ece340_lab6

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Part I

CMOS inverter

This lab simulates, constructs, and measures a CMOS inverter. The purpose is to observe and correlate physical construction with measured performance characteristics.

1 Introduction

Many parameters of a circuit can be extracted by careful observation of its response to various inputs. Rise times can be used to estimate the effective capacitance at a node, waveform slopes can be used to measure or estimate transistor currents without resorting to ammeters or adding current-measuring resistors to the circuit.

Parasitic inductance and capacitance as a result of physical construction can greatly affect circuits with very fast edges, short delays, or high frequencies. The mere act of attempting to measure a circuit changes its characteristics. Good measurement and construction techniques can minimize these disturbances, but not entirely eliminate them.

2 Experiment

1. Construct the circuit shown in **Figure 1** except for the capacitors. It is important to make all connections close to the transistors. Use extra resistor leads to make space to attach the various clips. Connect the transistors' gates and drains without using any extra wires.
   - Set the function generator frequency to $200\,\mathrm{kHz}$.
   - Setup the four measurement slots to measure the output's t_{rise}, t_{fall} and both propagation delays t_{pLH} and t_{pHL}.
   - It may be useful to refer to the oscilloscope's manual. A copy is posted on Blackboard's Content section at the bottom of the list.

- Report the four measured times.
- Carefuly observe and record or sketch the input and output waveform shapes. Note the cause-effect and interaction between the each waveform. Look for L-C ringing shapes.

2. Connect the $2.2\,\mu$F capacitor C_s between the two power supply terminals close to the transistor terminals. Be sure to observe the capacitor's polarity, electrolytic capacitors only work properly if the applied voltage is in the correct orientation.
   - Report the new time measurements.
   - Observe and describe the changes that happened to the waveforms. Which aspects changed? Explain why or what is causing the changes? It will be helpful to alternate between the capacitor in and out of the circuit while watching the display.
3. Connect the $10\,\mathrm{nF}$ capacitor C_{load}. All of these connections can be made using only 4 breadboard strips, use resistor lead wires to connect the signal generator, power supply, and oscilloscope probes. This makes changing the circuit easier.
   - Report the new time measurements.
   - Continue observing the details of the waveform shapes.
   - Is the output rising edge an exponential shape? What shape(s) make up the rising edge waveform.
   - Estimate the PMOS (BS250P) transistor's drain current from the output waveform.
   - Estimate the NMOS (BS170) transistor's drain current from the output waveform.
   - From these, also estimate each transistor's $K_n = \left(\mu_n C_{ox} \frac{W}{L}\right)$ or $K_p = \left(\mu_p C_{ox} \frac{W}{L}\right)$ value
4. While monitoring the output's rising edge, remove the power supply capacitor C_s.
   - Report the new time measurements.
   - Toggle back and forth between C_s in the circuit. Observe how the output rising edge shape varies between the waveform shape derived in Wednesday's lecture and that of a step response of an under-damped L-C circuit. Note the delay and rise-time changes.
5. Remove the load capacitor C_{load} and re-build your circuit and measurement setup to obtain as clean of waveforms as possible.
   - How much overshoot and ringing can you eliminate by careful construction?
   - Do not use oscilloscope settings to cleanup the displayed waveform, use the scope to clearly show all details of the waveforms.
   - Describe and document what changes or construction techniques you used to obtain these waveforms.

In addition to the analysis from the experiment:

Use the transistor datasheets to match and correlate parameters found or inferred from your measurements.

Modify the circuit from `hw20` to include the load capacitor value used in the lab. From transient simulations, measure the four time measurements. Compare and comment on the waveform shapes and the measurements on both the simulation and constructed measurement.