

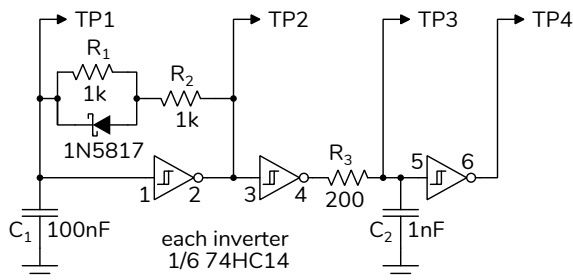
## Digital Waveform Measurement

### Introduction

In this lab you will build an oscillator and make measurements using an oscilloscope.

The oscillator uses a **Schmitt trigger** inverter. This type of inverter uses feedback to increase the input threshold when the output is high and decrease it when the output is low. This is called “hysteresis” and one application is to prevent noise from causing multiple undesired changes in the output when a signal crosses the input switching threshold.

The following schematic shows the circuit you will be measuring at the test points TP1 through TP3:



The Schmitt trigger inverter is configured as an oscillator. When the output of the inverter is high, the capacitor charges up through a 1k resistor and the Schottky diode until it crosses the upper switching threshold ( $V_{T+}$ ). Then the output switches off and discharges the capacitor through both 1k resistors in series until the input crosses the lower switching threshold ( $V_{T-}$ ). The different charge and discharge rates produce an asymmetrical waveform.

The RC circuit at the output of the second inverter increases the rise time of the signal so it can be measured by the AD2.

This type of oscillator’s frequency depends on switching thresholds and supply voltage, and so its accuracy and stability are much worse than for quartz-crystal, ceramic or MEMs oscillators. However, this oscillator has no start-up delay and the circuit components can be integrated into an IC. Thus this type of oscillator is used when start-up time and cost are more important than frequency accuracy.

### Oscilloscope Measurement Methods

Three ways to make measurements on digital ’scopes are:

- using measurement functions,
- marking the waveform feature(s) of interest using cursors, and
- estimating from the graticule markings.

*Measurement functions* are the most convenient and accurate but can give incorrect results if the waveforms don’t match what the function expects. In this case, *cursors* allow you mark the specific times or voltages that you want to measure from or to. If accuracy is not required, the fastest measurements can be made by *estimating* values from graticule markings and the display scale. This is computed by estimating the number of vertical or horizontal divisions and multiplying by the vertical or horizontal scale.

You will practice these three methods in this lab.

### Test Circuit

#### Component Values

Use your DMM to measure the three resistances ( $R_1$  through  $R_3$ ), two capacitances ( $C_1$  and  $C_2$ ) and the forward voltage drop of the Schottky diode. Record the values, including units. You will, of course, need to measure these with the components out of the circuit.

### Test Circuit

Assemble the circuit shown above using components from your ELEX 1117 and 2117 parts kits. Consult the 74HC14 datasheet on the course web site for pin-outs and specifications. Remember to connect unused IC inputs to  $V_{CC}$  or ground.

## Measurements

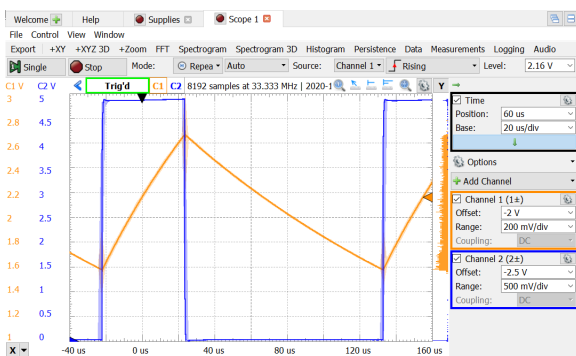
Start the Waveforms software, open a new workspace and add Supplies and Scope tabs.

In the Supplies tab, set the positive supply voltage to 5 V and enable it.

Connect the inverting scope inputs (orange/white and blue/white) to the ground of your circuit. Connect the Channel 1 (orange) and Channel 2 (blue) probes to TP1 and TP2 respectively.

Adjust the trigger level (move the orange triangle on the right of the screen) so it's in the range of the Channel 1 voltage swing.

Adjust the vertical scale and offset and the horizontal scale and offset to expand the waveform so that you can see one complete cycle and the waveform takes up most of the screen. For example:

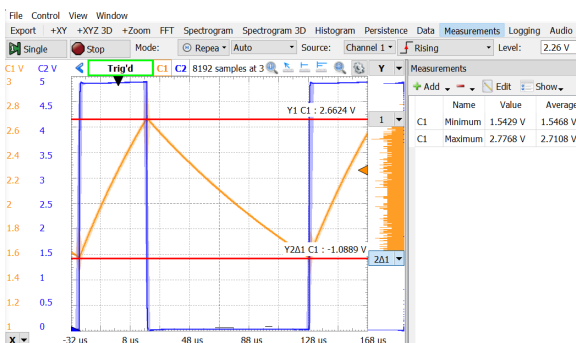


## Switching Thresholds

Click on the “Y Cursors” button, add two Y cursors for Channel 1 and adjust them to the maximum and minimum input voltages for Channel 1 (TP1, the inverting input).

Click on the “Measurements” button and add two measurements: Defined Measurement / Channel 1 / Vertical / Maximum and ... / Minimum. Click on Show / Average to display the average value.

Your screen might look like:

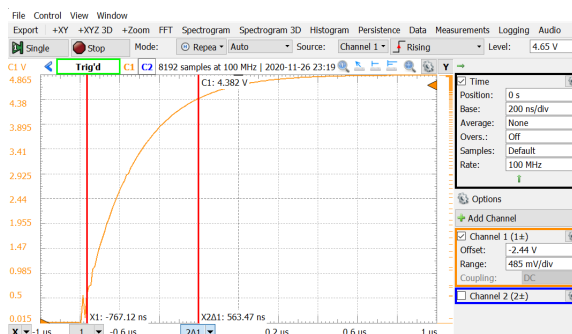


Make sure both the cursor and measurement values are displayed and take a screen capture for your report.

## Rise and Fall Times

Move the Channel 1 probe to TP3. Turn off Channel 2 (right-click on the C2 button). Remove the Y cursors. Change the horizontal position to center the rising edge in the center of the screen and change the horizontal scale until you can see the rising edge of the waveform and the maximum value:

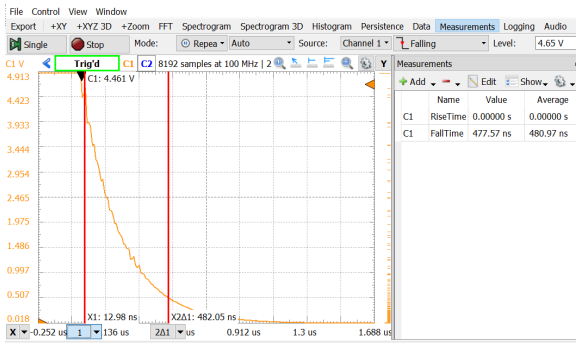
Hold down the shift key while moving the left (for position) or right (for scale) mouse buttons and adjust the vertical gain and position so that the waveform takes up all 10 vertical divisions. Add two X cursors and adjust them so that they intersect the waveform at 1 division from the bottom (10%) and 1 division from the top (90%):



The  $\Delta$  value shown is the rise time – the time taken to go from 10% to 90% of the maximum voltage.

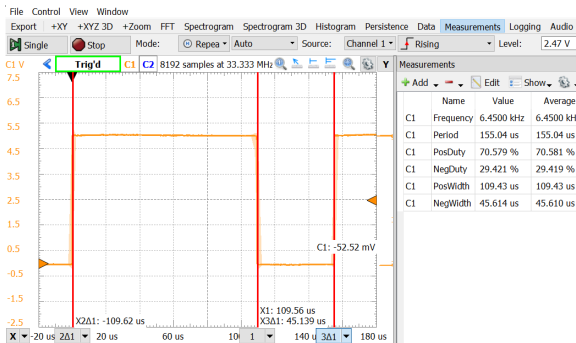
Add measurements of the rise and fall time (Defined Measurement / Channel 1 / Horizontal / Rise Time and Fall Time). Take a screen capture for your report, making sure both the cursor and measurement values are recorded.

To measure the falling edge, change the trigger slope to “Falling”, adjust the scale, position and cursors as necessary. Repeat both cursor and measurements of the fall time and take a screen capture for your report:



## Pulse Widths and Period

Move the Channel 1 probe to TP4. Trigger off the rising edge and adjust the horizontal scale and position to show one cycle. Use three X cursors to measure the positive and negative pulse widths as shown below. Also add the six horizontal measurements shown below.



Take a screen capture for your report, again ensuring both the cursor and measurement data is visible.

## 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 of the component values you measured. Columns should include the reference designator, the value and the units.

Reference	Value	Units
R1	997	$\Omega$
...		

- The four screen captures<sup>1</sup> listed above (thresholds, rise time, fall time, period and pulse

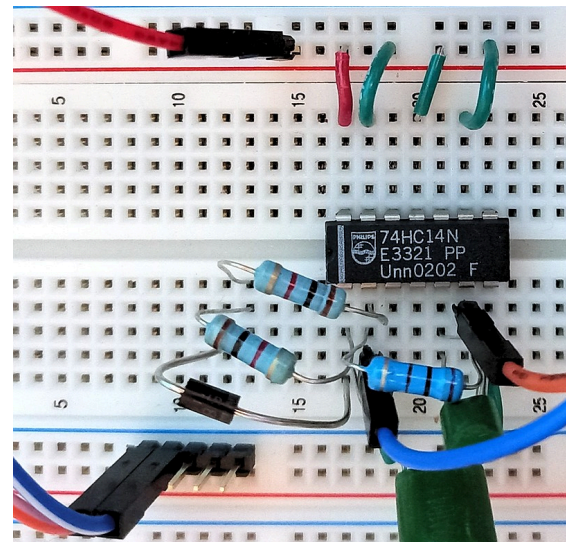
<sup>1</sup>Use a screen capture or the AD2 export feature (not a photograph of the monitor screen!

widths).

- A table summarising your measurements. Columns should include the measurement name (positive threshold, negative threshold, rise time, fall time, positive pulse width, negative pulse width, and period), the value estimated from the grid on the screen (“graticule”), the value estimated from the cursors, the “Measurement” value and the units.

Type	Estimated	From Cursor	Measured	Units
Rise Time	550	563	570	ns
...				

- A photograph of your circuit. For example<sup>2</sup>



<sup>2</sup>The photo may not match the schematic; wire your circuit from the schematic.