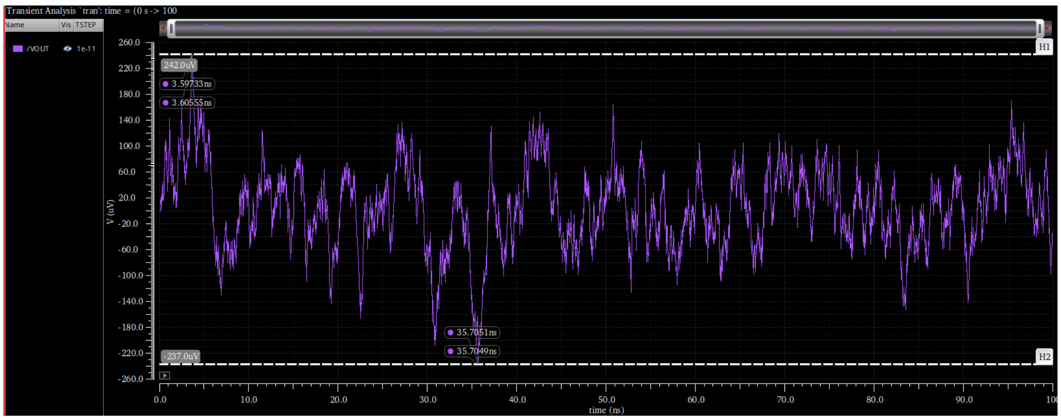
- The results at each value of R are almost identical, as the rms noise is independent of resistance value.

Part 2: LPF Transient Noise Analysis

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

Setup transient noise analysis as shown below. Fmax is set to 1/TSTEP and Fmin is set to 1/TSTOP. You can think of these as the start and end frequencies used in generating the noise samples.

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



Noise o/p waveform

- 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_09_noise_rc:1	tran_rms	63.53u			

rms value obtained from transient analysis

Quantity	*Part 1*	*Part 2*
rms noise	$64.32u$	$63.53u$

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

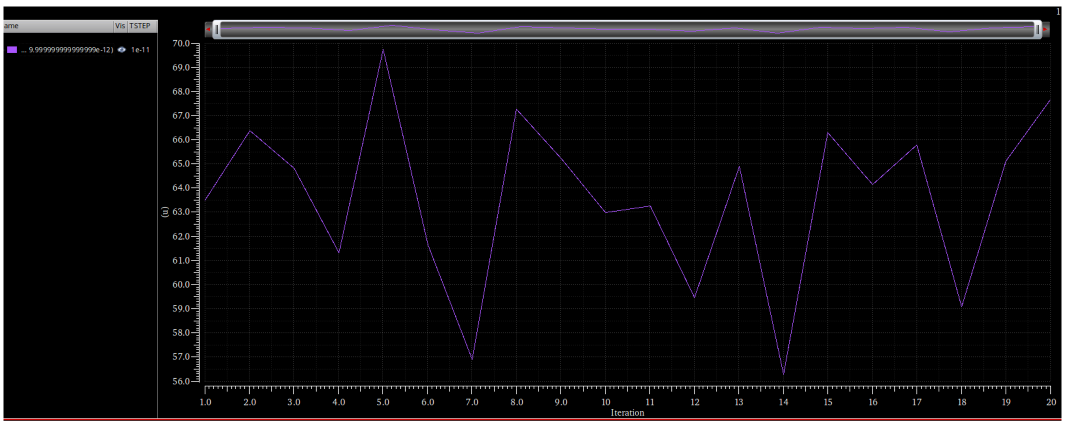
Test	Output	Nominal	Spec	Weight	Pass/Fail
ITI_labs:lab_09_noise_rc:1	tran_repeated_rms	66.57u			

rms noise after repeating sim

- Increasing TSTEP corresponds to reducing Fmax, meaning lower integration range and thus lower mean square voltage noise and higher rms noise (mean square noise is lower than one, taking sqrt of it to obtain rms makes the final value higher).

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

  Report the rms noise vs iteration.



rms noise vs iterations

	Iteration	rms(VT("/VOUT"))
1	1.000	63.53E-6
2	2.000	66.41E-6
3	3.000	64.84E-6
4	4.000	61.35E-6
5	5.000	69.78E-6
6	6.000	61.66E-6
7	7.000	56.92E-6
8	8.000	67.29E-6
9	9.000	65.24E-6
10	10.00	63.01E-6
11	11.00	63.29E-6
12	12.00	59.48E-6
13	13.00	64.94E-6
14	14.00	56.30E-6
15	15.00	66.32E-6
16	16.00	64.16E-6
17	17.00	65.81E-6
18	18.00	59.10E-6
19	19.00	65.14E-6
20	20.00	67.66E-6

rms noise vs iterations

- 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_09_noise_rc:1	rms_noise_avg	63.51u			

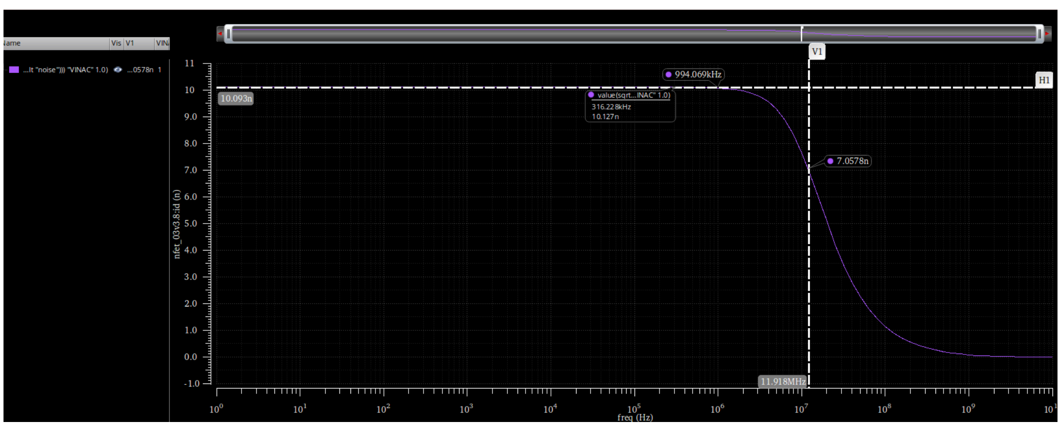
avg rms noise

$Quantity$	$Part\ 1$	$Part\ 2$	$avg\ value$
$rms\ noise$	$64.32u$	$63.53u$	$63.51u$

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 analysis.

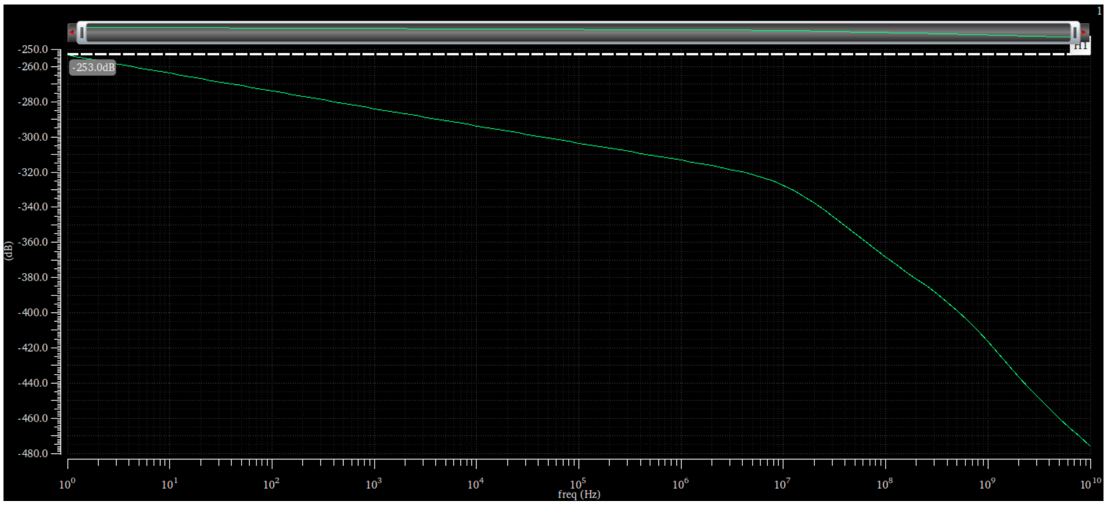
  Report output thermal noise vs frequency. Annotate noise density and bandwidth in the plot. Compare the simulation results with hand analysis.



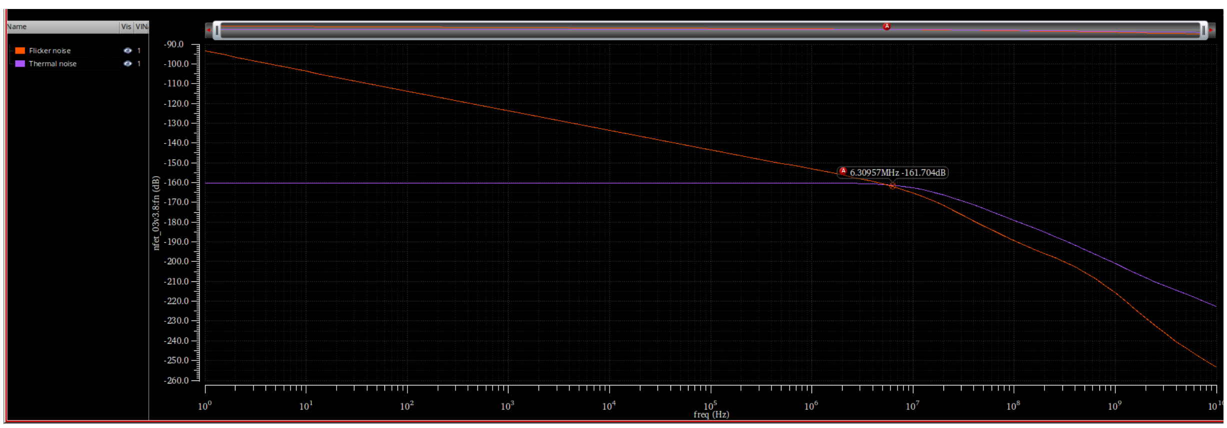
Thermal noise vs frequency

$Quantity$	$Simulated$	$Calculated$
$Thermal\ noise$	$10.093n$	$10.0488n$

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



Thermal + flicker with noise density annotated



Thermal and flicker noise vs frequency with flicker noise corner annotated

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

$Quantity$	$Simulated$	$Calculated$
$Noise\ density$	$-253dB$	$-252.56dB$
$BW\ (thermal)$	$11.8M$	$11.3M$
$rms\ noise$	$98u$	$99.86u$

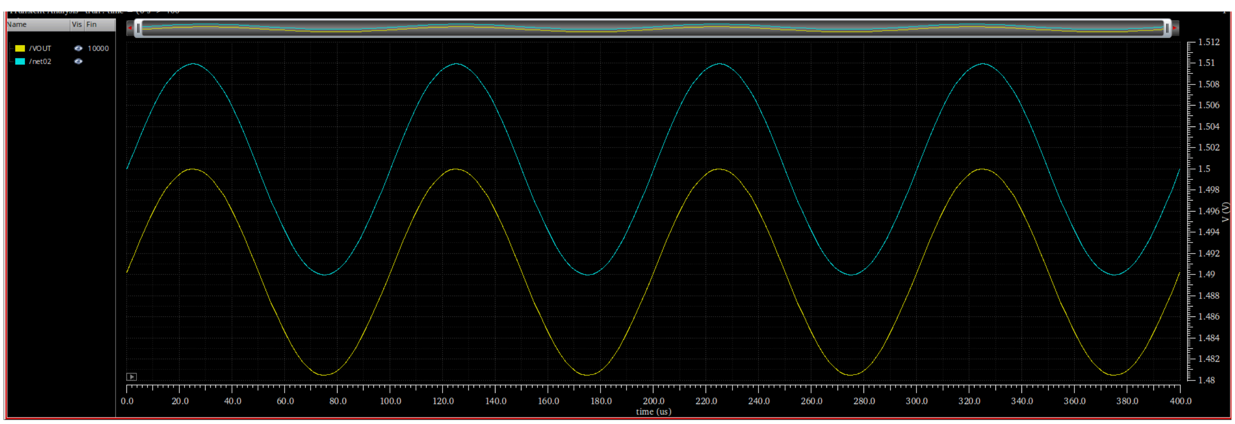
Part 4: 5T OTA Transient Noise Analysis

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

  Set the input signal as a sine wave with amplitude = 10mV and fin = 10kHz frequency superimposed on a CM level equal to the middle value of the CMIR.

  Run transient analysis with max time step = 0.02/fin (50 points for cycle) and stop time = 4/fin (simulate 4 cycles).

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



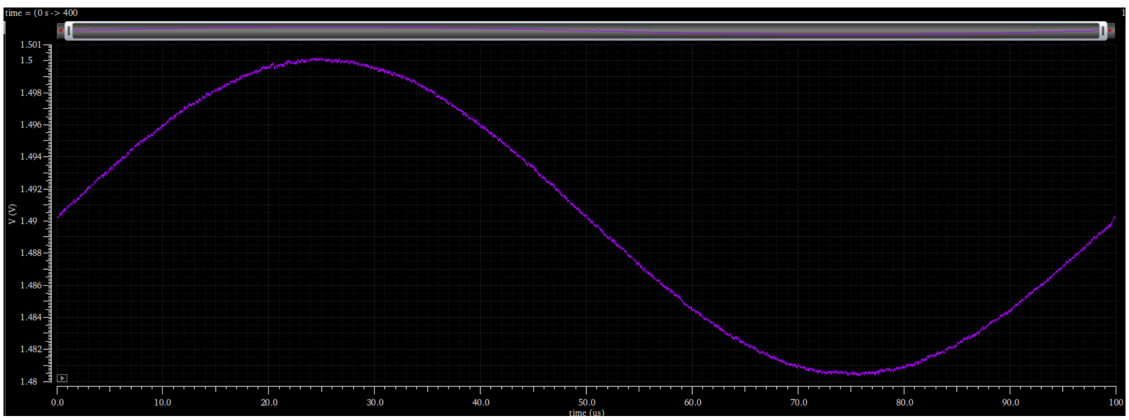
VIN and VOUT vs time

Test	Output	Nominal	Spec	Weight	Pass/Fail
ITI_labs:OTA_tb:1	VIN_PP	20m			
ITI_labs:OTA_tb:1	VOUT_PP	19.54m			

The circuit is verified to be working as a buffer

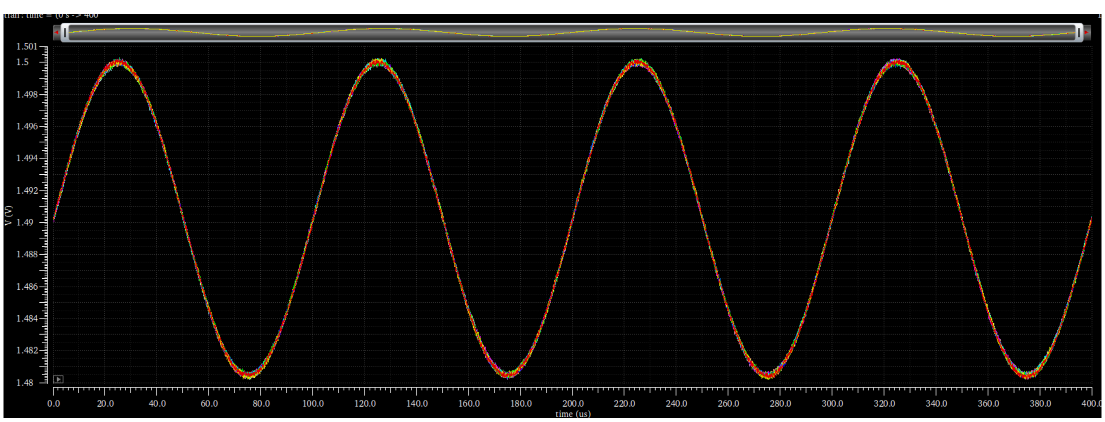
- Now we will run transient noise analysis similar to Part 2. Use a single noise simulation run. Set transient noise upper frequency at 10 times the OTA GBW.

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

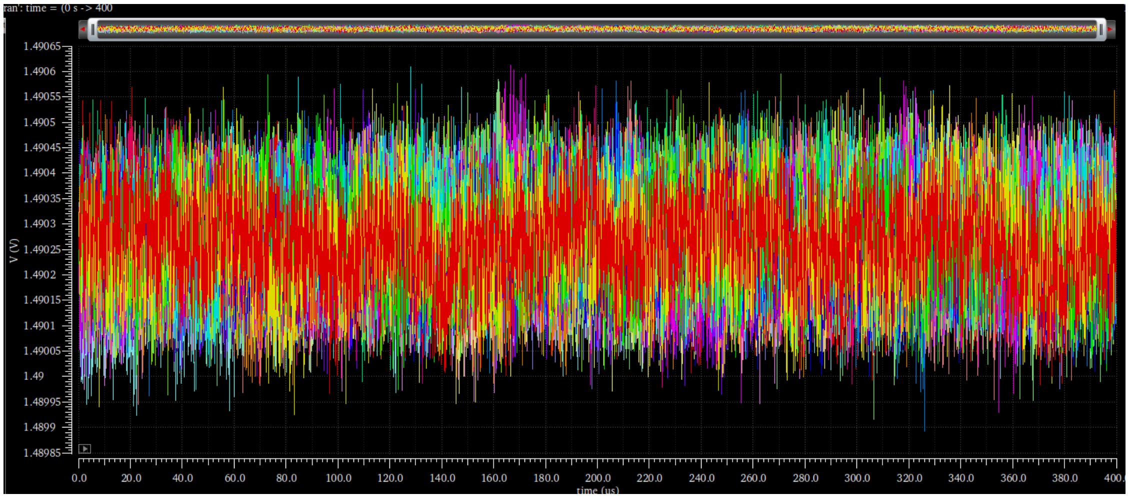


Noise superimposed on the o/p signal

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

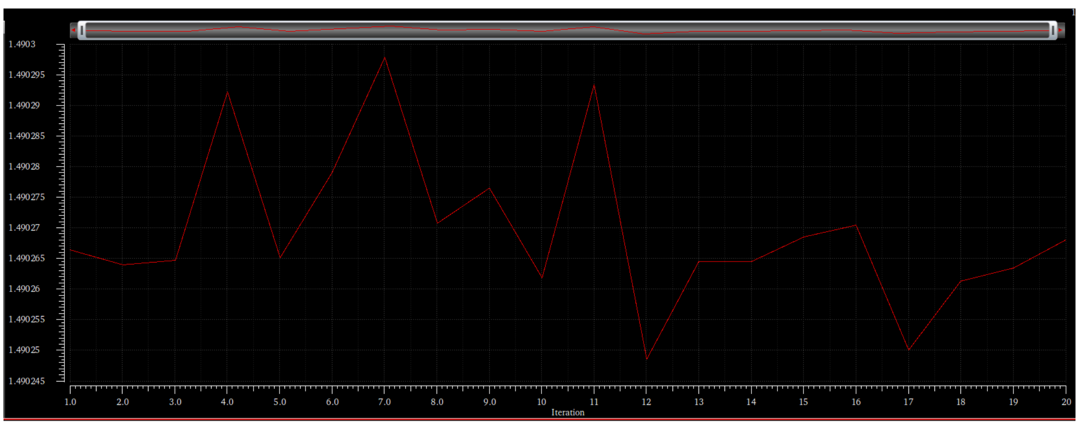


20 o/p signals with superimposed noise



o/p noise in response to DC CM i/p

- Report the rms noise vs iteration.



rms o/p 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.

	FIN	average(...tran")))
1	10.00E3	9.728E-3

avg(rms(VOUT-VIN))

$Quantity$	$Part\ 4$	$Part3$
avg	$9.72m$	$98u$