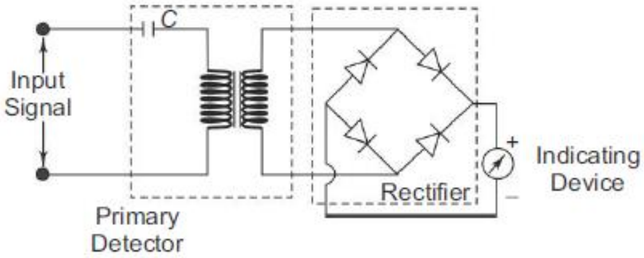
Module-4
SIGNAL ANALYZERS AND OSCILLOSCOPES

WAVE ANALYZERS:

Analyzing the relative amplitudes of individual frequency components within a complex waveform is the purpose of a wave analyzer. The amplitude, frequency, and phase angle of the harmonic components can all be determined by analyzing the waveform. Within the audible frequency range (20Hz to 20 KHz), the wave analyzer's extremely narrow pass-band filter portion can be set to a specific frequency.

BASIC WAVE ANALYZER:

A rudimentary wave analyzer is depicted in the following figure. The primary detector is a basic LC circuit that makes up this setup. For the purpose of measuring a certain harmonic component, the resonance frequency of this LC circuit is set.

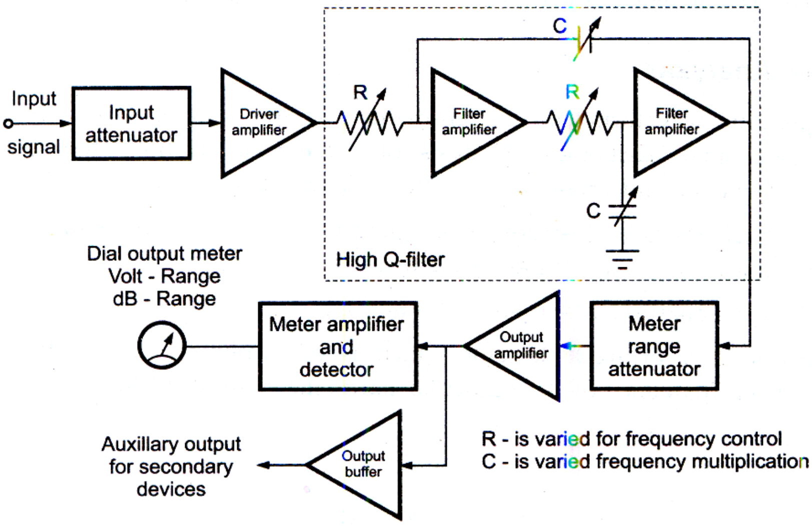


The full wave rectifier is the intermediate stage, which is used to determine the input signal's average value. With calibration set to read the peak value of the sinusoidal input voltage, the indicating device is a basic DC voltmeter. All other frequencies are rejected by the LC circuit, which is only tuned to one frequency, and only passes the frequency to which it is tuned. A practical Wave analyzer would require several fine-tuned filters connected to the indicating device via a selector switch.

Types of wave analyzer

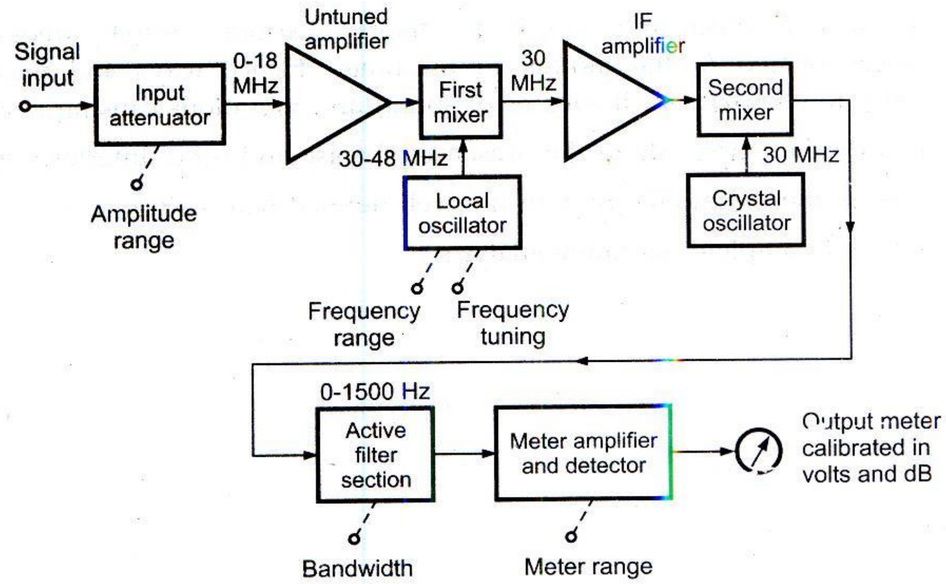
- ☐ Frequency selective wave analyzer.
- ☐ Heterodyne wave analyzer.

Frequency selective wave analyzer



An adjustable attenuator filters the waveform that will be examined. This multiplies the range. The waveform is fed to a high Q filter by the driver amplifier. The RC resonant portions and filter amplifiers are arranged in a cascade fashion to create this filter. The capacitors are employed to alter the range. Within the chosen pass band, the potentiometer is used to adjust frequency.
In the RC sector, the switching capacitors cover the entire AF range in decade steps. The chosen signal is sent to the meter circuit and an untuned buffer amplifier by the last amplifier step. Driving output devices, such as recorders and electronic counters, is the purpose of the buffer amplifier. Low input distortion is required for the analyzer input. The meter is marked with multiple voltage ranges and a decibel scale. It is powered by a detector of the average reading rectifier type.

Heterodyne wave analyzer



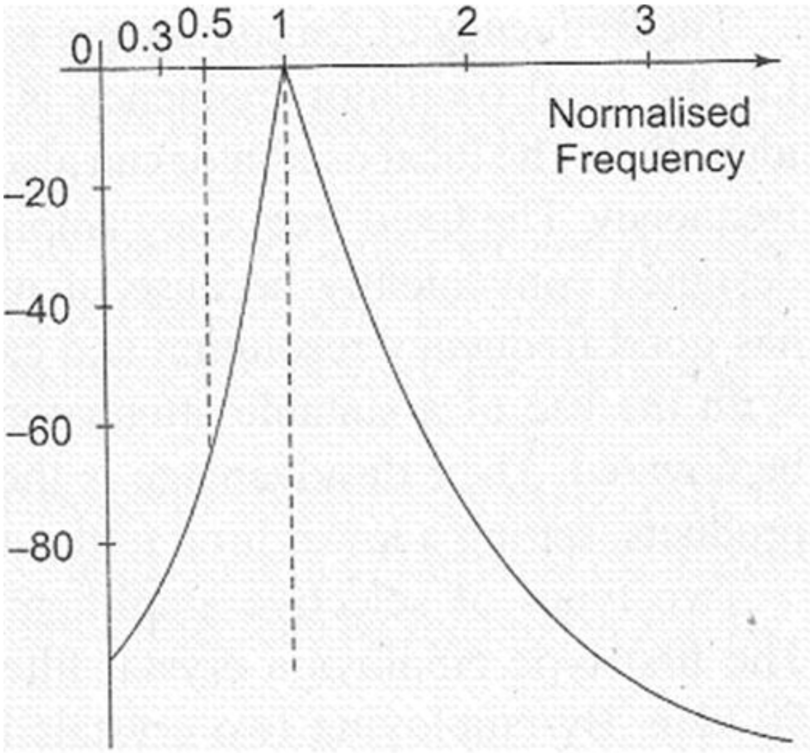
The heterodyning, or mixing, principle underlies the operation of this RF range analyzer.

This kind of wave analyzer uses an internal local oscillator to heterodyne the input signal to a higher intermediate frequency (IF).A local oscillator's tuning causes the different signal frequency components to move into the IF amplifier's pass band.The metering circuit is then fed with the rectified output of the IF amplifier.In the attenuator part, the input is applied first. In the range of 0 to 18 MHz, this indicates the output frequency.This signal is sent to the first mixer by the untuned amplifier, which enhances it.First, a local oscillator's frequency is used to heterodyne the input in the mixer. With a frequency range of 30-48 MHz, this oscillator.

The 30 MHz difference in frequency of the first mixer's output.This signal is amplified by the IF amplifier before being sent to the second mixer.Using a crystal oscillator operating at 30 MHz, the second mixer heterodynes the signal.Consequently, the zero difference frequency is produced at the mixer's output.After selecting the desired component, the meter amplifier and detector receive it via the active filter, which has a regulated bandwidth and symmetrical slopes of 72 dB per octave.The output meter, which has a decibel calibrated scale, is then utilized to provide the final indication based on the output from the meter detector.One possible application for the detector's output is a recording device.

Applications of wave analyzer

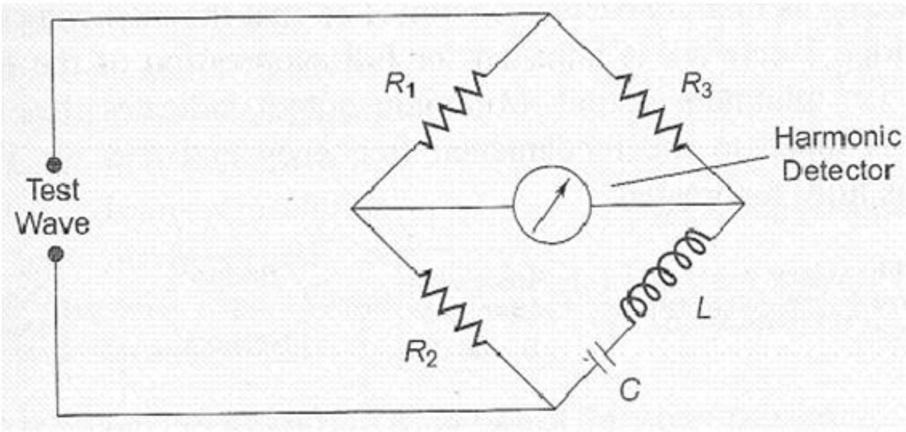
- Measurement of an amplifier's harmonic distortion
- To do a comprehensive harmonic analysis
- To use a well-defined bandwidth to quantify the signal energy



Marked on the meter are decibel grades and multiple voltage levels. A rectifier type detector with an average reading powers it. Extremely low input distortion that the wave analyzer itself cannot detect is a requirement. As seen by the response characteristics shown in figure, the instrument's band width is exceedingly narrow, often about 1% of the selective band.

HARMONIC DISTORTION ANALYZER:
Fundamental Suppression Type
Rather than measuring the distortion brought on by each component individually, a distortion analyzer examines the total harmonic power contained in the test wave. The easiest technique is to use a high pass filter with a cut-off frequency that is slightly above the fundamental frequency to suppress the fundamental frequency. Measuring the overall harmonic distortion is possible once this high pass lets only the harmonics pass through. The following are further varieties of fundamental suppression-based harmonic distortion analyzers:

1. **Employing a Resonance Bridge**



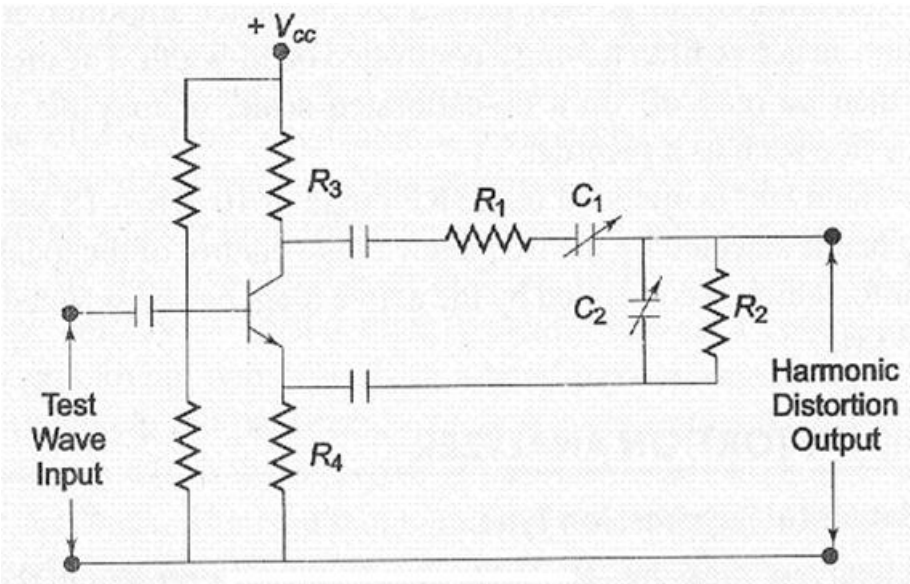
L and C are tuned to the fundamental frequency in Figure, which is balanced for the fundamental frequency. Only harmonic power will be available at the output terminal and measurable since the bridge is not balanced for harmonics. Rebalancing the bridge is necessary if there is a change in the fundamental frequency. Only when the test wave has a set frequency is this procedure appropriate if L and C are fixed components. Thermocouples and square law VTVMs are two types of indicators. This shows each harmonic's rms value.

2. **Wien's Bridge Method**

As seen in figure above, a Wien bridge configuration is utilized when a continuous adjustment of the fundamental frequency is necessary. A basic frequency balance is maintained in the bridge. Within the bridge circuit components, the fundamental energy is lost. To the output terminals alone come the harmonic components. You can then use a meter to measure the output of harmonic distortion.

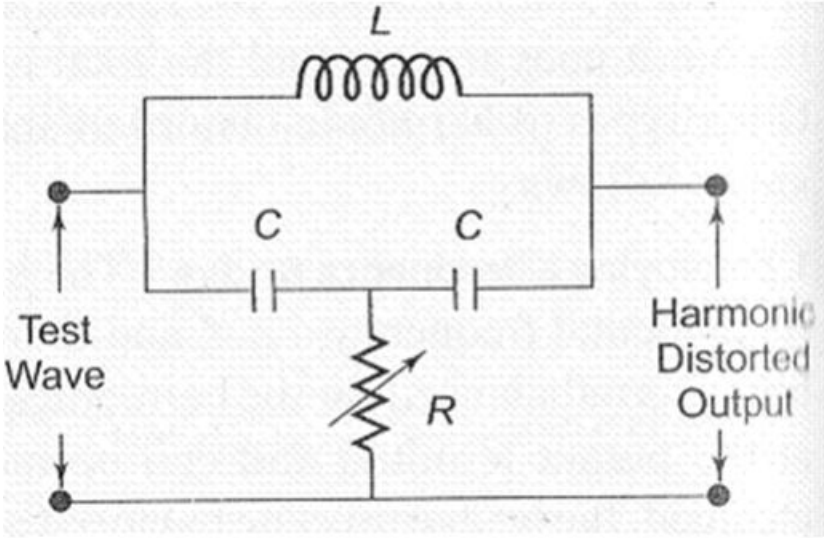
For balance at the fundamental frequency

$$C_1=C_2=C,\ R_1=R_2=R,\ R_3=2R_4.$$

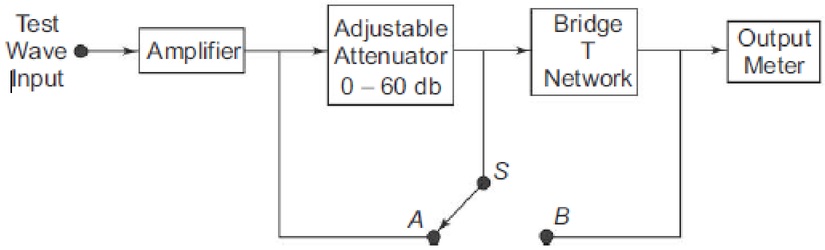


3. **Bridged T-Network Method**

The L and C frequencies in Figure are tuned to the fundamental frequency, but the R is modified to avoid the fundamental frequency. The fundamental energy will circulate in the tank and be circumvented by the resistance as the tank circuit is adjusted to the fundamental frequency.



The bridge T-network is set up for complete suppression of the fundamental frequency, or minimal output, after switch S is initially linked to point A. This excludes the attenuator. The minimum output shows that the fundamental frequency is completely muted and that the bridged T-network is tuned to it.



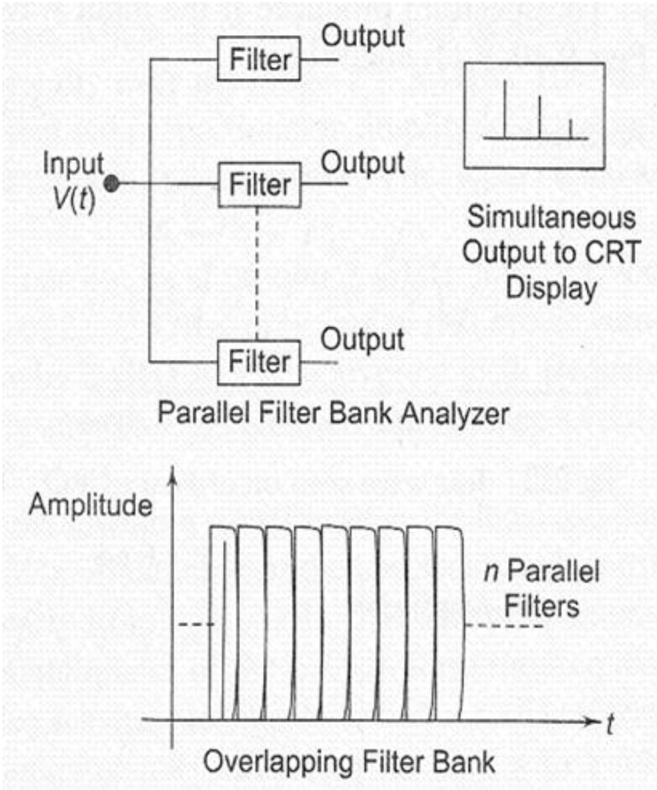
Next, the switch is linked to terminal B, meaning that the bridged T-network is not included. The attenuation is changed until the meter reads the same amount. The overall rms distortion is shown by the attenuator measurement. With a wave analyzer, distortion can also be measured and the harmonic distortion may be computed by knowing the frequency and amplitude of each component.

However, compared to wave analyzers, distortion meters based on fundamental suppression are less expensive and easier to develop. Their inability to provide the magnitude of individual distortion components, just the overall distortion, is a drawback.

SPECTRUM ANALYZER:

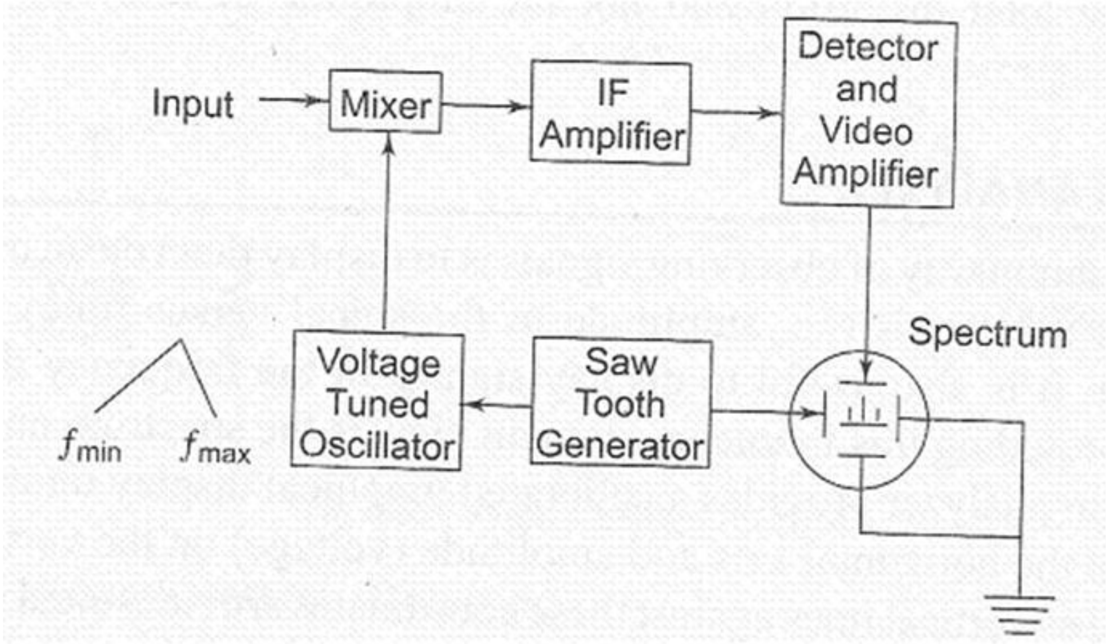
Signals are most commonly observed by plotting them on an oscilloscope with time as the X-axis (i.e., signal amplitude vs time). The temporal domain is this. The presentation of signals in the frequency domain is also beneficial. The spectrum analyzer is what provides this image of the frequency domain.

With frequency on the horizontal axis and amplitude (voltage) on the vertical, a spectrum analyzer's CRT displays a calibrated graphical display.

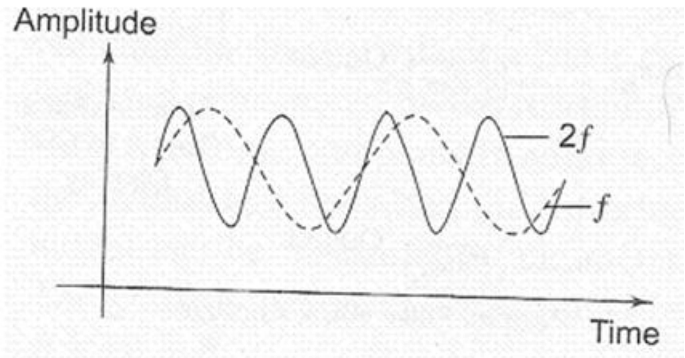


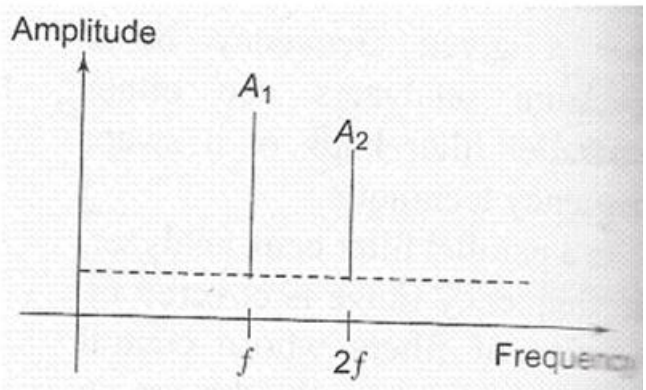
The sinusoidal components that make up the input signal are shown as vertical lines against these coordinates. The horizontal position denotes frequency, while the height denotes absolute magnitude. The frequency spectrum for a certain frequency band is displayed by these devices. Both swept frequency and parallel filter banks are employed by spectrum analyzers.
Figure shown above illustrates how a set of filters with well chosen core frequencies and bandwidths overlap each other to cover the frequency range in a parallel filter in a parallel filter bank analyzer.
These filters cover a third of an octave apiece, and an audio analyzer typically has 32 of them.
Wide band narrow resolution analysis is best performed using the Sweep Technique, especially for RF or microwave signals.

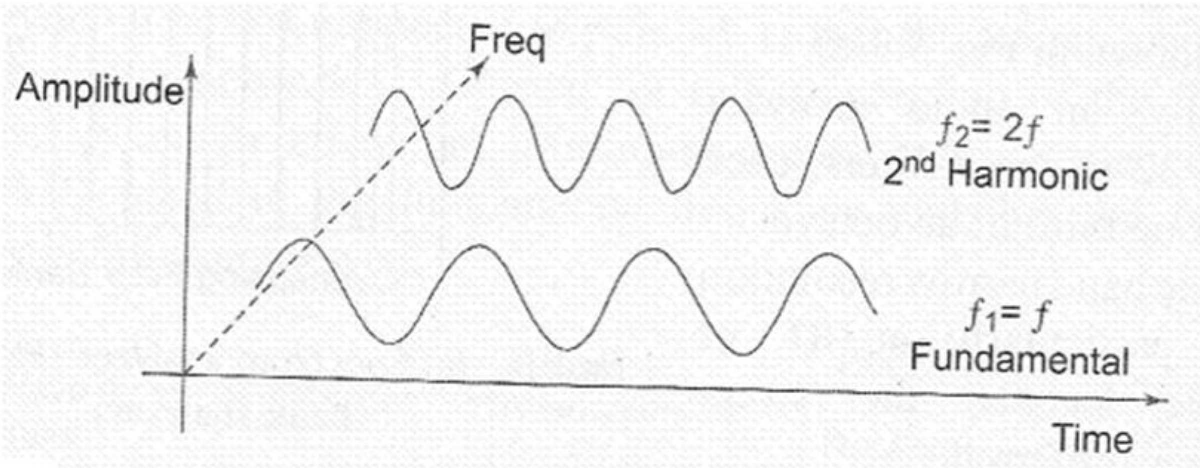
Basic Spectrum Analyzer Using Swept Receiver Design
The saw tooth voltage, which powers the scope's horizontal axis element and is the frequency-controlled component of the voltage-tuned oscillator, is provided by the saw tooth generator, as shown in the block diagram of Figure shown below. The oscillator beats with the frequency component of the input signal while it sweeps at a linearly repeating rate from fmin to fmax of its frequency band. Whenever a frequency component is reached during its sweep, the oscillator produces an IF.



In below figures, the spectrum generated if the input wave is a single toned A.M.

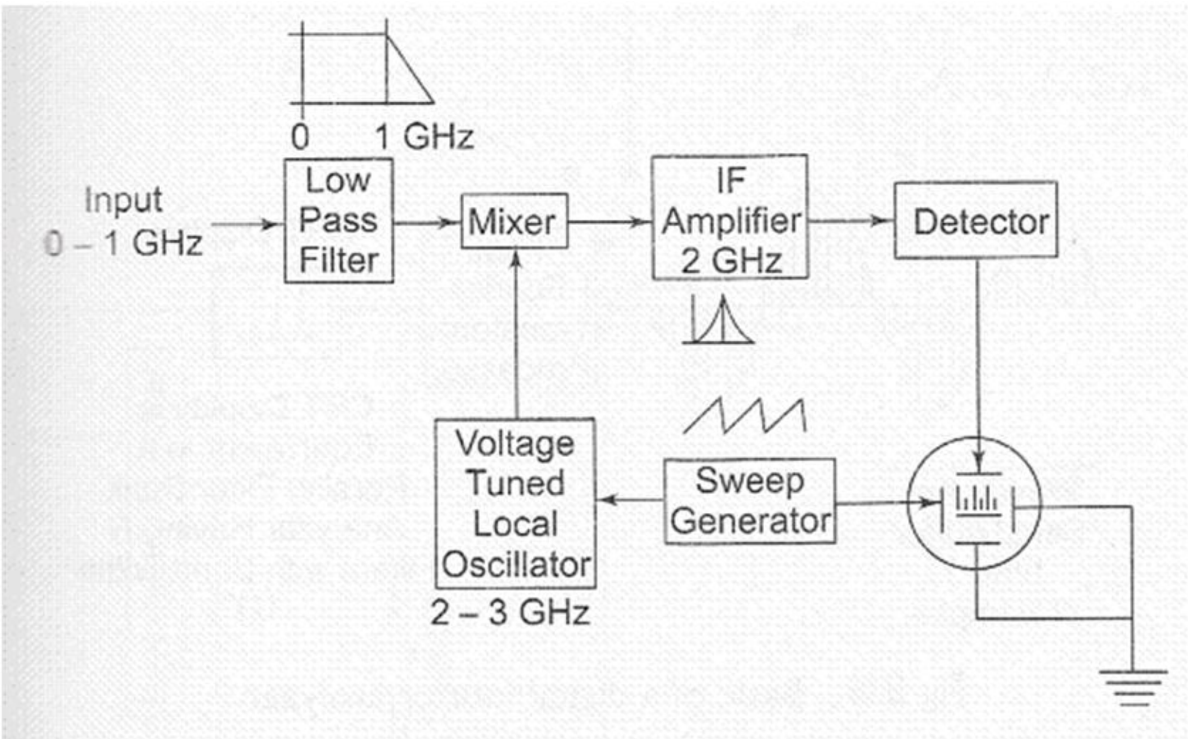






The analysis of the radio frequency spectrum generated by microwave devices has been a primary use for spectrum analyzers. In a microwave instrument, the horizontal axis can show a highly magnified picture of any small section of the spectrum at as narrow as 30 kHz, or as wide as 2 - 3 GHz for a broad survey. Individual signals at microwave frequencies separated by a few KHz are visible.

This device operates in the frequency range of I MHz to 40 GHz. The fundamental block diagram shows a spectrum analyzer operating in the super heterodyne type range of 500 kHz to 1 GHz.



The mixer receives the input signal and is powered by a local oscillator. Over the frequency range of 2 to 3 GHz, this oscillator can be electrically tuned linearly. The mixer outputs two signals that are the same frequency as the input signal plus the difference between the input signal and the local oscillator frequency. These signals are proportionate in amplitude to the input signal.

Only inputs that are separated from the local oscillator frequency by 2 GHz will be converted to the IF frequency band, pass through the IF frequency amplifier, get rectified, and cause a vertical deflection on the CRT. The IF amplifier is tuned to a narrow band around 2 GH4. This is because the local oscillator is tuned over a range of 2 - 3 GHz.

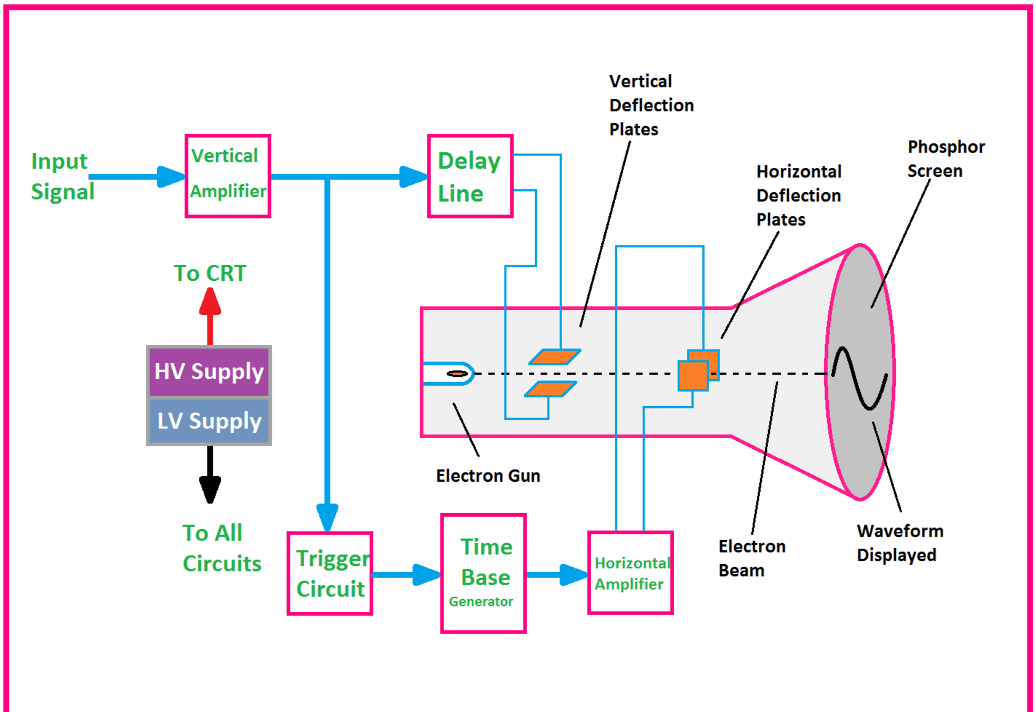
This leads to the observation that the local oscillator likewise sweeps linearly between 2 and 3 GHz when the saw tooth signal does. A swept receiver, which sweeps linearly from 0 to 1 GHz, is how the spectrum analyzer is tuned. The CRT's horizontal plates receive the saw tooth scanning signal as well, forming the frequency axis. (Signals from 4–5 GHz, also known as the super heterodyne's picture frequency, can also be detected by the spectrum analyzer. These erroneous signals are suppressed by an input low pass filter with a cutoff frequency exceeding I GHz.) Radars, oceanography, and the biomedical sciences all make extensive use of spectrum analyzers.

Cathode Ray Oscilloscope

An electrical device that shows a voltage waveform is called an oscilloscope. The Cathode Ray Oscilloscope (CRO), the most basic oscilloscope, shows a signal or waveform that varies over time.

Block Diagram of CRO

Blocks comprise the Cathode Ray Oscilloscope (CRO). These include a power supply, a horizontal amplifier, a time base generator, a vertical amplifier, a delay line, a trigger circuit, and a television tube (CRT). In the graphic below, the CRO block diagram is displayed.

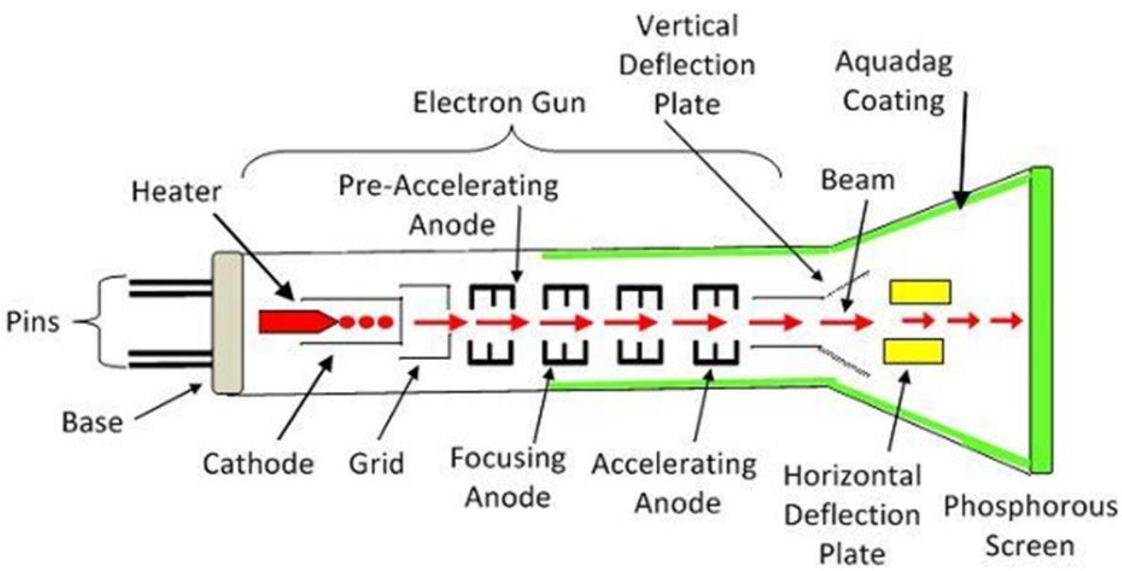


CRO Block Diagram

The **function** of each block of CRO is mentioned below.

- **Vertical Amplifier :** Using a vertical amplifier, the input signal intended to be shown on the CRT screen is amplified.
- **Delay Line :** The signal obtained at the output of the vertical amplifier is given a certain degree of delay by the delay line. Then, the CRT's vertical deflection plates get this delayed signal application.
- **Trigger Circuit :** The trigger circuit generates a signal to synchronize the deflections of the electron beam in both the horizontal and vertical directions.
- **Time base Generator :** One important tool for deflecting an electron beam horizontally is the Time Base Generator, which generates a sawtooth signal.
- **Horizontal Amplifier :** The sawtooth signal is first amplified before being connected to the CRT's horizontal deflection plates via a horizontal amplifier.
- **Power supply:** It generates voltages that are both high and low. To the CRT and other circuits, the corresponding high and low voltages are applied, correspondingly.
- **Cathode Ray Tube (CRT) :** The fundamental component of CRO, the cathode ray tube (CRT), is made up of four key elements. These are fluorescent screens, electron cannons, and horizontal and vertical deflection plates.

Two vertical and two horizontal deflection plates, respectively, deflect the electron beam that is created by an electron cannon in both directions. Finally, on the fluorescent screen, the deflected beam will show up as a spot.
The input signal will be applied and shown on the CRT screen using CRO in this manner. In this way, we may use CRO to analyze the signals in the temporal domain.



Definition: A display screen that generates images from a video signal is called a CRT. This particular kind of vacuum tube produces images when it strikes a phosphorescent surface with an electron beam fired from electron cannons. Put otherwise, in order to create the images on the phosphorous screen and make the beam visible, the CRT creates the beams, accelerates them at a high speed, and deflects them.

The electron beams that are produced by electron guns are accelerated at high voltage and produce a luminous spot when they strike a fluorescent screen. The electron beams exit the electron gun and pass through pairs of electrostatic deflection plates, which deflect the beams when voltage is applied across them. The first pair of plates moves the electron beam upward, while the second pair moves it from one side to the other. The electrons move independently in both the horizontal and vertical directions, allowing the electrons to be positioned anywhere on the screen.
A vacuum glass envelope encloses the CRT's working components, allowing the electrons that are released to flow freely from one end of the tube to the other.

Construction of CRT

Important components of the CRT are the glass envelope, base, fluorescent screen, electron gun assembly, and deflection plate assembly. Emitted from the electron cannon, the electron beam hits the phosphorous screen by way of deflecting plates.

Electrons Gun Assembly

The source of the electron beams is the electron gun. The electron cannon comprises of an accelerating anode, focusing anode, pre-accelerating anode, grid, and heater. The strongly emitted cathode is the source of the electrons. The cathode has a cylinder-shaped structure, and at its end is a layer of strontium and barium oxide that produces a high electron emission at the tube's end.
The electron travels through each individual electron in the tiny grid. The nickel material used to make this control grid has a hole in the middle that runs parallel to the CRT axis. Pre-accelerating and accelerating anodes are subjected to a high positive potential applied by the electrons that are fired from the electron cannon and travel through the control grid.
The focusing anode concentrates the beam. Each of the cylindrical focusing and accelerating electrodes has a tiny aperture in the center of it. The beams go via the horizontal and vertical deflecting plates after leaving the focusing anode. The positive high voltage of approximately 1500V is connected to the pre-accelerating and accelerating anodes, while the lower voltage of approximately 500V is connected to the focusing anode.The electron beam can be focused in two different ways. These are the electromagnetic focusing and the electrostatic focusing beam.

Electrostatic Deflection Plates

The uniform electrostatic field is produced by the deflection plate only in one direction. The electrons in the electron beam that enters the deflection plates will only accelerate in one direction; they will not move in any other direction.

Screen For CRT

The face plate is the term for the CRT's front. Fiber optics, which have unique properties, make up the entire face plate of the CRT. Phosphorus is applied to the inside surface of the faceplate. Light energy is produced from electrical energy by the phosphorus. When electron beams strike phosphorous crystals, their energy level increases. The term cathodoluminescence refers to this phenomena.
Fluorescence is the name for the light that results from phosphorous excitation. A quantum of light energy known as phosphorescence or persistence is released by the phosphorous crystals when the electron beam stops and they return to their original position.

Aquadag

The Aquadag, which is linked to the anode's secondary, is an aqueous graphite solution. In order to maintain electrical equilibrium on the CRT screen, secondary released electrons must be collected by the Aquadag.

With CRO, we are able to perform the following measurements: Amplitude measurement, Time period measurement, Frequency measurement, and Period measurement.

Measurement of Amplitude

The voltage signal is shown on CRO's screen as a function of time. The voltage signal's amplitude remains constant, but we can adjust the number of vertical divisions covering it by adjusting the volt/division knob on the CRO panel. Consequently, we will use the following formula to obtain the signal's amplitude that is displayed on the CRO screen.

$A=j \times nv$

Where,

A is the amplitude

J is the value of volt/division

Nv is the number of divisions that cover the signal in vertical direction.

Measurement of Time Period

CRO shows the voltage signal on its screen as a function of time. The period of that periodic voltage signal is always the same, but by adjusting the time/division knob on the CRO panel, we may change the number of divisions that make up a single horizontal cycle of energy.

Thus, we can use the following formula to obtain the Time period of the signal that is displayed on the CRO screen.

$T=k \times nh$

Where,

T is the Time period

j is the value of time/division

nv is the number of divisions that cover one complete cycle of the periodic signal in horizontal direction.

Measurement of Frequency

A periodic signal's frequency, f, is equal to the reciprocal of its time period, T.

Mathematically, it can be represented as

$$f=1/T$$

So, we can find the frequency, f of a periodic signal by following these two steps.

First, ascertain the periodic signal's time period.

Step 1 yields the periodic signal's time period, which is then taken as the reciprocal in Step 2.

Dual beam oscilloscope

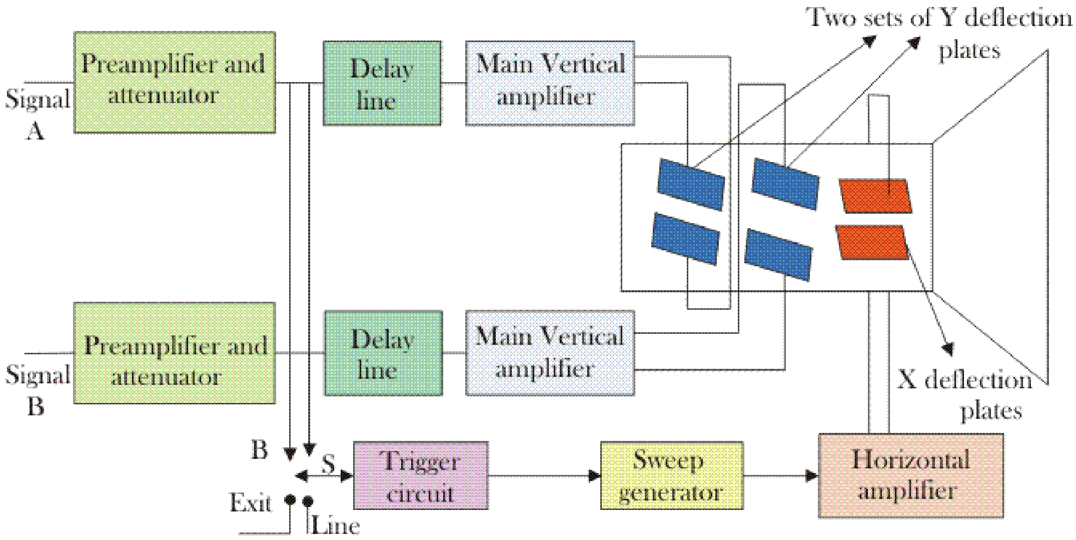
The dual beam oscilloscope can be operated independently or in tandem to produce two electron beams that are seen concurrently on a single scope. The dual beam oscilloscope differs greatly from the dual trace oscilloscope in both design and operation. Both the construction of the tubes and the overall cost have increased.

Through beam generation or deflection, a unique kind of double beam oscilloscope may display two electron beams. These days, double beam oscilloscopes are obsolete since digital scopes can accomplish the same task more effectively and don't need a dual-beam display. A single electron beam is captured by the digital scope, which splits it into multiple channels simultaneously.

Construction of Double Beam Oscilloscope

For two electron beams emanating from separate sources, there are two separate vertical input channels. Every channel possesses a separate pre-amplifier and attenuator. Consequently, it will soon be possible to alter each channel's amplitude.

Different sweep rates are possible depending on whether the two channels have independent or shared time base circuits. Every beam traverses distinct channels for independent vertical deflection prior to crossing a solitary set of horizontal plates. The sweep generator compiles the horizontal amplifier, which drives the plate and provides a common horizontal deflection. Parallel passage of both electron beams across the screen is made possible by the horizontal plates.



Duel beam oscilloscope with common time base

Dual beam oscilloscope: With a twin electron gun tube or by splitting the beam, a dual beam oscilloscope can produce two electron beams inside the cathode ray tube. Each beam's focus and brightness are adjusted independently using this manner. However, the oscilloscope appears hefty and is larger and heavier due to its two tubes.

The alternate approach uses a split beam tube and only requires one electron cannon. The last anode and the Y deflection plate are separated by a horizontal splitter plate. Between the two vertical deflection plates along the tube's length, the plate's potential is the same as that of the final anode. As a result, the two channels are isolated.

The brightness of the resulting beam is half of the original beam when it splits into two. It functions as a drawback at high frequencies. Having two sources rather than one in the final anode to allow beams to come from it is an alternate method to increase the brightness of the resulting beam.

Dual Trace oscilloscope

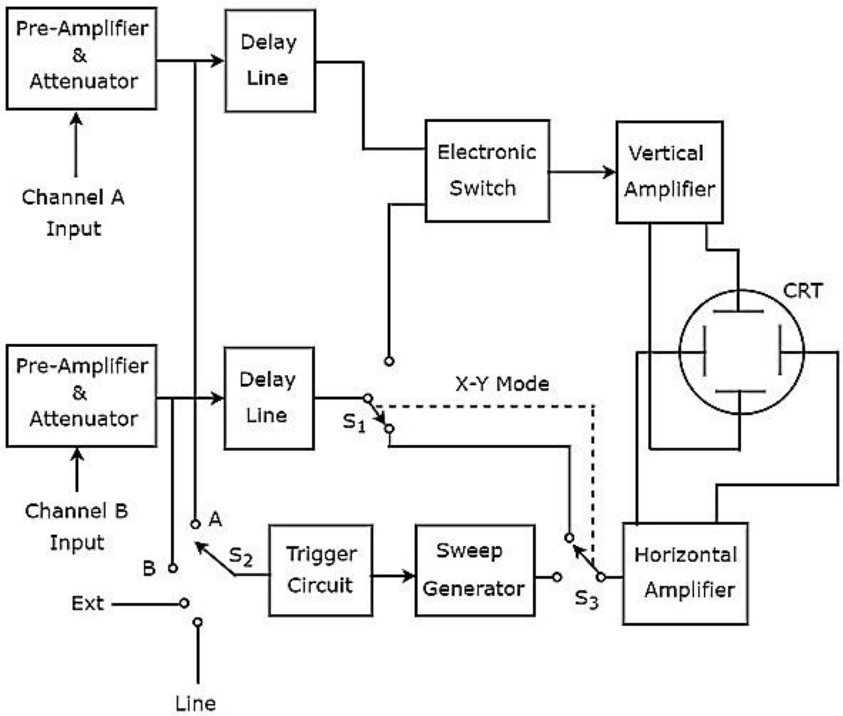
In a dual trace oscilloscope, two traces are produced by a single electron beam and are deflected by two different sources. Essentially, two techniques—the chopped mode and the alternate mode—are employed to create two distinct traces. The two switch operating modes are another name for these. The comparing of voltages is a crucial step in the analysis and research of multiple electrical circuits. So, one can utilize numerous oscilloscopes to compare the various circuits. However, it's a challenging operation to simultaneously activate each oscilloscope's sweep. In order to give two traces using a single electron beam, we have employed dual trace oscilloscopes.

Working: Its two distinct vertical input channels are called A and B. The preamplifier and attenuator stages receive separate feeds of each inputs. After that, the electronic switch receives the outputs from the two independent preamplifiers and the attenuator stage. Only one channel input, specifically at a time, is passed to the vertical amplifier by this switch. A trigger selection switch on the circuit enables the circuit to be triggered by an external signal or by an input from either the A or B channel. The sweep generator or switches S0 and S2 on channel B receive the signal from the horizontal amplifier and feed it to the electronic switch.

The oscilloscope operates by means of the CRT receiving the vertical signal from channel A and the horizontal signal from channel B. This oscilloscope mode allows precise X-Y readings. It is called the X-Y mode. Essentially, the oscilloscope's modes of operation depend on the controls selected from the front panel. Similar to how a trace of channel A or channel B must be obtained independently, or both, depending on the situation. Dual trace oscilloscopes operate in two different modes, as we have already mentioned.

ALTERNATE MODE OF DUAL TRACE OSCILLOSCOPE The alternate mode allows for the alternating connection between the two channels whenever it is activated. Each subsequent sweep starts with this alternation, or flipping, between channels A and B. Additionally, there is synchronization between the sweep rate and the switching rate. This results in the detection of each channel's traces in a single sweep. For example, if traces of channel A are detected in the first sweep, the CRT will evaluate traces of channel B in the subsequent sweep. This completes the alternate connection between the vertical amplifier and the two-channel input.

For the duration of the flyback sweep, the electronic switch changes from one channel to another. The transition from one channel to another will occur during the flyback period when the electron beam becomes invisible. The screen will therefore show the entire sweep signal from a single vertical channel. While the signal from a different vertical channel will be seen on the following sweep. By using this technique, we can keep the signals from channels A and B in the correct phase relationship.
Nevertheless, this method is also linked to a drawback in addition to its benefits. The alternate mode results in a display that shows both signals occurring at separate times. In reality, though, the two things happen at the same time. Furthermore, the low-frequency signal cannot be represented using this method. The oscilloscope's alternate mode waveform is depicted in the following figure:



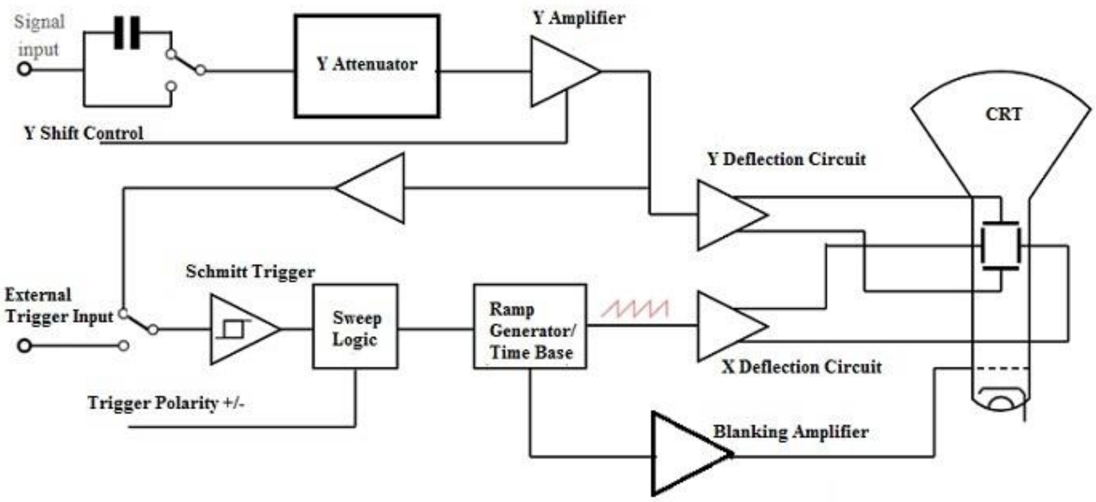
Analog Storage Oscilloscope

Waveforms can be stored for subsequent visualization with an analog storage oscilloscope, which is one kind of oscilloscope. Since these oscilloscopes were relatively expensive and had very basic performance, they were typically reserved for specialized uses. With a long persistence facility, these oscilloscopes use a unique cathode ray tube. Though these CRTs might be set to different persistence levels, there's a risk of permanently burning traces on the screen if very bright traces are maintained above long periods of time. As such, careful use of these displays is necessary.

An unique CRT with extended persistence is used by analog storage oscilloscopes. In order to prolong the fluorescence's duration beyond that of typical displays, a unique CRT structure is utilized to store charge inside the display region where the electron beam had struck.
All that this oscilloscope needs to function is to apply a voltage that can be directly measured to an electron beam that travels over its screen. The beam is focused on a screen that has been coated with phosphor, which causes the screen to glow. The signal then deflects the beam, allowing it to trace the waveform on the screen.The beam will be correspondingly deflected up and down by the voltage in order to trace the waveform on the display. As a result, a waveform image is displayed instantly.

Block Diagram

The following block diagram illustrates an analog storage oscilloscope that makes use of a CRT. In order to provide significantly faster electron stream control and enable analog oscilloscopes to operate at very high frequencies, this oscilloscope uses an electrostatic CRT type rather than a magnetic deflection type. An stable image of the incoming waveform can be obtained from the analog oscilloscope, which has several circuit blocks.



Signal Inputs

The Y-axis or signal input on the display is connected to a number of controls. Often, signals under a DC bias will be overlaid. Consequently, in order to ensure that the DC is blocked, a capacitor must be connected in series through the input. Selecting AC will indicate that there may be limitations on low-frequency transmissions when a capacitor is used.

Y Attenuator

The purpose of the Y attenuator is to ensure that the signals are sent to the Y amplifier at the appropriate level.

Y Amplifier:

All that the oscilloscope's Y amplifier does is amplify the signal to provide the desired output. Since it will determine the oscilloscope's accuracy, this amplifier is primarily linear.

Y Deflection Circuit:

The Y deflection circuit receives the amplified signal from the Y amplifier and provides the necessary levels to the CRT plates. Because it offers the high-speed deflection needed for this oscilloscope, the CRT's deflection is electrostatic.

Trigger Circuitry:

Whether a stable waveform appears on the display or not is determined by the trigger system. Every cycle of the incoming signal that needs to be examined must have the ramp signal set to begin at the same location. In this way, the display will display a similar spot on the waveform at a similar position.

A signal is received from the output of the Y amplifier and sent to another conditioning amplifier in the block diagram above. Subsequently, it is routed via a Schmitt trigger circuit, which offers a single switch point for both rising and falling waveforms. Either the increasing or decreasing edges of the waveform that can be picked before being delivered to the ramp circuit, or wherever the trigger signal supplies the start point for the ramp, is the necessary sense that is chosen for the trigger.
It is also possible to employ a signal from an external source. Given that the trigger may need to be obtained from a source other than the incoming signal, this functionality can be highly appropriate.
Blanking Amplifier
During this fly-back phase, a blanking amplifier is used to clear the screen. All that is needed to generate a pulse that is sent to the CRT grid is the reset element of the ramp. This effectively blanks the display and lowers the electron flow for the duration.
Ramp Generator (Time Base)
The analog storage oscilloscope's time base control is one of its most important controls. This will be significantly different in speed and time for every section on the scope CRT. In order to display the specific waveform that is needed, it is crucial to choose the appropriate timebase speed.
With this analog storage oscilloscope, signals are displayed in both the horizontal and vertical axes on the CRT. The ramp waveform usually represents the horizontal axis, and the instantaneous incoming voltage value typically represents the vertical axis. A horizontal trace slides across the display as the voltage of the ramp waveform increases. The waveform returns to zero and the trace restarts at the beginning of the screen once it reaches the conclusion. With this method, amplitude is represented by the vertical axis, while time is represented by the horizontal two. The common waveform plots can therefore be shown on the CRT in this way.
Advantages and Disadvantages
The **advantages of analog storage oscilloscope** include the following.

- The oscilloscopes that have analog storage typically have lower costs. They can offer a reasonable performance range for many laboratory and service scenarios.
- Especially for laboratory operations, these oscilloscopes deliver precise performances.
- These oscilloscopes don't need an ADC, microprocessor, or acquisition memory in order to measure anything.

The **disadvantages of analog storage oscilloscopes** include the following.
These oscilloscopes are not intended for the analysis of sharp-rise-time transients at higher frequencies found in electronic circuits, and they do not provide any extra capabilities over digital oscilloscopes. Additionally, operating these oscilloscopes requires hands-on expertise.
Applications
The **applications of analog storage oscilloscopes** include the following.

- It shows waveforms with a single shot and a long duration.
- Stable incoming waveform pictures are produced by the analog oscilloscope.
- These oscilloscope types are often utilized for real-time observation of one-time events.
- Very low-frequency signals are displayed using it.
- The major application for these oscilloscopes is in situations where the screen display time is insufficient to verify the signals that need to be monitored.
- The oscilloscope employs an electron beam to map and show the continuously varying input voltages of the signal.

Digital Storage Oscilloscope

Definition: Oscilloscopes with digital storage allow users to save digital waveforms or digital copies of them. Digital signal processing techniques can be used to the signal and it enables the storing of the waveform or signal in digital format and digital memory. Both the scope's sampling rate and the type of converter affect the highest frequency that may be measured with a digital signal oscilloscope. In just a few seconds, the vivid, well-defined traces in DSO are shown.

Block Diagram of Digital Storage Oscilloscope

An analyzer circuits, memory, digitizer, and amplifier make up the digital storage oscilloscope's block diagram. Cathode ray tubes (CRTs), horizontal amplifiers, vertical and horizontal plates, triggers, clocks, and time base circuitry are included in waveform reconstruction. Below is a figure that displays the digital storage oscilloscope block diagram.

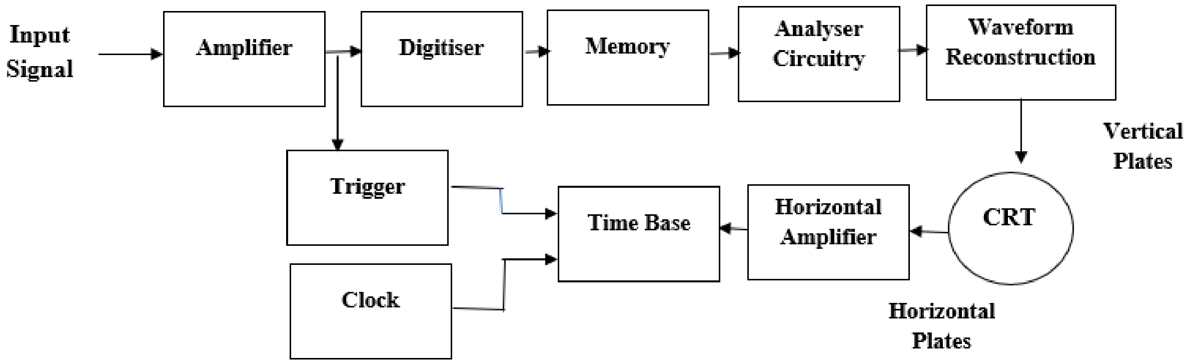


Figure above illustrates how the analog input signal is first digitized by a digital storage oscilloscope and then amplified by an amplifier if necessary. The digitizer then digitalizes the signal once it has been amplified, and memory stores the digitalized signal. Following the digital signal's processing by the analyzer circuit, the waveform is rebuilt (converting the digital signal into analog form once more), and the signal is subsequently applied to the cathode ray tube's vertical plates (CRT).

The inputs of the cathode ray tube are twofold: vertical and horizontal. The "X" axis represents the horizontal input signal and the "Y" axis the vertical input signal. Because the time base circuit is activated by both the trigger and the clock input signal, it will produce a ramping time base signal. The horizontal amplifier will then send the input to the horizontal plate after amplifying the ramp signal. The input signal's waveform versus time will be displayed on the CRT screen.

An input waveform sample is taken at regular intervals to facilitate digitization. Meaning that we take signal samples at the periodic time interval, which occurs when half of the time cycle has elapsed. The sampling theorem should be adhered to when digitizing or selecting samples. The rate of sample taking should be more than double the highest frequency found in the input signal, according to the sampling theorem. Aliasing is the result of improper conversion of the analog signal into digital format.

As soon as the analog signal is appropriately converted to digital, the A/D converter's resolution is reduced. An A/D converter can operate at up to 100 mega samples per second when it can read out the input signals from analog store registers at a much slower rate than it can from digital stores, where the digital output is stored. A digital storage oscilloscope operates on this principle.

DSO Operation Modes

Three modes of operation are available for the digital storage oscilloscope: roll mode, store mode, and hold or save mode.

Roll Mode: The display panel changes very quickly when the roll mode is activated.

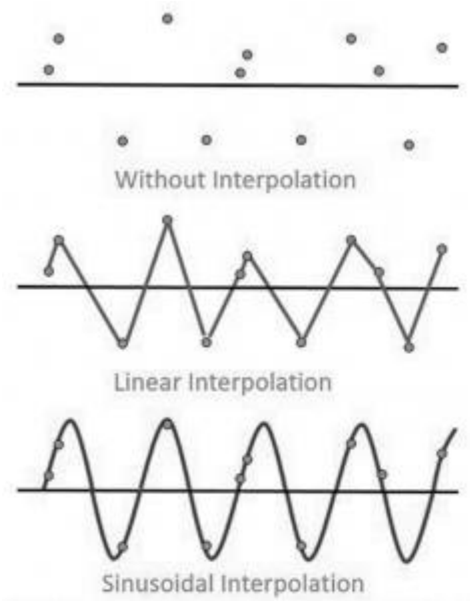
Store Mode: When in store mode, the signals are stored in RAM.

Hold or Save Mode: When in hold or save mode, a portion of the signal will be held for a while before being stored in memory.
These are the three oscilloscope operation modes for digital storage.

Waveform Reconstruction

Linear interpolation and sinusoidal interpolation are the two types of waveform reconstructions.
Linear Interpolation: The dots are connected by a straight line in linear interpolation.

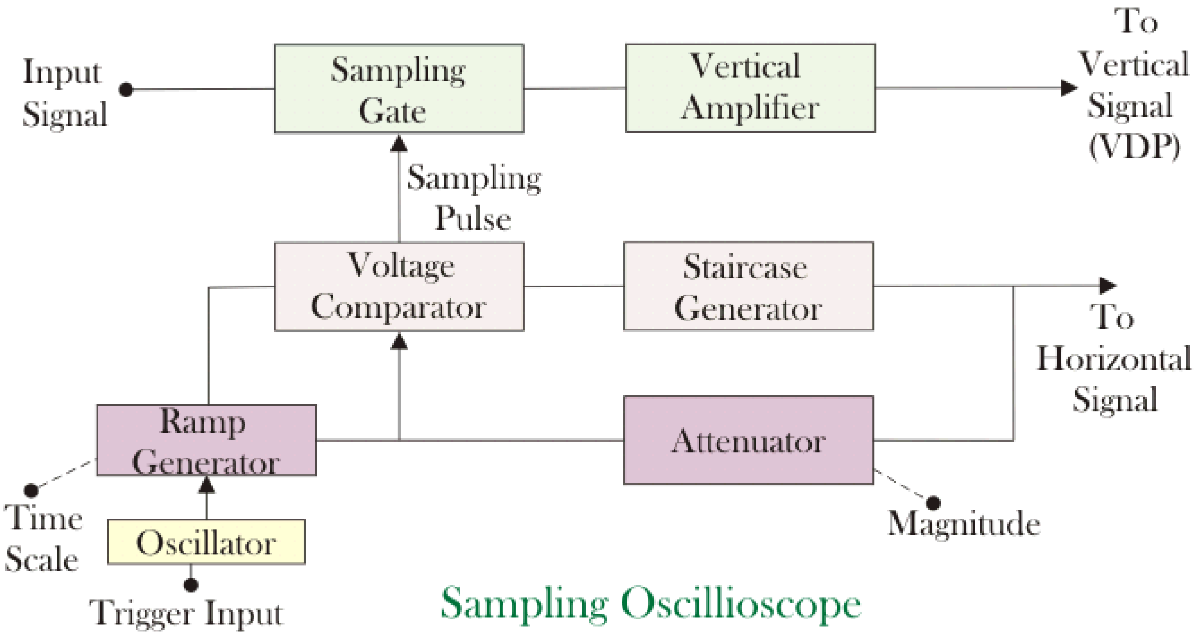
Sinusoidal Interpolation: In sinusoidal interpolation, a sine wave connects the dots.



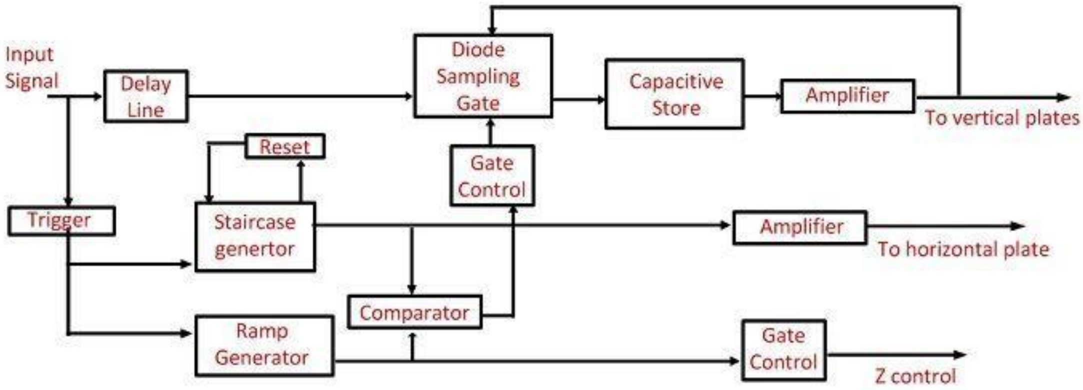
Waveform Reconstruction of Digital Storage Oscilloscope

Sampling Oscilloscope
Understanding the fundamentals and operation of a standard oscilloscope is required. It is an apparatus that concurrently projects the waveform onto the screen after receiving one or more electrical impulses. The sampling oscilloscope is a more sophisticated model of the digital oscilloscope that has additional functions and is intended for specialized applications.
Its purpose is to sample multiple wave forms one after the other in order to produce an extremely high-frequency function. The sampling theorem is used by this type of oscilloscope to create a waveform from several input signals. A portion of the motion may be seen by utilizing strobe light, but when several pictures are taken, a very quick mechanical motion is noticed. The sampling oscilloscope is a tool for observing extremely fast electrical impulses that works similarly to the stroboscopic approach. A waveform requires about a thousand points to be created.
Functioning of Sampling Oscilloscope
As implied by the name, it gathers data from many waveforms and uses the combined information to create a whole image of the waveform. The resulting waveform is displayed on the screen after being amplified using a low band pass filter. The entire shape of this waveform is created by connecting numerous dots that are connected to one another.

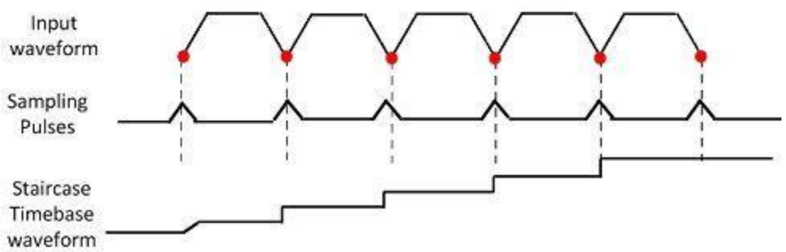
The vertical deviation of the progressive layer's point in each subsequent cycle of a staircase waveform is represented by each dot on the wave. They are employed to keep an eye on high-frequency communications that reach at least 50 GHz. The waveform that is being presented has a frequency that exceeds the scope's sample rate. It has a huge amplifier bandwidth of roughly 15 GHz and approximately 10 pieces per division or more. Signals are low-frequency during the sampling step, and they combine with an attenuator to achieve a large band-width.
However, the instrument's dynamic range is diminished. The sampling oscilloscope can only detect repeating signals; it cannot detect sporadic occurrences. Only when the range is restricted do they exhibit high frequency.



Sampling Oscillioscope



Sampling Oscilloscope Block Diagram



Principle of Sampling Oscilloscopes

Below is a figure that displays the sampling scope block diagram. To the delay line—where the signal is delayed—the input signal is sent. The precise timing difference that forms between the input and output signals is indicated by the signal delay. To the diode sampling gate is passed the output obtained from the delay line. In the capacitor is stored the signal sampled from the diode gate. Following amplification, it is supplied into the amplifier and sent to the display screen's vertical axis. From the amplifier to the diode gate, there is just one feedback. Based solely on the variation in the internal signal between samples, the feedback indicates that the voltage stored on the capacitor increases.

The following figure displays the waveform of a staircase. There is a reset after a number of steps, as the waveform indicates. In order to create the waveform, the screen contains more than 1000 points. In a cathode ray tube, the staircase waveform is employed. The spot on the screen is removed using it.

Delayed Sweep in sampling Oscilloscope

This method involves extending the duration of the scope sweep from its beginning to its triggering point. This enhances the instrument's versatility. One way to enhance the undelayed signal is via a delayed sweep oscilloscope. Numerous other applications can also benefit from it, such as determining the waveform's rising time or pulse time modulation.

Sampling Method

An oscillator and liner voltage are produced prior to every sample cycle by means of the trigger pulse. A sampling gate is opened to allow for an input voltage sample when the amplitudes of the two voltages are equal. The staircase moves one step forward and generates a sampling pulse. The staircase generator's step size determines how well the waveform resolves. Two methods are frequently employed, while there are other approaches as well. Both the equivalent sample approach and the real-time sample are used.

Real Time Sample Method

The high speed of the digitizer in the real-time approach allows it to register the most points in a single sweep. Its primary goal is to accurately record transitory occurrences with high frequency. Because the transient waveform is so distinct, it is impossible to correlate its voltage or current level at any one moment with those of its closest counterparts. Since they don't happen again, these occurrences must be recorded as soon as they happen. The sampling rate is approximately 100 samples per second, and the frequency is a relatively high 500 MHz. It takes a high-speed memory to store a waveform with such high frequency.

Equivalent Sample Method

The analogous technique of sampling operates on the premise of prediction and approximation, which can only be achieved with a recurring waveform. Similar to this, a digitizer obtains samples from numerous signal repetitions. For every iteration, it might use one or more samples. This improves the precision of signal capture. The resulting waveform's frequency is far more than the scope's sample rate. There are two ways to accomplish this kind of sampling: sequential and random.

Random Method of Sampling

The most popular sampling technique is the random method. It operates on an internal clock that has been set up so that it operates in response to input signals and continually records signal trigger samples, independent of the location of the trigger. The samples are taken on a regular basis in terms of timing, but they are randomly selected in terms of trigger.

Sequential Method of Sampling

This method of taking samples is independent of time setting and is triggered-agnostic. Sample recording occurs with a slight delay after each trigger detection. A very brief but well defined delay is what you want. In comparison to the preceding trigger, the next one is registered with a slight time delay. From a few microseconds to a few seconds, the delayed sweep can be used. In this way, samples are obtained repeatedly with incremental delays until the time frame is filled. Assuming the delay for the first time is "t," the delay for the second time will be somewhat greater than "t."

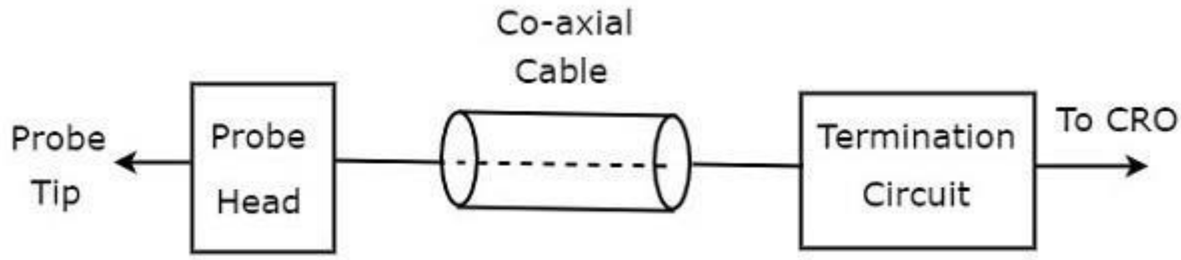
CRO Probes

Every test circuit can be connected to an oscilloscope using a probe to create an oscilloscope. The probe attached to the CRO oscilloscope, which is a simple oscilloscope, is also known as the CRO probe. The test circuit should not have any loading problems as a result of the probe that we have chosen. so that the test circuit with the signals accurately analyzed on the CRO screen.

CRO probes should have the following characteristics.

- ✓ High impedance
- ✓ High bandwidth

The block diagram of CRO probe is shown in below figure



The three blocks that make up the CRO probe are mostly depicted in the figure. The probe head, coaxial cable, and terminating circuit are those. The probe head and termination circuit are merely connected by coaxial cable.

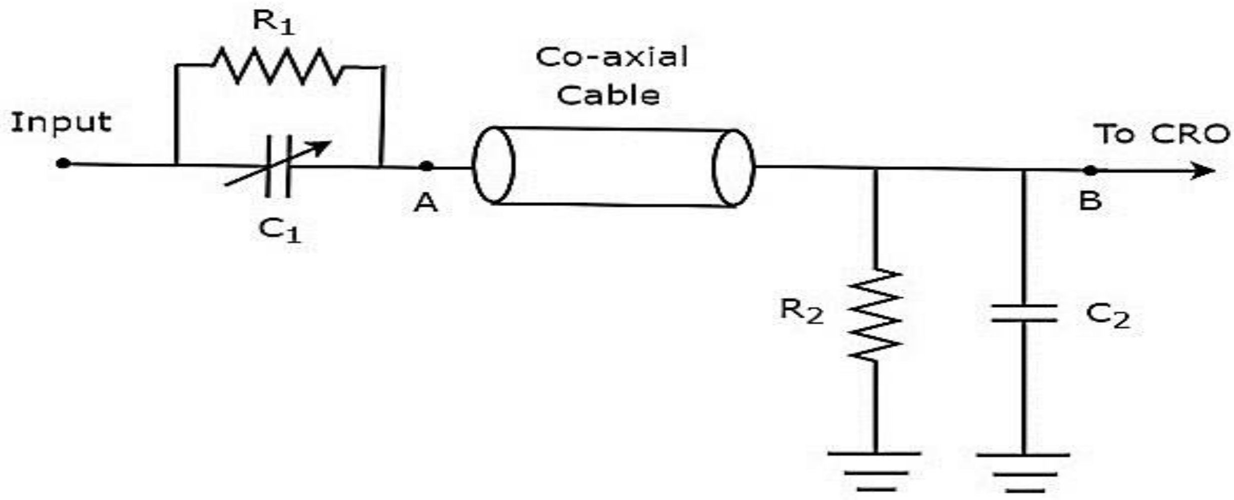
Types of CRO Probes

The two categories of CRO probes are as follows.

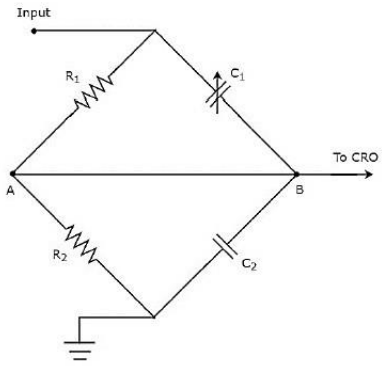
1. **Passive Probes**
2. **Active Probes**

Passive Probes

A probe is considered passive if its head is made up entirely of passive components. The passive probe's circuit diagram is displayed in the image below.



The probe head, as depicted in the picture, is made up of a variable capacitor, C1, and a resistor, R1, combined in parallel. Likewise, the circuit for termination has a parallel arrangement of resistor R2 and capacitor C2. The updated bridge circuit version of the preceding circuit diagram is depicted in the picture below.

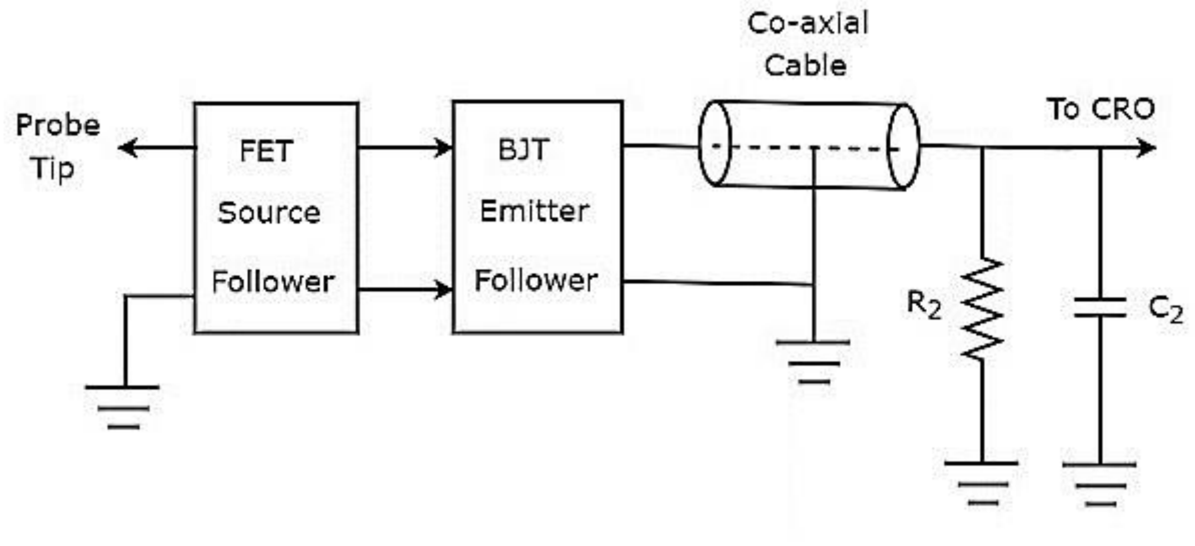


Adjusting the value of variable capacitor C1 will allow us to balance the bridge.

Z1Z4 = Z2Z3

In the equation above, replace the impedances Z1, Z2, Z3, and Z4 with R1, 1jωC1, R22, and 1jωC21, respectively.
R1(1/jwc2)=R2(1/jwc1)
R1C1=R2C2
The voltage across resistor R2 can be obtained using the voltage division method as
V0=Vi(R2R1+R2)
Input voltage (Vi) to output voltage (V0) is the ratio known as the attenuation factor. Thus, we may obtain the attenuation factor, ɑ, from the equation above as
ɑ=ViV0=R1+R2R2

Active Probes



If the probe head consists of active electronic components, then it is called active

The term "active probe" refers to a probe head that has active electronic components. Figure following displays the active probe's block diagram.

The probe head is comprised of a BJT emitter follower and a FET source follower in cascade, as depicted in the image. Low output impedance and high input impedance are provided by the FET source follower. In contrast, the aim of the BJT emitter follower is to prevent or remove impedance mismatching.

In both active and passive probes, the other two components—the termination circuit and coaxial cable—remain the same.