

## Appendix C

### The Oscilloscope

Because the oscilloscope is used throughout the course as a measuring and detecting device, a good understanding of its operation is required. Besides observing the changes that occur in an electrical signal when various control knobs are turned, measurements of peak-to-peak voltages, frequencies, and DC voltages will be made.

#### Theory

The main component of the oscilloscope is the cathode ray tube (CRT) on whose screen the externally applied electrical signal is detected. In its barest essentials, the operation of the CRT can be understood as an application of the basic principle that similar electrical charges repel each other while unlike charges attract.

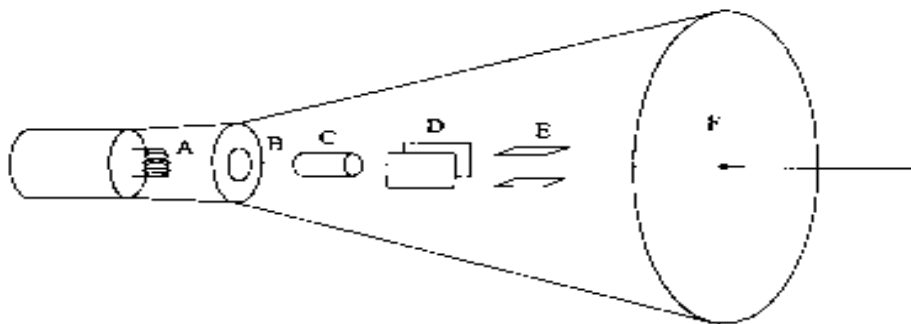


Figure 1. A simplified diagram of the CRT.

The fundamental parts of the CRT diagrammed above are:

- A) A filament which is heated to incandescence by passing a current through it so that negatively charged electrons are emitted from it
- B) An anode, positively charged, which exerts a large accelerating force on the electrons so that they move to the right along the horizontal axis of the tube. The resulting beam that passes through the central opening in the anode moves along the axis of the CRT.
- C) A focusing electrode, which focuses the electron beam into a narrow beam by the application of a proper positive or negative voltage.

- D) A pair of vertically-oriented plates that the internal circuitry of the oscilloscope alternately charges and discharges with charges of opposite sign so that the electron beam is swept horizontally to the left and right of its axial path.
- E) A pair of horizontally-oriented plates, which control the vertical motion of the beam.
- F) A fluorescent screen that shows where the beam of electrons is hitting the screen.

The type of oscilloscope used in the experiment is the Leader LBO-514A oscilloscope. It is a dual trace oscilloscope. That is, the oscilloscope allows two signals to be applied to two separate vertical input terminals, and the two signals can be observed simultaneously on the screen of the CRT. In this experiment only one of the inputs is used.

The following information describes the primary front panel Features the turn-on procedure, and the signal application procedure for the Leader LBO-514A oscilloscope.

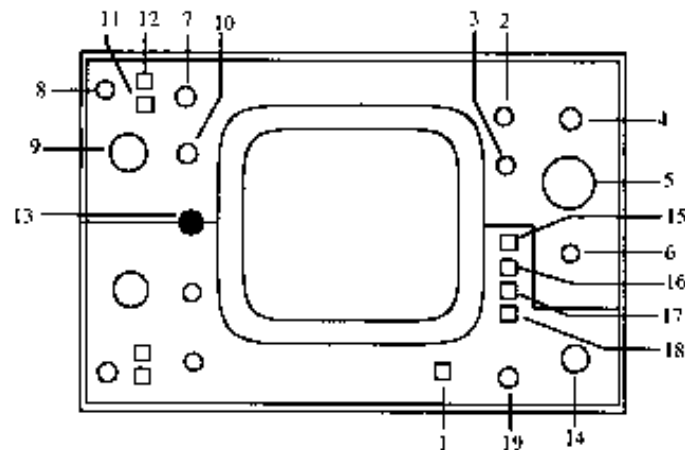


Figure 2. Front panel diagram.

Primary Front Panel Features:

1. POWER. Applies line power.
2. INTEN. Controls brightness of display.
3. FOCUS. Controls sharpness and clarity of display.
4. X. Controls horizontal position of display; when pulled outward, it horizontally expands display by a factor of 5.

5. TIME/DIV. Controls sweep time of display.
6. VARIABLE. Varies sweep speed- in CAL'D position, sweep speed is as selected by TMM/DIV setting.
7. Y. Controls vertical position of display; when pulled outward, it vertically expands display by a factor of 5.

Note: The following instructions are written for input signals to both channel 1 (CH-1) and channel 2 (CH-2).

8. INPUT Y. Vertical signal input.
9. VOLTS/DIV. Selects vertical deflection sensitivity measured in volts per division.
10. VARIABLE. Adjusts vertical deflection sensitivity between ranges- in CAL'D position, vertical sensitivity is as selected by VOLTS/DIV setting.
11. DC-AC. Selects direct (DC) coupling or capacitive (AC) coupling to vertical amplifier.
12. GND. In ground (GND) position, disconnects input signal applied to channel used.
13. VERT MODE. Selects channel or channels to be displayed on CRT.
14. TRIGGER. Selects point on signal that starts the horizontal sweep.
15. MODE. Selects normal (NORM) or automatic (AUTO) triggering of horizontal sweep.
16. SLOPE. Selects negative (-) or positive (+) slope of trigger signal to start the sweep.
17. COUPLING. Selects input coupling.
18. SOURCE. Selects external (EXT) or internal (INT) signal to start sweep.
19. EXT TRIG INPUT. Input for external signal to trigger sweep.

#### Turn-on Procedure

1. Set intensity control (INTEN) to low intensity (counterclockwise).

2. Set VERT MODE to channel 2 (CH-2).
3. Set horizontal (X) and vertical (Y) position controls to midrange.
4. Set horizontal and vertical VARIABLE controls to calibrated (CAL"D) position.
5. Set TIME/DIV control to one millisecond/div (1 ms) position.
6. Set SOURCE to INT.
7. Be sure that all other pushbutton switches are disengaged.
8. Set POWER switch to ON and allow the oscilloscope to warm-up.
9. Slowly turn intensity control (INTEN) clockwise until a trace is visible on the RT. Do not allow the signal to get too bright, (Caution: A trace or spot of very high intensity will burn the phosphor coating on the inside face of the CRT. To prevent such damage, always adjust the intensity of the signal as low as possible for comfortable viewing.)
10. Set channel 2 DC-AC switch to AC.

#### Signal Application Procedure

1. Set channel 2 DC-AC switch to appropriate position for signal.
2. Set channel 2 VOLT S/DIV control to 0.1 volt/div
3. Connect signal to channel 2 INPUT Y connector.
4. Position display on CRT using horizontal (X) and vertical (Y) position controls.
5. If necessary, adjust TRIGGER control to stabilize the display.

The oscilloscope is a versatile instrument from which quantitative measurements of voltage and time can be made. Advantage is taken of this capability in order to measure the peak-to-peak voltage and the frequency for two different alternating current (AC) sinusoidal signals produced by a signal generator. In addition, the voltage across a dry cell (direct current, DC) is determined.

In order to perform these measurements, refer to Figure 3.

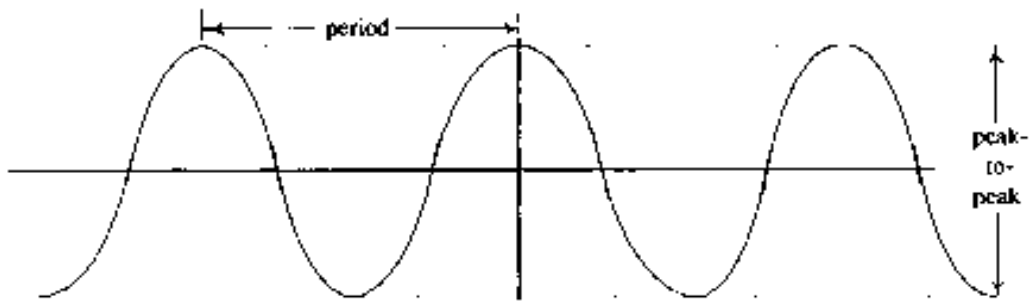


Figure 3. A typical sinusoidal signal on the screen of an oscilloscope.

#### Peak-to-peak measurements:

In order to perform this measurement, record the VOLTS/DIV setting on the oscilloscope and multiply this value by the number of vertical divisions from a crest to a trough of the signal. For example, if the VOLTS/DIV knob is 0.2 and the number of divisions from a crest to a trough is 3.7, the peak-to-peak voltage is  $(3.7 \text{ divisions}) \times (0.2 \text{ volts/div}) = 0.74 \text{ volts}$ . (Note that the calibration knobs (CAL'D) must be clicked in their full clockwise positions.)

#### Frequency measurements:

In order to determine the frequency the period of the signal is first found, then the reciprocal of this quantity is the frequency ( $f = 1/T$ ). The period is the time for one complete oscillation and is represented on the oscilloscope by the horizontal distance from one crest to the next adjacent crest. The value of the period is found by multiplying the TIME/DIV setting of the oscilloscope by the number of divisions from crest to crest. For example, if the TIME/DIV setting is 0.5 ms/div and the number of divisions is 6.3, then the period is  $(6.3 \text{ divisions}) \times (0.5 \text{ ms/div}) = 3.15 \text{ ms} = 3.15 \times 10^{-3} \text{ sec}$ . The corresponding frequency is  $1/(3.15 \times 10^{-3} \text{ sec}) = 317 \text{ Hz}$ . (Remember that the calibration knobs (CAL'D) must be turned all the way in the clockwise direction until they click.)

### Apparatus

- o oscilloscope with leads
- o dry cell
- o signal generator

### Procedure

- 1) Connect the leads of the oscilloscope to the signal generator - red to red and black to black. Plug the oscilloscope and signal generator into the sockets. Turn on the oscilloscope and the signal generator.
- 2) Adjust the frequency knob on the signal generator until it is generating a sinusoidal signal of arbitrary amplitude and one kHz frequency.
- 3) Adjust the horizontal (X) and vertical (Y) position knobs until the pattern is centered on the screen of the oscilloscope.
- 4) Change the setting of the VOLTS/DIV knob until the signal fills vertically as much of the screen as possible.
- 5) Change the setting of the TIME/DIV knob until approximately four full cycles of the signal fill the screen horizontally.
- 6) Record the number of vertical divisions for the peak-to-peak voltage.
- 7) Record the number of horizontal divisions for the period calculation. (Measure the horizontal distance over as many cycles as possible, then divide this figure by the number of cycles.)
- 8) Repeat steps (3) through (7) for a 5299 Hz signal.
- 9) Disconnect the oscilloscope leads from the signal generator and adjust the oscilloscope to read DC voltages. Adjust the vertical position of the horizontal line seen on the oscilloscope screen to a convenient position. Set the VOLTS/DIV setting to 1 volt per division. Take the leads from the oscilloscope and connect them to the dry cell. Notice that the horizontal line jumps to a new position indicating that the voltage has changed. Record the number of divisions through which the line changes in order to compute the DC voltage.

### **Analysis**

Clearly show your calculations of the peak-to-peak voltages, the frequencies, and the DC voltage. Report the theoretical frequencies of the applied signal (signal generator readings), the experimental values of the frequencies from the oscilloscope measurements, the percentage error between the theoretical and experimental values of the frequencies, and the peak-to-peak voltages for each sinusoidal signal applied (Note that there is no theoretical value with which to compare the experimental voltage.) In a second table report the experimental value of the voltage across the dry cell, the theoretical value of the voltage, and the percentage error.