Ground Bounce

High Speed Digital Design
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1. Introduction

I had a difficult time at the beginning of this project. At first, I had no idea what I wanted to do for an experiment. For some reason, I did not know that I could do projects similar to those of other people. I also had trouble finding something that interested me enough to put a lot of time into. I thought I would just build some mutual capacitance and mutual inductance experiments and fit twenty or more experiments in the 3" x 3". After Forest showed me his ground bounce experiment though, I changed my mind. I liked the idea of having several chips with a lot of traces. I felt more chips would help me learn OrCAD better while testing my board at the same time.

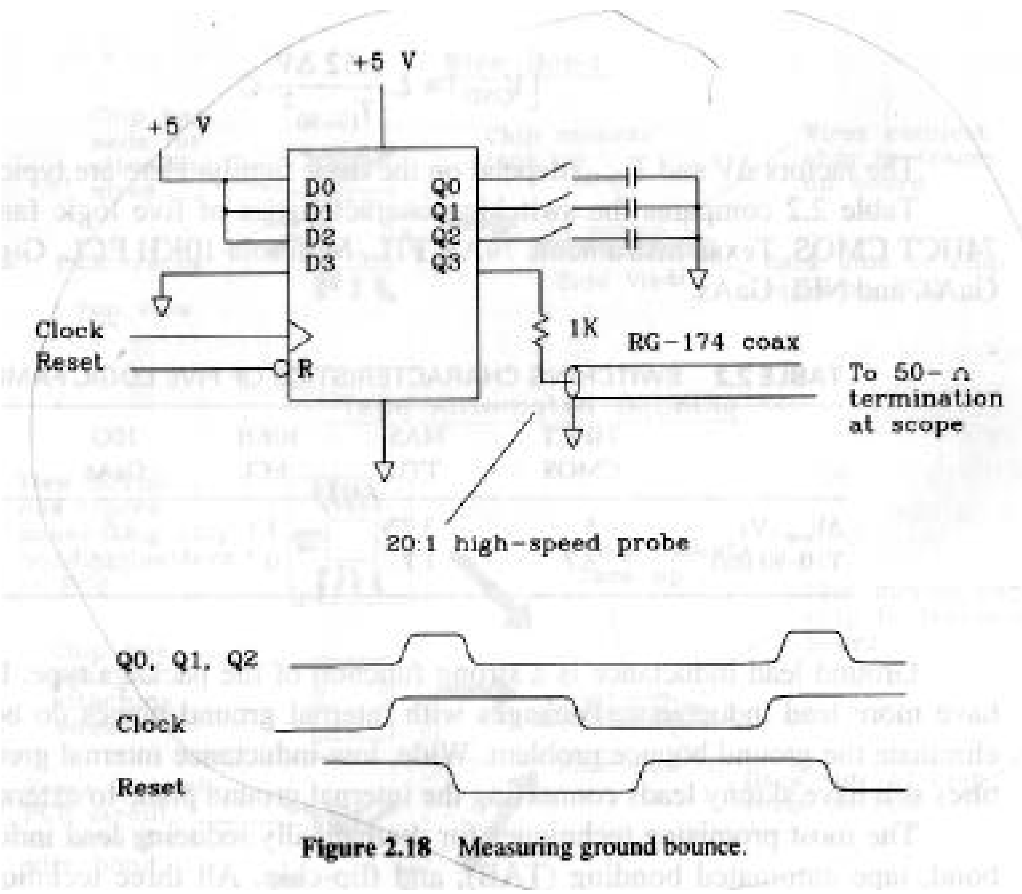

Figure 1. Ground bounce experiment design from the High Speed Digital Design text book.

2. Concept and Design

Ground bounce is when the ground of a circuit has a voltage spike. The experiment outlined in the book on page 71(see Figure 1.) uses a latch to drive capacitive loads to demonstrate. If the capacitive loads are all charged and a reset signal is sent to the latch, all of the loads discharge at the same time sending a quick surge of current thought the ground. Ground bounce high enough to move the ground voltage up by several volts can throw off ground references.

Design of the ground bounce experiment was not terribly difficult because it was already diagramed in the book. A quick search revealed that Digikey had the 74HC174 which is the chip used in the book. Most of my time spent on design was spent figuring out how to deliver the correct reset and clock signals. I could have done them by hand by charging all the capacitors and then sending a reset but that would mean I would only get one pulse to measure. The reset signal on the 74HC174 is active low and the capacitors would need enough time to charge. The easiest way to set up the clock and reset signals was to deliver the reset signal right away and send the same signal (delayed by 1/4 of a cycle) to the clock.

For delay, I could put the signal though a gate several times or use a transmission line. I wanted to do a design with a trace so I tried to design a trace narrow enough and long enough to give me a good time delay. Unfortunately, my trace would have had to be thirty-five inches long. I used an inverter because I thought placing the inverter chip would be easier than routing all that wire. The input signal to the latch would have a frequency with a period four times that of the delay through the inverter. In order to calculate the correct input signal, I placed a 21:1 shop probe SMA connector at the last inverter output. That way, I could measure the delay through the inverter using a pulse.

I saw other people that were doing ground bounce setting up to use jumpers to switch their capacitive loads on and off. I decided on a rocker switch because it would be easier to switch and it had the added bonus of having less inductance.

Drawing the design in Capture was easy. The only confusing part was making sure that the inverters tied together to form the same chip. Layout was more difficult mostly because I knew less about it. I had been using Capture for a year in other classes but had never touched Layout. I could not find a ten pin DIP footprint so I created one but I made the hole sizes wrong. I did not know that we could use the auto-router so I spent many hours routing it by hand.

3. Product and Surgery

I do not know where the error came from but all of my through holes were attached to the ground plane where they were not supposed to be. I spent a long time separating each hole from the ground plane with the dremel. I also found that I had put a sixteen pin DIP footprint in place where a fourteen pin DIP chip footprint should have been and I have highlighted it in the attached sheets. This made it so that half of the pins were wired wrong. After several hours of surgery drilling away at the ground plane and soldering tiny wires all over the place, I was satisfied and the board checked out on continuity.

	Without bypass to V_{cc}		With 0.01uF bypass to V_{cc}	
Load	V_{max}(Ground) mV	RMS(Ground) mV	V_{max}(Ground) mV	RMS(Ground) mV
0.00	16.10	5.17	16.80	5.01
33.00	18.00	4.40	17.60	4.35
66.00	22.60	4.40	22.20	4.62
99.00	25.00	4.60	25.80	4.75
132.00	28.20	5.04	28.60	5.39
165.00	32.40	5.91	34.20	6.20

Figure 2. Measurements of V_{max}(Ground) and RMS(Ground) with and without a bypass capacitor from the probe point to V_{cc}.

4. Results and Analysis

The delay through the inverter worked out to somewhere between 30ns and 50ns. Unfortunately, that gave me a frequency range from 5MHz to 8.33MHz. I settled for 6.5MHz. After a few silly problems with the equipment, I was able to get a reliable ground bounce. I took the measurements depicted in Figure 2 of the magnitude of ground bounce vs. load capacitance. Unfortunately, I did not have access to SMA to BNC cables when I took the measurements and I had to jerry-rig the BNC to JUMPER cables which gave me more noise.

Using my results in Figure 2., I approximated the amount of ground bounce per unit of capacitance to be 9.01mV per 33pF and 0.125mV(RMS) per 33pF which works out to 0.273mV per 1pF and 3.78uV(RMS) per 1pF. The largest ground bounce my circuit produced was 34.20mV with the bypass capacitor attached which just added one more capacitor to the bounce. However, I am using one latch to drive only five loads. If I used 5pF as a hypothetical load for one memory unit, then I would have 1.36mV per unit. Assuming the linear relationship as depicted in Figure 3., driving one thousand units would be enough to set a ground bounce of 1.36V which would definitely affect the circuit.

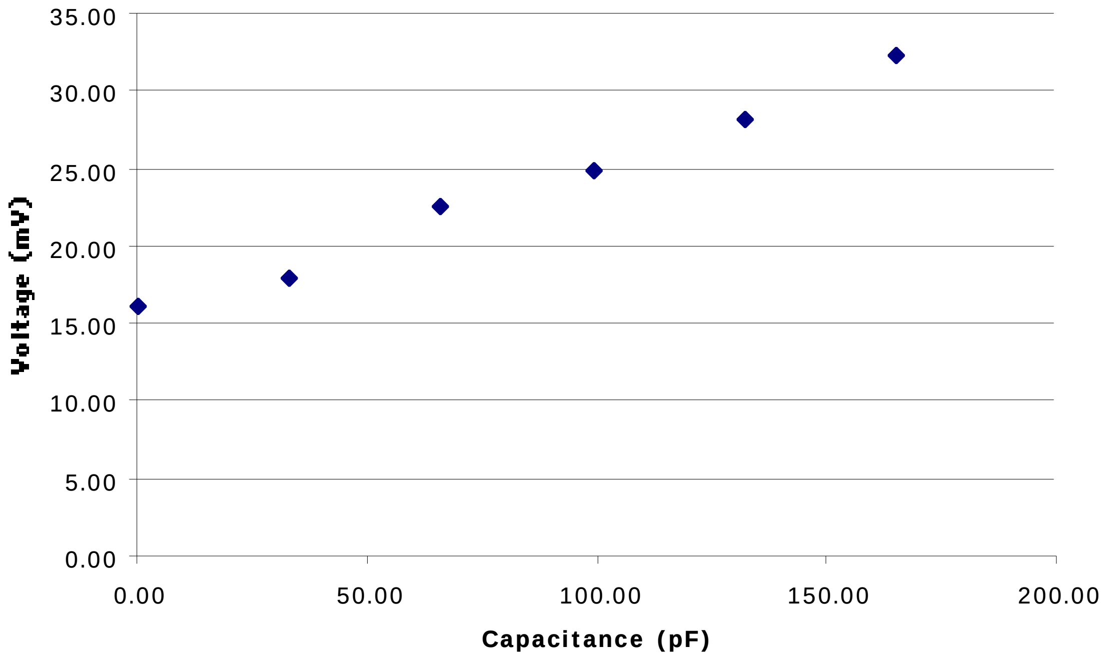

Figure 3. Voltage vs. Capacitance without the bypass capacitor.

5. Conclusion

Ground bounce can be a very real problem. If precautions are taken though, it can be avoided all together. Using separate ground references for the clock and the chip is one way to solve the problem. I noticed that attaching a 0.01uF bypass capacitor from the probed point to ground completely eliminated bounce. If I made a new version of my board, I would make it possible to test different remedies to see which is best. Needless to say, I did not have the time to do it this quarter but the next time the class is taught, people will know sooner and be able to start looking for their ideal experiment earlier than I was able to. They will also have past projects to look at and study. This project did a great job of showing me a complete design process from Idea to Design to Implementation to Testing to Results.