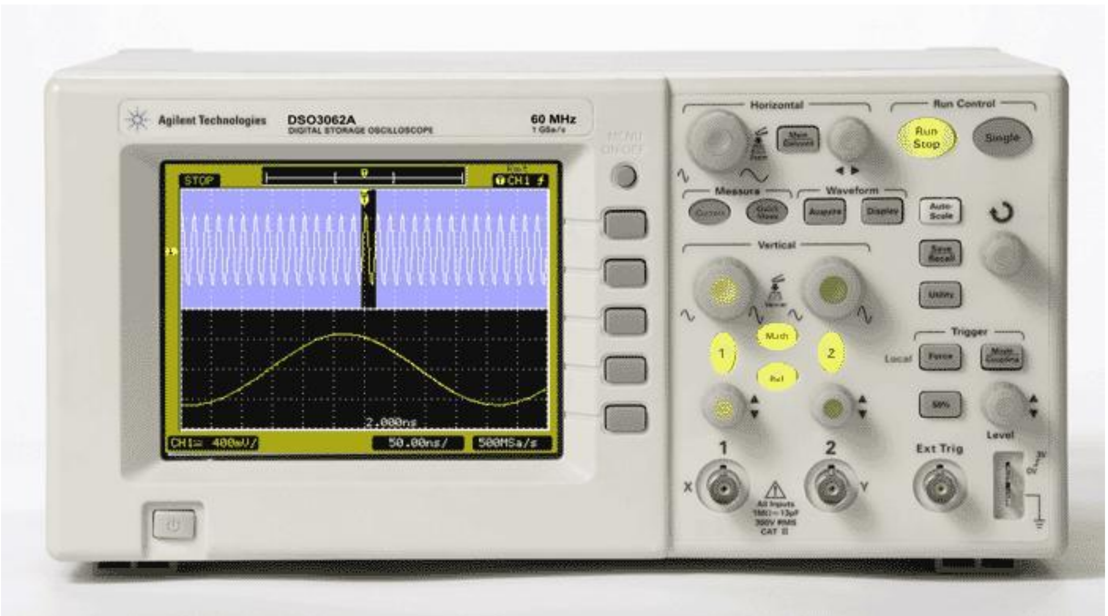
NOTES ON

OSCILLOSCOPES



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Oscilloscope

In many applications, observing certain voltage waveforms in a circuit plays a crucial role in understanding the operation of the circuit. For that purpose several measurement instruments are used like voltmeter, ammeter, or the oscilloscope.

An oscilloscope (sometimes abbreviated as "scope") is a voltage sensing electronic instrument that is used to visualize certain voltage waveforms. An oscilloscope can display the variation of a voltage waveform in time on the oscilloscope's screen

Figure 1.

A probe is used to connect the oscilloscope to the circuit. Figure 1 shows an oscilloscope and a probe connected to it.

Figure 2.

Figure 2 shows a typical probe. Oscilloscope shows the potential difference between the two terminals of the probe. The terminal ending with a hook is usually connected to the node in the circuit whose voltage is of interest. The other terminal is usually (but not always) connected to the ground. The probes are attached to input channels of the oscilloscope. Most oscilloscopes have at least two input channels and each channel can display a waveform on the screen. Multiple channels are useful for comparing waveforms. For example, one can observe the voltage waveforms at the input and the output terminals of a circuit simultaneously, by using a two channel oscilloscope.

Analog and Digital

Electronic equipments can be divided into two types: analog and digital. *Analog* equipment works with continuously variable voltages, while *digital* equipment works with binary numbers (1 and 0's) that may represent voltage samples. For example, a conventional cassette player is an analog device; a compact disc player is a digital device.

Oscilloscopes also come in analog and digital types. An analog oscilloscope works by directly applying a voltage being measured to an electron beam moving across the oscilloscope screen. The voltage deflects the beam up and down proportionally, tracing the waveform on the screen. This gives an immediate picture of the waveform. In contrast, a digital oscilloscope samples the waveform and uses an analog-to-digital converter (or ADC) to convert the voltage being measured into digital information. It then uses this digital information to reconstruct the waveform on the screen.

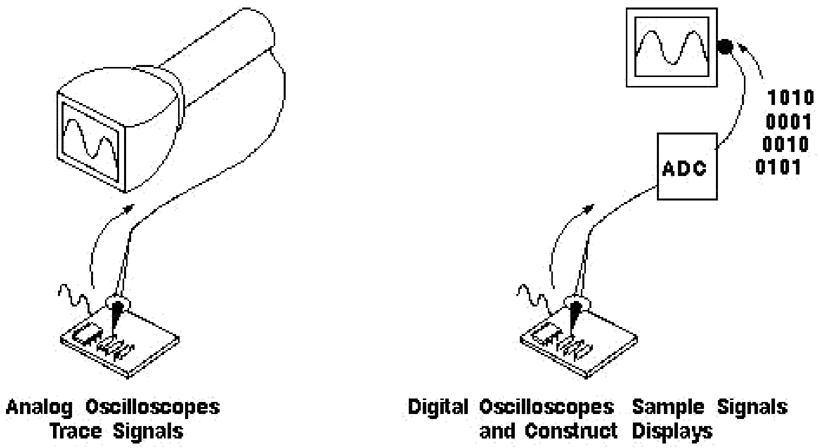


Figure 3: Digital and Analog Oscilloscopes Display Waveforms.

Analog Oscilloscopes

An analog oscilloscope displays the voltage waveforms by deflecting an electron beam generated by an electron gun inside a cathode-ray tube on to a fluorescent coating. Because of the use of the cathode ray tube, analog oscilloscopes are also known as cathode ray oscilloscopes. To understand how an analog scope displays the voltage waveforms, it is necessary to understand what is inside the unit. The following section describes the general principles of the operation of cathode ray oscilloscopes.

Figure 4 shows the structure, and the main components of a cathode ray tube (CRT). Figure 5 shows the face plane of the CRO screen.

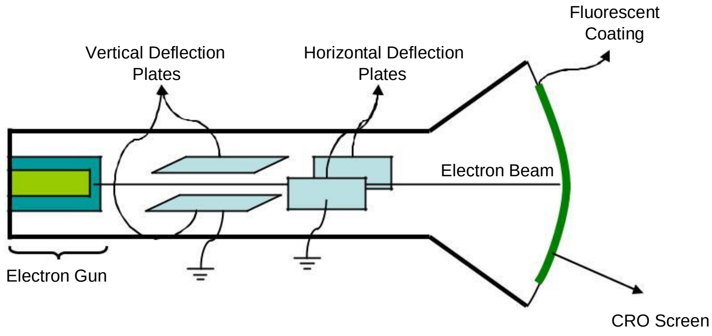


Figure 4.

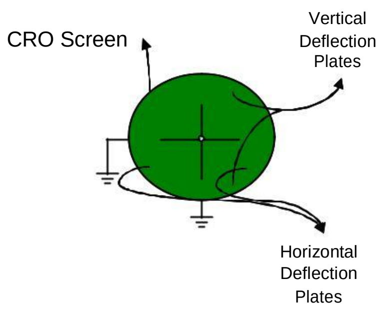


Figure 5.

Electron beam generated by the electron gun first deflected by the deflection plates, and then directed onto the fluorescent coating of the CRO screen, which produces a visible light spot on the face plane of the oscilloscope screen.

A detailed representation of a CRT is given in Figure 6. The CRT is composed of two main parts,

- Electron Gun
- Deflection System

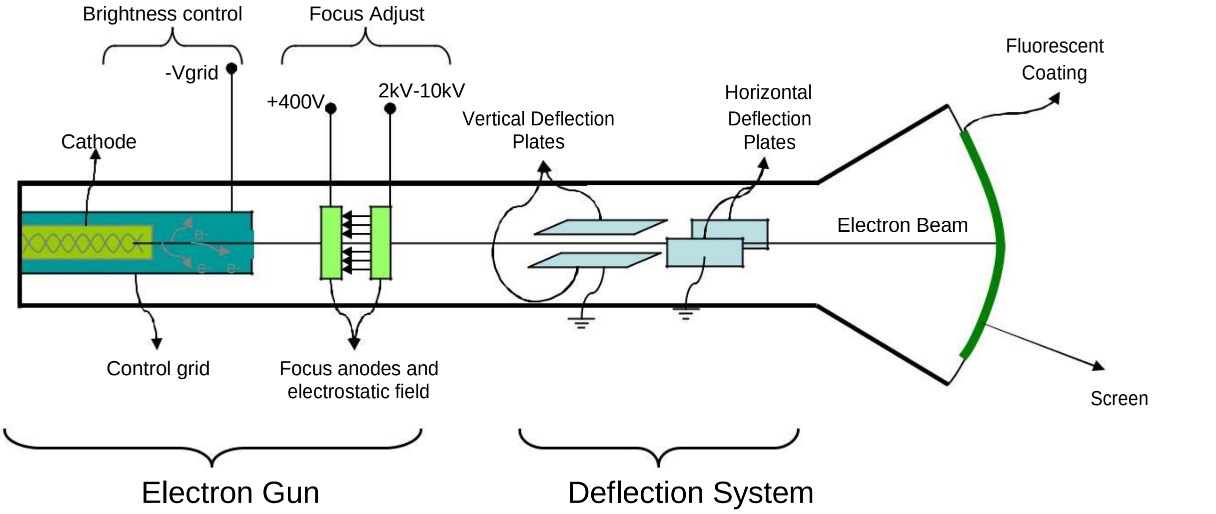


Figure 6.

Electron Gun

Electron gun provides a sharply focused electron beam directed toward the fluorescent-coated screen. The thermally heated cathode emits electrons in many directions. The control grid provides an axial direction for the electron beam and controls the number and speed of electrons in the beam.

The momentum of the electrons determines the intensity, or brightness, of the light emitted from the fluorescent coating due to the electron bombardment. Because electrons are negatively charged, a repulsion force is created by applying a negative voltage to the control grid, to adjust their number and speed. A more negative voltage results in less number of electrons in the beam and hence decreased brightness of the beam spot.

Since the electron beam consists of many electrons, the beam tends to diverge. This is because the similar (negative) charges on the electrons repulse each other. To compensate for such repulsion forces, an adjustable electrostatic field is created between two cylindrical anodes, called the focusing anodes. The variable positive voltage on the second anode cylinder is therefore used to adjust the focus or sharpness of the bright spot.

The Deflection System

The deflection system consists of two pairs of parallel plates, referred to as the vertical and horizontal deflection plates. One of the plates in each set is permanently connected to the ground (zero volt), whereas the other plate of each set is connected to input signals or triggering signal of the CRO.

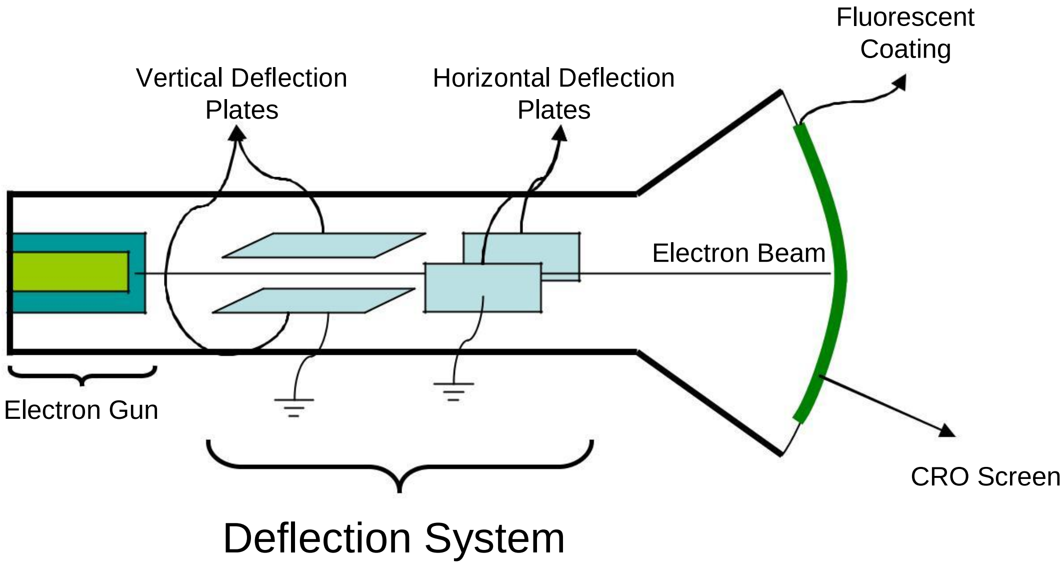


Figure 7.

As shown in Figure 7, the electron beam passes through the deflection plates. In reference to the schematic diagram in Figure 8, a positive voltage applied to the Y input terminal causes the electron beam to deflect vertically upward, due to attraction forces, while a negative voltage applied to the Y input terminal causes the electron beam to deflect vertically downward, due to repulsion forces. Similarly, a positive voltage applied to the X input terminal will cause the electron beam to deflect horizontally toward the right, while a negative voltage applied to the X input terminal will cause the electron beam to deflect horizontally toward the left of the screen.

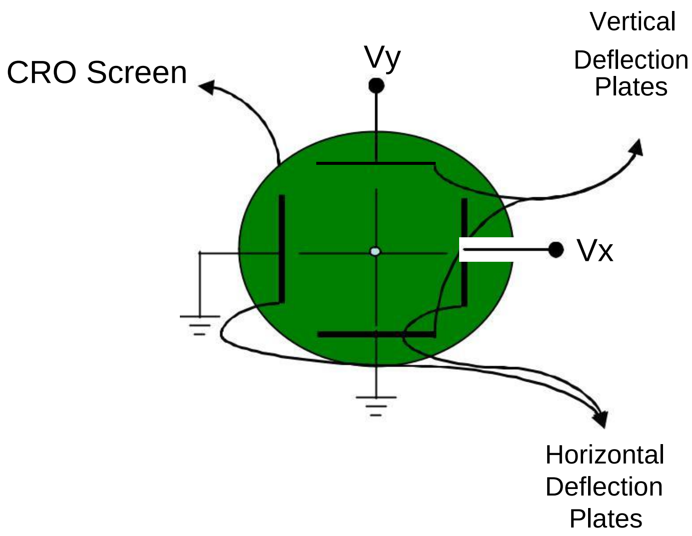


Figure 8.

The amount of vertical or horizontal deflection is directly proportional to the corresponding applied voltage. When the electrons hit the screen, the phosphor emits light and a visible light spot is seen on the screen.

Since the amount of deflection is proportional to the applied voltage, actually the voltages V_y and V_x determine the coordinates of the bright spot created by the electron beam.

Example 1:

Suppose $V_x = \sin(t)$, $V_y = \cos(t)$ are applied to the horizontal and vertical deflection plates respectively. Then the bright spot would follow a circular path on the CRO screen.

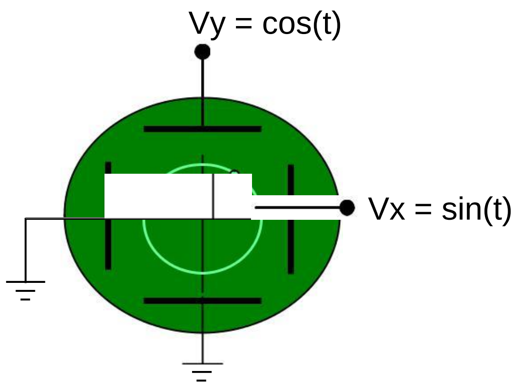


Figure 9.

Example 2:

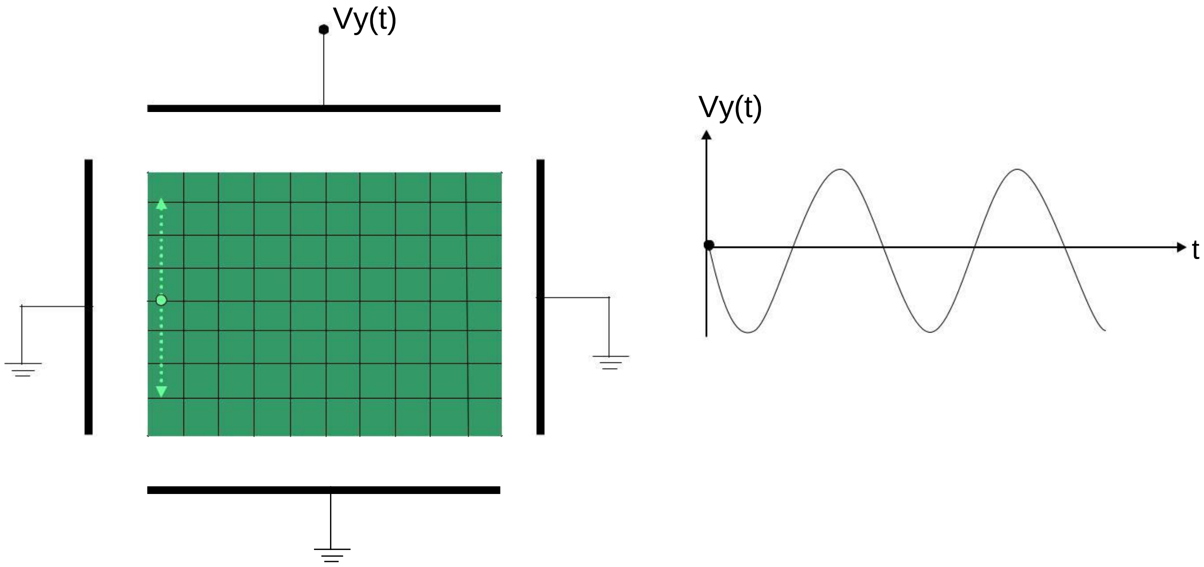


Figure 10-a.

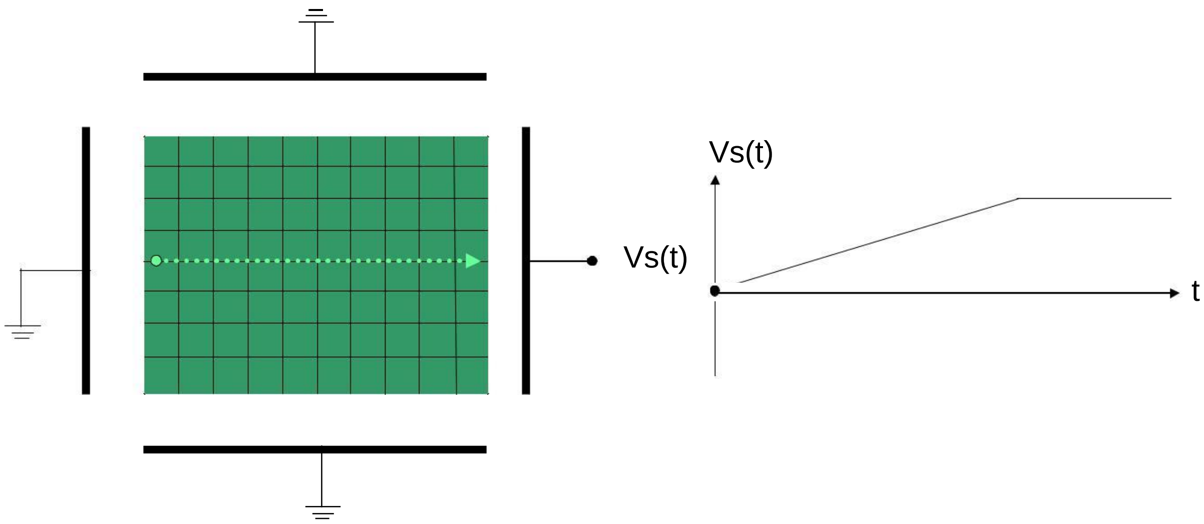


Figure 10-b.

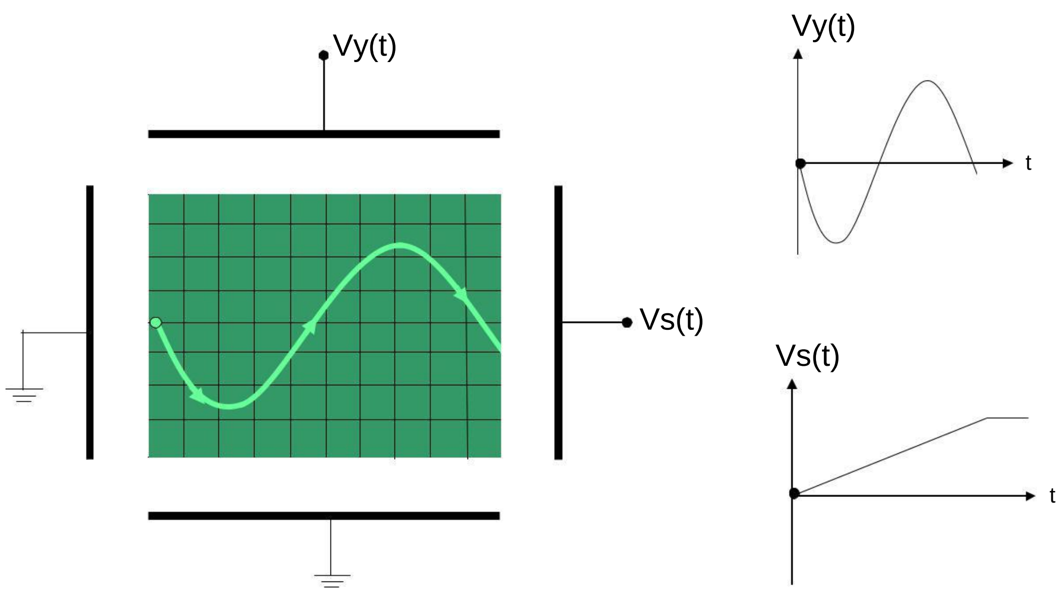


Figure 10-c.

In Figure 10-a, the input signal $V_y(t)$ is applied to the vertical deflection plates, whereas the horizontal deflection plates are connected to ground. It is assumed that the electron beam is kept at the extreme left position when the horizontal deflection plates are connected to ground. Under this configuration, the bright spot in the CRO screen will follow a vertical path (will go up and down) at the extreme left position of the screen.

In Figure 10-b, the input signal $V_s(t)$ is applied to the horizontal deflection plates, whereas the vertical deflection plates are connected to ground. This time, the bright spot will travel from extreme left to extreme right end of the screen and will stop there.

In Figure 10-c, the signals $V_y(t)$ and $V_s(t)$ are applied to the vertical and the horizontal deflection plates respectively. This time the bright spot will follow a sinusoidal path, resulting a visualization of the input signal $V_y(t)$ on the CRO screen.

Actually the bright spot must follow the same path fast and repetitively (at least 30 times in a second) so that the human eye can perceive the motion of the bright spot as a continuous curve. Therefore, in order to display the waveform on the CRO screen for the example in figure 10-c, the signals $V_y(t)$ and $V_s(t)$ should be applied to the vertical and the horizontal deflection plates periodically and in synchronization. The next section discusses the details of this procedure and depicts how CRO handles this problem.

Displaying a Voltage Waveform

In numerous applications it will be required to display a periodical voltage waveform as a function of time. By applying the voltage to be displayed on the CRO, to the vertical deflection plates (V_y), the vertical deflection of the beam spot will be proportional to the magnitude of this voltage. It is then necessary to convert the x axis (horizontal deflection) into a time axis. Notice that, in the example given in figure 10-c, the voltage waveform $V_s(t)$ (which varies linearly in time before the bright spot reaches the extreme right end of the screen) is used for this purpose and the bright spot have traveled the path determined by $V_y(t)$. If the signal to be observed is periodic, then a periodic voltage waveform that varies linearly with time, as shown in figure below, is applied to the horizontal deflection plates. This type of waveform is called the sawtooth waveform.

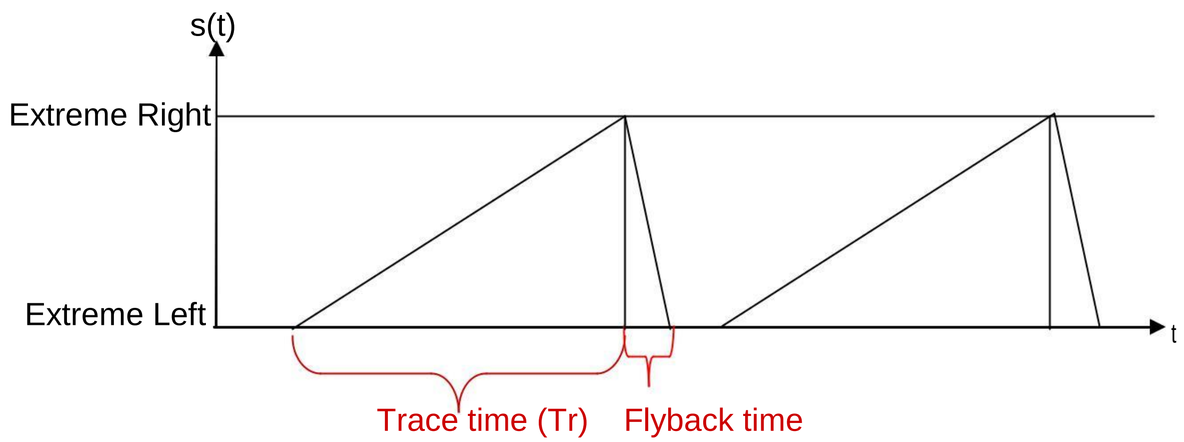


Figure 11

When s(t) is zero volt, the bright spot is at the extreme left-hand position, and when s(t) is maximum, the bright spot is at the extreme right position. Therefore, the bright spot travels from extreme left to extreme right in a time equal to the trace time. During the flyback time, which is usually very short compared to trace time, a high negative voltage pulse is applied to the control grid of the electron gun to prevent electron beams reaching the CRO screen. This action is called blanking and prevents any reverse retrace (or shadow) as the beam is going back to the extreme left-hand position. The time period including the trace time and the flyback time is called the sweep period.

The period of the sawtooth waveform plays a crucial role in obtaining a steady waveform on the CRO screen. The following section discusses the requirements on the period of the sawtooth waveform and the need of a synchronization between the sawtooth waveform and the input waveform.

Triggering

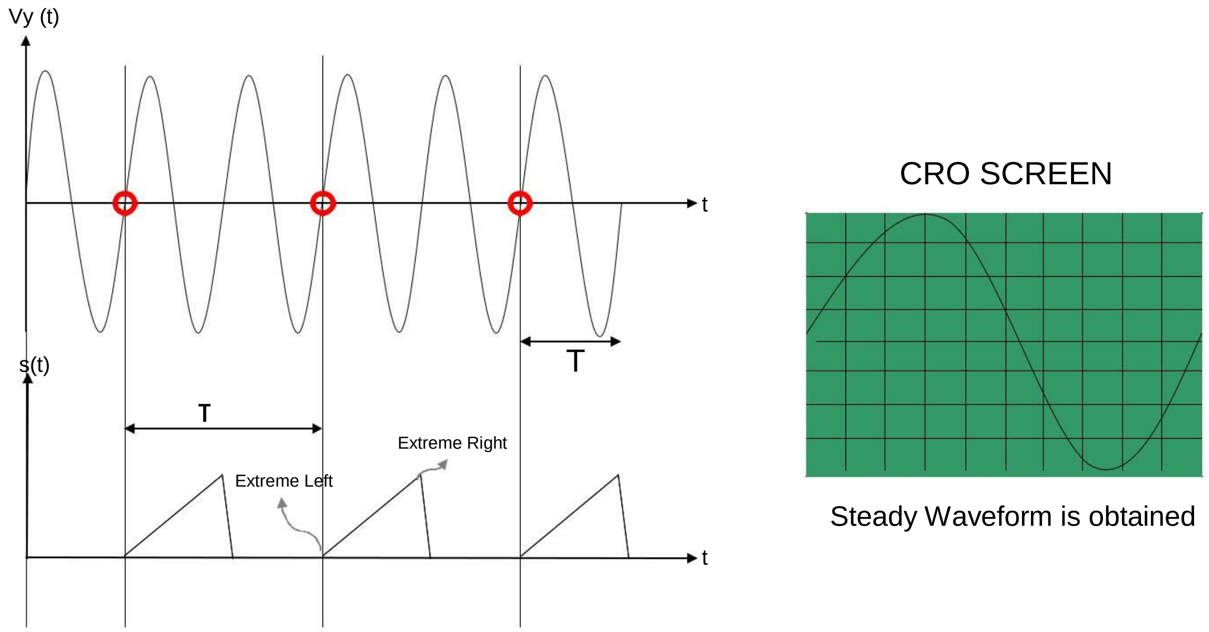


Figure 12

Suppose the input $V_y(t)$ and s(t) shown in Figure 12 are applied to the vertical and horizontal deflection plates of the CRO respectively. Note that, At the beginning of each sweep cycle, (i.e when the bright spot is at extreme left) $V_y(t)$ gets exactly the same value (The points indicated by red circles). Therefore the bright spot is following exactly the same path in each sweep cycle. Thus, we can observe a steady waveform on CRO screen. Notice that the time between the beginning of two consecutive sweep cycles is a multiple of input signal period. (i.e. τ = n T. T, τ are shown on the figure 12, n is a positive integer.)

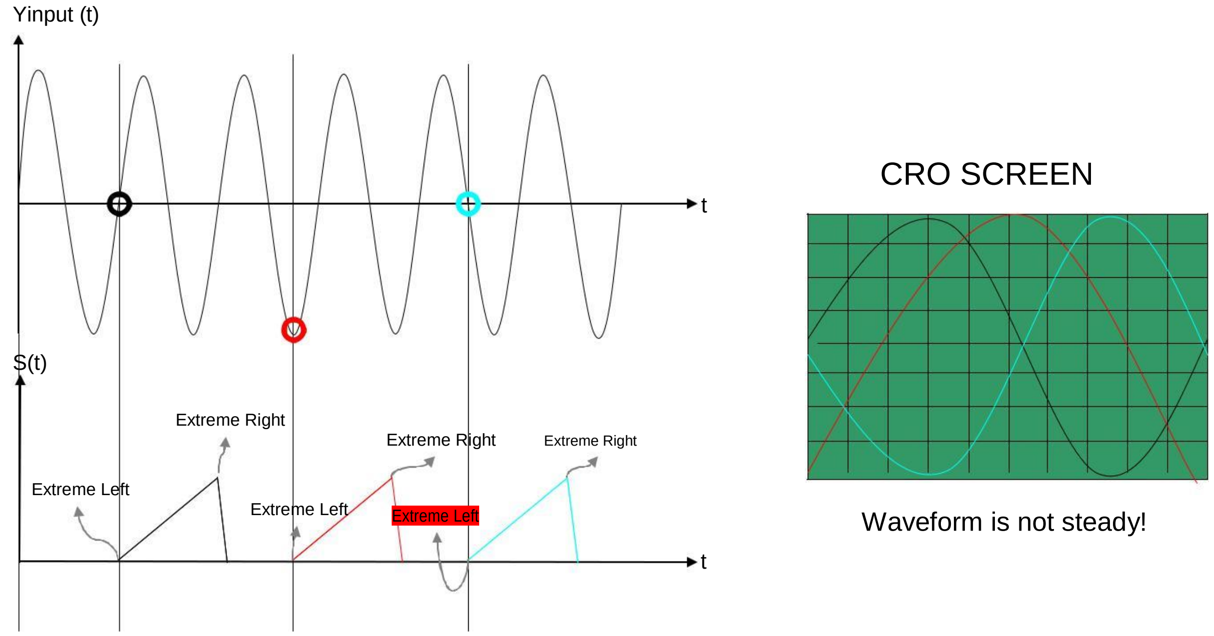


Figure 12

For the given case, the bright spot is following different paths in different sweep cycles, therefore we can not obtain a steady waveform on CRO screen.

In order to obtain stable and stationary waveform displays, the sawtooth signal should be applied to the horizontal deflection plates, in synchronism with the waveform being displayed. CRO handles this synchronization problem by using the following structure.

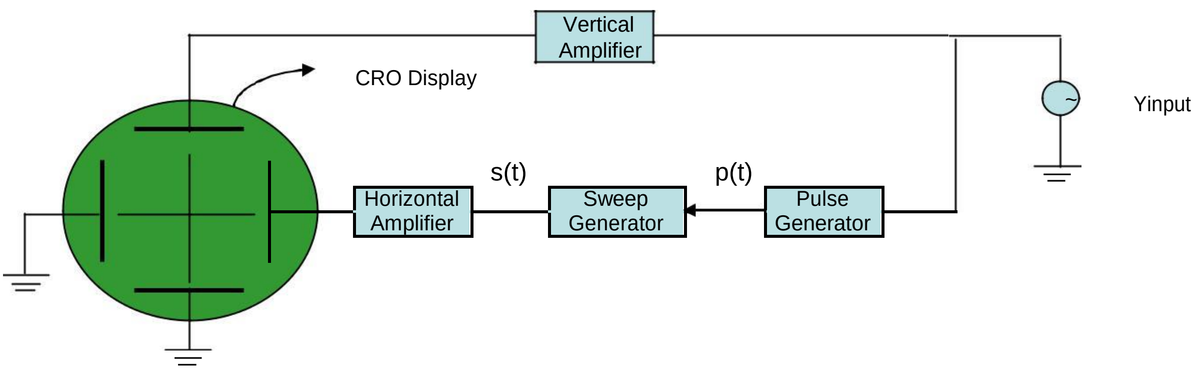


Figure 13

Notice that, the voltage waveform which is to be displayed on the CRO screen (Yinput in this case) is applied to the vertical amplifier. In the amplification stage, only the amplitude of the input waveform is changed. After the amplification stage, the output of the vertical amplifier is applied to the vertical deflection plates. Then in order to obtain a steady waveform on the CRO screen, a sawtooth waveform having a period which is an integer multiple of the period of the input voltage waveform should be applied to the horizontal deflection plates.

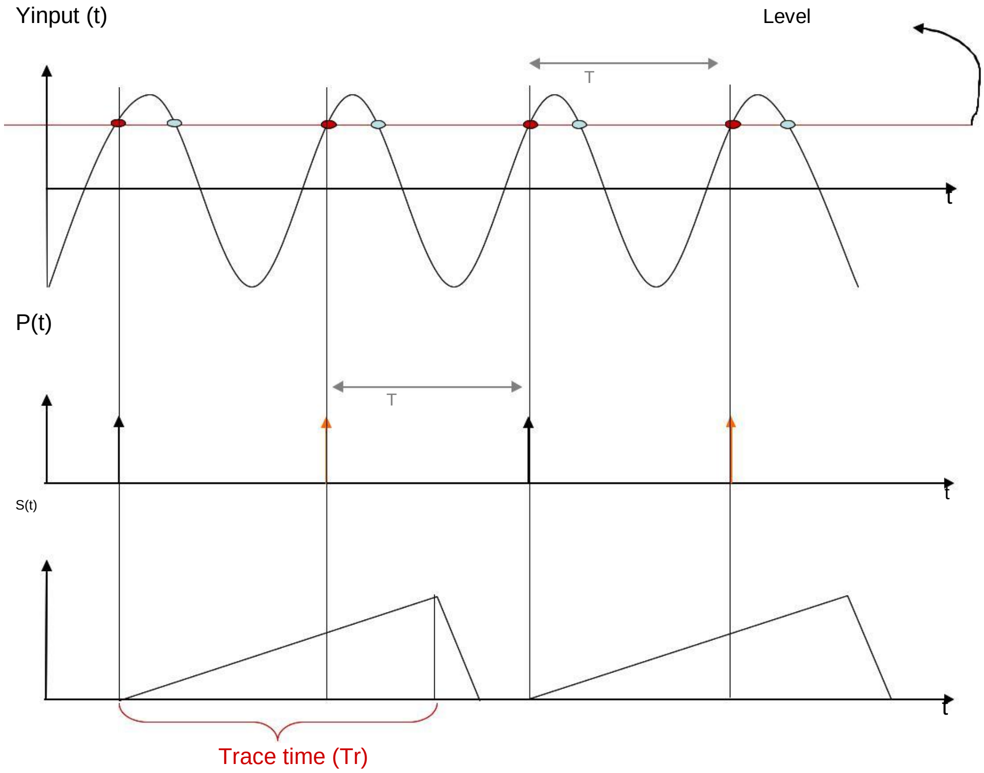


Figure 14

Pulse Generator:

The main function of the pulse generator (PG) (see figure 13.) is to produce periodical pulses with a period of T, which is equal to the period of the input signal. For that purpose, the input signal is compared to a certain voltage level ('Level' on the figure 14). Producing pulses each time the input voltage is equal to that certain voltage level, may seem to result pulses which are periodic with period T. But this is not the case. Notice that, the 'Level' intersects the input signal more than once in one period. Therefore, one of the intersection points is neglected in each period. The decision on which intersection point to neglect is made by inspecting the slope of the signal at the intersection point.

The pulse generator produces pulses each time the input voltage level is same as the 'Level', after checking the slope of the signal at that time instant. In the example given in figure 14, there are two intersection points at each period, and the one with the negative slope (blue points) are neglected. (The selected slope is positive for that case). Actually, the sign of the slope can be selected by using the +/- button of the CRO. Also the voltage level that the signal is being compared to, can be adjusted by using the level button on the oscilloscope.

Sweep Generator

The main function of the sweep generator is to produce one cycle of a sawtooth waveform, when it receives a pulse at its input. If the sweep generator receives a trigger pulse during its sweep cycle (i.e., during the trace period Tr), it will simply ignore the pulse and continue with the completion of its sweep cycle.

Depending on the selected level and the slope of the input signal, the output of the pulse generator will consist of narrow trigger pulses separated from each other by one period T. Each time the input signal crosses a preselected level (and a preselected slope), the pulse generator emits one narrow trigger pulse. The emitted pulse triggers the sweep generator to begin producing one cycle of the sweep waveform; its duration is the trace period Tr. At the end of each sweep cycle, the sweep generator stops its output and awaits the arrival of the next trigger pulse before producing a new sweep cycle.

Notice that if the sweep generator receives a trigger pulse during its sweep cycle (i.e., during the trace period Tr), it will simply ignore the pulse and continue with the completion of its sweep cycle. The trigger pulse received after the completion of the trace period will initiate the new sweep cycle. This allows the scope to display more than one cycle, of period T, of the signal connected to its vertical deflection plates.

The following figure illustrates an example.

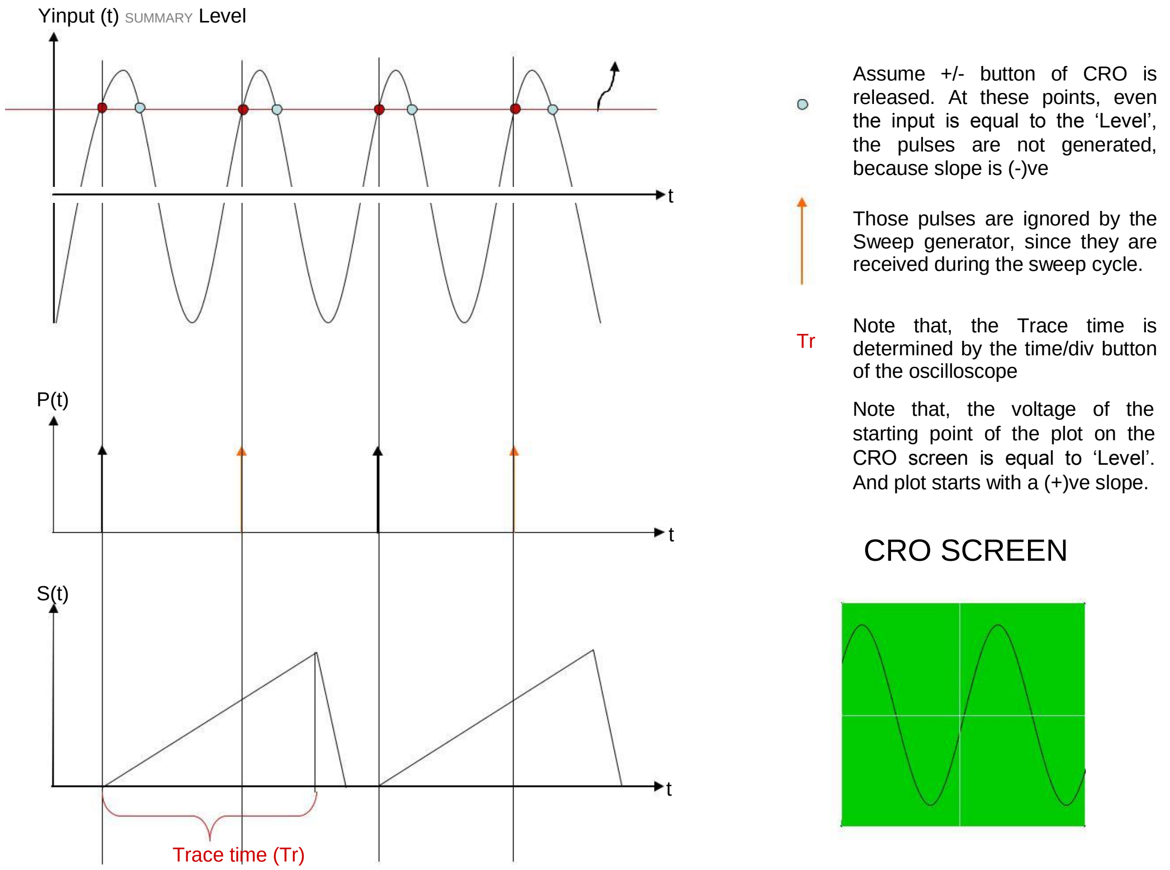


Figure 15.

In the given example, first the voltage waveform to be displayed on the CRO screen is compared with a voltage level. The blue and the red points show the intersection of the input signal with the level. Assuming the positive slope is selected, pulse generator produces pulses at each time the input signal is equal to 'level', and its slope is positive. The pulses generated by the pulse generator, trigger the sweep generator, which produces one cycle of the sawtooh waveform. The trace time of the sweep generator is adjusted by the time/div button which is available on the front panel of the oscilloscope. The resulting sawtooth waveform is applied to the horizontal deflection plates, which leads to a steady display of the input signal on the oscilloscope screen. Notice that, at the beginning of each sweep period (when the bright spot is at the extreme left), input signal voltage is equal to `level` and has a positive slope. Therefore, the waveform shown on the CRO screen starts with a positive slope at the extreme left and its value is equal to the 'level'. One can change these settings by varying the 'level' control or the +/- button of the oscilloscope.

The whole process is called triggering because, obtaining a steady plot on the CRO screen can only be achieved by producing pulses at the input of the Sweep Generator at the correct time instances. (i.e. triggering the Sweep Generator at the correct time instances.)

X-Y Operation

When the variation of one voltage waveform, Vy(t), as a function of another, Vx(t), eliminating the parameter time, t, is desired, X-Y mode of operation is used. In X-Y mode, one signal is applied to the vertical deflection plates whereas the other signal is applied to the horizontal deflection plates. The XY button on the front panel of the oscilloscope disconnects the triggering signal from the horizontal deflection system, and connects the second input signal instead. This process is done by using a switch shown as 'X-Y button' on the figure below.

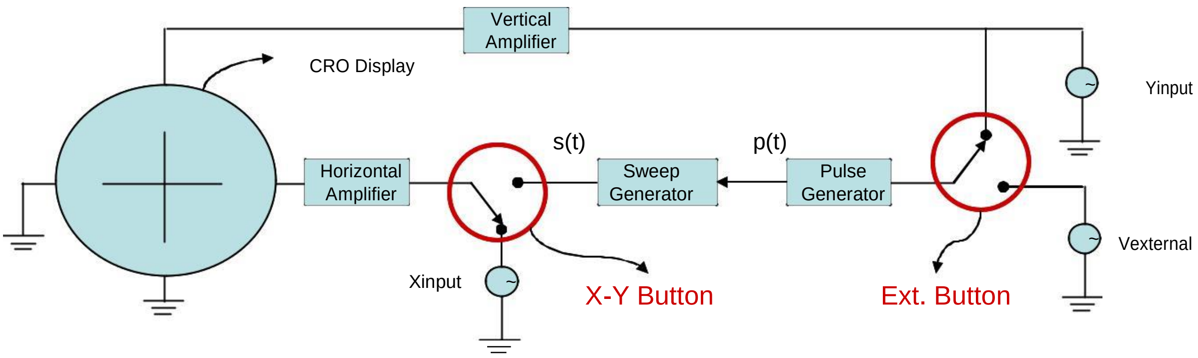


Figure 16

External Triggering

Rather than the input signal itself, an external signal can also be used for triggering. For that purpose multi-positional switch, which corresponds to Ext. Button of the CRO, should be set to position 2, as shown in Figure 16. The external signal should satisfy certain conditions in order to obtain a steady waveform on the CRO screen. Keeping in my that the period of the sawtooth waveform, s(t), should be an integer multiple of the period of the input signal, can you find the conditions needed on the frequency of the external triggering signal?

See also: http://www.eee.metu.edu.tr/~ee213/CRO/CRO.htm

Digital Storage Oscilloscopes (DSO)

The concept behind the digital oscilloscope is somewhat different to an analogue scope. Rather than processing the signals in an analogue fashion, the DSO converts them into a digital format using an analogue to digital converter (ADC), then it stores the digital data in the memory, and then processes the signals digitally, finally it converts the resulting signal in a picture format to be displayed on the screen of the scope.

Since the waveform is stored in a digital format, the data can be processed either within the oscilloscope itself, or even by a PC connected to it. One advantage of using the DSO is that the stored data can be used to visualize or process the signal at any time. The analogue scopes do not have memory therefore the signal can be displayed only instantaneously. The transient parts of the signal (which may vanish even in milliseconds or microseconds) can not be observed using an analogue oscilloscope.

The DSO's are widely used in many applications in view of their flexibility and performance.

Measurement Techniques

The major concern in observing a signal on the oscilloscope screen is to make voltage and time measurements. These measurements may be helpful in understanding the behavior of a circuit component, or the circuit itself, depending on what you measure. Except for the X-Y mode of operation, the oscilloscope displays the voltage value of the waveform as a function of time. The oscilloscope screen is partitioned into the grids, which divides both the horizontal axis(voltage) and the vertical axis(time) into divisions which will be helpful in making the measurements. See Figure 17.

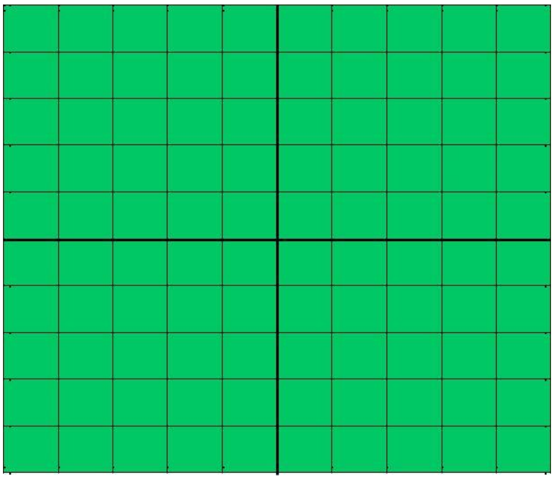


Figure 17: Oscilloscope Screen.

Obviously one needs to know the time or the voltage values corresponding to each division, in order to make accurate calculations. These values are determined by two variables namely the **time/div** and the **volt/div** both of which can be adjusted from the relevant buttons available on the front panel of the oscilloscope (see Figure 10-13). Also note that, the time/div button controls the trace time of the sweep generator, whereas the volt/div button controls the `gain` in the vertical amplifiers in the vertical deflection system.

Typical quantities, which are of primer interest when observing a signal with the scope, are shown in Figure 18.

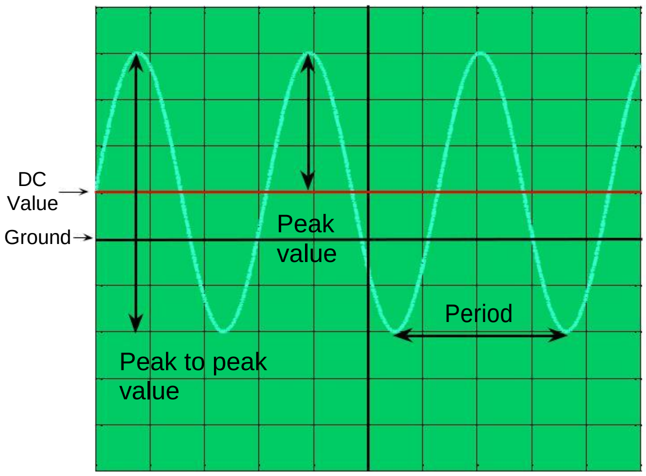


Figure 18: Sinusoidal Signal on Oscilloscope Screen.

For the given figure, suppose that the variables **volt/div** and **time/div** are set to:

volt/div = 2Volts/div.
time/div = 1millisecond/div

Then the corresponding values shown on the figure are calculated to be;

Peak Value = 6volts
Peak to peak value = 12 Volts
DC Value (Average Value) = 2 Volts
Period = 3 milliseconds
Frequency = $\frac{1}{Period}$ = 333 Hz.

Note that the signal s(t), shown on the oscilloscope screen can be expressed as,

$$
\begin{aligned}
s(t) &= V_{peak} \sin(2\pi ft) + V_{DC} \\
&= 6 \sin(2\pi 333t) + 2 \\
&= 6 \sin(666\pi t) + 2 \ Volts.
\end{aligned}
$$

Phase difference:

In some applications, one may need to monitor or compare two or more signals simultaneously. A typical example can be the comparison of the input voltage with the output voltage of a two-port (input and output ports) circuit. If the signals that are being monitored have the same frequency, a time delay may occur between the signals (i.e. one signal may lead the other or vice versa). Two waves that have the same frequency, have a phase difference that is constant (independent of t). When the phase difference (modulo 2π) is zero, the waves are said to be **in phase** with each other. Otherwise, they are **out of phase** with each other. If the phase difference is 180 degrees (π radians), then the two signals are said to be ***in anti-phase***. If the peak amplitudes of two anti-phase waves are equal, their sum is zero at all values of time, t.

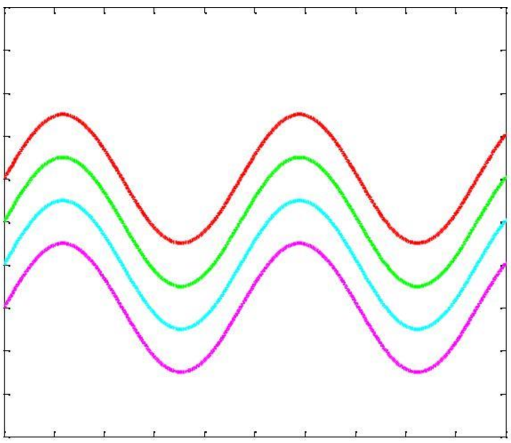


Figure 19: In-phase Waves

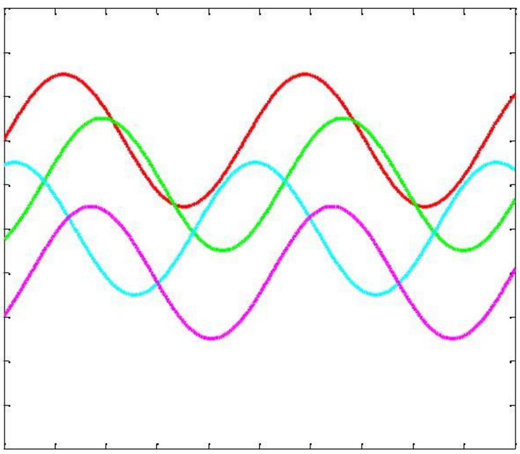


Figure 20: Out of phase Waves

The phase difference is expressed in terms of radians or degrees. In **Dual Mode** of the oscilloscope the phase difference can be calculated easily as follows.

Given the two signals having the same frequency, as shown in Figure 21,

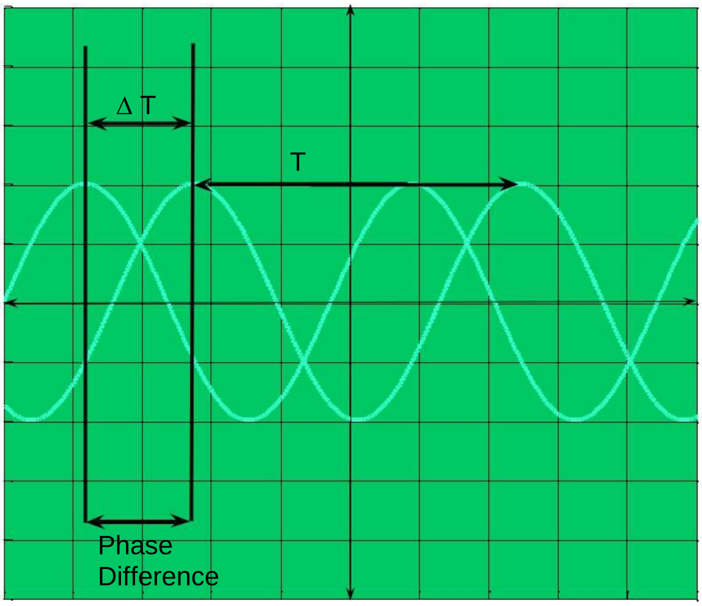


Figure 21: Two Signals Displayed in DUAL Mode

define,

ΔT = horizontal spacing of the peak values (or the zero crossings) of the two signals.
T = horizontal spacing for one period.

Then the phase difference, θ is;

$$\theta = \frac{\Delta T}{T} \times 360^o \quad \textit{in degrees}$$

$$\theta = \frac{\Delta T}{T} \times 2\pi \quad \textit{in radians}$$

Note that, one has to specify the leading or the lagging signal in order to fully describe the time difference between the two signals. In the figure above, the signal represented with dashed curve leads the other. Suppose that the signal represented by the dashed curve is connected to Channel I of the oscilloscope, and the other one is connected to Channel II. In such a case Channel I is **leading** the Channel II with phase difference equal to θ, and Channel II is **lagging** the Channel I with phase difference equal to θ. Determining the leading or the lagging signal may be frustrating at first, but note that the dashed curve reaches its maximum value before the other does.

The phase difference between the signals can also be determined in **XY mode** of the oscilloscope. In the **XY mode**, the **x-axis** data is taken from one channel, **y-axis** data is taken from the other. In that way, **Channel I** vs **Channel II** graph can be obtained, so that the variation of a signal with respect to another can be observed. Figure 22 shows a typical graph in **XY mode**, of two signals having a constant phase difference.

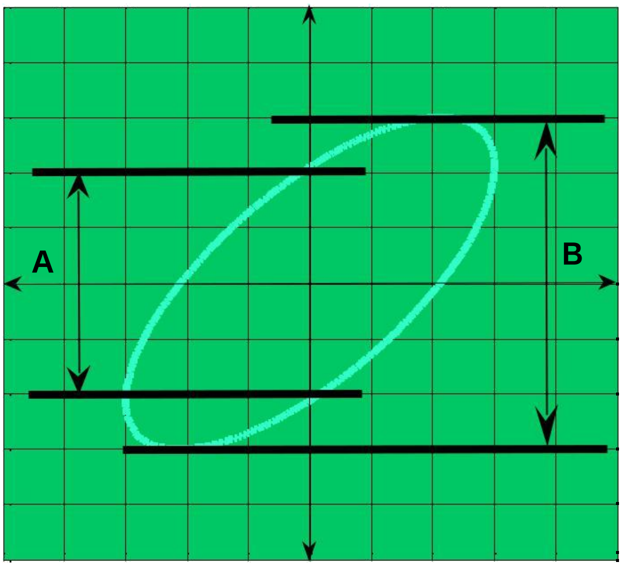


Figure 22: Phase Difference Calculation in XY Mode

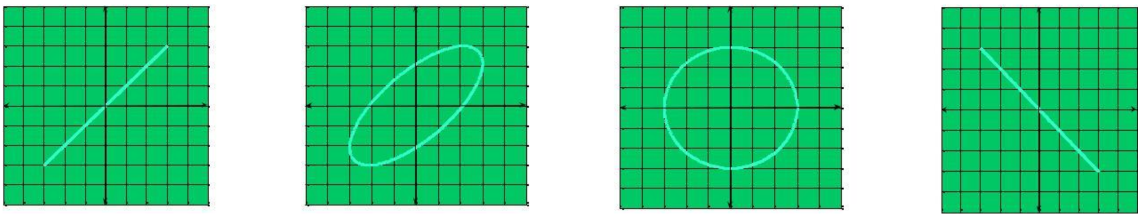
Phase difference is equal to,

$$\theta = \sin^{-1}\left(\frac{A}{B}\right)$$

One can show this relation by expressing one signal as, $y(t) = \frac{B}{2}\sin(\omega t \pm \theta)$ and the other signal as, $x(t) = \frac{C}{2}\sin(\omega t)$. Then consider the value of y(t) when x(t) is zero volts. It should be noted that, the center of the ellipsoidal shape (sometimes circular or linear shapes) on the screen should be at the origin of CRO unless any DC component is added to one of the signals.

In XY mode, the leading or the lagging signal can not be determined. One has to switch to **DUAL mode** in order to specify the leading signal.

Figure 23 shows typical graphs in XY mode corresponding to different values of phase difference.



0° 45° 90° 180°

Figure 23: The Graphs in XY Mode for Different Phase Difference Values

Controls

Display Controls

Display systems may vary between analog and digital oscilloscopes. Common controls include:

- An intensity control to adjust the brightness of the waveform. As you increase the sweep speed of an analog oscilloscope, you need to increase the intensity level.
- A focus control to adjust the sharpness of the waveform. Digital oscilloscopes may not have a focus control.
- Other display controls may let you adjust the intensity of lights and turn on or off any on-screen information (such as menus).

Vertical Controls

Vertical controls are used to position and scale the waveform vertically. Oscilloscopes also have controls for setting the input coupling and other signal conditioning, described in this section. Figure 24 shows the vertical controls of the DSO3062A

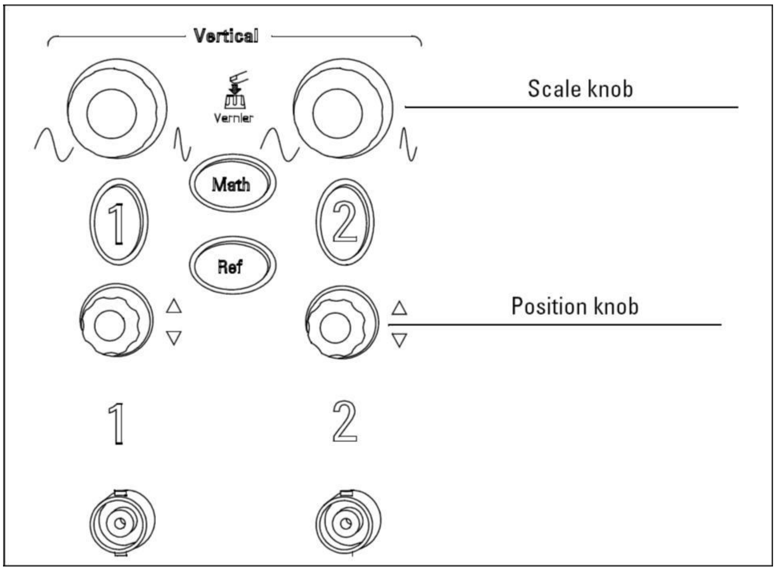


Figure 24: Vertical Controls of DSO3062A.

Position and Volts per Division Settings

The position knob moves the waveform vertically. The scale knob varies volts per division (usually written volts/div), which determines the voltage value corresponding to each vertical division on the oscilloscope's screen. As the volt/div value is altered, the size of the waveform on the screen changes.

The volts/div setting is a scale factor. For example, If there are ten vertical divisions on the oscilloscope screen and if the volts/div setting is 5 volts, then each of the vertical divisions represents 5 volts and the entire screen can show 50 volts from bottom to top. If the setting is 0.5 volts/div, the screen can display 5 volts from bottom to top, and so on. The maximum voltage you can display on the screen is the volts/div setting times the number of vertical divisions.

Often the volts/div scale has either a variable gain or a fine gain control for scaling a displayed signal to a certain number of divisions. Figure 25 shows the vertical controls of the HM203-7 CRO.

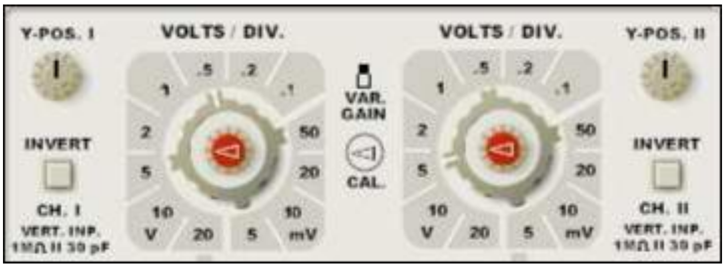


Figure 25: Vertical Controls of HM203-7 CRO

Horizontal Controls

Horizontal controls are used to position and scale the waveform horizontally. Figure 26 and 27 show typical front panel for the horizontal controls.

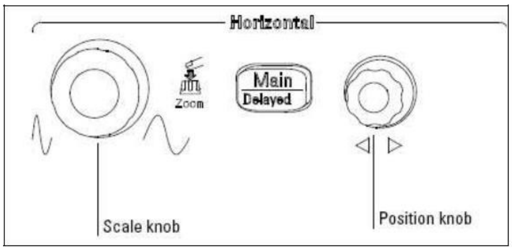


Figure 26: Horizontal Controls of DSO3062A

Figure 27: Horizontal Controls of HM203-7 CRO

The horizontal position control (x-pos.) is used to move the waveform from left and right to exactly where you want it on the screen.

The time per division (time/div) setting lets you select the rate at which the waveform is drawn across the screen (also known as the time base setting or sweep speed). This setting is a scale factor. For example, if the setting is 1 ms, each horizontal division represents 1 ms and the total screen width represents 10 ms (ten divisions). Changing the time/div setting lets you look at longer or shorter time intervals of the input signal.

As with the vertical volts/div scale, the horizontal sec/div scale may have variable timing, allowing you to set the horizontal time scale in between the discrete settings.

Also note that, the time/div button actually controls the trace time of sawtooth waveform in the sweep generator. When sawtooth waveform is zero volt, the bright spot is at the extreme left-hand position, and when it is maximum, the bright spot is at the extreme right position. Therefore, the bright spot travels from extreme left to extreme right in a time equal to the Trace time. Assume that the CRO screen is divided into N equal horizontal divisions. The bright spot travels the N divisions in Tr seconds. Therefore each division corresponds to

(Tr/N) seconds. If the Trace time is changed, the corresponding time for each division is changed. Time per division controls can be used to select the appropriate time/div (i.e., the Trace time of the sawtooth waveform).

Input Coupling

Coupling means the method used to connect an electrical signal from one circuit to another. In this case, the input coupling is the connection from your circuit to the oscilloscope. The coupling can be set to **DC**, **AC**, or **ground (GND)**. By setting the coupling control to **AC,** the **DC offset** voltage is removed form the input waveform, so that you see the waveform centered at zero volts. When **DC** coupling is selected, both **AC** and **DC** components of the input waveform are passed to the oscilloscope. Figure 28 illustrates the difference. The signal in Figure 28 is $y(t) = 3 + \sin(wt)$ where 3 Volts is DC component and sin(wt) is AC component. By selecting **AC** coupling, DC component is eliminated and only the signal of sin(wt) is shown on the screen (Figure 28-b). The AC coupling setting is useful when the entire signal (alternating plus constant components) is too large for the volts/div setting.

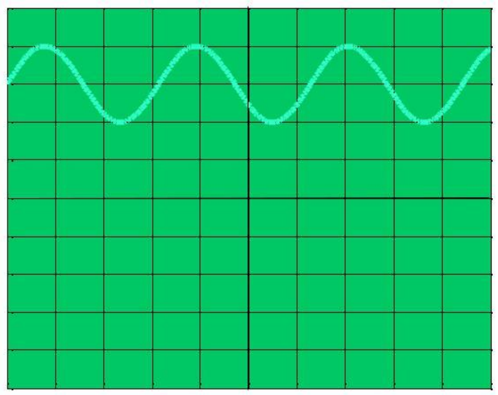
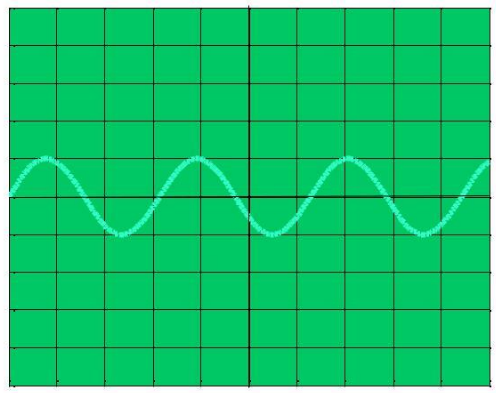
	

Figure 28-a: 2V peak to peak sinusoidal with 3 Volts offset, shown in **DC** mode.	Figure 28-b: 2V peak to peak sinusoidal with 3 Volts offset, shown in **AC** mode.

The ground setting disconnects the input signal from the vertical system, which lets you see where zero volts is on the screen. With grounded input coupling and auto trigger mode, you see a horizontal line on the screen that represents zero volts. Switching from DC to ground and back again is a handy way of measuring signal voltage levels with respect to ground.

X-Y Button

Most oscilloscopes have the capability of displaying a second channel signal along the X-axis (instead of time). This is called XY mode. Pressing the **X-Y** button the oscilloscope is used in XY mode. See Also (Notes on CRO)

DUAL Button

The oscilloscopes have the capability of displaying both channel signals on the screen at the same time. This is called the Dual Mode. This mode is usually used to measure phase difference between two signals which is explained in Phase difference part on page 17.

Alternate and Chop Buttons

On analog scopes, multiple channels are displayed using either an alternate or chop mode. (Digital oscilloscopes do not normally use chop or alternate mode.)

Alternate mode draws each channel alternately - the oscilloscope completes one sweep on channel 1, then one sweep on channel 2, a second sweep on channel 1, and so on. Use this mode with medium- to high-speed signals, when the time/div scale is set to 0.5 ms or faster. Alternate mode is available when only **DUAL** button is depressed.

Chop mode causes the oscilloscope to draw small parts of each signal by switching back and forth between them. The switching rate is too fast for you to notice, so the waveform looks whole. You typically use this mode with slow signals requiring sweep speeds of 1 ms per division or less. Chop mode is available when both **DUAL** and **ADD** button are depressed. Figure 29 shows the difference between the two modes. It is often useful to view the signal both ways, to make sure you have the best view.

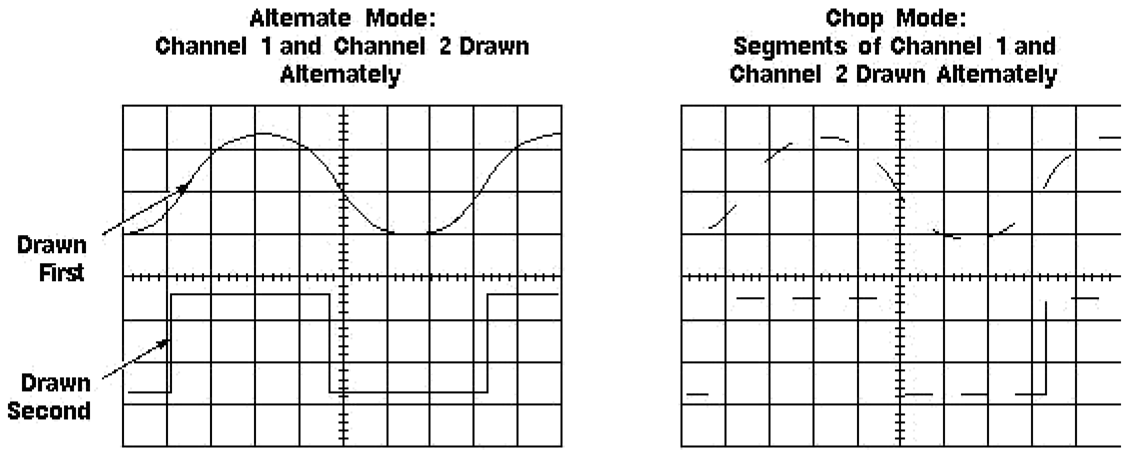


Figure 29: ALT and CHOP modes

ADD Button

When ADD button is depressed, the signals of both channels are algebraically added and the result is displayed on the screen. Volt/div scales of two channels should be the same in order to appropriately see the summation of the signals. When the volt/div scales of the channels are not the same, the signals are summed up as they are displayed on the screen (i.e. graphically). Assume a signal 2 sin(wt) is connected to Channel I and a signal 2 sin(wt) is connected to channel II. CH I is set to 2 volts/div (Figure 30-a) and CH II is set to 1 volt/div (Figure 30-b). When the ADD button is depressed, the resulting signal on the screen is shown in Figure 31.

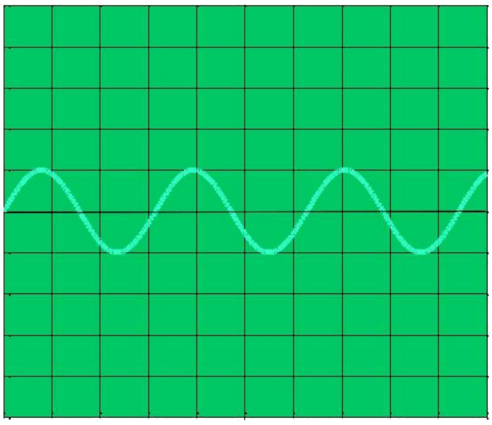
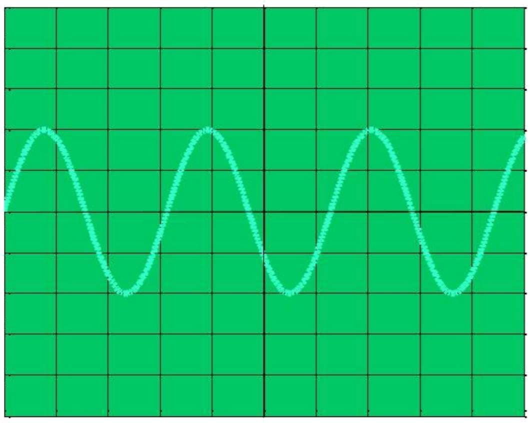
	

Figure 30-a: The first signal seen on the oscilloscope with 2 volt/div scale.	Figure 30-b: The second signal seen on the oscilloscope with 1 volt/div scale.

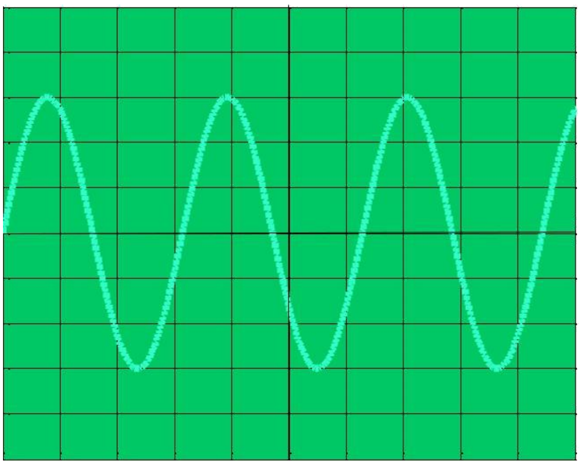


Figure 31: The sum of two signals in Figure 30-a and 30-b when ADD button is depressed.

INVERT Button

When the **INVERT** button of a channel is depressed, negative of the signal is displayed on the CRO screen.

EXT Button

When the **EXT** button is depressed, the oscilloscope is used in external triggering mode. External triggering is explained at Section External Triggering at page 14.

AT/NORM Button

Using the AT/NORM button you can switch between automatic trigger level selection (AT) and manual trigger level selection (NORM). When the AT/NORM button is released, the automatic trigger level is selected as zero volts, so that the value of the signal on the extreme left of the screen is equal to zero. When the AT/NORM button is depressed, the user can determine the trigger voltage level (the voltage on the extreme left) manually by adjusting LEVEL knob.

LEVEL and +/- Buttons

The trigger level can be set using the **LEVEL** knob when the **AT/NORM** button is depressed. Using the **LEVEL** knob, the trigger voltage level can be set to values different than zero. However, if the trigger level is set to a voltage value that is higher/lower than the positive/negative peak of the signal, the signal can not be triggered and therefore can not be displayed on the CRO screen (Figure 32-d). The **+/-** button is used to determine whether an increasing signal passing from trigger voltage, starts the sawtooth waveform (**+/-** button released) or viceversa. To be familiar with these buttons, the signals seen on the oscilloscope with various button configurations for the signal in Figure 30-b (1.5sin(wt)) are given in Figure 32.

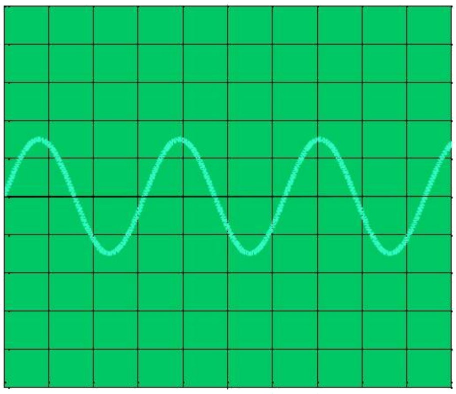
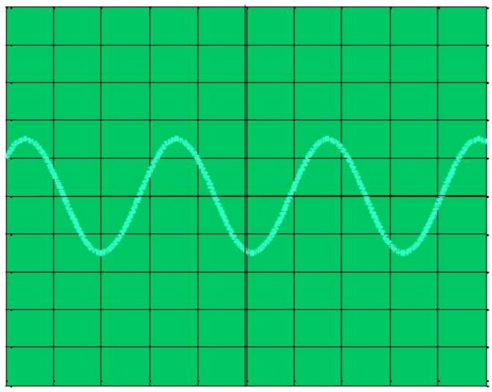
	

Figure 32-a: The signal when **AT/NORM** button is released. (**LEVEL** is automatically set to 0 volt.)	Figure 32-b: The signal when **AT/NORM** button is depressed, **LEVEL** is set to 1 Volt and **+/-** button is released.

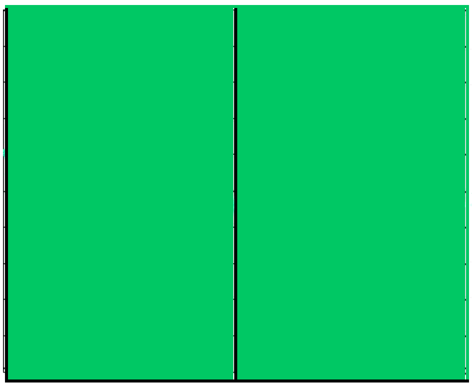
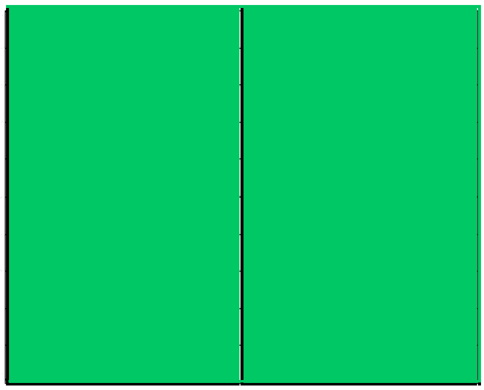

	

Figure 32-c: The signal when **AT/NORM** button is depressed, **LEVEL** is set to 1 Volt and **+/-** button is depressed.	Figure32-d:Thesignalwhen **AT/NORM** button is depressed, **LEVEL** is set to 2 Volt.

Appendix

The front panel of the oscilloscopes DSO3062A and the HM203-7 CRO are shown in the following figures respectively.

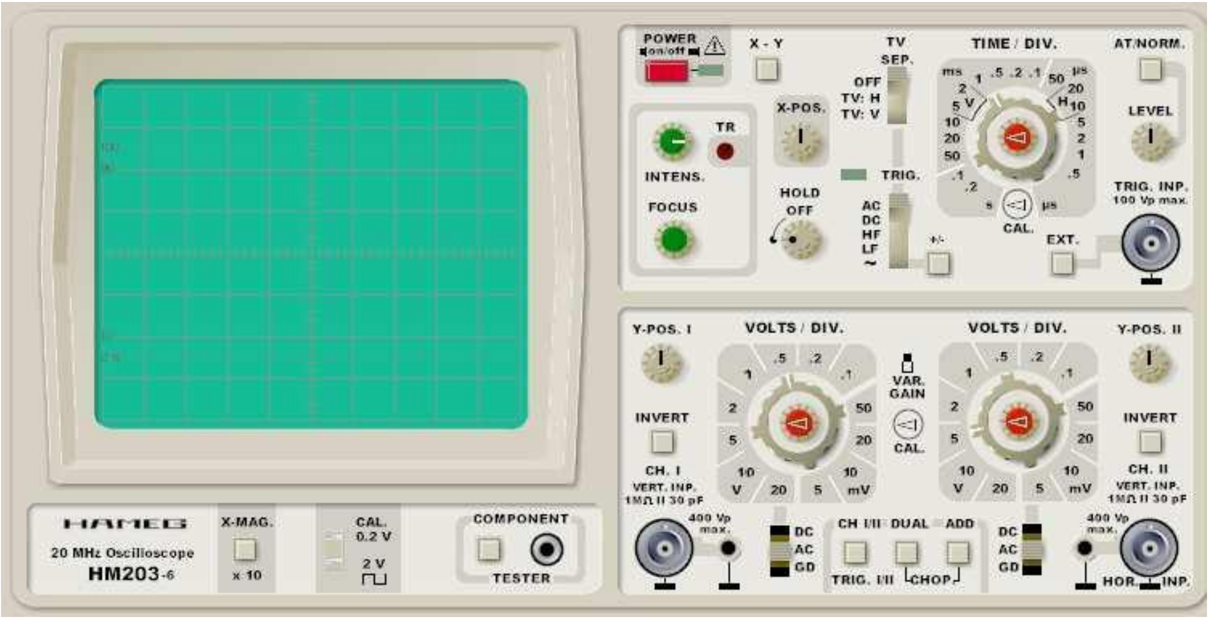


Figure A1: Front Panel of the HM203-7 Cathode Ray Oscilloscope.

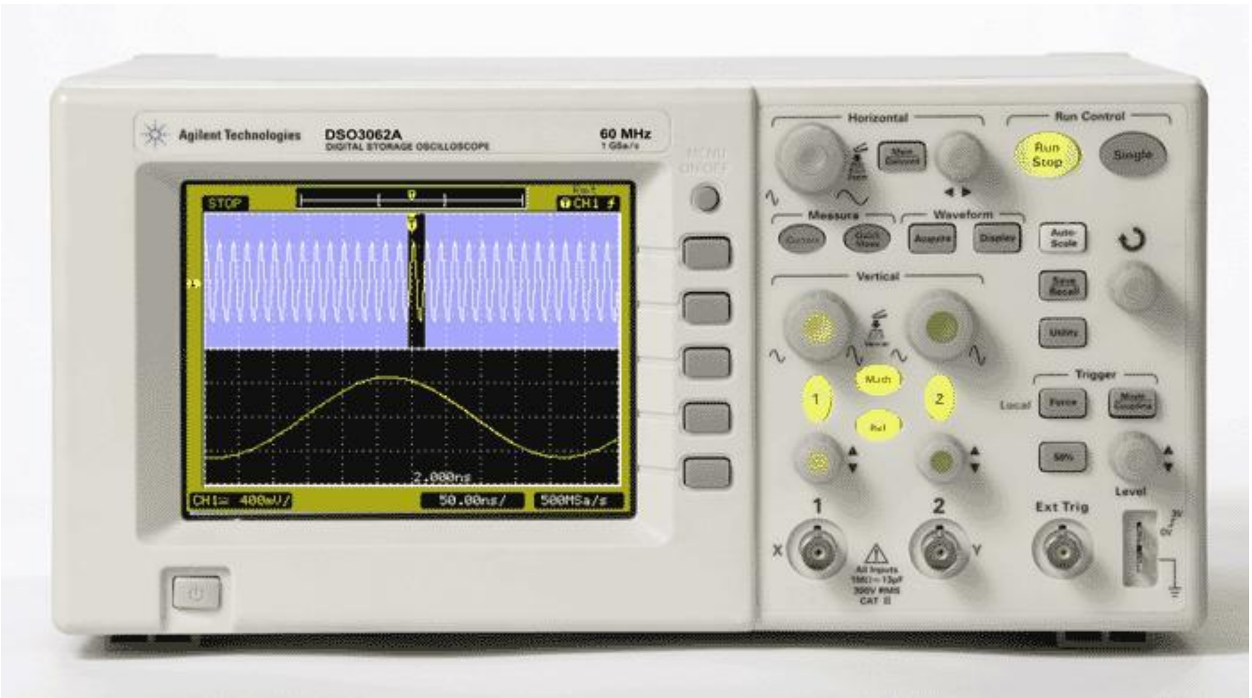


Figure A2: Front Panel of the DSO3062A.

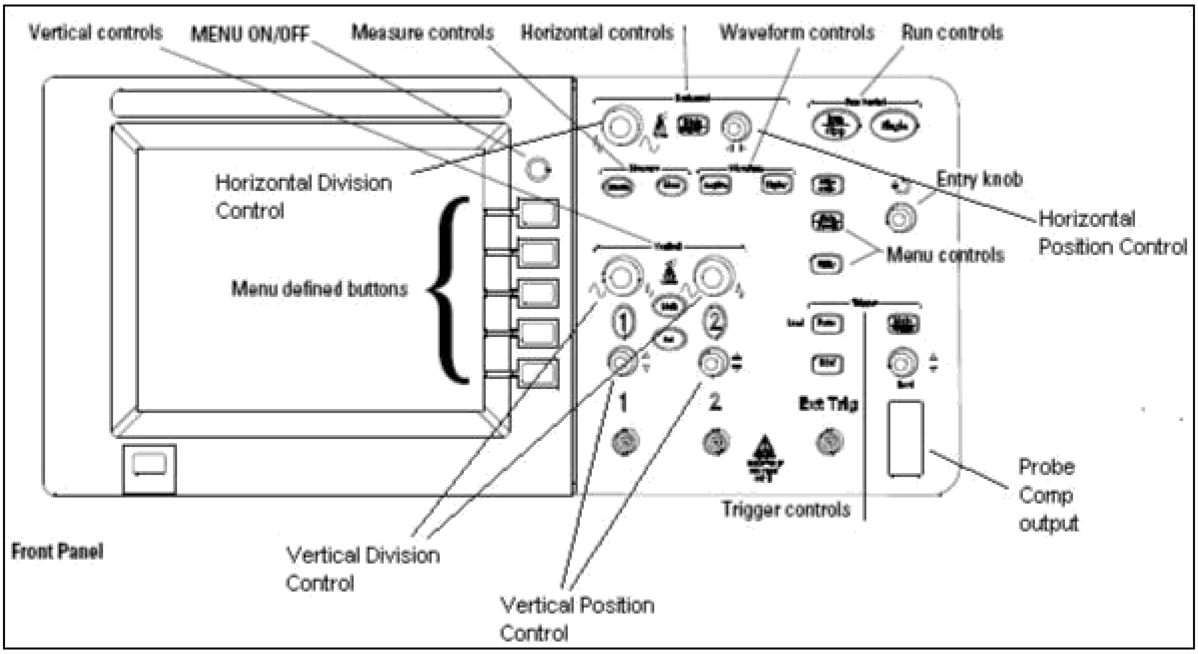


Figure A3: Schematic for the Front Panel of the DSO3062A.