

**Oscilloscope
Exercises**

for

**Analog &
Digital 'scopes**

Physcs 431, 432, 433

OSCILLOSCOPE_EXERCISES_09_20_04.sxw

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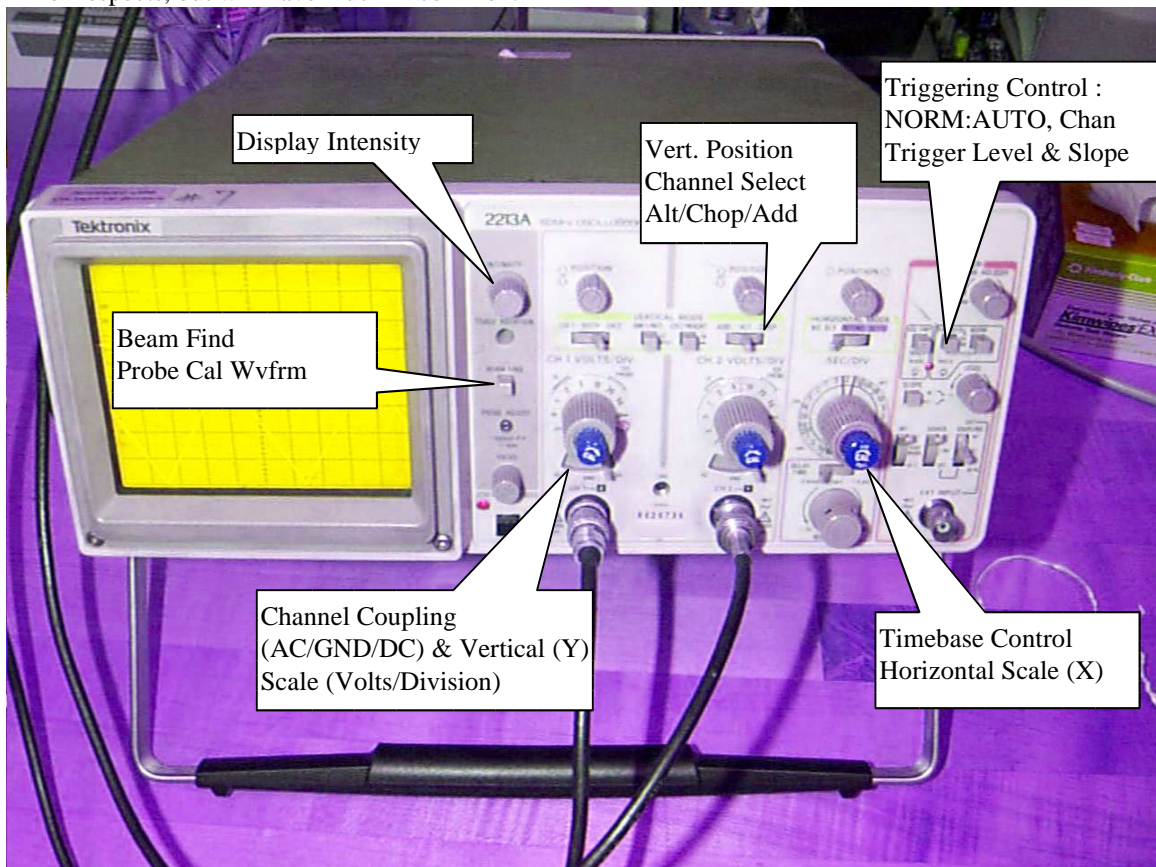
OSCILLOSCOPE EXERCISES

The oscilloscope is probably the most ubiquitous piece of equipment in the laboratory environment. In most of the experiments that you are going to perform, either all or part of the information will be displayed on the screen of an oscilloscope. Most of the oscilloscopes in this lab are of the analog type, though there are a few digital scopes that are used on some of the more complicated experiments.

Each scope type and model has its own particular strengths and limitations. The purpose of the scope exercises described below is to have you become more familiar with some of the simple procedures that will allow you to get a display and observe a signal on the scopes in the lab, as well as to recognize some of the possibilities and limitations of these instruments. The digital scopes are a bit more challenging and may require more practice or the assistance of your TA in some instances in the lab. If you have previously had an electronics course or have a strong electronics background, you may find the exercises trivial, but please do them anyway.

Using the Analog Scope

The front panel of a typical analog oscilloscope used in the lab is pictured below. Yours may differ in minor respects, but will have much in common.



The analog scopes are as a general rule, easier to use to start with, so we will begin exploring these scopes first.

PRELIMINARY EXERCISE -- Getting up and running:

Find the ground traces:

1. Set the intensity (using a small twist in the CCW direction) to a low value & switch all channel inputs to ground (GND)
2. Set the trigger to "P-P-AUTO", ***NOT*** "NORM" and the horizontal-mode knob to "NO DLY". Other trigger switches should be set to "AC", "INT", "CH1".
3. Choose Channel-1 by putting the vertical mode switch to "CH1"
4. Turn on the power and note that the trace is a straight line. If you do not immediately see a trace, gently push and hold the "BEAM FIND" button and adjust channel 1 vertical position knob until the trace is found. Adjust until the trace is about 1-2 cm (major divisions) above the center of the screen.
5. Move the Vertical-Mode switch to CH2 and repeat steps 3&4, such that the channel 2 trace is about 1-2cm below the center of the screen.
6. Select "BOTH" and "ALT" with the Channel Select switches so that you see both traces on the display.

View a signal & explore signal probe effects and scope

7. Now, take a 10X-scope probe (which divides the voltages down by a factor of 10) and put a BNC-T on the cable end. Then plug this BNC-T into the CH1 input. Take a short piece of BNC cable and connect the other end of the BNC-T to the Channel2 input. Next, clip the probe tip to the gold pin emerging from the "PROBE ADJUST" output (labeled 500mV pp at 1-kHz" on some scopes).
8. Turn both CH1 & CH2 inputs to AC with vertical-gain knobs each at 20mV/cm. (Remember, you are using a 10X probe & gently check that the red "CAL" knobs are turned fully clockwise.) You should now see two (roughly) square wave traces on the display. Can you explain why the peak to peak amplitude is half what it is labeled to be?
HINT: Disconnect the short BNC cable to CH2 and observe the CH1 signal alone. Then, add the provided 1Mohm and 100kOhm resistors to the end of the BNC cable attached to CH1. Explain what you see. Moral of the story: Your scope input, while relatively high impedance, can affect the circuit you are observing!
9. Reconnect the short BNC cable between the CH1&2 inputs. Change the horizontal time base knob until two full cycles are shown on the display (0.2ms/div where each div. = 1cm)
10. Move the vertical mode switch to "ADD" and see the signal trace with twice the amplitude.
11. Now go back to ALT and push the CH2 INVERT button. This causes the CH2 signal to be 180° out of phase with the CH1 signal. Now switch to ADD and see the signal disappear to a straight line.
12. Change each vertical-gain knob to a more sensitive scale and note the signal comes back when both channels are on the same scale.
13. Flip the trigger switch down to CH2 and remove the BNC cable from the CH2 input. You will now see the CH1 display running free, i.e. without being triggered into a stationary trace. You can trigger, and thereby stabilize, this trace by flipping trigger switch back to CH1

14. With CH1 triggering enabled, place the vertical mode switch to CH1. Then, switch the trigger from the PPAUTO to NORM and see the signal disappear. Now, rotate the trigger level until you regain a stable trace. The differences between the PPAUTO and the NORM (which stands for "Normal") trigger modes are that in the PPAUTO mode, the range of the trigger level control is restricted to the peak to peak range of the trigger signal, and that the scope will automatically initiate (trigger) a sweep if it must wait more than about 50msec for a trigger signal. The result is that the scope will always trigger when a signal is present, and even when one is not (which can sometimes be a hindrance).
15. Switch the trigger back to PPAUTO and remove the BNC cable from the BNC-T. Now, still looking at the CH1 display, check the vertical calibration on a number of the vertical scales. Also, check the time base calibration on as many scales as possible using the time-base calibration knob by checking to see if the appropriate number of calibration cycles are being displays.
16. Move the probe to the CH2 input and repeat the last step.

Scope Exercise #1 -- Use Tek 2213A ANALOG SCOPE

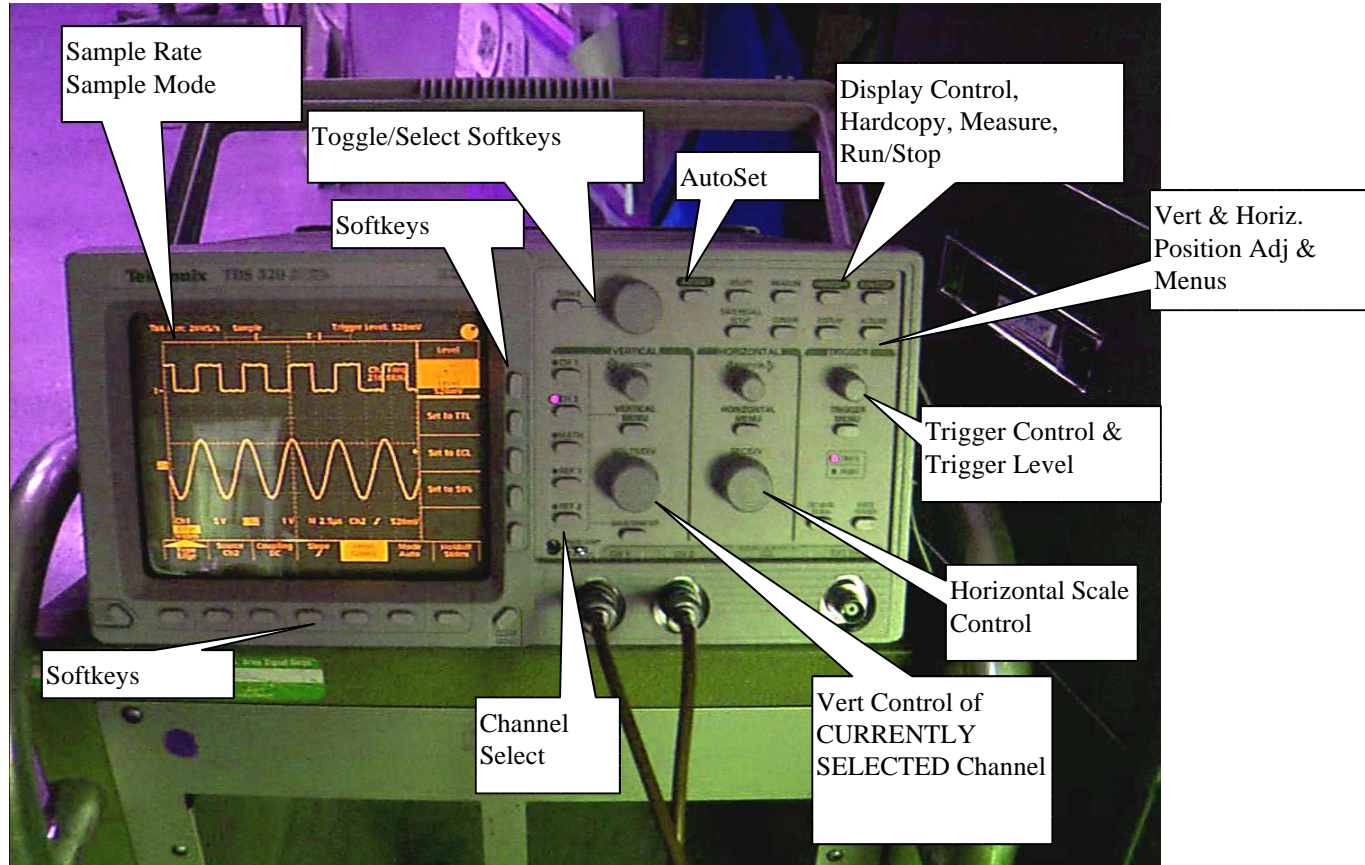
1. Observing a signal: Connect a single function generator to either the CH1 or CH2 input.
 - a. Using a sine wave signal, display various frequencies and adjust the time-base as required to easily observe several distinct cycles.
 - b. Now use a square wave signal and measure the initial rise time of the triggered square pulse, using a suitable choice of time-base setting and the vertical gain scale.
2. Observing two sine-wave signals: Connect a separate function generator to each of the CH1 and CH2 inputs.
 - a. Set one of the function generators to a 1.0 kHz sine-wave and set the other one to 2.0 kHz sine-wave. Set both signals to have about the same peak-to-peak amplitude, and use the same vertical gain scale for both inputs. Observe both signals using the ALT mode. Then observe them with the vertical-mode switch in the ADD position. Finally, observe them with the CH2 INVERT button pushed. Note that you can get some very complex-looking superpositions.
 - b. Repeat part a. using 100 Hz and 105 Hz on the respective inputs. With the vertical mode switch in the ADD position, you should now be seeing somewhat less complex looking superpositions. Reverse the order of the two inputs to see the superposition wave traveling in the opposite direction on the screen. Why is this so? Hint: try changing the trigger source.
3. Producing Lissajous' figures: With the same setup as in part 2., rotate the time base knob fully counter-clockwise to the X-Y position. Observe stationary patterns when various ratios of frequencies are used from both oscillators. Note that CH1 is the X-input and CH2 is the Y-input.

Scope Exercise #2 -- Use Tek 2213A ANALOG SCOPE

1. Assemble an R-C low pass filter (i.e. input to a resistor followed with the output bypassed by a capacitor to ground) on an all-purpose "bread-board" circuit. Connect the input to a function generator using a square-wave signal and connect the output to CH1 of the scope. Using a BNC-T, connect the output of the function generator to CH2 of the scope and observe both waveforms using the ALT mode.
 - a. Adjust the frequency of the function generator and change the time-base scale until you can see considerable rounding on each transition. A square wave can be thought of as a superposition of a large number of odd-harmonics of the fundamental, which produce the sharp transition. The nature of a low-pass filter is to attenuate most of the higher harmonics, leaving the fundamental as the dominant waveform.
 - b. Now, change the time base scale until only the first half-cycle is visible on the screen. Determine the time constant (τ) for the filter, using the fact that the signal relaxes back to roughly 63% of the peak-to-peak transition voltage every $\Delta t = \tau$. You may need to adjust the frequency a little to optimize the figure. Does your result agree with what is expected?
2. Remove the function generator from the CH2 input and connect a pulse generator in its place. Set the pulse generator to give a positive rising pulse and set the vertical-mode switch on the oscilloscope to CH2. Then change the trigger to CH2 and observe the characteristics of the pulses as you vary amplitude, pulse duration (width), and pulse repetition rate.
3. Observe both generators at the same time on the screen by using the ALT and chopped modes of the vertical amplifier. You will probably need to adjust frequencies and/or trigger settings to get a reasonably stationary display.
4. Finally, move the pulse generator to the EXT trigger input and switch to EXT trigger mode. Try to observe the low-pass filtered square-wave on Channel 1 where the trace is started by the pulse from the pulse generator. Change the pulse repetition rate to see how it affects the displayed signal.

WHEN YOU FINISH THE EXERCISE, AS ALWAYS, IN CONSIDERATION OF THOSE WHO WILL COME AFTER YOU IN THE LAB, PLEASE RETURN CABLES AND LEAVE THE EQUIPMENT AS YOU FOUND IT.

Using the Digital Scope



The digital scopes are used in some of the more complicated experiments where the special options available to analyze the waveform in a digitized form are of use. However, there are some subtleties in using these scopes and utilizing their measurement capabilities, without first carefully considering how they are acquired, can lead to incorrect measurements and erroneous conclusions.

Try to resist the temptation to assume that because the digital scopes are flashy, newer, and have a funky CRT type display that they're somehow better than the analog scopes. For some things they are... For others, they're in fact a step in the wrong direction. We won't go into all the gory detail about when one is better than the other, but will give you a little appreciation for some of the differences and special considerations when using a digital scope.

1. Power up one of the Tek320 scopes. The scope will go through a power up self test, after which you'll be prompted to press the CLEAR MENU button to proceed.
2. Turn on the function generator (preferably a digital one) supplied for this exercise, then set the amplitude control to $\sim 1/4$ of it's highest value with no DC offset and select ~ 2 kHz triangle wave from the function generator. Now connect the function generator to the scope. Use a BNC cable from the "OUTPUT" connector of the function generator to the CH1 input on the scope, and from the TTL output to the CH2 input.
3. Press the CH 1 and CH 2 buttons at the right of the screen to enable the control to each channel. You'll see a 1&2 "arrow" appear at the left side of the screen (if they weren't already there) as each channel is turned on. Use the VERTICAL POSITION knobs to move the indicator arrows to the center of the upper and lower halves of the screen. The VERTICAL POSITION knob controls

the position of the currently selected waveform; To move the other waveform, select it using the buttons at the right hand of the screen.

4. Press the "TRIGGER MENU" key. Be sure your scope has the following settings for the softkeys across the bottom of the screen :
TYPE:EDGE ; COUPLING:DC ; SOURCE:CH1 ; SLOPE:RISING ; MODE:AUTO ;
HOLDOFF : SET TO MIN (500ns)
Press the CLEAR MENU button to turn off the softkey prompts.
5. At this point, you'll probably see some sort of trace on the scope screen, if not, press the CH1 & CH2 buttons just to the right of the screen to be sure each waveform is on. If you still do not see a waveform, press the AUTOSET button near the top center of the control panel. (n.b. If you have a good, low noise, periodic signal, using AUTOSET as a first step often helps get you on the right track -- This function looks for a periodic signal and sets timebase, voltage, and trigger levels it thinks appropriate to a signal it finds on the currently selected trigger channel -- But it's far from a panacea and don't expect it to be a cure-all, especially if you have irregular, noisy or otherwise more "challenging" waveforms you're trying to view)
6. Experiment with the Volts/Div, Timebase, and trigger level settings. Note the changing values near the bottom of the screen. You'll find they work similarly to, but not identical to, those on an analog scope. Also try different frequencies from the function generator.

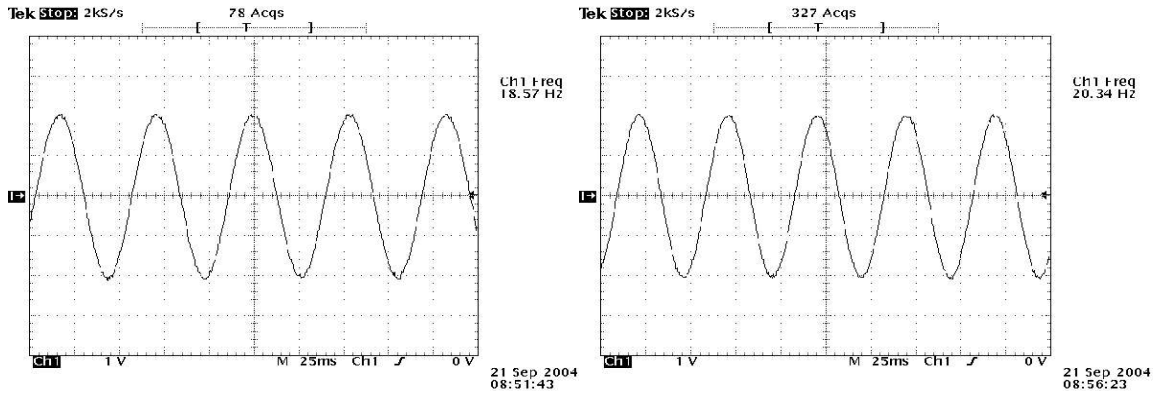
DIGITAL SCOPE GOTCHAS

7. Select a $< \sim 20$ Hz signal on your function generator, again with no offset and $\sim 1/4$ full amplitude. Press the AUTOSET button on the scope to find the signal.
8. Press the CH2 button, then WAVEFORM OFF, so that you are observing CH1 only.
9. Adjust the vertical position to the center of the scope screen.
10. Try using the cursors to make a measurement. Press the cursor button in the upper right corner of the panel. Choose V(ertical) Bars on the soft keys to the right of the screen. Position the cursors at an appropriate location on the waveform to make a period measurement. The uppermost knob near the toggle button can be used to control the position of the solid cursor. Change cursors using the toggle button. Does the measurement make sense with the waveform you've selected? Note that these are "softkeys" as well and may have different functions depending on the currently selected mode of the scope. Can you find a case where the toggle buttons or knob have another function?
11. The digital scope can be useful as a general purpose measurement device, and will even make the measurements for you. Press the MEASURE key, then select the softkeys for SELECT FOR MEASRMNT 1: FREQUENCY. You should see something like that shown in the figures below:

Does the measurement agree with what you expect?

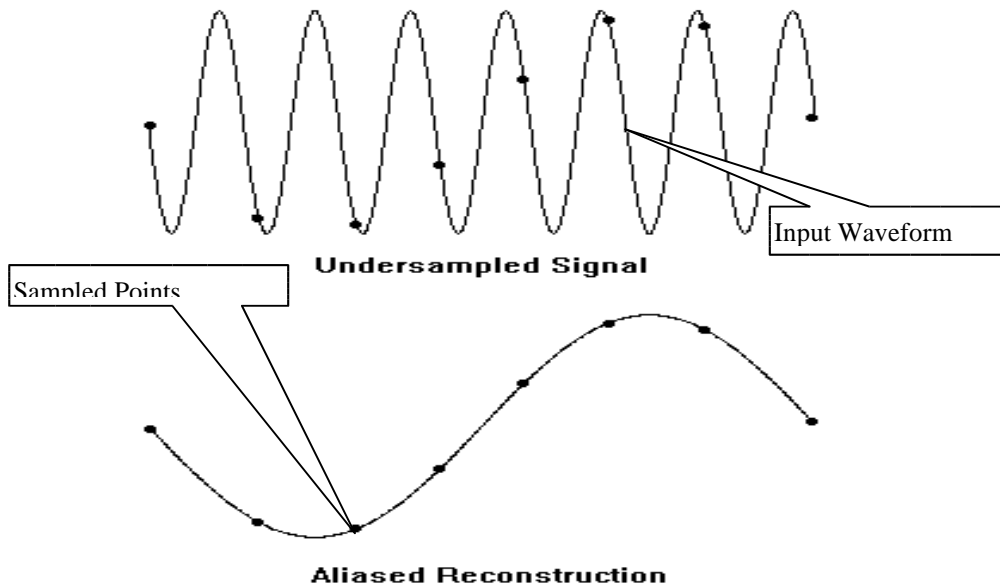
Now change the range on the function generator to slightly more than 2 kHz (If you have a digital display on your function generator, ~ 2025 - 2050 Hz or so) What do you get for a measurement now? Is the measurement still what you expect? What's going on here?

No, there's nothing wrong with your scope -- You've been duped by Prof. Nyquist --



TWO WAVEFORMS DISPLAYED ON THE SCOPE. IN ONE CASE THE INPUT WAVEFORM IS AN 18HZ SINE WAVE, IN THE OTHER, ~2018 HZ SINE WAVE. CAN YOU TELL THE DIFFERENCE BY THESE SCOPE TRACES (I THOUGHT NOT)

A digital scope turns an input voltage into a digital "number" periodically and the frequency at which this happens is called the "sampling frequency". The sampling frequency on this scope can be found in the upper left hand corner of the screen -- In the case of this exercise, 2kS/sec (2000 samples/second). At a minimum, you have to sample a couple times per cycle to be able to reconstruct a waveform and meet the "Nyquist Criterion". If you don't, you are "undersampling" the waveform, and the waveform you will see is called an "aliased" waveform and will give incorrect measurements. See the below diagram for an example of how undersampling can lead to an aliased waveform. Analog scopes do not suffer from this disease, so this is just one of many reasons that analog scopes still have their own merits.



MORAL OF THE STORY: When acquiring data on a digital scope, make sure that you're sampling at an adequate rate. This was a fairly transparent example; "Real life" aliasing can be considerably more subtle, so keep an eye on that sample rate and be sure it's AT LEAST 2X the highest frequency waveform you're expecting to see.