University of Pennsylvania
Department of Electrical and System Engineering
Circuit-Level Modeling, Design, and Optimization for Digital Systems

ESE3700, Spring 2024
Monday, April 22

Inductive Noise, Crosstalk, and Transmission Lines

In Detkin Lab: Monday, April 22, 1:45PM

You will work in teams of two to complete part A, B and C. Write your names and answers on this handout and turn it in at the end of lab for HW 7 credit.

1. **Part A: Inductive Noise** Observe and measure switching dynamics for the following cases of switching for a 74HC04 (6 inverters with one power and ground pad in a 14 pin package). Pinout for IC is on the next page. You should use a 5V power supply and drive an input with a 5 V_{pp} 1MHz square wave from the function generator. Set your scope to view the input, output, and Vdd simultaneously, and make sure you set scope triggering on the input signal channel.

   - PC Board with 74HC04. Get part from instructor. Note the DIP socket has 16 pins. The two extra sockets on the top of the chip are tied to GND and Vdd (from left to right) respectively to allow you to insert the bypass capacitor easily.
     - DIP IC on PC board with no bypass capacitor
     - DIP IC on PC board with bypass capacitor (non-polarized cap $> 2.2\mu$F.)

   For each case:

   - Observe the output **data** signal from the DIP

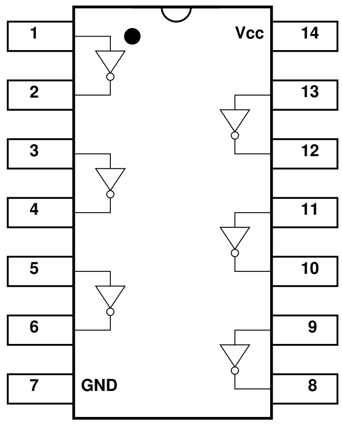
	What is the magnitude of the “unintended” ringing?	How long does the signal take to settle within 10% of its intended final value? (for both rise and fall)
With no bypass		
With bypass		

   - Observe the **power and ground pins** while the component is operating.

	How far from the steady-state value does the power rise and/or fall?	Over what period of time does the disturbance occur?
With no bypass		
With bypass		

   - What is the impact of bypass capacitors?

Pinout for 74HC04:



2. **Part B: Crosstalk** Observe and measure crosstalk. With the function generator drive one wire with the same 1MHZ 5 V_{pp} square wave and observe the impact on another wire. Use a T-junction to display the square wave drive on the oscilloscope. How large is the voltage swing on the observed wire? You may need to adjust the V/div to see the voltage swing.

   - Use PCB trace with 4 different trace wire lengths corresponding to wavelength ratios–full wavelength, 3/4 wavelength, 1/2 wavelength and 1/4 wavelength. For only the full and 1/4 wavelength PCB trace wire lengths, drive wire A and measure:

	Voltage Swing
B with B and C undriven/floating	
C with B and C undriven/floating	
B with B grounded	
C undriven/floating with B ungrounded	

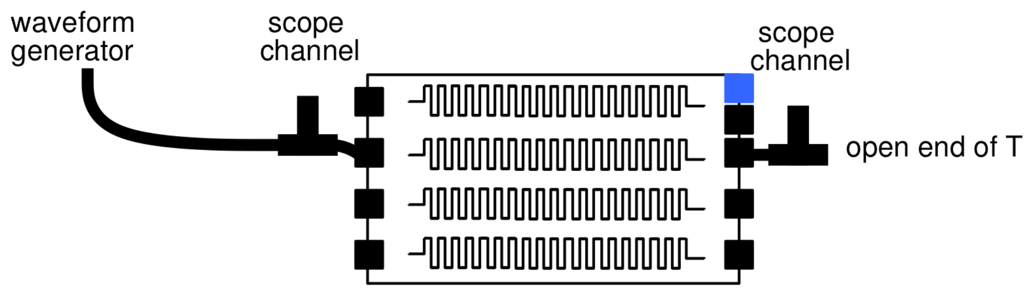
   - What is the impact of crosstalk on driven vs. undriven signals?

   - What is the impact of wire length on signal crosstalk?

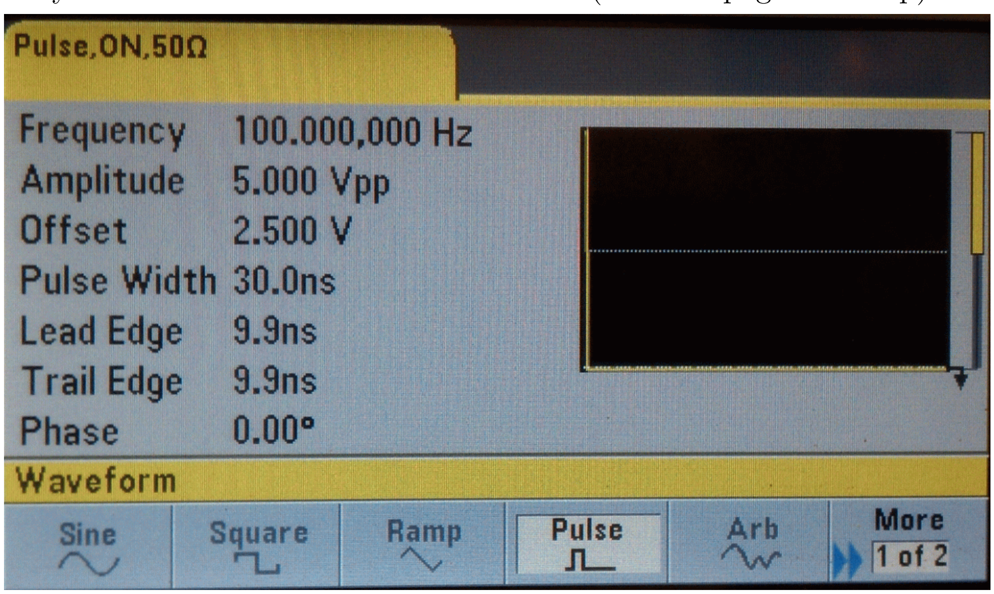
3. **Part C: Transmission Line** Observe and measure transmission line behaviour.
We suggest you collect the answers on this sheet and capture screenshot waveforms on scope. The data is not needed.
You only need to capture voltages and resistances to 2 decimal significant figures.

(a) Setup to drive a pulse into the long (5.34m) PCB stripline trace and watch both ends of the transmission line.

- Waveform generator drives short coaxial cable
- Use T-junction to couple short coaxial cable to long trace and observe this source end on one channel of oscilloscope
- Use T-junction to observe sink end of long trace on a second oscilloscope channel
- Initially, leave this final T-junction unterminated



- Set waverform generator to generate a small pulse of 30ns with a long period between pulses.
- Set the waveform generator for internal termination at 50Ω (not high-Z). This gives you a series termination at the source. (see next page for setup)



(b) Observe and characterize the result.

i. You should see the pulse at the far end of the long trace. You may need to adjust the trigger level for the associated scope channel. You might need to adjust the time/div to view your signals (eg. 5ms/div, 200ns/div, and 50ns/div).

ii. What is the delay between the two ends of the trace? Measure from 50% rise to 50% rise.

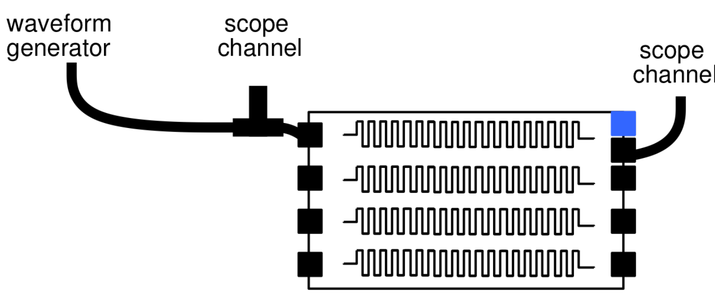
iii. How does the pulse at the far end of the trace compare to the source end? (shape? voltage compared to original pulse?)

Shape	
Voltage	

iv. What reflections (if any) can you see at either end (source or sink) of the line? What is the shape? What is the peak voltage? How does this relate to the peak voltage of the original pulse?)

Source	Number	
	Shape	
	Voltage (each pulse)	
Sink	Number	
	Shape	
	Voltage (each pulse)	

(c) Change trace lines using the topmost one with a potentiometer terminator.



i. For what resistance do you see minimal or no reflection? Use the multimeter to measure the potentiometer resistance.

ii. For what resistances do you get a negative reflection?

iii. For what resistances do you get a positive reflection?