Oscilloscope Measurements

Introduction

In this lab you will make measurements using an oscilloscope (often called a "'scope"), an instrument that shows how voltages vary with time.

For digital circuits, 'scopes are mainly used to measure signal integrity (e.g. noise or distortion) rather than correct logic operation because 'scopes can only display 2 or 4 signals at a time.

A different instrument, a logic analyzer, is used to capture the values of multi-bit logic signals over time. Today, logic analyzer functions are usually embedded into ICs because high clock rates and the large number of test points makes it difficult to connect an external instrument to test points in an IC.

Older oscilloscopes were based on CRT (cathode ray tube) technology and could only display repetitive signals. A modern oscilloscope, a digital storage oscilloscope (DSO), consists of an ADC (analog to digital converter), memory, and a digital display. This allows intermittent events to be captured and examined.

It's important to understand the limitations of your instruments to avoid unjustified conclusions about the signal you are measuring. The performance of a DSO will often be limited by its analog bandwidth and sampling rate.

In this lab you will practice making measurements of digital signals using a DSO. The signals will be generated by your CPLD configured with a `.pof` file supplied by the instructor.

Some basic digital waveform measurements include: period, frequency, rise and fall times, delays, pulse widths, and duty cycles.

Oscilloscope Measurement Methods

You will practice three basic DSO measurement techniques in this lab.

Measurement functions are the most convenient and accurate way to make measurements. The 'scope measures period, duty cycle, and pulse widths by measuring the time between crossings of a threshold.

However, complex waveforms that include multiple threshold crossings within the same period will show incorrect measurements. In this case...

Cursors can be used to visually identify and mark features on the waveform. The 'scope can then compute the time difference between the two points.

Divisions on the graticule[1] between the two points can be counted to measure time differences by multiplying by the time per division (usually shown on the display). This is faster but less accurate and more error-prone.

The three methods described above can also be used to make *voltage* measurements in similar ways.

Procedure

For this lab you will need your CPLD board, three jumper leads, and a USB flash drive to save 'scope screen captures. You should make the measurements on the lab 'scopes during your assigned lab session.

Download the `.pof` file corresponding to your student ID from the course web site and use the Quartus programmer to program your CPLD.

Use jumpers to connect the 'scope probe to the signals described below and the 'scope ground clip to a CPLD ground pin (labelled GND on connectors P1 and P3).

Initial Setup

To configure the 'scope:

- reset the scope to factory defaults
- use the calibration test point on the front of the 'scope to check the vertical and horizontal scales and probe compensation

[1] The grid on the display.

Not doing this could result in incorrect measurements and wasted time (or worse).

The lab instructor will demonstrate how to do this for the 'scopes in your particular lab.

Measurement Procedure

1. Set the vertical and horizontal scales appropriately and capture a suitable waveform.

   Single-sweep mode is often more convenient than Normal or Auto modes because it avoids the need to configure the 'scope to trigger at a specific point in the waveform's period.

   You can capture the waveform using one horizontal scale ("sweep rate") and then "zoom in" by changing the scale after the waveform has been captured. The "zoom" range will be limited by the 'scopes memory.

2. Measure the parameter of interest using the following three methods:

   (a) the graticule

   (b) cursors, and

   (c) a measurement function if available and applicable.

   and record each of your measurements as shown in Table 1.

3. Save a screen image to your USB flash drive. Do *not* use your phone camera to record the lab 'scope screen unless the lab instructor has approved this.

   Record the screen capture file name.

When recording the measurements from the graticule, write down the time per division, the number of divisions and the calculated time. For example:

$$5.6\,\text{div} \times 10\,\mu\text{s/div} = 56\,\mu\text{s}$$

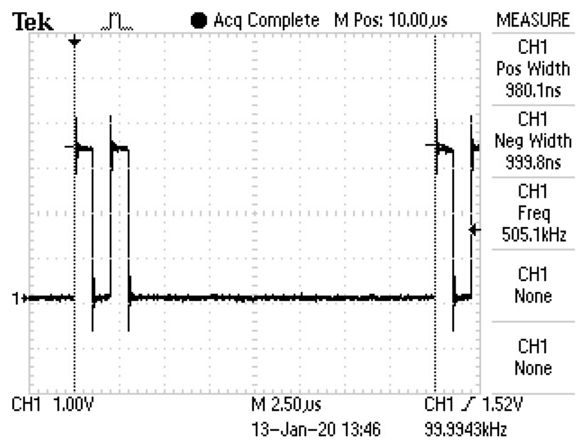
When using the cursors or the measurement function, write the time difference as displayed on the 'scope or the measured value.

Period and Frequency

Measure the period of the signal on pin 2 (P3, bottom left). The frequency of the waveform is the inverse of the period.

Note that this waveform is periodic but has several pulses per period. Adjust the 'scope to show more than one cycle and measure the period. Compute the corresponding frequency. Be ready to explain any differences between your calculations and the 'scope's frequency or period measurement results.

For example, your screen capture might look like:



Rise and Fall Time

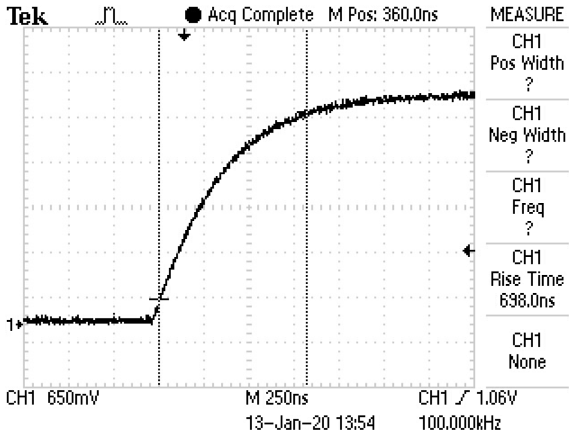
The rise time is the time for a signal to go from 10% to 90% of its peak value. The fall time is measured from 90% to 10%.

Measure the rise and fall times of the positive pulse appearing on pin 30 (P2, bottom left). To get adequate resolution you will need to measure each edge separately.

The bandwidth of the 'scope will be marked on the front of the instrument. The rise time of a 'scope is approximately $^{0.35}/_{\text{bandwidth}}$. The probe also has a limited bandwidth and a rise time.

Record the bandwidth of the 'scope and estimate its rise time. Be ready to explain whether you are measuring the rise and fall times of the 'scope (and probe), that of the signal, or both.

For example, the rise time measurement might look like:



Delay

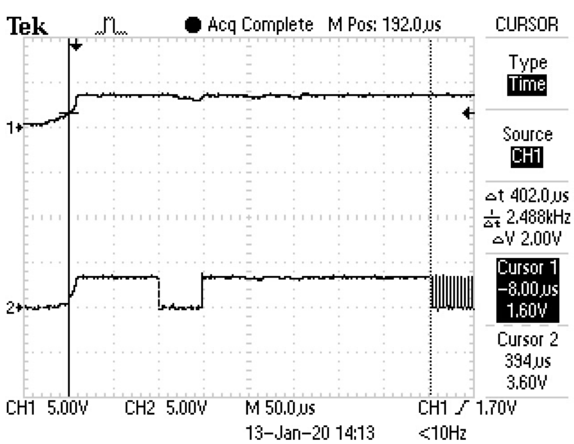
Delays are measured between points on two signals. It is typically measured between points at 50% of the high logic level [2].

You will measure the time it takes for the CPLD to start operating after power is applied.

Connect one jumper to the 3.3 V supply rail pin (P1, bottom right pin). Connect another jumper to pin 29 (P3, bottom right). Measure the 3.3V supply with the 'scope's Channel 1 and pin 29 using Channel 2.

Measure the delay between the rising edge of the power supply and the start of the pulse train on pin 29. This is the time it takes for the CPLD to configure itself after power is applied. You will need to use single-sweep mode and switch the power off and on for each measurement.

The results might look like:

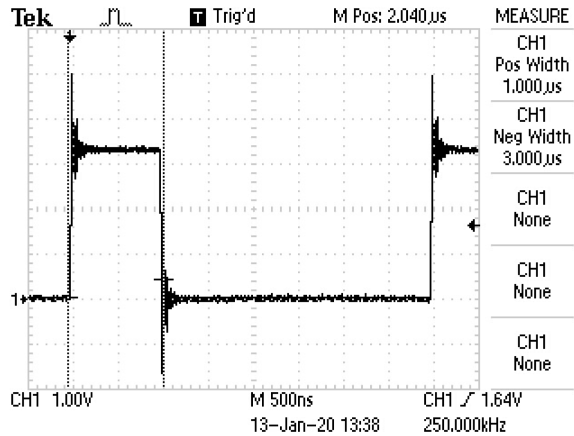


Pulse Widths and Duty Cycle

Measure the positive and negative pulse widths of the signal on pin 29 (P3, bottom right). The pulse widths should be measured between the 50% levels.

Compute the duty cycle in percent assuming the signal is active-high. The duty cycle is the fraction of the period duration that the signal is active. It is typically given as a percentage.

For example, your screen capture might look like:



Remember to take your USB drive when you leave the lab.

Report

To get credit for completing this lab, submit a PDF document containing the following items to the appropriate Assignment folder on the course website:

- A table similar to 1 summarizing your measurements. Include units.
- The five screen captures listed in the table.
- An explanation of any anomalous period measurements.
- The 'scope bandwidth, an estimate of the rise time and an explanation of how this might affect your rise time measurement.

[2] Or sometimes at the logic thresholds V_{IH} and V_{IL}.

Measurement	Using Graticule (give divisions, time/division, time)	Using Cursors (Δt)	Using 'scope Measurement	Screen Capture File
period (pin 2)				
frequency (computed)				—
rise time (pin 30)				
fall time (pin 30)				—
delay (3.3V to pin 29)				
positive pulse width (pin 29)				
negative pulse width (pin 29)				
duty cycle (computed)				—

Table 1: Measurements. Give units (e.g. ms or μs).