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Laboratory 6: Digital Circuits

Introduction

In this lab we cover the specifics of digital circuits. Rather than talking about how to build specific digital circuits (and gate, or gate), we talk about the real characteristics of such circuits. These include the transfer function of the circuit, noise margins, and propagation delay. We will use simulation and experimental analysis to observe these characteristics. We then determine the bounds of said circuits based on these values and analyze how they change depending on input signal.

Procedure

Exercise 6.1 - Noise Margins Complimentary BJTs (LTspice)

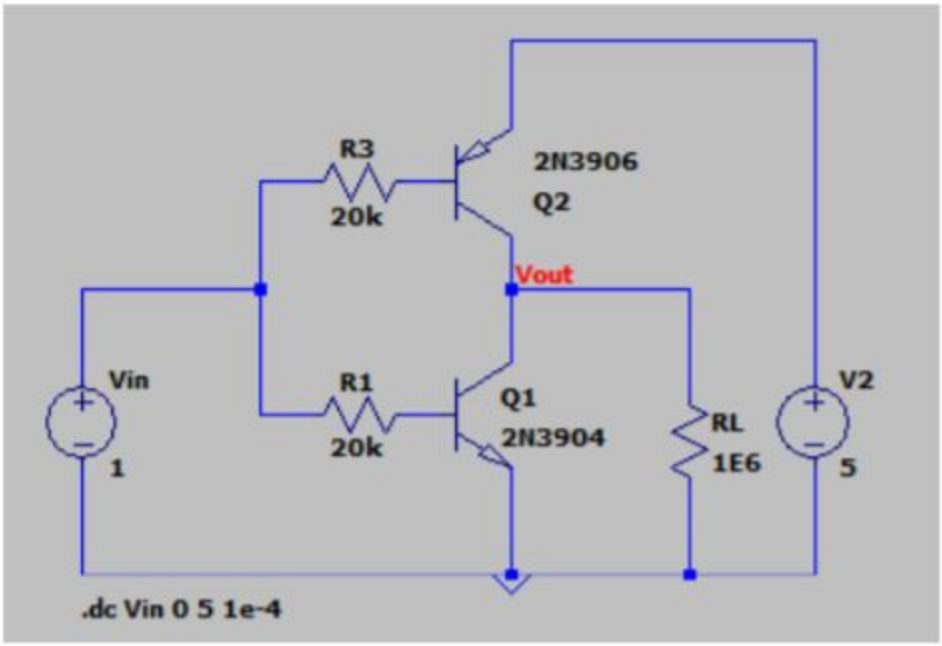


Figure 6.1.1 Complementary BJT Inverter

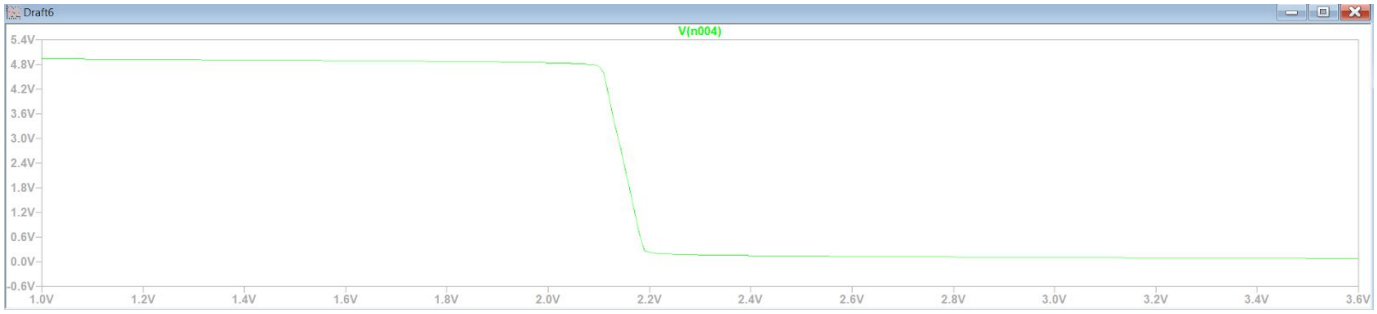


Figure 6.1.2 Transfer Function for circuit

1. R3 and R1 are acting as pull down resistors in this circuit, to help the transistors turn on and off faster.
2. V_{OH} = 4.757 V

V_{IH} = 2.1 V

V_{OL} = 234 mV

V_{IL} = 2.19 V

$NM_{LOW} = V_{IL} - V_{OL}$

$NM_{HIGH} = V_{OH} - V_{IH}$

NM_{LOW} = 2.19 V - 234 mV = 1.956V

NM_{HIGH} = 4.757 - 2.1V = 2.657 V

Figure 6.1.3 Transfer function with 200Ω Load Resistor

3. V_{OH} = 4.778 V

   V_{IH} = 1.05 V

   V_{OL} = 223 mV

   V_{IL} = 2.15 V

   $NM_{LOW} = V_{IL} - V_{OL}$ = 2.15V - 223mV = 1.927V

   $NM_{HIGH} = V_{OH} - V_{IH}$ = 4.778V - 1.05 V = 3.728

   This circuit is affected by load resistance because vout goes across the load resistor.

Exercise 6.2 – Propagation Delay – Complimentary BJTs

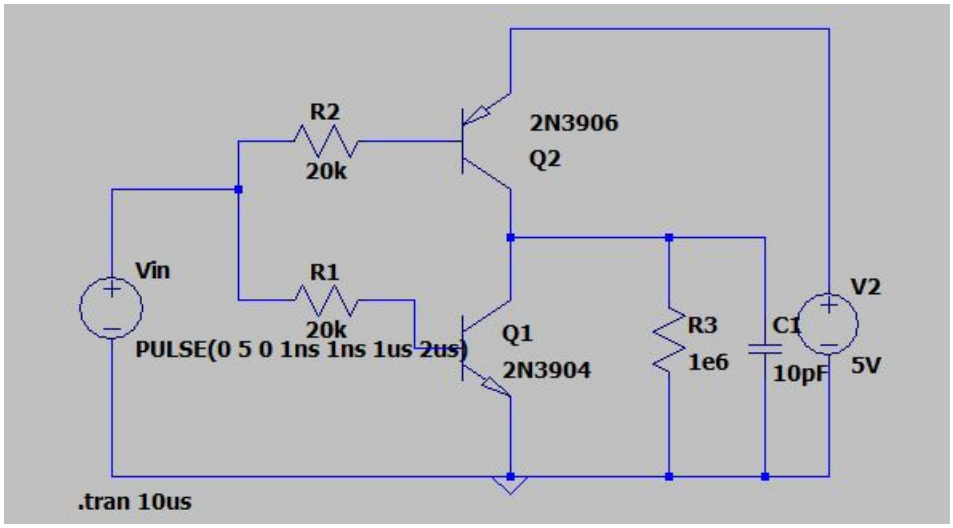


Figure 6.2.1 Circuit schematic

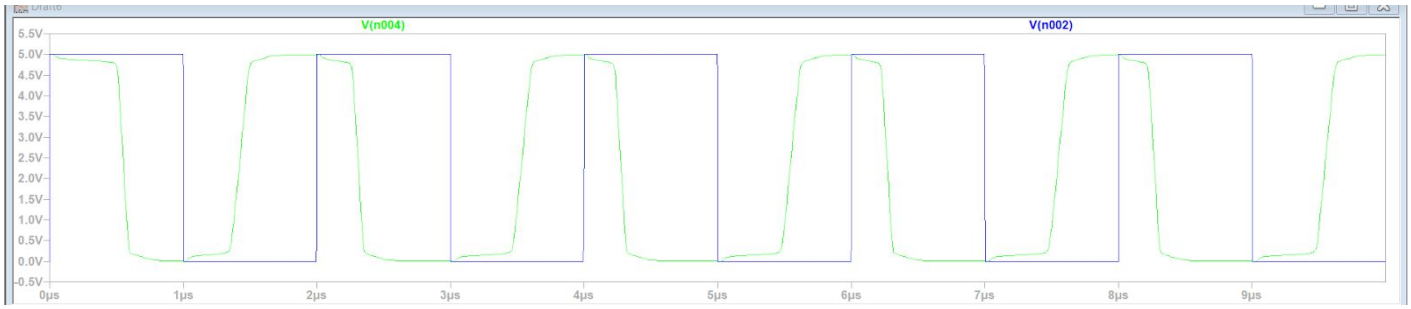


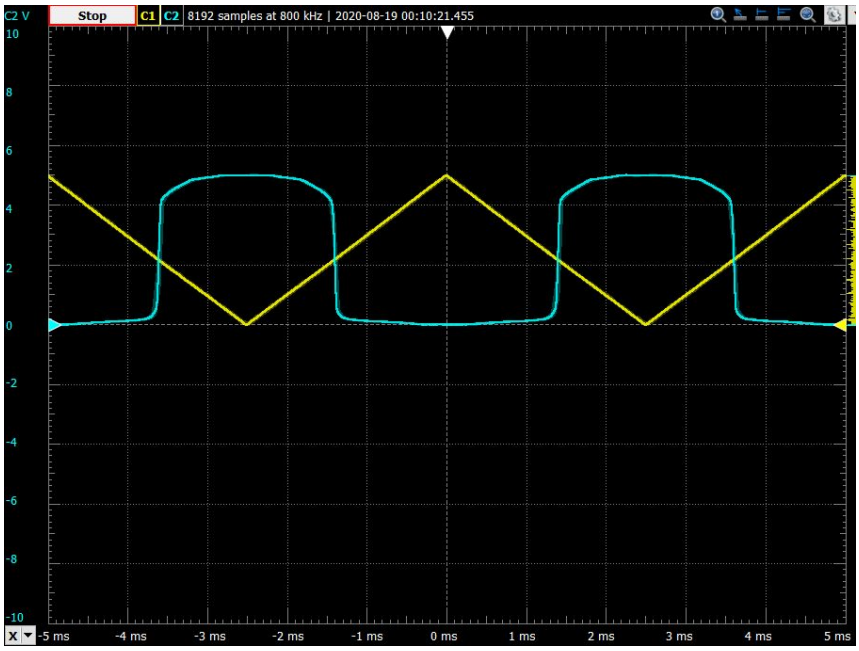
Figure 6.2.2 Vout and Vin for circuit above

t_{PLH} = 1.2 us

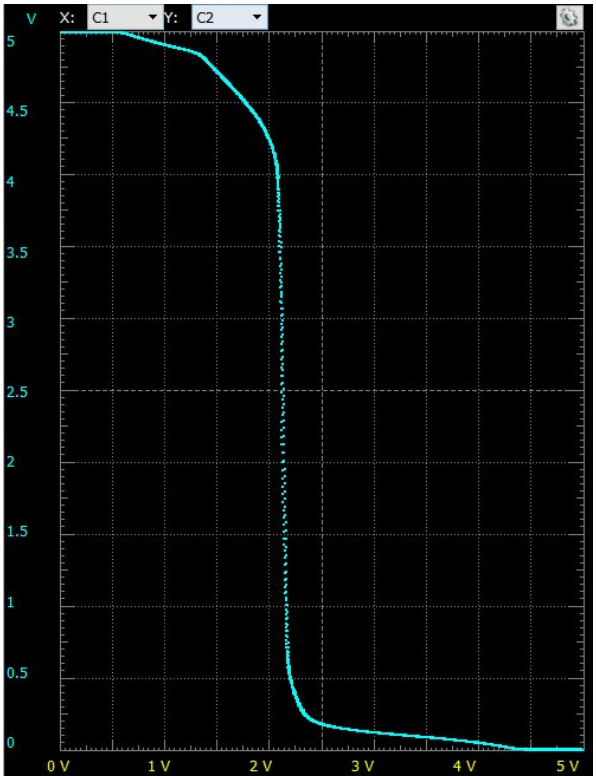
t_{PHL} = 1.8 us

Exercise 6.3: Complimentary BJTs (Discovery Board)

Discovery Board of Complimentary BJTs

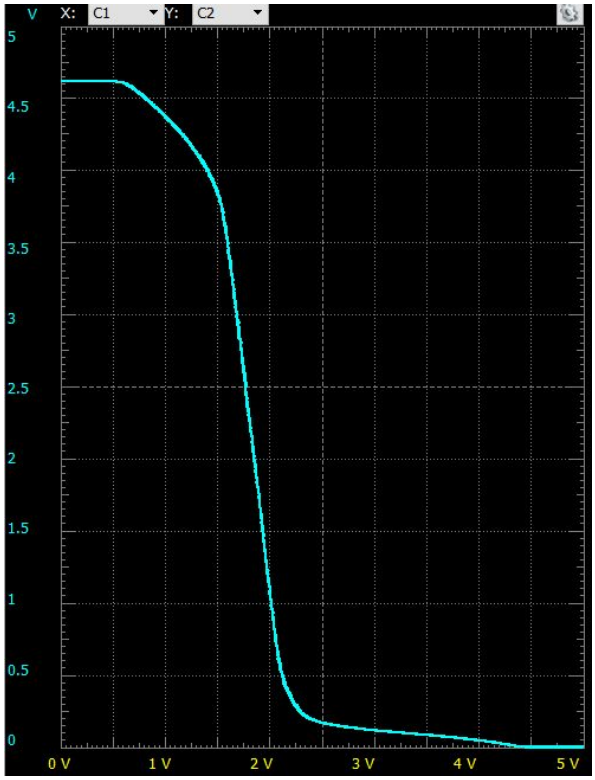


XY function of Vout vs. Vin



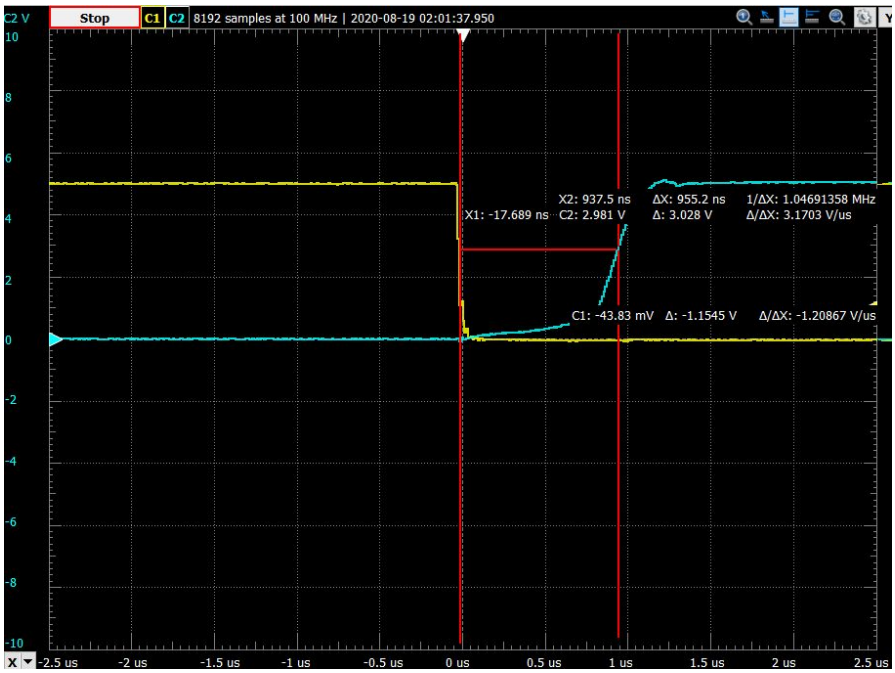
$$NM_L = V_{IL} - V_{OL} = 1.5 - 0.25 = 1.25V$$
$$NM_H = V_{OH} - V_{IH} = 4.5 - 2.25 = 2.25V$$

470 Ohm Vout vs Vin



$$NM_L = V_{IL} - V_{OL} = 1 - 0.25 = 0.75V$$
$$NM_H = V_{OH} - V_{IH} = 4.25 - 2.25 = 2V$$

Measuring Propagation Delay



We measure the propagation delay to be $1\mu s$

We see that the transfer function changed on resistance because the transfer function itself is based on resistance. There is only so much current that can be drawn by the transistor and that is dependent on the load resistor as it does draw current away from the bottom BJT. Furthermore tolerances and internal capacitance of the components can affect at which frequencies does the circuit operate as expected.

Conclusion:

Our analysis and experiments matched decently well. The experimental curves were not as sharp as the simulated one but that is expected due to the nature and tolerances of the real components that we use. We measure the propagation delay to be 1 microsecond which means that even for these non optimized real components they are decently fast to respond.The noise regions of the circuit is quite reasonable as well. Transistors open up the gate to controlled signal systems as seen in many electronics today. Understanding how their tolerances function and what affects them leaves the engineer with a sense on how to build the best circuit for them.