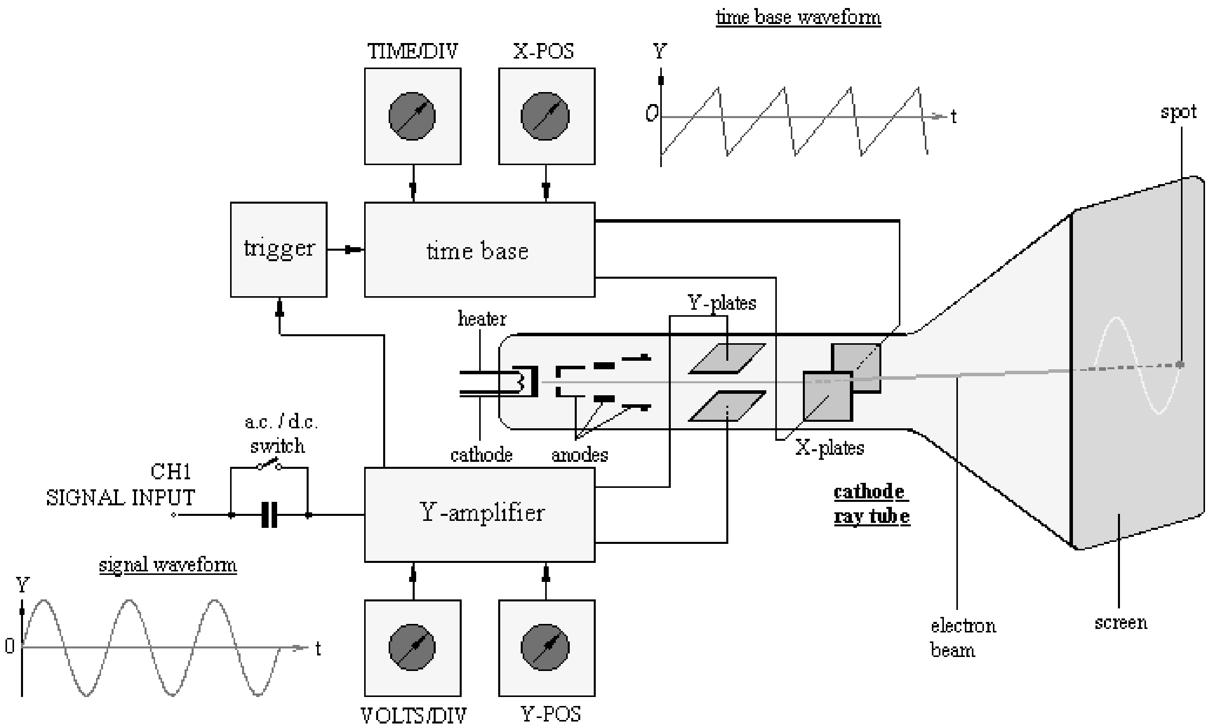
The University of Hong Kong
Department of Physics
Experimental Physics Laboratory

PHYS2255 Introductory Electricity and Magnetism
2255-1 LABORATORY MANUAL
Experiment 1: Operation of a cathode ray oscilloscope (CRO)

Introduction

The cathode ray oscilloscope (CRO) is one of the most commonly used and most useful instruments in a physics laboratory. It is conventionally an analog system (some modern high performance CROs digitize the signals and process them digitally) and produces two dimensional displays of analogy signals. A CRO consists of three main parts: an electron gun, a fluorescent screen, and two pairs of deflection plates (X-plates and Y-plates). Other major additional feature includes trigger units.

When voltage signals V_x and V_y (or quantities converted to voltages) are applied to the X- and Y-plates, the horizontal defection *x* and vertical deflection *y* of the spot on the screen will be proportional to V_x and V_y. The voltage fed to the X-plate can be either an external voltage signal V_x or a time base voltage. In the former case, the CRO shows a graph of V_y versus V_x. In the later case, the CRO will show a graph of V_y versus time *t*. The time base generates a voltage which rises steadily to a certain value and then falls to its original value in a short time. The spot sweeps steadily from left to right when the voltage is rising, then flies rapidly back when the voltage falls, and then the process repeats. To make the time base frequency to synchronize with that of the input signal, a triggering pulse is applied to the time base generator from the Y- or input- signal through the trigger unit.



(A) Initial setting up (for all models of CRO)

Before connecting the power cord to an AC line outlet, check that the AC line voltage selector plug on the rear panel of the instrument is correctly set for the AC line voltage. After ensuring the voltage setting, set the switches and controls of the instrument to the following settings:

POWER	II OFF position
INTEN	Clockwise (3-O'clock position)
FOCUS	Mid-position
ILLUM	Counterclockwise position
VERT MODE CH1 (**X**)	
↑ position	mid-position, push in
VOLTS/DIV	500 ***mV/DIV***
VARIABLE	(Red knob) CAL'D fully clockwise, push in
AC-GND-DC	GND
SOURCE	Be selected automatically to CH1
COUPLING	AC
SLOPE	+
LEVEL	Lock (fully counterclockwise)
HOLDOFF	Norm (counterclockwise)
SWEEP MODE	AUTO
TIME/DIV	0.5 ms***/DIV***
VARIABLE	(Red knob) CAL'D fully clockwise, push in
↔ position	Mid-position

Initial Adjustment

After setting the switches and controls as indicated above, connect the power cord to the AC line outlet and proceed as follows:

1. Turn-on the POWER switch and make sure that the power pilot LED is on. In about 20 seconds, a trace will appear on the screen. If no trace appears after about 60 seconds, repeat the switch and control settings as tabled above.

2. Adjust the trace to an appropriate brightness and to the sharpest image with the INTEN and FOCUS controls.

3. Align the trace with the horizontal center line of graticule by adjusting the CH1 POSITION control.

4. Connect the probe to the CH1 INPUT terminal.

5. Adjust the FOCUS control until the trace becomes sharp.
   Connect the signal generator output to the CRO and switch the AC-GND-DC setting to DC.

6. Adjust the VOLTS/DIV switch and TIME/DIV to appropriate positions so that the signal waveform is displayed with an appropriate amplitude and an appropriate number of peaks.

7. Adjust the ↑ position and ↔ position controls to appropriate positions so that the displayed waveform is aligned with the graticule and the voltage $V_{p\text{-}p}$ and period T can be read as desired.

The above is the basic operating procedure for single-channel operation with CH1. Single-channel operations with CH2 can also be made in a similar manner.

Disconnect the probe and CH1 input terminal, and leave the horizontal line on the screen. This horizontal line is due to the "sweep voltage" applied to the X- plates. At the 100μs/cm setting, since the screen is about 10cm wide, the sweep time is about 10×100μs or 1ms. If we neglect the short rest time before the sweep resumes, the sweep repetition frequency will be of the order of 1kHz.

Now turn the TIME/DIV control to 100ms and observe the spot sweeping slowly across the screen. Please check/answer the followings:

(i) *Calculate what is the sweep period now.*
(ii) *Check your answer by timing the sweep roughly (an ordinary watch will do)*
(iii) *Compare your measurement and your prediction. Are they the same/different?*

(B) Measuring a dc voltage

Connect a 1.5V dry cell across the CH1(X) input-earth or CH2(Y) input-earth terminal with either polarity. Set the AC-GND-DC setting to DC. This would apply a direct current (dc) potential to the Y-plates. Measure the shift in cm and convert it to volts according to your setting of 0.5V/cm. Now repeat with reversed polarity. You are now using the CRO as a simple voltmeter.

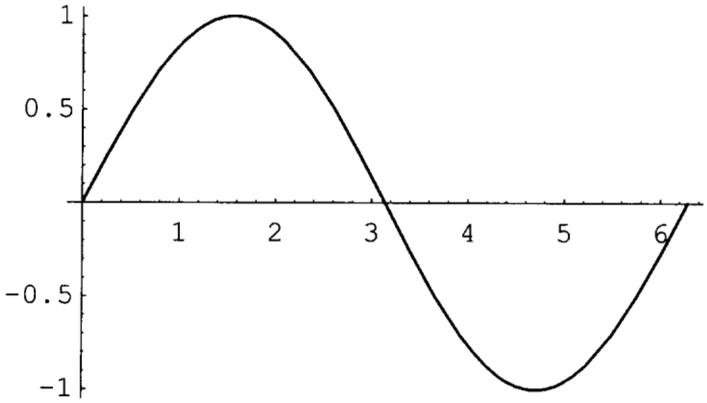
Note : When you measure the voltage of a dc supply, you cannot switch the AC-GND-DC TO AC. The reason is that switching to AC inserts a capacitor in series with the Y-input terminal. This would cancel out or "block" any dc component of the input.

(C) Displaying an ac waveform: Use of the Signal Generator

First, change the AC-GND-DC switch to AC. To provide alternative current (ac) input of various frequencies we need an Oscillator or Signal Generator.

First, select the required SINE OUTPUT setting. Then set the OUTPUT RANGE to a suitable position, and the OUTPUT LEVEL to 5 or 6 (and adjust later if desired). Set the frequency to 1000Hz. Then connect to the mains and connect the CH1(x) (or CH2(y)) input terminal of the CRO and the SINE OUTPUT of the signal generator, thus supplying a 1000Hz ac signal to the y-plates. By adjusting the ↑

and ↔ POSITION controls, you can see a stable, steady, single, sinusoidal waveform which (if you are on 100μs/cm setting) should show one complete cycle:



If needed, please turn the signal generator's **<u>OUTPUT ADJUST</u>** control and/or the CRO **Volts/cm** control for a convenient amplitude. You get about one cycle because the period of the input (1 ms) is also approximately the period of the sweep (10 × 100μs).

Now turn the Time/Div setting to 1ms, 10 ms, 10μs, etc, and report what you observe on the screen.

*After trying these different **Time/Div** settings, return to the 100μs/cm setting.*

(D) <u>Measurements of ac voltages : sine-wave and square-wave</u>

(i) A multimeter measures the root-mean-square (rms) voltage of an ac signal on the assumption that it is sinusoidal. On the other hand, the CRO allows you to measure peak-to-peak voltage, V_{pp}, for <u>any</u> periodic signal, whether sinusoidal or not. If it is sinusoidal, then

$$V_{PP}=2\sqrt{2}\, V_{rms}$$

Now please measure the V_{pp} for the maximum output of the Sig. Gen., still on sine-wave, at about 1000Hz. Record the results.

(ii) Now change the **<u>OUTPUT</u>** of the signal generator to square wave. You will find the vertical parts of the "square" (actually rectangular) waveform to be very faint, and you may have to adjust the INTEN setting to see the entire waveform on screen.

(iii) Now measure V_{pp} at maximum output. Record the results.

*After completing the experiment on square wave, change the signal generator **OUTPUT** back to sine wave.*

(E) Adjustment of input signal frequency

(i) Change the signal generator frequency range so that the input frequency to the CRO is about 10kHz.
(ii) Adjust the **Time/Div** setting to get one complete cycle displayed on the screen.
(iii) Now change the input 100kHz and try again to display one complete cycle.

After completing the experiment on input signal frequency, set the system back to1000Hz input and 100μs/cm setting again.

(F) Use of CRO to measure unknown frequencies

The **Time/Div** scale allows us to measure the period of any input signal and hence its frequency. One can measure the spread of the signal on the screen for one full cycle, one half cycle, or any whole number of cycles whichever is more convenient.

IMPORTANT: Note that the **Time/Div** scale is valid only when the *VARIABLE* control is fully clockwise and pushed in.

(i) Assume now that the *nominal frequency*, that is, the frequency shown on the signal generator dial, is unreliable, while assume also that the **Time/Div** setting of the CRO is reliable and accurate (These are actually quite commonly true!)
(ii) Set the signal generator dial to an arbitrary setting and use the CRO to measure the "true" frequency. Repeat the measurements for a total of 5 different frequencies.
(iii) Complete Table 1 of the Laboratory worksheet.

(G) The VARIABLE control

Up to now on any given input frequency you have had little control over the number of cycles displayed, since it is constrained by the **Time/Div** control settings (thus changing the sweep rate), which in turns changes only in powers of 10. The red VARIABLE control gives you a continuous range of sweep rate between the discrete positions of the **Time/Div** switch. Return to 100μs and 1000Hz, and try turning the VARIABLE knob anti-clockwise.

Report briefly your observations.

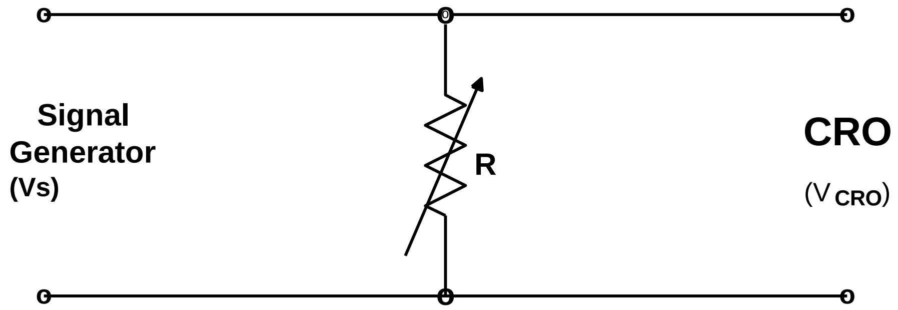
N.B. : *The **Time/Div** reading is valid only if VARIABLE is fully clockwise and pushed in (at CAL). Tthe Volt/Div reading is valid only if VARIABLE is fully clockwise and pushed in.*

(H) Output (or internal) Impedance of Signal Generator

The internal impedance of the signal generator, Z_i, will be in series with the resistor in our RC circuit which may need to be taken into account in your experiments. Notice that we *cannot* use an ohmmeter to measure Z_i.

The simplest method to find Z_i is described as follows.

1. Connect the signal generator to the CRO at about 800Hz (sine wave)
2. Adjust the peak-to-peak amplitude of the trace (using Volt/Div) to between 4 and 7 cm, and measure it.
3. Connect a variable resistance R (a decade resistance box) across the output terminals.



CAUTION : Be sure that you do not short the output (i.e., all decades at zero, and $R = 0\Omega$) which can damage the whole system. You may start with at least 1kΩ.

4. Adjust the value of R so that the amplitude of the trace falls to half its initial value (i.e. the value obtained by connecting signal generator directly to CRO without variable resistance R).
   If Z_i is resistive, then we have $Z_i = R$. To test whether it is resistive, you may change the frequency to some other values such as 80 Hz, 8 kHz, 80 kHz. If the amplitude does not change, then there is no reactance present. It is because reactance $X = \omega L - 1/(\omega C)$ varies significantly with frequency. If you find that the amplitude does not change at all, then it can be concluded that $Z_i = R$ where R_i is the internal resistance of the signal generator.
5. Measure R_i for a series of settings of Output Adjust from 5 to 9 and write down your results in Table 2 of your Report. Repeat the measurements for square waves. In what follows keep Output Amplitude within the range where R_i is known.

NOTE : The CRO also has an internal or input impedance which is harder to measure but is equivalent to a 1MΩ resistance with a 100pF capacitance (X=16 kΩ at 100kHz) in parallel. This may also need to be taken into account in your measurements.