Analog IC Design

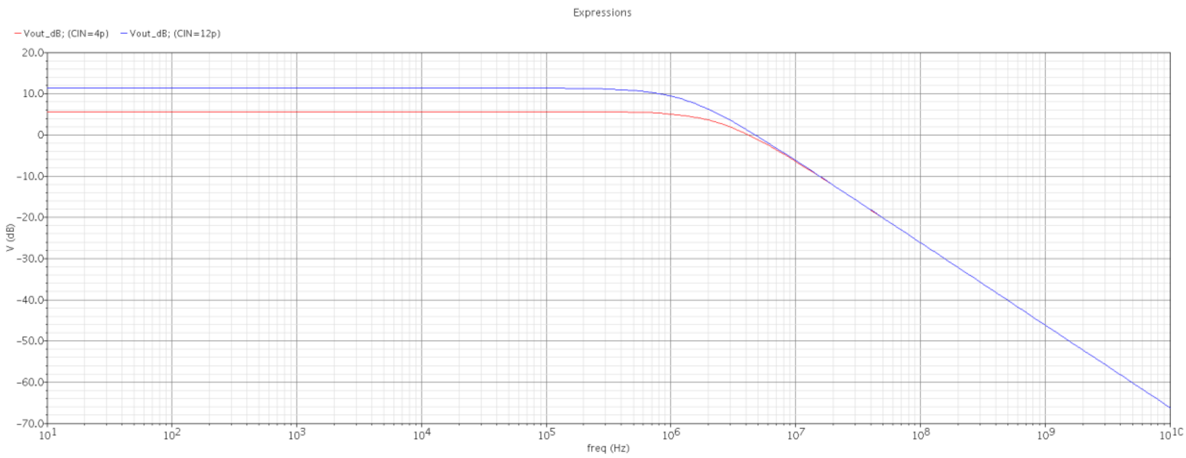
Lab 08

Negative Feedback

PART 1: Feedback with Behavioural OTA

1- <u>Closed loop gain vs frequency</u>

<u>Plot Vout in dB for the two values of CIN (4pF and 12pF). Indicate the DC gain, the bandwidth, and the unity gain frequency in the plot.</u>



Point	Test	Output	Nominal	Spec	Weight	Pass/Fail
Parameters: CIN=4p						
1	AIC_Training:Lab_08_part_1_2:1	VOUT				
1	AIC_Training:Lab_08_part_1_2:1	Ao	1.932			
1	AIC_Training:Lab_08_part_1_2:1	BW	2.553M			
1	AIC_Training:Lab_08_part_1_2:1	GBW	4.934M			
1	AIC_Training:Lab_08_part_1_2:1	Vout_dB				
1	AIC_Training:Lab_08_part_1_2:1	UGF	4.255M			
Parameters: CIN=12p						
2	AIC_Training:Lab_08_part_1_2:1	VOUT				
2	AIC_Training:Lab_08_part_1_2:1	Ao	3.737			
2	AIC_Training:Lab_08_part_1_2:1	BW	1.322M			
2	AIC_Training:Lab_08_part_1_2:1	GBW	4.941M			
2	AIC_Training:Lab_08_part_1_2:1	Vout_dB				
2	AIC_Training:Lab_08_part_1_2:1	UGF	4.797M			

<u>Compare the DC gain, BW, and GBW with hand analysis in a table.</u>

Hand analysis: from lab_07

$$\mathrm{gain} = \mathrm{g_{m1}} * (\mathrm{r_{o2}} \backslash\backslash\, \mathrm{r_{o4}}) = 157.4\mathrm{u} * (649\ \mathrm{k} \backslash\backslash\ 824\ \mathrm{k}) = 56.9$$

$$GBW = gain * BW = \frac{g_{m1}}{2 * pi * C_l} = 5.01\ MHz$$

$$BW = \frac{GBW}{gain} = 88.05\ KHz$$

At cin=4p ,Cf= 4p

$A_{vCL} = 1 + \frac{Cin}{Cf} = \frac{A_{ol}}{1+BA_{ol}}$ -> B= 0.48

$$A_{cl} = \frac{56.9}{1 + 0.48 * 56.9} = 2.009$$

$$BW_{cl} = BW_{ol} * (1 + b * A_{ol}) = 2.49MHz$$

GBW=5.008 M

At cin=12p ,Cf= 4p

B=0.2324

$$A_{vcl} = 4.004$$

$$BW_{cl} = 1.25MHz$$

GBW=5.0145M

	Hand 4p	Sim 4p	Hand 12p	Sim 12p
Dc gain	2.009	1.93	4.004	3.737
BW	2.49M	2.55M	1.25M	1.322M
GBW	5.008M	4.934M	5.0145M	4.941M

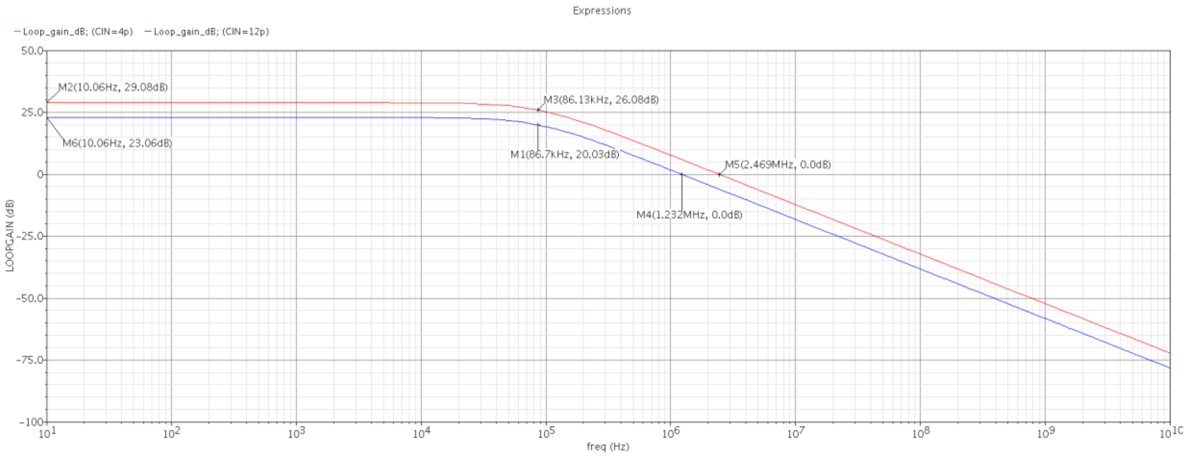
<u>Comment on the difference between the results for the two values of CIN</u>

As Cin increases , beta decreases as beta is a voltage divider between the caps so when beta decreases gain it changes the values of the closed loop parameters.

But as we notice GBW remains unchanged almost.

2- <u>Loop gain vs frequency</u>

<u>Plot loop gain in dB for the two values of CIN. Annotate the DC loop gain, the dominant pole, and the unity gain frequency in the plot</u>



Point	Test	Output	Nominal	Spec	Weight	Pass/Fail
Parameters: CIN=4p						
1	AIC_Training:Lab_08_part_1_2:1	Loop_gain_dB				
1	AIC_Training:Lab_08_part_1_2:1	max_mag	28.45			
1	AIC_Training:Lab_08_part_1_2:1	max_mag_dB	29.08			
1	AIC_Training:Lab_08_part_1_2:1	UGF_loop_gain	2.477M			
Parameters: CIN=12p						
2	AIC_Training:Lab_08_part_1_2:1	Loop_gain_dB				
2	AIC_Training:Lab_08_part_1_2:1	max_mag	14.22			
2	AIC_Training:Lab_08_part_1_2:1	max_mag_dB	23.06			
2	AIC_Training:Lab_08_part_1_2:1	UGF_loop_gain	1.237M			

<u>Compare DC LG and GBW with hand analysis in a table.</u>

<u>Cin=4p</u>

$$\mathrm{LG} = \mathrm{beta} * \mathrm{A_{ol}} = 27.312 = 28.72\ dB$$
$$Bw\_\mathrm{lg} = BW = 88.05K$$

<u>Cin=12p</u>

$$\mathrm{LG} = \mathrm{beta} * \mathrm{A_{ol}} = 13.22 = 22.42\ dB$$
$$BW\_\mathrm{lg} = BW = 88.05K$$

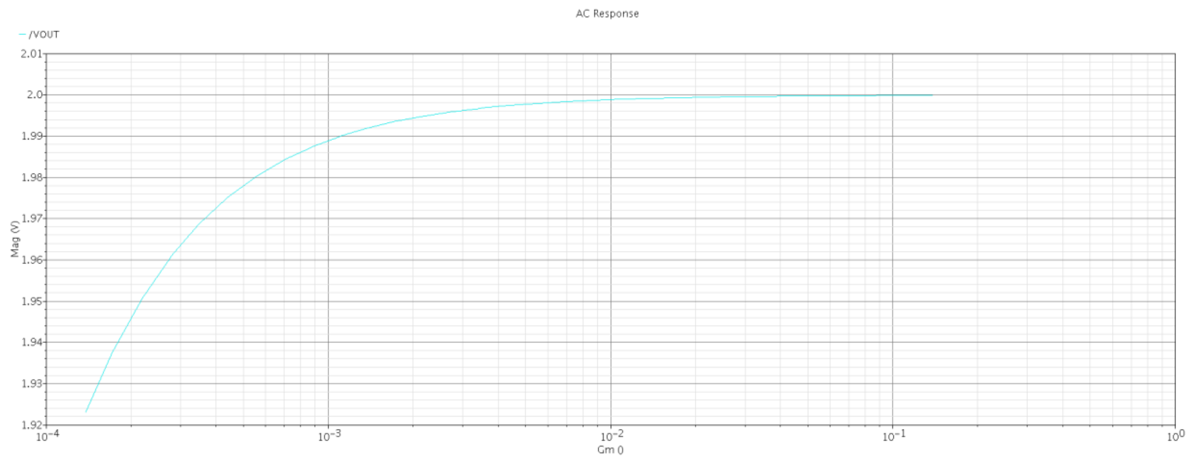
	Hand 4p	Sim 4p	Hand 12p	Sim 12p
LG	27.312	28.45	13.22	14.22
GBW	2.404M	2.477M	1.164M	1.237M

<u>Comment on the differences between the results for the two values of CIN.</u>

As cin increases , the loop gain decreases and the GBW decreases as the bandwidth is constant

3- <u>Gain Desensitization. Study the variation of closed loop gain with the variation of open loop gain. This is the most important property of negative feedback</u>

<u>Plot closed loop DC gain (magnitude at 10Hz, not dB) vs Av.</u>



<u>Calculate the percent change in closed loop gain (magnitude, not dB).</u>

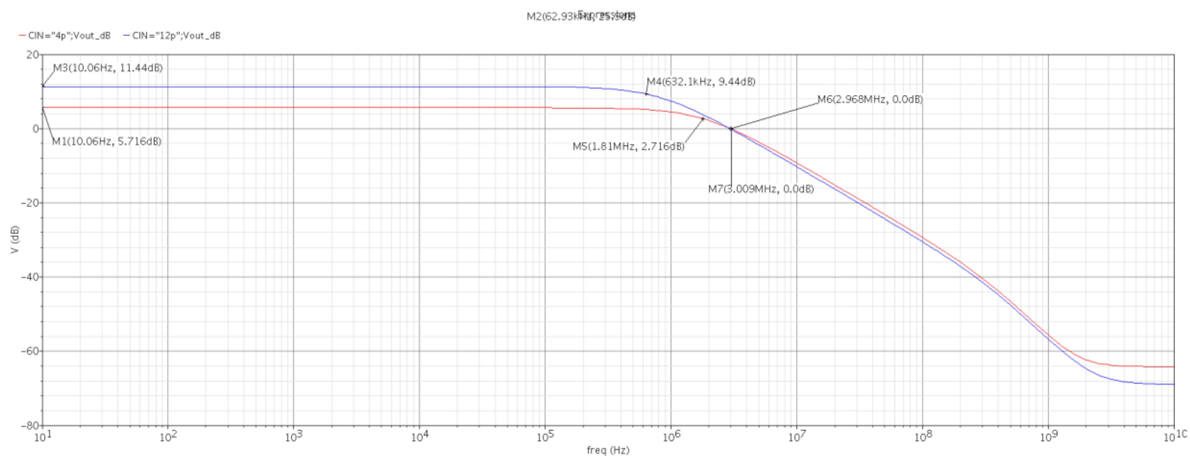
Change = $\Delta \text{ Avcl} - \Delta \text{ Avol} = 1.5\%$

<u>Comment</u>:

The gain desensitization spec which what made us go to the negative feedback system is achieved as a very massive change in the open look gain only result a small change in the closed loop gain.

PART 2: Feedback with Real 5T OTA

1- <u>Closed loop gain vs frequency</u>



Point	Test	Output	Nominal	Spec	Weight	Pass/Fail
Parameters: CIN=4p						
1	AIC_Training:Lab_08_part_1_2:1	Ao	1.931			
1	AIC_Training:Lab_08_part_1_2:1	BW	1.827M			
1	AIC_Training:Lab_08_part_1_2:1	GBW	3.528M			
1	AIC_Training:Lab_08_part_1_2:1	Vout_dB				
1	AIC_Training:Lab_08_part_1_2:1	UGF	3.03M			
Parameters: CIN=12p						
2	AIC_Training:Lab_08_part_1_2:1	Ao	3.734			
2	AIC_Training:Lab_08_part_1_2:1	BW	825.5k			
2	AIC_Training:Lab_08_part_1_2:1	GBW	3.083M			
2	AIC_Training:Lab_08_part_1_2:1	Vout_dB				
2	AIC_Training:Lab_08_part_1_2:1	UGF	2.997M			

Compare between the results you obtained here and the results in Part 1 in a table.

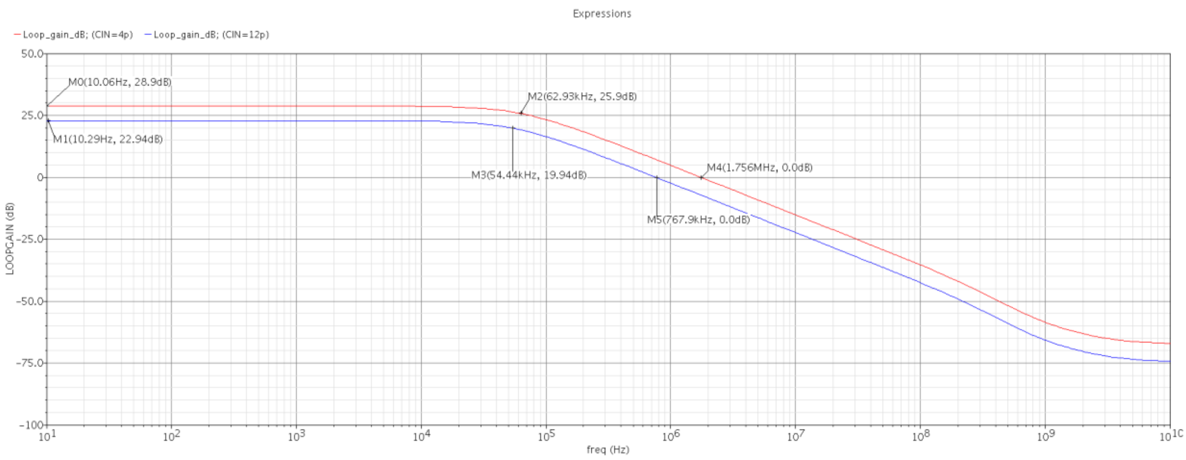
	Part 1 4p	Part 2 4p	Part 1 12p	Part 2 12p
Gain	1.93	1.931	3.737	3.734
BW	2.55M	1.827M	1.322M	825K
GBW	4.934M	3.528M	4.941M	3.083M

You will notice that the bandwidth, and consequently the GBW are much smaller than Part 1. Why? Comment.

in part 1 I used an ideal switch which acted as an ideal buffer which had no loading effects which resulted in a much higher BW
however in the real OTA the is a loading effect which was modelled as the Cout so it did affect the BW and therefore affected the GBW

in conclusion
The GBW and BW is lower in second stage due to loading effect presented in the real ota.

2- Loop gain vs frequency



Point	Test	Output	Nominal	Spec	Weight	Pass/Fail
Parameters: CIN=4p						
1	AIC_Training:Lab_08_part_1_2:1	Loop_gain_dB				
1	AIC_Training:Lab_08_part_1_2:1	max_mag	27.87			
1	AIC_Training:Lab_08_part_1_2:1	max_mag_dB	28.9			
1	AIC_Training:Lab_08_part_1_2:1	UGF_loop_gain	1.78M			
Parameters: CIN=12p						
2	AIC_Training:Lab_08_part_1_2:1	Loop_gain_dB				
2	AIC_Training:Lab_08_part_1_2:1	max_mag	14.03			
2	AIC_Training:Lab_08_part_1_2:1	max_mag_dB	22.94			
2	AIC_Training:Lab_08_part_1_2:1	UGF_loop_gain	772.6k			

Compare between the results you obtained here and the results in Part 1 in a table.

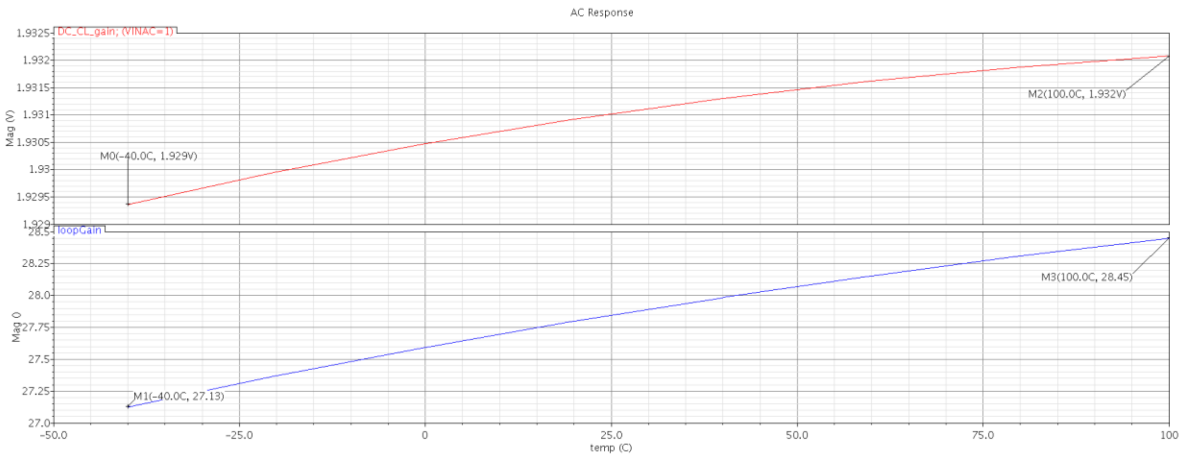
	Part 1 4p	Part 2 4p	Part 1 12p	Part 2 12 p
LG	28.45	28.87	14.22	14.03
UGF	2.477M	1.78M	1.237M	772.6k

You will notice that the unity gain frequency is much smaller than Part 1. Why? Comment.

The loop gain is nearly unchanged, while BW is affected by the loading which affected the UGF.

The negative feedback of the real ota presented a loading effect which translated in a decrease in the BW so it led to a decrease in UGF

3- Gain Desensitization. Study the variation of closed loop gain and open loop gain with temperature. Note that if the feedback factor is constant, the change in the open loop gain is itself the change in the loop gain.



Compare the percent change in the DC loop gain (from STB) and the DC closed loop gain (from AC) across temperature extremes. Do NOT use dB when calculating percent change. Comment.

Change in closedLoop: 4.88%

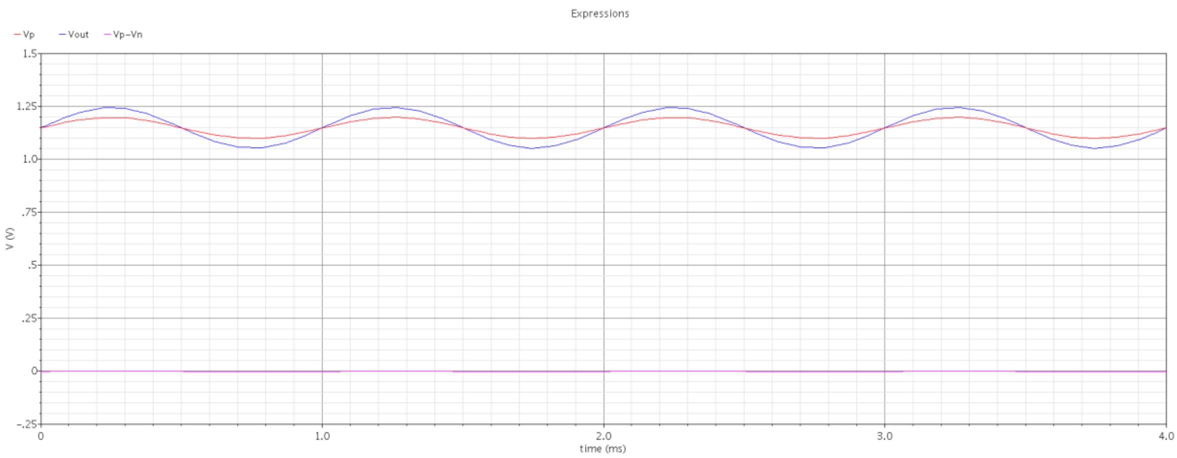
Change in LG: 0.15%

The change in the LG is very small and negligible compared to any change in the open loop that's because the negative feedback system.

4. Transient analysis.

Set the transient source to sine wave with frequency FIN = 1kHz and amplitude VP = 50mV, where FIN and VP are two variables defined in the parameters window.

Plot the input signal, the output signal, and the differential input signal of the OTA (VP – VN).

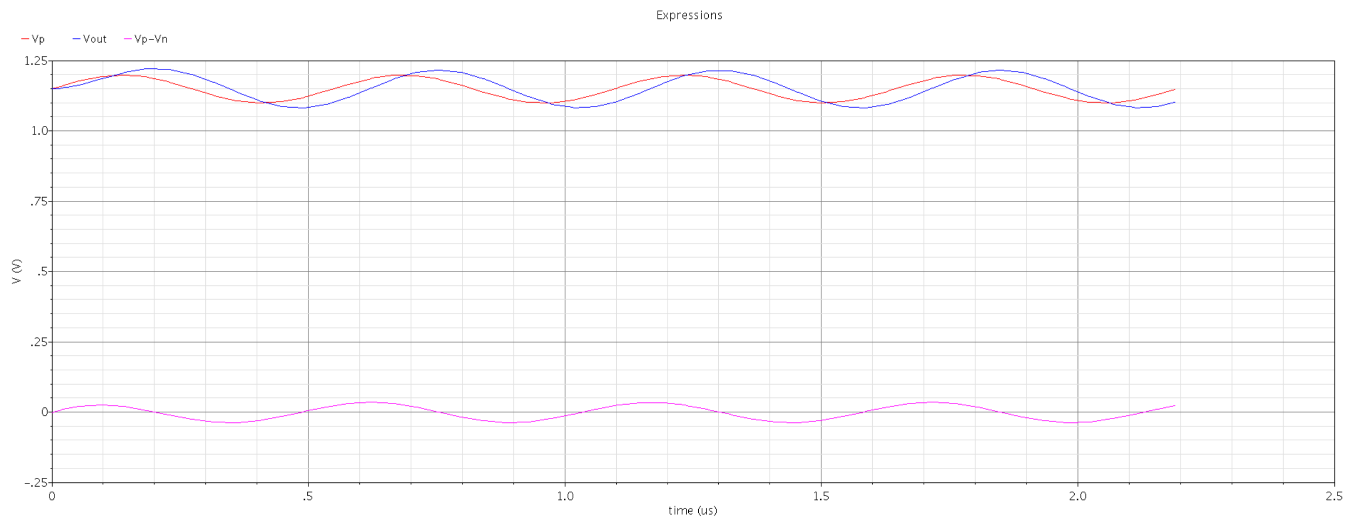


Calculate the peak-to-peak voltage of the previous three signals. What is the relation between the output and (VP – VN)? Comment.

Test	Output	Nominal	Spec	Weight	Pass/Fail
AIC_Training:Lab_08_part_1_2:1	Vp				
AIC_Training:Lab_08_part_1_2:1	Vout				
AIC_Training:Lab_08_part_1_2:1	Vp-Vn				
AIC_Training:Lab_08_part_1_2:1	VPP_VINP	99.78m			
AIC_Training:Lab_08_part_1_2:1	VPP_VOUT	192.7m			
AIC_Training:Lab_08_part_1_2:1	VPP_Vdiff	1.828m			

Vout = (Vp-Vn)*LOOP_GAIN + the dc shift of the Cm signal which is equal to 1.15V

Repeat the transient analysis with FIN exactly equal to the closed loop bandwidth. Plot the input signal, the output signal, and the differential input signal of the OTA (VP – VN).



<u>Calculate the peak-to-peak voltage of the previous three signals.</u>

Test	Output	Nominal	Spec	Weight	Pass/Fail
AIC_Training:Lab_08_part_1_2:1	Vp				
AIC_Training:Lab_08_part_1_2:1	Vout				
AIC_Training:Lab_08_part_1_2:1	Vp-Vn				
AIC_Training:Lab_08_part_1_2:1	VPP_VINP	99.78m			
AIC_Training:Lab_08_part_1_2:1	VPP_VOUT	137.7m			
AIC_Training:Lab_08_part_1_2:1	VPP_Vdiff	36.1m			

<u>What is the relation between the output and the input signal? What is the relation between the output and (VP – VN)?</u>

It is the same relation I mentioned in Fin=1K

<u>Compare between this case and the case of 1kHz input.</u>

Peak to peak values	1K	closed loop bandwidth
VINP	99.78m	99.78m
VIND	192.7m	137.7m
VOUT	1.828m	36.1m