Lab 1 – Notes

Spring 2024

JOHN GERGUIS

General Notes

- Please make sure to read the syllabus completely and entirely.
- Make sure to read the “Lab Report How-To-Guide” before doing the first report.

Format and notes on Write-ups

Header

(should include all the important info, including the number and name of experiment, your name, your partner, date, section, serial number of the AD2)

- Abstract: 1 abstract per report that summarizes the tasks in the experiment.
  - List of components/equipment: There should be a subsection including the components and equipment used in the experiment.
- Task 1
  - Objective: Should NOT be a copy of the header of the task
  - Procedure: The steps that you have done in building the circuit and taking measurements. Should be simple and preferably in bullets/steps. Should include the circuit diagram for the circuit built in this task. Must NOT be copied from the manual or anyone.
  - Results: Present your results in an easy way to understand. Make sure to have the S/N and time stamp of the AD2 on all the screenshots.
  - Conclusion: Make sure to summarize your findings, compute the errors and comment on the potential sources of errors.
- Task 2
  - Objective
  - Procedure
  - Results
  - Conclusion
- Task 3
  - Objective
  - Procedure
  - Results
  - Conclusion

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Task 1

Task 1.9.1: Measurement refresher

In order to refresh your knowledge of the measurement equipment, please complete the following:

1. Use the function generator to generate the following signal:

$$2\sin(2\pi 750t)$$

2. *Capture* a screenshot of the waveform using the oscilloscope.
3. *Adjust* the oscilloscope view to plot several cycles of the waveform.
4. *Vary* the trigger level from -4 V to 4 V.
5. *Adjust* the horizontal offset.
6. *Adjust* the vertical offset.
7. *Describe* what each control does.
8. *Connect* the power supply output to the DMM input.
9. *Set* the power supply to 3.3 V.
10. *Measure* the DC and AC RMS values of the power supply output using the DMM.[a]

[a] Use the "voltmeter" tool on the AD2

* You are encouraged to use the benchtop equipment.

1. Please note that the amplitude (not the Vpp) is 2.

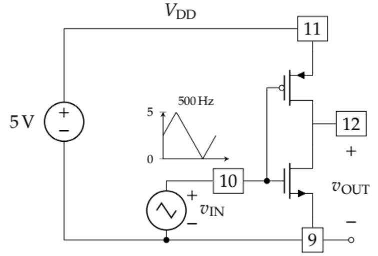
4. The trigger should be within the voltage range of the input signal to trigger correctly, why? Comment on that.

9/10. It's a DC source, it should have zero AC signal. Due to noise, you will measure some AC RMS, which should be pretty low.

Task 2

Task 1.9.2: Measure the voltage transfer characteristic of a CMOS inverter

1. *Build* the CD4007UB circuit shown in figure 1.10. It is important to connect pin 3 and pin 6 to ground to prevent oscillations in the other two inverters as well as connect pin 7 and 14 correctly in order to bias the substrate.
2. *Add* the function generator and connect the oscilloscope to measure v_{IN} and v_{OUT} as shown in the circuit in figure 1.11.
3. *Draw* and *label* the circuit diagram for the circuit you built.
4. *Set* V_{DD} to 5 V.



5. *Apply* a 500 Hz 0 V to 5 V triangle wave to v_{IN}.
6. *Capture* a screenshot showing v_{IN} and v_{OUT} using the oscilloscope.
7. Change the display to XY mode and *Capture* the transfer characteristic and label the transition points:
   a) *Determine* by estimation and *label* the points

   $$(V_{GS(th)N}, V_{OH}), (V_{It}, V_{ONt}), (V_{It}, V_{OPt}), (V_{DD} - |V_{GS(th)P}|, 0\,V)$$

   b) *Label* the status of the NMOS and PMOS next to each of the five sections of the curve.
8. *Capture* another printout and label the noise margin parameters:
   a) *Determine* by estimation and *label* the points

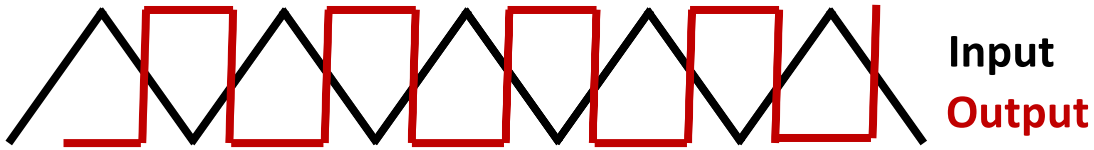
   $$(V_{IL}, V_{OH}) \text{ and } (V_{IH}, V_{OL})$$

   b) *Determine* the magnitude of the noise margins and *label* the transfer characteristic with the noise margins.
   c) *Compare* the noise margins with the margins specified by the CD4007UB datasheet [2]. Note that the datasheet provided values are worst-case values, so you should not treat them as ideal values.

1. Make sure to ground pins 3 & 6.

5. To have a triangular wave from 0-5, you need to have an amplitude of 2.5 and add an offset of 2.5.

6.



7/8 Switch to the X-Y mode and extract the plot twice for steps 7 and 8.

7. Annotate like Fig 1.6

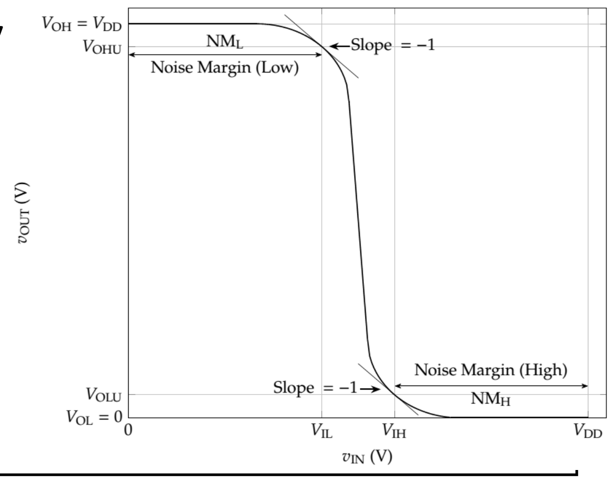
8. Annotate like Fig 1.7

Estimate VIL and VIH roughly

NML = VIL – VOL

NMH = VOH – VIH

Compute the NMs from the Datasheet & Measurements



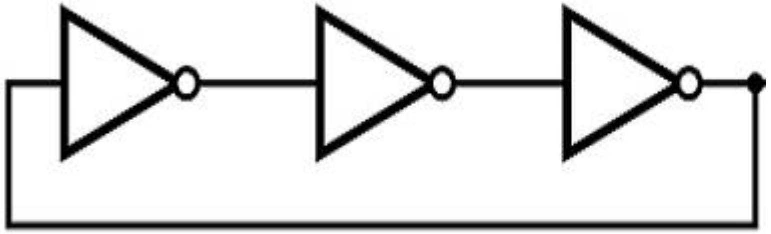
Task 3

Task 1.9.3: A Digital Ring Oscillator

Up to this point we have looked at the DC characteristics of an inverter. We will now explore how fast the inverter is by creating a ring oscillator. Ring oscillators are distributed across the surface integrated circuit (IC) wafers to test the wafer's quality by determining the speed of the inverters.

1. *Create* a digital ring oscillator by cascading three logic inverters in series, with the output each stage driving the input of its successor. Feedback the output of the third inverter to the input of the first one. If the circuit does not start oscillating on its own, connect the input of one of the inverters to V_{DD} through a 100 kΩ resistor temporarily. The ideal oscillation frequency is $f_{osc} \approx 1/3(t_{PLH}+t_{PHL})$.
2. *Obtain* an scope printout showing the oscillator working using an x10 probe[a] and *measure* the oscillation frequency, f_{osc}.
3. *Measure* the propagation delay of the inverters using a ×10 probe to measure the time from the $V_{DD}/2$ of the input to the $V_{DD}/2$ of the output of a single inverter using cursors on the oscilloscope display.
4. *Compare* the measured propagation delay with the CD4007UB datasheet [2].

[a] The normal inputs of the AD2 cannot be adjusted to x10, but that is acceptable for this experiment.



- Make sure to unground pins 3 &6.
- Connect the output of each inverter to the input of the next one, till you close the loop.

2. If you are using the benchtop oscilloscope, please use the 10X mode (ask the TA). If you are using the AD2, it just has X1 probe, so you should be expecting he error to be higher.

3. Measure both, Tplh and Tphl