Controls and functions of Oscilloscope

Objectives : At the end of this lesson you shall be able to
- **explain the use of different controls**
- **explain the use of Alternate and Choped modes for two inputs**
- **explain sweep mode and relevent controls**
- **state the use of different sweep display modes**
- **explain the use of X-Y mode of operation**
- **explain the use of Z -axis input.**

Introduction

In addition to the standard front panel controls of a general purpose oscilloscopes, certain of the controls and functions which are essential while displaying the measurand clearly are discussed in this lesson. Also some tips while using the oscilloscope are also discussed in this lesson.

Focus and Intensity

When the oscilloscope is switched on with the power on switch, the first thing to do is to get a beam trace on the oscilloscope screen. Focus and intensity controls together help to get a sharp, low intensity trace. Lower intensity not only allows to focus the display to a very fine trace, but also increases the life of the CRT of oscilloscope. The trace intensity should never be so bright that it burns a hole in the phosphor coating on the CRT screen.

The damage to the CRT with an extra bright trace is much more severe, particularly when you are working at slower sweep speeds.

Astigmatism

Some oscilloscopes have astigmatism control that should be so adjusted that the focus control is effective on the horizontal and vertical portions of the trace. Simultaneously, astigmatism control should be adjusted with a pulsed waveform displayed on the screen.

Trace rotation

It can be used to make the beam trace perfectly horizontal in the absence of any input signal. It is usually a trimmer whose adjustment screw can be seen on the scope's front panel or on the rear panel.

Beam find

Often we come across a situation where we have switched the oscilloscope ON, increased the intensity level, selected the auto sweep mode and tried to adjust the horizontal and vertical position controls but still have not been able to see the beam trace. Beam find control can be used to locate the beam irrespective of where it is. Pressing this button compresses the range of horizontal and vertical position controls and the result is a dot somewhere on the screen. Keeping the button pressed, adjust the two position controls to bring the dot to the centre of your scope's screen. Release the button and you will see a trace right in the middle of the screen.

Horizontal and Vertical position

Horizontal position (indicated on some scopes as <---> and vertical position (indicated on some scopes as   ) are used to shift the trace horizontally and vertically respectively. There is usually a common horizontal position control in a dual trace oscilloscope. The position control shifts both the traces in the horizontal direction simultaneously. However, there are two separate vertical position controls for the two channels.

Calibration

All oscilloscopes have a CAL output. The amplitude and the frequency of the calibration signals are indicated on the front panel by the side of the output. The calibration signal can be used to check the amplitude and the time base calibration of the oscilloscope.

Some oscilloscopes provide two calibration signals, both having the same frequency but different amplitudes. Oscilloscope may have two calibration signal outputs i.e. 2Vp-p at 1 kHz and 200mvp-p at 1 kHz should be checked with both the signals. Scope's calibration should be adjusted at regular intervals.

In some oscilloscopes, the output of calibration is indicated by a glowing LED. You will find an LED near the time base setting and LEDs near the vertical deflection factor selector switches of the vertical input channels. Calibration signal is also employed to adjust the probe. The conditions of an under compensated or an overcompensated probe can be easily seen with the calibration signal used as a reference.

Bandwidth limit

Many high sensitivity, high bandwidth oscilloscopes have bandwidth limit control. Though higher bandwidth capability lets you capture high frequency signals, the unwanted high frequency noise also creeps in. It is particularly troublesome when we are viewing a very low level signal (say a few millivolts) of moderate frequency. Due to high bandwidth capability of the scope, the desired signal is often seen accompanied by a lot of hash.

Volts/div and time/div controls

Volts/div and time/div are the controls that need frequent adjustment while viewing and analysing signals. While the former selects vertical sensitivity and is set as per the amplitude of the signal to be viewed, the latter sets sweep speed and its setting is governed by the signal frequency. Both these controls have a selector switch setting and a fine control. The fine adjustment control in both cases should be kept in the calibrated position. The selectable positions in case of these controls are in the decades of 1-2-5.

In most oscilloscopes, there is provision for X5 magnification in the vertical deflection factor control which makes the oscilloscope more sensitive by a factor of 5. That is, 5 mV/

div to 5V/div range becomes 1mV/div to 1V/div. But then we must always remember that this enhancement in vertical sensitivity is at the cost of reduced accuracy. Accuracy specification of typically ±3 percent may deteriorate to ±5 percent. This magnification is usually obtained by pulling the fine adjust control knob in the vertical deflection factor selector switch.

Similarly, a magnification of X10 is usually available in the time base setting, which means that sweep speed at any setting can be increased by a factor of 10 by using this feature. This enhancement is also at the expense of degradations in sweep speed accuracy. The change in accuracy may again be from ±3 percent to ±5 percent. X10 magnification is also achieved by pulling the fine control adjust knob in the base selector switch.

In some oscilloscopes, the time base selector has two switches and a fine adjust. One of the two switches, selectable by bigger of the two knobs, is used to select the main sweep speed. There is another switch concentrically located with a smaller knob. This is used to choose the delayed sweep speed. This second rotary switch is present only in oscilloscopes having delayed sweep facility. Also, the two switches are so internally arranged that the delayed sweep speed can never be set to be slower than the main sweep speed.

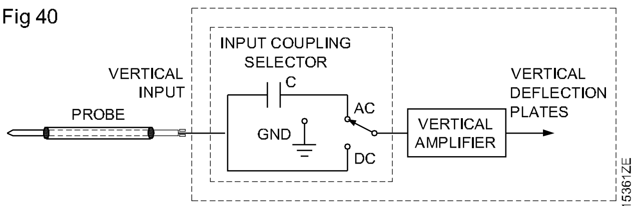
Input coupling

The coupling selector is a three-way switch, to select either DC or AC coupling and ground. In DC coupling, the input signal is fed directly into the amplifier, while AC coupling enables blocking of the DC component of the input signal and passes only the AC component of the signal to the Y amplifier. In the ground position, the input of the Y amplifier is grounded. Hence, care should be taken to ensure that the input signal is not grounded in the ground position and that only the input point of the Y amplifier in the oscilloscope is grounded.

Vertical input coupling modes

All oscilloscopes have two vertical input coupling modes, namely AC coupling and DC coupling as shown in Fig 1. In DC coupling selection, the signal to vertical input BNC receptacle is directly routed to the input of the relevant vertical amplifier as shown in Fig 40 inside the scope. As a result, what you see on the oscilloscope is what you feed into it.

Fig 40



VERTICAL INPUT COUPLING MODES

The DC coupling mode is used in majority of oscilloscope measurements whether it is measuring DC amplitudes or seeing logic low and high levels over analysing transient and repetitive AC waveforms over the specified bandwidth of the oscilloscope. However, when it comes to measuring only the amplitude of a certain DC voltage with no intention of analysing the quality of DC or looking for presence of any noise spikes, the oscilloscope in the DC coupling mode does the job.

In the AC coupling mode, the applied signal is routed to the vertical amplifier input through capacitor (Fig 1) with the result that DC, if any, in the signal gets blocked and only the AC or the time varying part is able to get through and reach the vertical amplifier input. So the displayed waveform is not what you actually feed. For instance, if you want to analyse noise spikes or ripple content riding on a DC you would have no option other than going in for the AC coupling mode.

In the DC coupling mode, the beam would go off the screen as you increase the vertical sensitivity to get an expanded display of comparatively much smaller ripple amplitude. In the AC coupling mode, you could expand the display and make the ripple portion fill the entire screen for detailed analysis.

There is a ground position (designated GND) available on the coupling selector. In this position, the input of the vertical amplifier is grounded and this position can be used to know the position of the beam for zero input.

Input impedance

This is the impedance at the Y input point and is normally specified as 1 M ohms shunted by 25 pF. It is actually the effective resistance and capacitance across the Y input. All oscilloscopes have a standard input impedance of 1M ohm paralleled approximately by 25 pF.

Maximum input voltage

It is the maximum voltage that can be safely applied to the Y input of the oscilloscope. For example, a model specifying the maximum input voltage to be 400V (DC + peak AC) means that the voltage of the signal to the input cannot exceed 400V, which includes both the DC voltage and the peak AC voltage of the signal.

Vertical operating modes and relevant controls

In a dual trace oscilloscope, if the two vertical input channels are designated CH1 and CH2, the available vertical operating modes usually are CH1, CH2, ALT (alternate), CHOP (chopped) and CH1 + CH2. CH1 mode selection implies that the beam traces the waveform applied to the channel-1 vertical input every time it sweeps across the screen.

With CH1 + CH2 mode selected, each sweep across the screen traces channel 2 vertical input waveform. When CH1 + CH2 mode (also referred to as ADD mode) is selected, what we see on the screen is sum of CH1 and CH2 signals as a function of time. Alternate (ALT) or chopped (CHOP) modes are selected when we intend to see two different signals simultaneously.

Alternate or chopped

ALT and CHOP modes are used in two different situations. In the ALT mode, CH1 and CH2 signals are traced on alternate sweeps, i.e if nth sweep traces CH1 signal then (n+1)th sweep would trace the CH2 signal, (n+2)th would trace the CH1 signal again and the process would continue.

If the sweep speed is low, say slower than 10 ms/div or so, we will see a blinking display of the two sweeps. For faster sweep speeds, the two displays appear to be present at the same time. The ALT mode display of two channels thus gives an uncomfortable display when the signal frequencies are low. This mode should preferably be used for viewing high frequency signals.

In the CHOP mode, each sweep across the screen switches the beam between CH1 and CH2 at a very fast rate (the chopping frequency is typically 50 kHz to 100 kHz). In fact, we can see this chopping effect by selecting the CHOP mode and choosing a time base setting faster than the chopping frequency. CHOP mode is not suitable for viewing very high frequency signals as you are likely to miss vital signal information during the time period when the sweep is tracing the other signal. CHOP mode is, however, the right mode to select for viewing signals having frequencies of a few kilohertz or more.

In some oscilloscopes (usually the ones with lower bandwidth) we do not have a separate select button for CHOP and ALT modes. Instead, we have the dual mode in which the oscilloscope has in built circuitry to give a chopped sweep operation for lower frequency signals (or slower time base settings), and an ALT mode for viewing high frequency signals (or faster time base settings). The range of time base setting for which the scope offers a CHOP mode or an ALT mode is usually indicated on the time base selector switch.

In the front panel of a oscilloscope you would notice a light coloured semi-circular band from 0.5 s/div setting to 1 ms/div setting indicating the CHOP mode and another dark semi-circular band from 1 ms/div indicating ALT mode.

LF Rejection

This is a method of coupling the trigger signal with the trigger circuit. The trigger signal is fed to the trigger circuit via a high-pass filter, where the low frequency component (less than 10 kHz) is eliminated. Thus, triggering is effected only by the high frequency component. When the trigger signal contains low frequency noise (particular hum) it is eliminated so that the triggering is estabilished.

HF Rejection

In this method, the trigger signal is fed via a low-pass filter where the high frequency component (more than 30 kHz) is eliminated. Triggering is effected only by the low frequency component.

Triggering modes and relevant controls

All modern oscilloscopes are triggered sweep oscilloscopes, i.e. each sweep across the screen is initiated by a trigger signal either generated inside the scope or supplied externally. The source of trigger signal, the way it is coupled and the controls like ‘trigger slope’, ‘trigger level’ and ‘trigger hold off’ enable you to make full use of the equipment and get a stable display of many a complex waveforms or trigger on the most elusive transient events.

Source of trigger signal

This first relevant control is the one that selects the source of trigger signal. The available options in most of the oscilloscope are internal (INT) line, external (EXT).

When we have selected the INT source of trigger, the trigger signal is generated from the signal to be viewed. A small part of the vertical input signal is taken off, amplified, shaped and then treated as the trigger signal. In a dual channel oscilloscope, where we have two vertical inputs, a separate control decides whether it is a part of CH1 signal or CH2 signal that is to be used for generating the trigger signal. Here, if we select ALT, the trigger signal source is according to the vertical mode displayed. We should also remember that selection of CH1 signal or CH2 signal or ALT trigger arises only when trigger source selection is on INT.

When the trigger source is line, the oscilloscope picks up 50 Hz signal from its power transformer and uses this for producing trigger signal. It is suitable for getting a stable display of signals having power line frequency like ripple on a power supply.

In the EXT mode, the trigger signal is applied externally. The trigger signal amplitude requirements are specified by the manufacturer. Some scopes also have EXT/5 or EXT/10 trigger inputs. The trigger signal applied to this input is alternated by the given factor before it is applied to the trigger circuit. This mode is used when the external trigger signal level is too high.

Trigger source coupling mode

The coupling mode selector determines the way the trigger signal is coupled to the trigger amplifier. The available options on most of the 100 MHz oscilloscopes are DC, AC, Low Freq Rej (low frequency reject), High Freq Rej (high frequency reject) and TV. The Low Freq Rej coupling mode is usually not present in lower band-width oscilloscopes (upto 50 MHz bandwidth).

In DC coupling of trigger source, the trigger signal is directly coupled to the trigger circuitry. This mode is used when triggering is required to be effected including the DC component of the trigger signal. It is suitable for viewing DC and low frequency signals.

In AC coupling, the trigger signal is AC coupled to the trigger circuit. This is the most commonly used trigger source coupling mode as stable triggering can be achieved without being affected by the DC component of the input signal.

In the Low Freq Rej mode any frequency component below a few kilo-hertz present in the trigger signal attenuated. This mode should be used when low frequency components, 50 Hz hum for instance, is present in the trigger signal. High Freq Rej mode is used when any high frequency components present in the triggering signal are creating problems in getting a stable display. In this mode, high frequency components greater than 50 kHz present in the trigger signal are attenuated.

The TV coupling mode is used exclusively for viewing TV video signals. The signal is AC coupled to the TV sync separator circuit. The sync separator picks up the sync signal which is then used as the trigger signal. With this mode we can obtain a stable display of TV video signals.

Trigger slope and level

Trigger slope selection determines the slope of the trigger signal that triggers the sweep. When we select a (+) slope, the sweep is triggered anywhere on positive going or low-to-high transition of the signal. In case of (-) slope, the sweep is triggered anywhere on the negative going or high to low transition of the signal.

The trigger level decides the signal level (positive or negative) where the triggering takes place. If the signal has both positive as well as negative amplitudes, we can trigger on a positive slope and a negative level or a negative slope and a positive level as well. When we select a positive slope, the waveform can be triggered anywhere on the positive slope of this waveform, i.e. from negative peak towards positive peak. The level can be either negative or positive. Similarly, when we select a ($-V_e$) slope, the waveform can be triggered anywhere on the negative slope, i.e. from positive peak towards negative peak. The level can either be positive or negative.

Trigger hold-off control

This control can be used to adjust the pause between initiation of two successive sweeps and is particularly useful for viewing signals that do not repeat symmetrically. In the absence of trigger hold-off feature, it may be difficult to get a stable display of waveform of this kind. The trigger hold-off control can be used to trigger the sweep at the right time.

Sweep modes and relevant controls

The first selection that we have got to do is that of the sweep triggering modes. Usually, three modes are available on almost all oscilloscopes. They are auto (automatic), normal and single sweep modes.

In the auto sweep mode, the sweep generator is a free-running oscillator if there is no triggering signal, internal or external. That is, if the trigger source has been chosen to be INT, we will see a beam trace even in the absence of any vertical input. When a triggering signal is applied, the scope becomes a triggered sweep one and the trigger signal initiates the sweep as per slope and level settings. The auto mode is quite convenient when we are interested in seeing DC voltages or simple waveforms.

In the normal sweep mode, the triggering signal only initiates the sweep. In the absence of any trigger, we do not see any trace on the oscilloscope screen. In the normal mode, we have to carefully select the slope and adjust the level to get a display of the signal. This mode is suitable for viewing complex waveforms and single shot events.

In the single sweep mode, when a triggering signal is applied, the first genuine trigger initiates a sweep and after that all subsequent triggers are ignored. So there is only a single sweep. When the single sweep mode is selected, the oscillosope gets ready to receive the trigger. This mode is very useful for viewing single-shot events.

Sweep display modes

The second selection that needs to be done is that of the sweep display mode. The available choices are the main sweep, delayed sweep, intensified sweep, triggered delayed sweep. These may be designated as A-sweep (mainsweep), B-delayed sweep (delayed sweep), A-intensified (intensified sweep) where the two input channels are referred to as A and B.

The main sweep is what we have been referring to so far. Its speed is set by the main time/div selector switch. It is suitable for most measurements. But what happens when we want to view a small part of a comparatively lower frequency signal on an expanded scale to look for noise glitches? If we try to expand the time base, the desired portion on the waveform is likely to go off the screen and all our efforts to bring it to the centre of the oscilloscope screen with the horizontal position control are rendered unless. One method to overcome this is to use X10 magnifier available with the main sweep. Engaging the magnifier expands the time base by a factor of 10 around the centre of the screen with the result that the desired portion stays on screen. This process is known as magnified sweep.

Magnified sweep too has its own problems. First, the intensity of the sweep diminishes quite a bit on expansion and second, this expansion may not be sufficient to permit a view of very fast glitches, for instance, a few nanoseconds wide glitch sitting somewhere on a waveform with a time period of a few milliseconds.

Delayed sweep is what comes to our rescue in such cases. As mentioned earlier, we have at our disposal two independent time base settings, one for the main sweep and the other for the delayed sweep. To make use of the delayed sweep facility, set the delayed time base at a much faster speed than the main time base. There is also a delay time multiplier (a multiturn potentiometer) control on the panel. Set that to the centre of its range. Engage the intensified sweep button. We would notice a small portion of the waveform being viewed on main sweep getting intensified. This implies that we have engaged the delayed sweep. The width of this intensified portion depends upon the time base setting of the delayed sweep.

The photograph is for a delayed sweep of 5ms/div. The width becomes narrower as we make the sweep faster. Thus, faster the delayed sweep, narrower is the intensified portion and larger is the magnification that we get. The position of this intensified portion is as per the part of the waveform we wish to expand.

After having adjusted the two things, engage the delayed sweep mode. The intensified portion fills the entire screen. In this mode, we can achieve much higher magnification without sacrificing the intensity. In some scopes, there is a provision for viewing the main sweep signal and the intensified delayed signal simultaneously. Most of the 100 MHZ oscilloscopes have this facility. The availability of this feature is indicated by the ALT sweep display mode. To use this facility, depress ALT sweep display instead of main sweep.

B Ends A mode

Sometimes it is observed that when the delayed sweep to main sweep speed ratio is very high, the expanded display in the delayed sweep mode has somewhat reduced intensity. B Ends A mode can be used to increase the intensity of delayed sweep display by ending the main sweep at the minimum required point and increasing the display time for the delayed sweep. This happens because the slow main sweep runs for the full screen and there is very little time for the much faster delayed sweep.

Some oscilloscopes also have triggered delayed sweep facility. Operationally, it is similar to delayed sweep. In the delayed sweep mode, the delay time multiplier can be adjusted to smoothly move the intensified portion on the screen. In the triggered delayed sweep, the intensified portion jumps from one level transition to the next as the adjustment is done. After selecting the desired transition level where you want to trigger the delayed sweep and after selecting a proper slope (+) for positive going and (-) for negative going transition - the delayed sweep is engaged. This mode gives a highly reduced display jitter as the sweep is triggered by a definite trigger signal level.

X-Y operation

In the X-Y mode, the horizontal axis of the oscilloscope also represents a voltage rather than time as is the case in the usual oscilloscope operation. The time base circuitry gets bypassed. The signal to be represented on the horizontal or X-axis is applied to the horizontal deflection input available on the front panel of the oscilloscope having X-Y mode feature.

CH3 input is the horizontal input. It has two selectable horizontal deflection factors of 100mV/div. and 1V/div. i.e. 100mV signal (in case of 100mV/div. selection) and 1V signal (in case of 1V/div. selection) will sweep the beam horizontally by one division. The other signal is applied to the vertical input (one of the two vertical inputs in a dual channel oscilloscope). The result is the desired X-Y display.

A major problem with this kind of X-Y mode of operation is that it offers an uncalibrated fixed sweep speed. This problem is, however, overcome in majority of modern dual channel scopes by letting one of the two vertical inputs to be used as a horizontal input in the X-Y mode. The oscilloscopes having this provision will have the letters 'X' and 'Y' written near the input connectors of the two channels to indicate X and Y inputs when we select the X-Y mode. Thus, both horizontal and vertical axes have variable calibrated deflection factors.

One can also notice that the vertical position control corresponding to vertical channel being used for X-input in X-Y mode can be used to deflect the X-Y display horizontally. X-Y operational mode has numerous applications like plotting transfer characteristics of devices and circuits, measuring phase difference between two given signals having same frequency, measuring an unknown frequency etc.

Z-axis input

The oscilloscope display has three components: the horizontal component (X-axis component), the vertical component (Y-axis component) and the beam intensity (Z-axis component). The intensity remains constant for a particular setting of the intensity control during normal operation. Most of the scopes have an external Z axis input located on the rear panel. A signal fed to this input can be used to modulate the intensity of the display. Use of this input in conjunction with vertical inputs has many interesting applications.

This class room session is expected to be highly interactive and brainstorming. In this session, the instructor should take-up each of the objective listed above separately and guide the trainees to develope a procedure for carrying out the task. For example, in this classroom session, the instructor should first take-up the first objective "**procedure to calibrate the given CRO using internal calibration signals"** and brief the trainees the nature of task (calibration of CRO).

The instructor should then divide the class into 4 groups and instruct them to draft the procedure to carry out the task in hand ("to calibrate the given CRO using internal calibration signals"). To aid the trainees work, they should be provided with copies of the oscilloscope manuals, related reference books (available in the library) and advised to refer previous lessons on oscilloscope. With these reference materials in hand and the demonstration witnessed by them in the previous exercises, the trainee groups should draft the procedure for carrying out the task in hand (each group should develop one draft).

The draft developed by each group should be discussed with the entire class. During the discussion, the trainees should be motivated to point out procedural errors in the drafts and suitable correction to it. After discussing all the drafts (4 drafts in a class of 16 trainees), the instructor should generate a procedure taking all vital points from the drafts. This shall be used as the final procedure for carrying out the task in the laboratory.

L.C.R. Meter

The LCR meter is an electronic test equipment used to measure among other parameters the impedance of a component (fig 41 and 42)

Fig 41

Usually the device under test (DUT) is subjected to an AC voltage source, then the voltage over and current through device under test are measured. The measured inpedance consists of real and complex components. The phase angle is also an important parameter.

Fig 42

L.C.R. METER

EMN15361ZG

A signal generator with a multimeter and an oscilloscope forms the trio work-horse instrument of an electronic mechanic. The signal generator generate a wide variety of signal waveforms covering broad signals. Therefore, signal generators are classified in two main subdivisions based on waveforms produced and frequency ranges covered. Based on the signal waveforms produced the following main types are popular;

1 The sine-wave generator

It is most common for general-purpose testing. It is widely used in both continuous-wave (CW) and amplitude-modulated (AM) forms.

2 The square-wave generator

It is also commonly found in laboratories and is used for amplifier response testing and in performing other wave-shaping functions.

3 Pulse generator

With a facility for broad selection of pulse duration and repetition rates, these are employed for example for timing and testing electronic circuits both analog and digital.

Square-wave generators

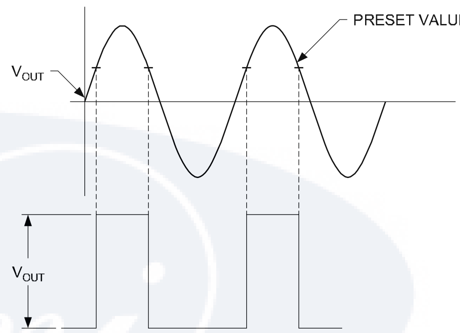
Generators for producing this type of waveform fall into two main groups: the combination sine and square-wave generators and the square-wave generators.

The first group offers a choice of either waveform but does not give the precision of square-wave output of the second group. The square wave generators provides only square waves with high precision. In relatively inexpensive combination generators, a pseudosquare wave is often produced by simply clipping the original sine wave either by diode clipping or overdriven amplifier action. As a result, the products of such action retain the rise and fall portions of the sine wave. In such cases, only an approximate square wave is produced, suitable only for limited wave-shaping observations.

Combination generator

A typical laboratory combination generator generates true square waves as shown in Fig 43 with a Schmitt-trigger circuit. It generally provides frequency ranges of 10 hertz to 100 kilohertz for the square wave section. The rise time of the square wave at full-scale deflection will be generally less than 750 nanoseconds and the tilt is approximately 5 percent at 20 hertz. The peak-to-peak square-wave output will be generally 6 volts, with provision for attenuation in steps of 10 decibels each. Direct output upto 73 volts (p-p) is also provided by-passing the attenuator section.

Fig 43



EMN15361ZH

Square wave generator

A typical laboratory square-wave generator, produces square waves with flat horizontal portions, free of any noticeable overshoot and ringing. The square waves will generally have a rise time of less than 0.02 microsecond (20 nanoseconds) over the frequency range of 25 hertz to 1 megahertz. The frequency, obtained by the setting of a step switch and a continuously variable fine-frequency control can be read directly from the meter provided on the equipment.

Signal generators based on its frequency coverage

The frequency range in a signal generator can affect its operational characteristics markedly. Ranges vary from audio frequency (AF from 20 to 20,000 hertz) to radio frequency. The R-F ranges in telecommunication alone extend well into the gigahertz region, covering ranges where the higher frequencies are millions of times greater than the lower R-F frequencies as given in the Table below.

Table : Regions of the frequency spectrum

Region	Frequency band	ITU Band* No.
(VLF) Very low frequencies	3×10^3 to 3×10^4 (30 kHz)	4
(LF)Low frequencies	3×10^4 to 3×10^5 (300 kHz)	5

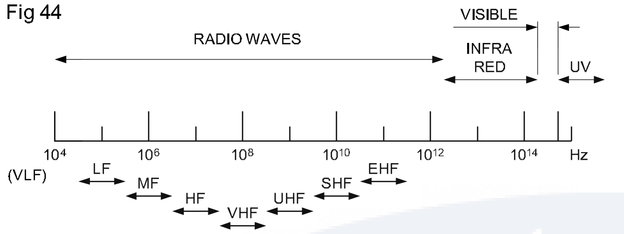
(MF) Medium frequencies	3 x 10^5 to 3 x 10^6 (3 MHz)	6
(HF) High frequencies	3 x 10^6 to 3 x 10^7 (30 MHz)	7
(VHF) Very high frequencies	3 x 10^7 to 3 x 10^8 (300 MHz)	8
(UHF) Ultrahigh frequencies	3 x 10^8 to 3 x 10^9 (3 GHz)	9
(SHF) Superhigh frequencies	3 x 10^9 to 3 x 10^{10} (30 GHz)	10 (or 1cm)
(EHF) Extremely high frequencies	3 x 10^{10} to 3 x 10^{11} (300 GHz)	11 (or 1cm)

***International Telecommunication Band Number**

The more common name microwave frequencies is generally used to span the regions of SHF and EHF. Radar bands in these regions have distinctive names, such as the X-Band at around 10 gigahertz.

Useful frequency regions are being explored at both the lower and upper edges of the electromagnetic spectrum shown graphically in Fig 44.

Fig 44



GRAPHIC VIEW OF ELECTROMAGNETIC SPECTRUM

Audio frequency generators

Signal generation is based on the oscillator. in addition to the common regenerative feed-back amplifier with LC resonant circuit various RC combinations can be used for the oscillating circuit of a signal generator. The one almost universally employed in practical AF generators is the Wien-bridge circuit.

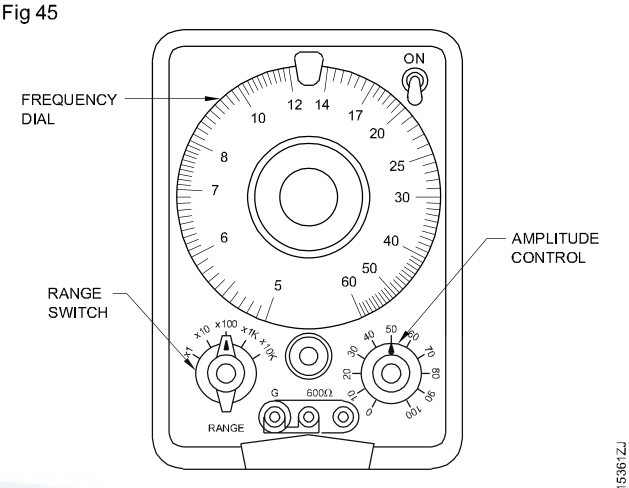
An LC circuit would require bulky nonlinear inductors for changing frequency ranges at lower frequencies. The RC circuit changes range by the use of precision resistors. Moreover, the stability of the RC circuit against changes in load is much better than the stability of an LC circuit, which reacts to load changes with variations in both the frequency and amplitude of the output. Thus even though the RC circuit requires more stages of amplification that required in an LC circuit, the resulting circuit is much more suitable for laboratory purposes and for use in practical instruments.

The AF oscillator shown in Fig 45 generates practically pure sinusoidal waveforms over the range 5 hertz to 600 kilohertz. This range includes signals in the subsonic, audio and ultrasonic bands. There are five overlapping decade bands. The first covers 5 to 60 hertz and the last 50 to 600 kilohertz. At all frequencies, output can be as great as 20 volts runs on open circuit; when delivering a signal to a 600 ohm load, the voltage across the load is one-half the open-circuit voltage, or 10 volts. The power in this matched load is thus E^2/R or

10 x 10 volts/600 ohms = 1/6 watt or 167 milliwatts

Although 167 milliwatts does not look to be large value remember that it represents a comparatively large voltage

Fig 45



AUDIO FREQUENCY GENERATOR

under ordinary test conditions. For any given setting of the amplitude control, the output signal is stable as the frequency is varied and remains undistorted within the tolerances below.

Frequency coverage: 5 hertz to 600 kilohertz (or 1 hertz to 100 kilohertz in alternate model)

Calibration accuracy: ±2 percent under normal conditions

Frequency response: Within ±1 decibel (of a 1000 hertz reference) over entire frequency range.

Frequency stability: Negligible shift in output frequency for ±10 percent line-voltage variations.

Distortion: Less than 1/2 percent below 500 kilohertz (less than 1 percent above 500 kilohertz) independent of load impedance.

Balanced output: May be obtained (at maximum output) with better than 1 percent balance; or may be operated single-ended (with low side grounded), at an internal impedance of 600 ohms, for any portion of output attenuator.

When desired, the output can be obtained ungrounded by using only the high and low output terminals and leaving the ground terminal unconnected. The circuit retains its desirable characteristics throughout a variety of AF and even RF testing conditions where a pure sine-wave signal of constant amplitude over a wide frequency range is required in the laboratory.

Other version of the AF signal generator using the Wien-bridge arrangement, offers some interesting additional features. One such is that it can be synchronized from an external source and extended frequency range of 2 hertz to 2 megahertz.

When an external signal of atleast 1 volt is introduced into the ext sync jack, the oscillator locks in when it is within ±3 percent of the frequency of the introduced signal. This lock-in range can be increased proportionally as the external sync signal becomes greater. If it is a 10 volt sine wave, the frequency of the oscillator may be locked within 30 percent either side of the input signal. Besides the obvious synchronizing application of locking the oscillator output to a crystal-frequency standard, other applications include service as a phase shifter in an amplitude modulation source and an automatic phase-controlled oscillator.

Radio frequency generator

A radio-frequency generator suitable for laboratory applications as a "standard signal generator" must be able to generate frequencies from, around 100 kilohertz upto about 30 megahertz. Also it must have an output signal stable both in frequency and amplitude. It is easy to get an oscillator to oscillate in this range; but difficult to keep the frequency and amplitude constant in spite of slight changes in normal operating conditions.

A ±1 percent change in a nominal output frequency of 1000 hertz (or ±10 hertz) might easily be tolerated for an AF signal; the same change in a 10 megahertz signal would shift the frequency of 100,000 hertz and might easily detune a high-Q tuned circuit. Maintaining and checking the frequency stability of high frequency circuits is greatly simplified by the use of crystal oscillator and crystal calibration circuits. The crystal oscillator is inherently very stable and can provide constant frequencies within much better than 0.01 percent (or 1 part/10,000). When used in a crystal oven it will furnish accuracies of 1 part/1,000,000 (±0.0001 percent). For most laboratory applications, direct reading of the variable-frequency dial to around 1 percent is sufficient, if this dial frequency can be checked against a crystal calibrator whenever greater precision, usually upto ±0.01 percent is desired.

Besides being able to generate a reliably known frequency the standard signal generator must also provide that the signal be accurately calibrated in microvolts of amplitude and be capable of being modulated to a known percentage. The known amplitude calibrated in microvolts is provided by a low-impedance, variable attenuator, monitored by a meter generally labeled carrier microvolts. The low impedance is necessary to maintain constant output as the generator is fed into various loads. The output of the generator is normally provided by a coaxial cable terminated in a low resistance, generally of 50 ohms. The impedance seen by the load, which is this resistor in parallel with the attenuator is usually much lower. This low output impedance is maintained at all settings of the attenuator, which can vary the output from a few microvolts up to calibrated values of 100,000 microvolts and also upto 1 or 2 volts uncalibrated.

Typical specifications of a RF generator

Frequency range: 75 kilohertz to 30 megahertz in different ranges. Each range is push-button selected, and the frequency dial set for any frequency within that range by a reversible motor, which turns the variable capacitors.

Modulation: Continuously variable from 0 to 100 percent either at 400 or 1000 hertz or from an external source.

Output: Continuously variable from 0.1 microvolt to 2.2 volts, at an output impedance of 5 ohms (upto 2 megahertz) rising to 25 ohms (at 30 megahertz). Incidental frequency modulation is less than 0.01 percent at 30 percent amplihertz (or ±10 hertz) might easily be tolerated for an AF signal; the same change in a 10 megahertz signal would shift the frequency of 100,000 hertz and might easily detune a high-Q tuned circuit. Maintaining and checking the frequency stability of high frequency circuits is greatly simplified by the use of crystal oscillator and crystal calibration circuits. The crystal oscillator is inherently very stable and can provide constant frequencies within much better than 0.01 percent (or 1 part/10,000). When used in a crystal oven it will furnish accuracies of 1 part/1,000,000 (±0.0001 percent). For most laboratory applications, direct reading of the variable-frequency dial to around 1 percent is sufficient, if this dial frequency can be checked against a crystal calibrator whenever greater precision, usually upto ±0.01 percent is desired.

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The amplitude and frequency stability of standard-signal RF generator is obtained by careful design of amplifying and isolating circuits, as well as of the primary circuits, whose function is to produce stable oscillations.