ECE 3450
Digital Notebook
Practica 1 - 9
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Practicum I: Properties of Digital Devices

Part i: Voltage Transfer Characteristics

I. Purpose

Ideally, the input of a logic gate should always be either clearly “high” or clearly “low,” with nothing in-between. Thus, we must establish thresholds so that we can answer the question “how high must the voltage be to be counted as ‘logic high’ and how low must the voltage be to be counted as ‘logic low?’”

II. Procedure

To answer the above-stated question about voltage thresholds, we will observe the behavior of two inverters at all voltages between and including 0 and 5V. We will begin by setting up the function generator to give us a sawtooth waveform with an amplitude of 5V and a frequency of 1KHz. We will use this as the input to both a 74LS04 inverter and a CMOS 4069 inverter. In both cases we will ground all of the five remaining inputs to reduce the amount of noise.

We will capture all measured data from the oscilloscope, and mark up the graph with the values for $V_{IL}$, $V_{OH}$, $V_{IH}$, and $V_{OL}$. 
### III. Calculations, Data, and Graphs

#### Data Tables

**74LS04**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min</th>
<th>Typical</th>
<th>Max</th>
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<td>Low level Voltage Output, $V_{OL}$</td>
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<td>High level Voltage Output, $V_{OH}$</td>
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<td><strong>Hence calculated Noise Margin</strong></td>
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**CMOS 4069**

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Graphs

TTL (74LS04)

CMOS (CD4069)
IV. Discussion of Results

*TTL Results*
For the TTL inverter, we found that $V_{IL}$ is approximately 19% greater than manufacturer’s specification for $V_{IL\text{max}}$. Also, our measurement for $V_{IH}$ was approximately 12.5% less than the manufacturer’s specification for $V_{IH\text{min}}$. Our measurement for $V_{OL}$ was also approximately 20% greater than the manufacturer’s specification for $V_{OL\text{max}}$. Some of this error can be attributed to noise in the system.

We feel that these are reasonable calculations because the manufacturer specifications deal with the worst case scenario (with a large load on the inverter), while our test was done under close to ideal conditions (with very little load on the inverter).

Our measured value for $V_{OH}$ was above the manufacturer’s specification for a typical $V_{OH}$, but it was still in the normal operating range.

All of this resulted in the following noise margins:

\[
\begin{align*}
NM_H &= \quad \\
NM_L &= \\
NM &= 
\end{align*}
\]

Thus, our calculated noise margin of was slightly greater than the manufacturer’s value of . Again, this makes sense because our test did not involve such stringent conditions as the manufacturer’s test.

*CMOS Results*
For the CMOS inverter, we found that $V_{IL}$ and $V_{OH}$ were near the typical manufacturer’s specifications, and they were approximately a factor of 2 away from the manufacturer’s extreme conditions. Our measurements for $V_{OL}$ and $V_{OH}$ were exactly the same as the manufacturer’s typical measurements, and very close to the manufacturer’s extreme conditions. Again, we feel that these are reasonable calculations because the manufacturer specifications deal with the worst case scenario.

All of this resulted in the following noise margins:

\[
\begin{align*}
NM_H &= \quad \\
NM_L &= \\
NM &= 
\end{align*}
\]

Thus, our calculated noise margin of was nearly two times greater than the manufacturer’s value of . Again, this makes sense because our test did not involve such stringent conditions as the manufacturer’s test, and as a result it performed better.
V. Conclusions

From this part of this practicum, we were able to accurately determine the values for \( V_{IL} \), \( V_{OH} \), \( V_{IH} \), \( V_{OL} \), \( V_{LS} \), \( V_{TW} \), and both noise margins for both a TTL inverter and a CMOS inverter. In comparing this to the manufacturer’s data sheets, we found that our results were near the expected values in all cases.

In this lab, we learned a few things: first, that manufacturer’s spec sheets are designed to show the worst case conditions of a product, and that it may be in a designer’s benefit to test a component to get performance data for a particular application. Also, we learned the distinct differences between CMOS and TTL gates: specifically that TTL gates have different specification definitions (ie: \( V_{OH} \) and \( V_{OL} \)) because TTL gates do not perform as well. Finally, we learned more about how to use all of the lab equipment, and gained a general understanding of how different things (such as the data capture on the oscilloscope, and the different features of the wave generator) work.
## Practicum I, Part i: Pre-Lab

### Circuit Diagram

![Circuit Diagram](image)

#### 74LS04

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#### CMOS 4069 (Texas Instruments and National Semiconductor)

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#### CMOS 4069 (Motorola)

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