Lab 7 – Notes

Spring 2024

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General Notes

- Make sure to use your ESD wristband at all times when using the ALD chips.
- The lab practical is next week, please make sure to check the announcement on Piazza.
- Make sure to complete lab 7 before the lab practical.
- **EVERY student must have their own copy of the opamp for the lab practical.**

Task 1

Task 7.4.1: Op amp construction

1. Construct the op amp circuit in figure 7.5. This is the same circuit built in experiment 6. $Q_{2,3}$, Q_7 and Q_8 are still made with two transistors in parallel.

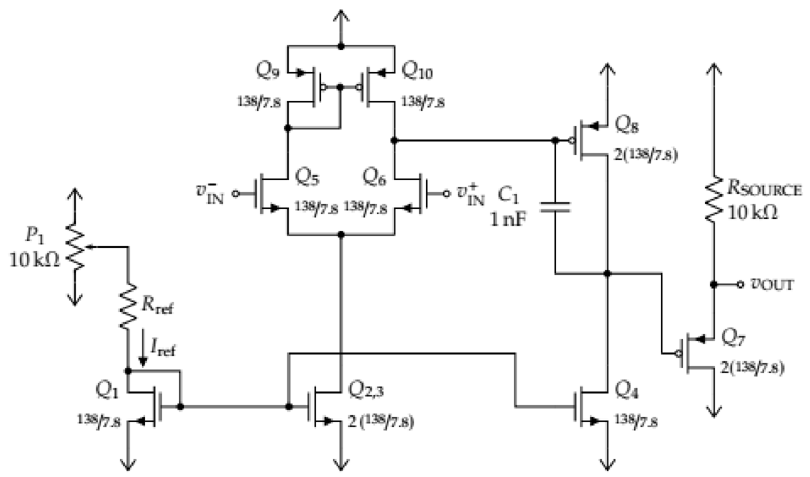


Figure 7.5: Op amp schematic.

2. *Set* I_{REF} to 200 µA
3. *Build* the circuit in figure 7.6 using the op amp.
4. *Apply* a 500 Hz 1 V_{p-p} sine wave signal to v_{IN} and capture and oscilloscope screenshot showing v_{IN} and v_{OUT}. Does this circuit behave like it would with an ideal opamp?

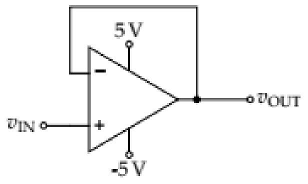


Figure 7.6: Op amp buffer circuit.

1. This is the same circuit in lab 6 and will be the same circuit that you will be using in the lab practical.

2. Measure the current by measuring the voltage across Rref, as usual.

3. Connect Vin- to Vout, and connect your wavegen to Vin+

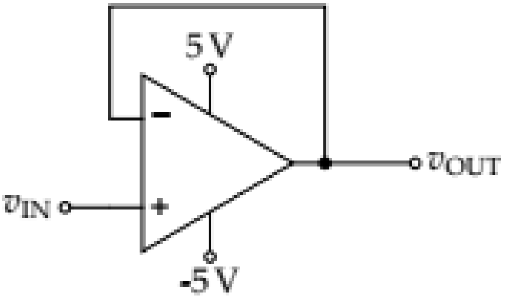
4. Show the input and the output signals, they should look very close to each other. Comment on that.

Task 2

Task 7.4.2: Slew rate

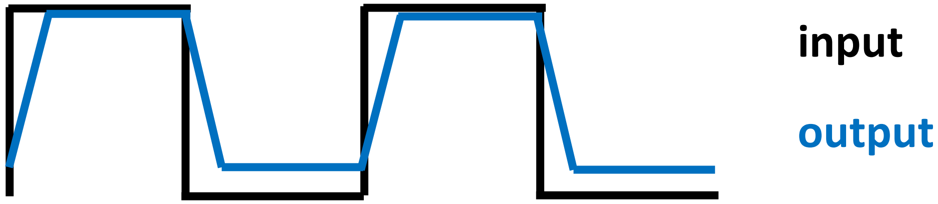
For this task, continue using the buffer circuit from figure 7.6.

1. *Apply* an input 5 V_{p-p} square wave at 1 kHz
2. Does the output look like you expect for a buffer circuit?
3. Zoom into the transition on the output and obtain a printout of v_{IN} and v_{OUT} for both a rising edge and falling edge.
4. *Measure* the rising edge and falling edge slew rate of the output using the cursors on the oscilloscope.



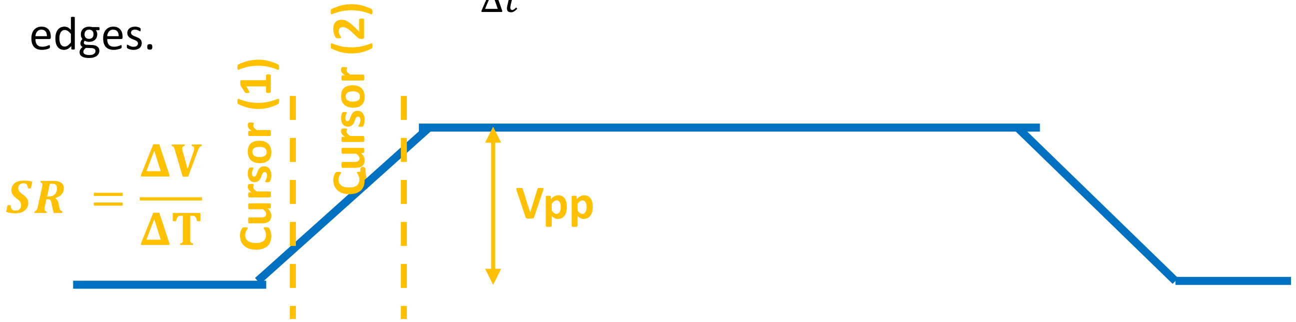
*This is the same circuit in task 1, the difference is that you need to put a square input signal instead of the sinusoidal one.

2. You might find a lower peak-to-peak output as well as slanted rising and falling edges. Comment on that.



3/4. You need to measure the slew rates for both the rising and falling edges. Procedure to measure that:

- Zoom into the rising/falling edge.
- Measure the peak-to-peak output (Vpp)
- Place cursor 1 at min voltage of the output + 0.1Vpp
- Place cursor 2 at max voltage of the output – 0.1Vpp.
- Measure slew rate $= \frac{\Delta V}{\Delta t}$ from the 10%-90% points for both edges.



Task 3

Task 7.4.3: Op amp open loop gain and phase measurement

1. *Construct* the circuit in figure 7.7

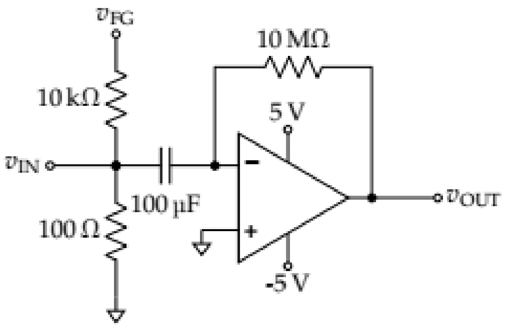


Figure 7.7: Open loop measurement circuit.

2. *Configure* the oscilloscope trigger to sync with the function generator.
3. *Apply* a 100 Hz 0.1 V_{p-p} sine wave to v_{FG}.
4. Obtain a printout showing v_{IN} and v_{OUT}.
5. Measure and *Plot* the gain and phase response from 10 Hz to 500 kHz.[a]
6. Measure the −3 dB points.
7. Measure or Estimate the unity gain bandwidth[b] What is the phase at this point?

[a] Ensure that the amplitude of the output is large enough to reliably measure the peak to peak value. You may need to increase the input amplitude at higher frequencies.
[b] This is the frequency when $|v_{OUT}| = |v_{IN}|$.

*The wavegen (your actual input) is connected to v_{FG} but you are measuring (using ch 1 of the scope) at v_{IN}.

2. The input will be very small and noisy (~ 1mV), so you need to set the trigger to sync with the function generator -> check the demo in the video.

5. In the network tool you will need to switch the mode to “Table” instead of “Constant” -> Check the demo in the video.

* For the table mode, you can use values of: 10Hz -> 50mV, and 10kHz -> 500mV.

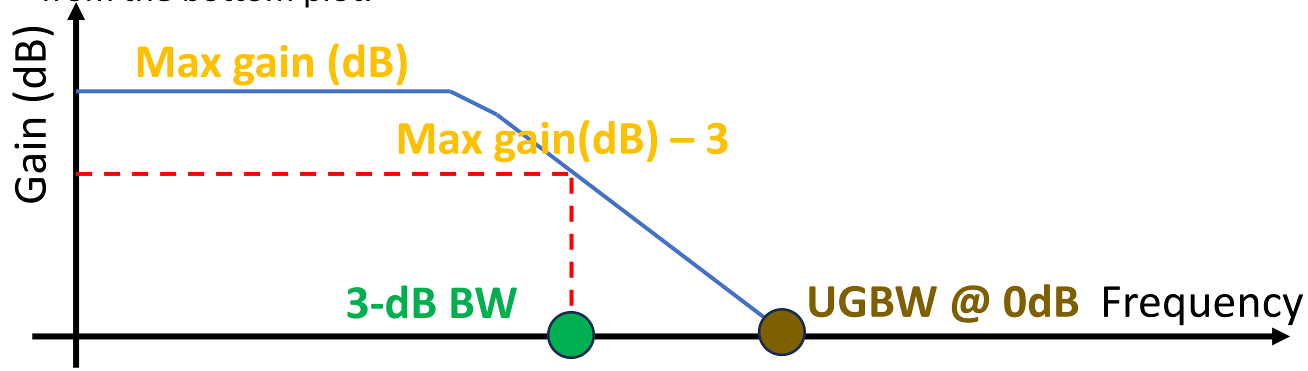
6. How to measure the 3-dB BW:

<u>In dB scale:</u>

- Measure the max gain in dB.
- Subtract 3 from the max gain. Place a cursor at this value, then measure the frequency from the x-axis and the phase from the bottom plot.

<u>In linear scale:</u>

- Measure the max gain in linear scale.
- Multiply the max gain by 0.707. Place a cursor at this value, then measure the frequency from the x-axis and the phase from the bottom plot.
- 7. To measure the unity gain BW, put the cursor at the point where the gain is 0 dB (or 1 in linear scale), then measure the frequency from the x-axis and the phase from the bottom plot.



Task 4

Task 7.4.4: Op-amp gain bandwidth measurement

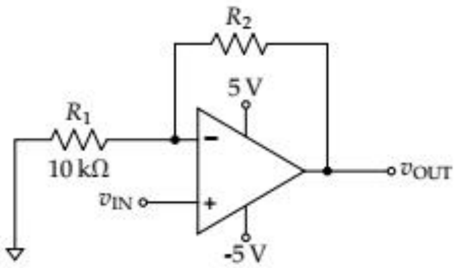


Figure 7.8: A non-inverting amplifier circuit.

1. Complete the following steps using $R_2 = 100\,\text{k}\Omega, 150\,\text{k}\Omega,$ and $220\,\text{k}\Omega$:
   a) *Determine* the expected gain of the amplifier.
   b) Using a sinusoid as v_{IN}, *select* an amplitude that produces a non-distorted output.
   c) Measure and *Plot* the gain versus frequency from 10 Hz to 1 MHz.
   d) From the gain plot, estimate the −3 dB point. Use the measured gain at low frequency as your reference gain.[a]
   e) Measure the phase at the −3 dB points.
2. What is the relationship of the gain bandwidth products over the different gains?

[a] For example, if you calculate that the gain should be 18 but the gain at 10 Hz is only 17.5, then your −3 dB point is when the gain is 0.707 · 17.5.

*The opmap is your circuit ☺

1. For each value of resistance (i.e. you need to repeat that 3 times):

a) Compute the theoretical gain from the gain relation of the non-inverting amplifier.

b) Pick a value of input amplitude that makes the output non-distorted. E.g. let's keep the output peak-to-peak to be 1 v, then estimate the required input for each case.

c) Make sure to change the input voltage in the settings of the Network tool when you measure the frequency response, because its default is 1v, this would make the results wrong because the output will be distorted.

d/e) Measure the 3-dB points the same way as in task 3.

2. Compute the GBW:

- Measure the max gain. Convert it to the linear scale.
- Measure the 3-dB BW as in task 3.
- $GBW = Max\ Gain_{linear} * BW$. It has the unit of frequency.