The ubiquitous oscilloscope

There's no substitute for 'looking inside' a circuit when you really want to know what's going on. The oscilloscope must surely be the most versatile electronic instrument ever invented. Les Bell and Roger Harrison take you on a guided tour, from how they work to how to buy to who supplies them.

ONE OF THE BIGGEST barriers people face when they take up electronics is cultivating the ability to visualise what is happening in a circuit. It is fairly easy to work out the dc conditions in a circuit, but electronic circuits are generally dynamic in nature; that is, the voltages and currents in a circuit change according to an applied signal or function of the particular circuit (as in amplifiers and oscillators, respectively).

The problem is, you can't *see* what's happening! The "good books" may tell you what happens *ideally*, but the real world is very often quite different.

What's needed is some kind of 'window' into the circuit, to enable you to 'see' what's happening, to get that intuitive 'feel' which will make understanding that much easier. That window is, of course, the oscilloscope. Without it, the circuit designer may very well be 'blinded'.

Oscilloscope basics

The heart of a Cathode Ray Oscilloscope, or CRO as they are more commonly called, is the *cathode ray tube*. Its construction and basic operation are explained in the accompanying box. There are two basic types of cathode ray tube – those employing electrostatic deflection and those employing magnetic deflection.

Electrostatic deflection types are commonly employed in measuring instruments as they offer much greater bandwidth operation than magnetic deflection tubes which are principally limited by yoke inductance. On the other hand, electrostatic deflection tubes are limited to beam deflection angles less than 20° off axis while electromagnetic systems can achieve a maximum deflection of ±55°. This is why oscilloscope tubes (electrostatic types) are so much slimmer than TV tubes (which use magnetic deflection) of similar length.

Some demonstration and teaching oscillopes use standard TV tubes with magnetic deflection. Whilst the display is massively larger than a standard oscilloscope, the bandwidth limitations only allow them to display signals generally less than 100 kHz maximum. Oscilloscopes using electrostatic Cr tubes may have bandwidths of 10 MHz commonly, and up to 100 MHz without using special techniques.

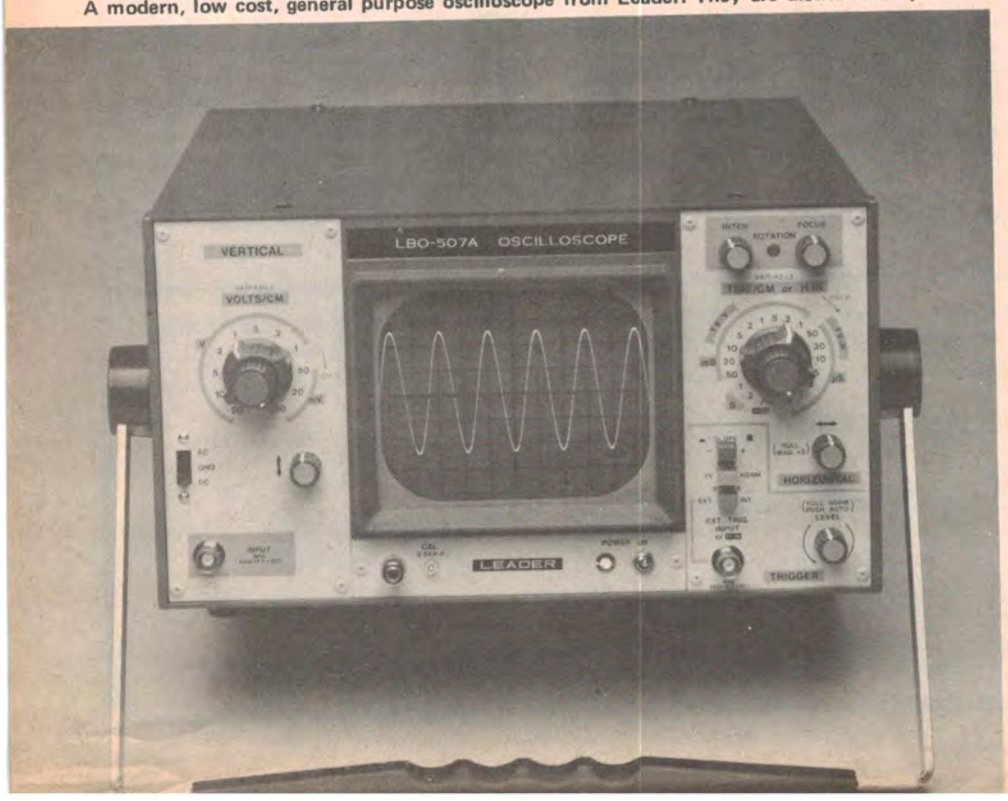
The general purpose of an oscilloscope is to examine voltages (or sometimes, currents) as they change with time. There are other modes of operation, but as this is the fundamental one, let's start with it.

In order to display a waveform that is varying with time, we must draw the 'spot' across the face of the tube, from left to right, return to the starting point and repeat. To do this, the voltage impressed on the X deflection plates is increased at a linear rate with time, to draw the spot from left to right, then reduced to zero (or the starting voltage) suddenly to return the spot to the starting point, and so on.

This establishes a 'time base' as the spot takes a known amount of time to travel from left to right across the screen.

At the same time, the waveform to be examined (suitably amplified) is applied to the Y deflection plates. The spot will then trace out a graph of the waveform on the CR tube screen as shown in Figure 1.

A modern, low cost, general purpose oscilloscope from Leader. They are distributed by Vicom.



If the time taken for the spot to travel across the screen has a definite relationship to the frequency of the waveform being examined, and if the start of the trace (at the left hand side) is arranged to commence at some definite point on the waveform (i.e. synchronised), then a stable trace will result on the screen.

For example, say we wish to display two cycles of a 50 Hz mains voltage. The horizontal deflection, or timebase, would have to 'sweep' the spot from left to right in the length of time it takes to complete two cycles at 50 Hz – 40 milliseconds. The timebase would make 25 sweeps per second: that is, it would be running at 25 Hz.

In a practical oscilloscope, during the 'return' sweep of the X deflection (sometimes termed the 'flyback'), the electron beam of the CR tube is turned off, or 'blanked', so that it is not displayed – otherwise, the resultant squiggle would become confused with the desired display!

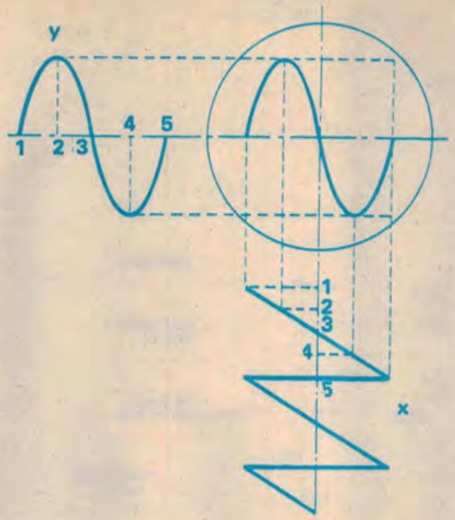
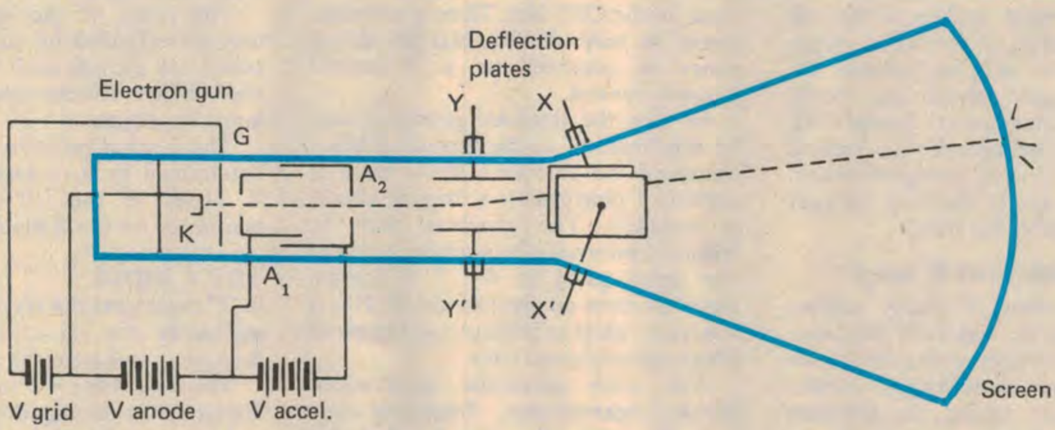


Figure 1. **Showing how the deflection waveforms applied to the X and Y plates of a cathode ray tube cause the electron beam spot to trace out a faithful replica of the Y-input waveform.**

The signal applied to the X deflection plates of the CR tube is often referred to as the 'sweep' voltage, or just 'the sweep', although the term 'timebase' is generally more common.

Oscilloscope manufacturers include a 'graticule' on the screen of their instruments as a convenient reference, enabling quite accurate time an amplitude measurements to be made. The graticule may be a transparent plastic cover placed over the CR tube face, scored with grid lines at convenient intervals (generally 10 mm) or, as in the more expensive types, it may be scored directly on the face of the CR tube during manufacture. The latter provides a more accurate reference than having a separate, external, graticule.

The general form of most general-purpose oscilloscopes is shown in Figure 2. As you can see, there are four basic components: the Cathode Ray Tube, the Vertical Circuits, the Horizontal Timebase Circuits and the Power Supplies.



The cathode ray tube

The component at the heart of the oscilloscope is the cathode ray tube. It consists of an evacuated, tubular glass envelope, flared at one end. In the tubular portion, or the neck, is an "electron gun". This generates a narrow, focussed beam of fast-moving electrons which are directed towards the flared end, past a set of parallel plates (the deflection plates), the large end of the tube being covered in a special coating (on the *inside*) called the 'phosphor'. When the electrons strike the phosphor, it emits light ('fluoresces') and you see a spot. Spot deflection is achieved by varying the electrostatic field between the deflection plates. Some CRTs use electromagnetic coils around the neck of the tube for spot deflection (TV tubes for example!)

The electron gun contains a *heated cathode* (K) which 'boils' off electrons. These are attracted to an *anode* (AI) which is very much more positive than the cathode, at least several thousand volts. As they accelerate towards the anode, the electrons pass through a *control grid* (G) which is a cap of metal around the cathode and somewhat negative with respect to it. This electrode is used to control the brightness of the spot. If the negative potential on G (with respect to K) is increased, fewer electrons will pass and the spot brightness will decrease, and vice-versa.

Between the control grid and the focussing grid there may be a second grid, the *screen grid,* which is usually around 300 V positive. Following the *focussing anode* (AI) there is usually a *second anode* (A2). Voltage on the final anode is very high – usually several kV. Alternatively, between the control grid and the second anode, there may be an *Accelerator* electrode (sometimes called a "pre-accelerator") at the full final anode voltage. This arrangement constitutes a focussing scheme called an 'einzel lens'. Varying the potential between K and A1 will vary the spot size. This is used to focus the spot.

The electron beam passes between the plates, in order to be deflected, but after the first set of plates the beam can be anywhere in quite a large area. This means that the second set of plates must be larger, with an associated increase in capacitance. Usually, the vertical deflection plates come first, since the Y channels require greater bandwidth, while the X channel or timebase requires a lower bandwidth.

The result of all this acceleration and focussing is a well-focussed, high-energy beam of electrons travelling straight down the centre of the tube. In order to deflect the electron beam and create a display, a pair of electrostatic deflection plates are provided for each axis (X and Y). An electric field will deflect the electron beam, providing spot movement over the face of the tube.

Following the deflection electrodes, many electrostatic CRTs have a *post-deflection accelerator* which usually takes the form of a graphite spiral around the envelope funnel between the neck and the face of the tube.

The use of electrostatic deflection is necessary because it offers a wider bandwidth than electromagnetic deflection systems which are limited (principally) by yoke inductance. Electrostatic deflection requires much longer tubes for a given screen size as beam defocussing limits deflection angles to less than 20° off axis, while electromagnetic systems can deflect up to ±55°.

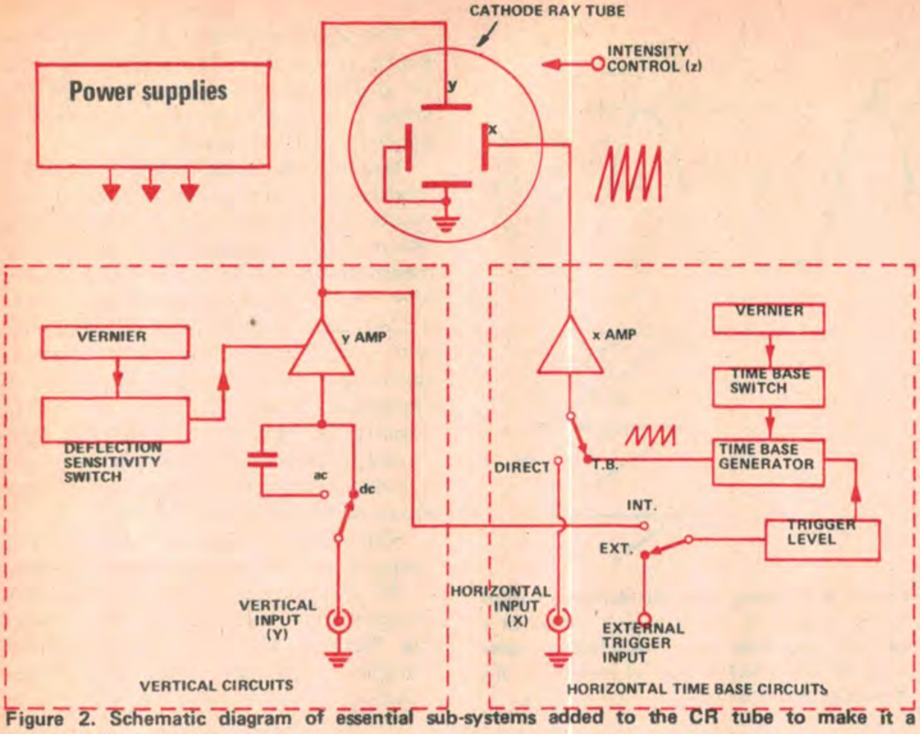


Figure 2. Schematic diagram of essential sub-systems added to the CR tube to make it a measuring instrument.

We have already spoken of the CR tube in some detail, so that's out of the way. The power supplies provide the various anode, grid, screen and accelerator voltages (plus heater) for the CRT and supply rail voltages for the vertical and horizontal circuits. Straightforward.

Now that's out of the way, let's get down to the interesting bits.

The timebase and X amp

So that waveforms of widely varying frequencies can be displayed the timebase must be variable over a very wide frequency range. Accordingly, oscilloscopes are made having the timebase 'range' switched at convenient increments. The actual ranges included on an instrument depend on the applications for which it is intended, but typically the minimum sweep rate may be 20 seconds for a full sweep (generally 2 s/division) ranging up to a maximum of one microsecond for a full sweep (0.1 us/division. The range steps generally go in intervals of 5,2, 1. A vernier control is always provided so that a display may be varied for some convenient purpose.

The timebase generator provides a 'sawtooth' waveform (as that's what it resembles) for the X deflection. This is amplified and applied to the X plates of the CRT. The 'width' of the timebase deflection on the CRT face depends on the amplitude of the sweep waveform. Thus, a *width* control may be provided by having a potentiometer to control the gain of the X amp. A dc voltage, or bias, applied to the X plates will determine the horizontal *position* of the trace on the CRT face. Thus, a potentiometer to vary the dc bias on the X plates is provided as a *horizontal position* control.

So that the timebase generator may be synchronised to the waveform being examined (to provide a stable trace as explained previously), a 'trigger' circuit is included. The timebase may be triggered internally by sampling some of the signal going to the Y deflection plates or from an external signal. This is very convenient in particular applications which are explained later.

For some particular applications (phase measurement, frequency comparison) a sawtooth sweep is undesirable for X deflection, so direct access to the X amp is required. For this purpose the input to the X amp can be switched to a front panel socket, generally marked *horizontal input* or an abbrevation of same.

The vertical or Y amp

The signals one may wish to examine might range from microvolts to hundreds of volts! The lower level signals will require amplification (as the deflection voltages required may be tens to hundreds of volts), the higher level signals will require attentuation. Accordingly, a *sensitivity* switch is provided ahead of a high gain, low distortion amplifier – the Y amplifier.

The most sensitive range of common oscillopes is typically 5 mV to 10 mV per centimetre (one graticule division). More expensive types may have a maximum sensitivity as high as 10 uV/cm. The insensitive end of the range will generally be around 50 V/cm for run-of-the-mill CROs but special instruments (eg: those used for electrical supply applications) provide for levels as much as ten times higher. As with the timebase range control, sensitivity steps are generally in 5, 2, 1 intervals. A *vernier* sensitivity control is provided for convenience.

The bandwidth of the Y amp is an important factor in the selection and application of an oscilloscope. A general purpose instrument may have a bandwidth extending from dc to 10 MHz or 15 Mhz. Inexpensive units may only extend to 3 MHz. Magnetic deflection units (generally for demonstration or teaching applications) may only reach 20-50 kHz, few struggle as high as 100 kHz.

High quality instruments ($$$$!) may have bandwidths as great as 350 MHZ. Special instruments, using 'sampling' techniques, may reach 1 GHz (1000 MHz!).

To examine ac waveforms superimposed on a dc voltage, the Y amp must be ac-coupled. Accordingly, a switch is provided that inserts a capacitor in series with the input.

The range of the input sensitivity may be extended by the use of *probes* which can provide such facilities as very high voltage attentuation and increased input impedance.

The *vertical position* of the trace is determined by a dc bias applied to the Y plates of the CRT, in the same manner as for the X plates.

The Z input

If 'Y' represents the vertical axis and 'X' represents the horizontal (time) axis, then what on Earth is the 'Z' axis?

The only thing left to vary on a CRT display, after moving the spot vertically and horizontally, is the intensity of the spot. Accordingly, most CROs will include a *Z input*. In general this allows for *blanking* and brightening of the display or for making particular types of measurements.

That completes the description of your 'basic' oscilloscope (. . . . therein lies the lesson for the day, as the preacher said).

Dual-trace operation

It is often helpful to be able to display two waveforms at the same time – for example, to measure the phase change on a signal passing through an amplifier stage. This can be achieved in two different ways.

One can simply build two completely separate guns and two sets of deflection plates into a single CRT envelope. These dual-beam CRTs are complex and expensive, and they require two completely separate sets of drive amplifiers – more expense. ▶

The alternative, used in most modern dual-beam scopes, is 'dual-trace' operation, in which a single-beam tube is used to display two traces by switching between them. Two methods of beam-switching are used; one can either switch between traces at the end of each sweep, which is suitable for high-frequency waveforms, or at lower frequencies one can switch alternately between the waveforms as the sweep progresses across the display.

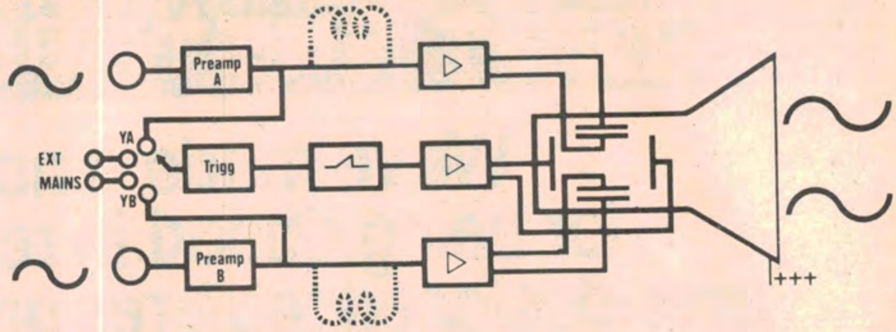
The first method is called *alternate trace*, the second is *chopped trace* operation.

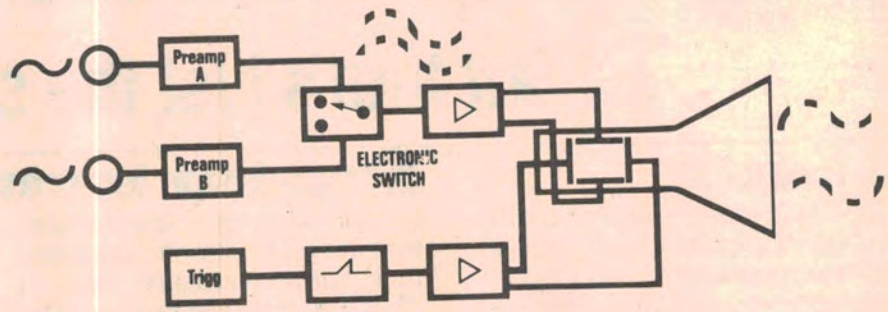
These basic principles apply to all oscilloscopes, except some types which are intended for specialised applications. Of course, oscilloscopes are more complex than this in practice, and perhaps the best way to see some of the more sophisticated facilities is through the controls on the front panel of an oscilloscope of medium complexity.

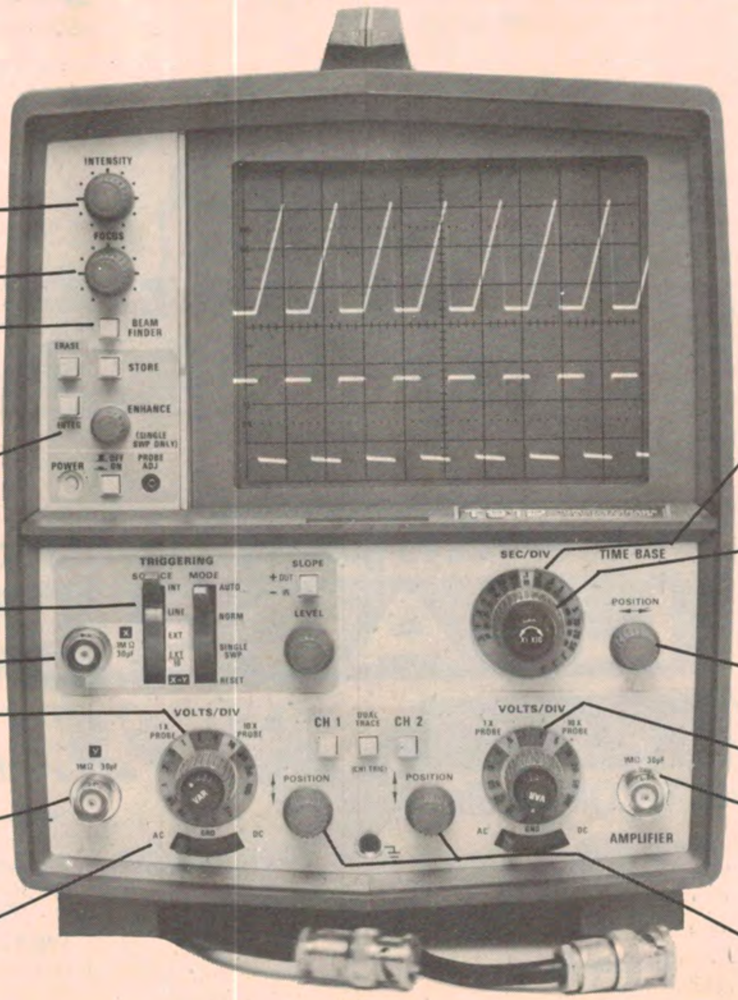
Choosing (not using) a scope

There comes a time in every young man's life when he can't figure out what

Dual-trace oscilloscopes can be implemented in two ways: using a *dual beam* cathode ray tube or using a single beam tube and *electronic switching* of the trace. The block diagram at the top is of a Philips model 3232 and is typical of dual-beam types. The block diagram at the bottom shows the electronic switching technique of obtaining dual-trace operation with a single beam cathode ray tube.







A modern dual-trace oscilloscope with trace storage facilities, the Tektronix model T912. The operation of the controls is explained in the notes here.

on earth that circuit's doing, and then he decides to buy an oscilloscope. Of course everyone has different requirements – digital circuitry, RF, high fidelity, process control, computer equipment – these applications all have widely varying characteristics – so what should one look for when evaluating the performance of a CRO?

The most obvious consideration is bandwidth. The bandwidth of a general purpose oscilloscope is the frequency at which the total gain of the oscilloscope is 3 dB down on its mid-band performance. There are several limitations on the bandwidth of an oscilloscope, ranging from the bandwidth of the amplifier stages themselves to the time which the electron beam takes to pass between the deflection plates and the amount of energy required to make the phosphor glow. For example, if the input waveform goes through a complete cycle during the time that an electron is passing between the plates, then the deflections will average out, giving a net deflection of zero!

In the dc mode, there is no problem with low frequencies right down to dc, particularly when using long-persistence phosphors. The bandwidth figure given in specifications is therefore the upper frequency limit of the scope.

Closely related to bandwidth is the risetime of the scope. This is the time taken for an input square (really square) wave edge to go from 10% to 90% of its value on the screen. Unfortunately, on high performance CROs, this is well-nigh impossible to measure, and it is usually calculated from the bandwidth instead, using the formula:

$tr = 0.35/BW$.

The vertical amplifier system of a scope should ideally have a risetime five or more times faster than the risetime of the fastest signal it is intended to examine. In this case, risetimes measured on the scope will have less than 2% error.

It is generally important to get the highest bandwidth and fastest risetime your money will allow. When examining a square wave signal, for example, Fourier analysis tells us that the square wave is actually composed of a series of harmonics of the fundamental frequency.

If the vertical amplifier and tube of a scope lop off the fifth and higher harmonics, the square wave will be noticeably rounded. In this case, risetime measurements will be virtually meaningless.

Glitches in digital circuitry will virtually disappear on a narrow bandwidth CRO, rendering it well nigh useless for digital troubleshooting. Thus, although you may be working

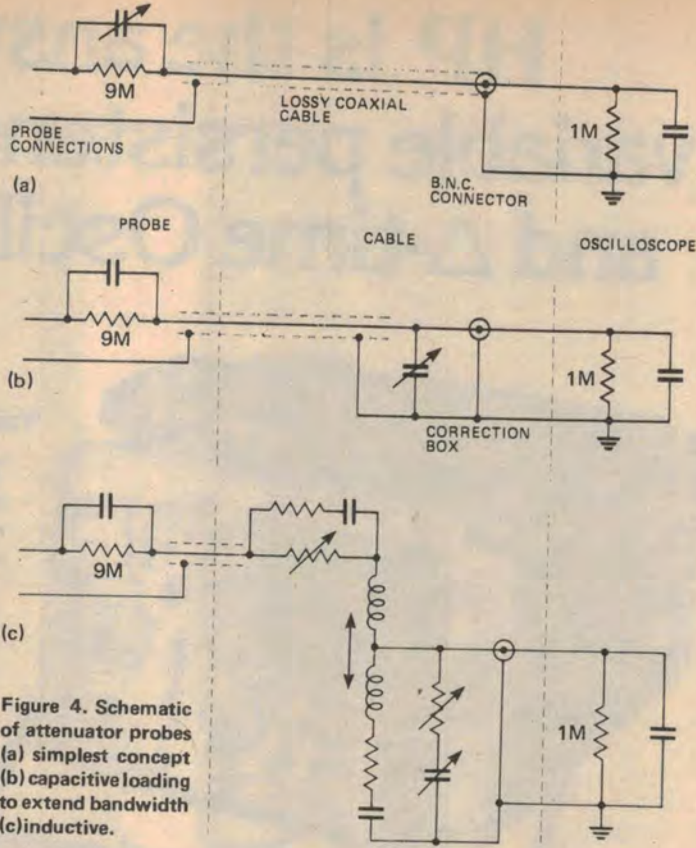


Figure 4. Schematic of attenuator probes (a) simplest concept (b) capacitive loading to extend bandwidth (c) inductive.

with quite slow logic, a high speed scope is still very useful. For a typical hobbyist, with no specific requirements or interests, a 15 MHz oscilloscope would probably be ideal.

Probes

A point to watch for, particularly with high frequency scopes, is the selection of suitable probes. The capacitance of the probe leads can severely limit the bandwidth of an instrument so it is essential to use the appropriate probes.

Most oscilloscopes have an input resistance of 1 M ohm, and x1 probes will give this resistance at the probe tip plus a capacitance which is in parallel with the scope input capacitance (usually around 20-30pF).

For higher input resistance, x10 probes are available which include a 9 M ohm resistor, thus raising the input resistance to 10 M ohm.

Probes require compensation for capacitive effects which limit their bandwidth. For very wide bandwidth operation, complex compensation network may be used. Typical probe circuits are illustrated in Figure 4.

Sensitivity and accuracy

The sensitivity of an oscilloscope is usually expressed in mV/cm or mV/div, and in general, a higher sensitivity scope is more useful than an insensitive one.

Accuracy, in the absolute sense, is probably less important than with other pieces of test equipment, as an oscilloscope is generally used for qualitative analysis. Most oscilloscopes have an accuracy of ±5%, but as one moves into laboratory, as opposed to service/general purpose machines, ±3% accuracy is more common. It is tempting to suppose that by buying a more accurate oscilloscope, one could save money on other test equipment but, this is not the case. Modern digital test equipment is now quite cheap, while accurate oscilloscopes are not, even leaving aside the inconvenience of making measurements by counting divisions on the graticule.

Other facilities

In deciding on an oscilloscope, several other factors ought to be taken into consideration. The obvious question is: will I need a dual-trace scope? There is very little to be said about this choice; you pays your money (as much as you can afford) and you takes your choice. Single-trace scopes are becoming quite rare beasties, in fact, as dual-trace types are considerably more versatile.

The triggering facilities of a prospective purchase should also be carefully examined. It's probably true to say that poor triggering on a scope can render it the greatest bugbear of the user's life – virtually useless, in fact.

Unfortunately, there is no universal way to specify the triggering performance of an oscilloscope. It is best to ▶

arrange a demonstration, either by the dealer or by an associate or friend who already has the oscilloscope in question. In any case, it is generally wise to ask around for other users' impressions when considering such a major purchase.

A useful facility on some oscillopes is the provision of two timebases with delayed sweep facility. In this mode of operation, for the first timebase, the delaying sweep is triggered by the trigger circuitry, and continues for selected delay time. When this time is reached, the second timebase takes over (usually at a higher speed), providing accurate resolution of an event which can occur some time after the trigger event. Incidentally, this is how we shot the cover photograph of the December 1978 issue of ETI.

Suppliers and brief product descriptions

BWD ELECTRONICS PTY LTD, Miles St, Mulgrave, VIC 3170. (03) 561 2888. BWD is a major Australian manufacturer of test equipment, including signal generators, power supplies, and of course, oscilloscopes. A range of models are available: the 540 is a dual channel 100 MHz lab scope with sensitivity down to 1 mV/div. The 539D is a 25 MHz dual trace general purpose oscilloscope. If you only require single trace operation, the 506 (15 MHz) or the 509B (10 MHz) may be suitable.

BWD also produce a plug-in scope, the 525, with a matching range of plug-ins, and a large screen oscilloscope, the 1722, also with a range of plug-ins, which is suitable for classroom demonstration use.

THE DINDIMA GROUP PTY LTD, P.O. Box 106, Vermont, Vic 3133. (03) 873-4455. These people handle the **Ballantine** range of instruments including a range of single- and dual-trace CROs in both portable and bench models.

Latest in the range is the "Series 1020" miniscopes available in single- and dual-trace models. Both are available in the same 203 mm wide by 187 mm deep by 83 mm high package weighing about 11 kg. The Series 1020 provides sweep rates from 100 ns/div to 100 ms/div in 12 calibrated steps plus a continuously variable x10 magnifier and a vertical bandwidth of 12 MHz. The 1020 operates from 12 Vdc which may be obtained from a battery pack (it draws less than 10 W) or external dc supply, or optional ac power converters (plug-in) for 120 V or 240 V, 50 Hz to 400 Hz mains. The screen area on both models is 50 mm x 40 mm (w x h) with a 5 mm/div graticule on the CRT face.

The case is fully sealed, there being no ventilating ports, and the unit is specified to operate over a temperature range of zero to +50°C. The Series 1020 scopes may be hung from a strap around the operator's neck in complete safety in cramped quarters as no mains voltages enter the equipment.

EAI-ELECTRONIC ASSOCIATES PTY LTD, 48 Atchison St, St Leonards, NSW 2065. (02) 439 7522. EAI manufacture a 300 mm slow-scan oscilloscope with a P7 phosphor. The major application of this unit is with EAI's analogue and hybrid computers, but it also has medical, scientific and engineering applications.

ELMEASCO INSTRUMENTS PTY LTD, PO Box 30, Concord, NSW 2137 (02) 736 2888. Elmeasco are agents for the British manufacturer **Gould Advance** whose product line includes 15 MHz dual-trace, 15 MHz dual-beam, 20 MHz, 25 MHz, 30 MHz, 40 MHz and 60 MHz dual-trace oscilloscopes with sensitivities down to 2 mV/cm. Delayed timebase is available on several models. Of special interest is the OS3350B, which is a BBC-designed unit, especially for TV signal examination, which can display a TV picture. Also available are the OS4000 and OS4100 digital storage oscilloscopes

Elmeasco also handle **Application Inc's** BS610 15 MHz dual-trace and BS310S 15 MHz dual-trace portable oscilloscopes. The BS310S features 2 mV/div sensitivity in a very compact unit. The **TTM Electronics** Model 303 is a competitive priced unit with internal NiCad battery, and 5 mV/div, 15 MHz performance. Lastly, the **Norland** 3001 is a very high performance digital scope with extremely advanced features way beyond the scope of this article.

JOHN HADLAND (AUST) PTY LTD, 7 Hampshire Rd, Glen Waverley, VIC 3150. (03) 560 2366. An unusual scope is available from John Hadland, agents for **Ealing Beck Ltd** of Watford England. This modular oscilloscope is designed for the classroom, teaching the principles of cathode rays, electrostatic and electromagnetic deflection and the operation of oscilloscopes. The kit consists of a CRT unit, around which can be placed deflection coils etc, a power supply, a CRT amplifier and time base. Instruction sheets provide several interesting experiments.

HEWLETT-PACKARD AUSTRALIA PTY LTD, 31-41 Joseph St, Blackburn, VIC 3130. (03) 89 6351. Hewlett-Packard is generally known as the 'Rolls-Royce of test equipment', but whether they hold that title in the field of oscilloscopes, considering the stiff competition from Tektronix, is a matter some would debate. Their oscilloscopes certainly are nice however, whichever camp you follow. The general top-of-the-line is the 180 series of plug-in scopes, which have vertical amps to 18 GHz (sampling) and sensitivities to 100μV.

In the more conventional portable range, the 1740A, 1742A and 1743A are 100 MHz dual-trace units, the 1715A is a 200 MHz unit and the 1725A and 1722B are 275 MHz types. The 1722B incorporates a microprocessor to calculate time delays, frequency, period, voltage and percentage difference measurements.

HP also have a range of storage oscilloscopes with variable persistence facility.

For less exacting applications, the 1220A and 1222A are a pair of 15 MHz dual-trace, 2 mV sensitivity general purpose scopes. The 1222A has a delay line, which allows examination of the leading edge of a waveform.

PARAMETERS PTY LTD, 68 Alexander St, Crows Nest, NSW 2065. (02) 439 3288. They handle **Trio** oscilloscopes which are among the most popular general-purpose and service types. Currently the most popular in the range is the CS-1560AII, a 15 MHz dual-trace model with easy TV sync triggering facilities. It has a sensitivity range of 10 mV/div to 20 V/div.

Also in the Trio range are: the CS-1570A, a 30 MHz, dual-trace, 5 mV/div model; the CS-1572, a similar model with delayed triggering facilities on video signals; the CS-1577, another 30 MHz, dual-trace type but with 2 mV/div sensitivity; the CS1575, a 5 MHz general-purpose type with 1 mV/div sensitivity and the CS-1830, a 30 MHz, 2 mV/div, dual-trace type with delayed triggering.

New from Trio is the MS-1650 Digital Memoryscope, a 10 MHz oscilloscope which incorporates an 8 bit x 1024 word digital memory. This scope can store a signal (up to 250 kHz) prior to the trigger pulse and can drive a pen recorder.

PHILIPS SCIENTIFIC AND INDUSTRIAL (Test and Measuring Instruments), 25-27 Paul St, North Ryde, NSW 2113. (02) 888 8222. Philips have quite a large range of oscilloscopes. Probably the most interesting from the general purpose, low cost, point of view is the PM3207, a dual-trace, 15 MHz unit with 5 mV/cm sensitivity. Auto triggering on this unit ensures that the trace will never leave the screen, and a B-invert mode allows inverted outputs from a circuit to be compared with the input. The PM3207 also has triggering on either A or B channel, and TV triggering. ▶

CHRISTIE RAND PTY LTD, 27 Windermere Road, Epping, NSW 2121. (02) 868 1209. The Scopex 4D-10B and 4D-25 are two British-made dual-trace scopes, with 10 MHz and 25 MHz bandwidth respectively. Both are 'value for money' designs, without fancy features or frills, but offer ±3% accuracy on both channels and sensitivity down to 10 mV/cm and up to 50 V/cm. The 4D-25 has signal delay, to allow investigation of the leading edge of a waveform, and a special version of the 4D-10B, the 4D-10B LS, is available with enhanced low frequency performance.

SCIENTIFIC DEVICES AUSTRALIA PTY LTD, 2 Vautier St, Elwood, VIC 3184. (03) 91 2223. Scientific Devices are the Australian agents for **Nicolet Instrument Corporation,** manufacturers of the **Explorer** digital oscilloscopes. Three models are available: the Explorer I is a two-channel 500 kHz unit, the II is a plug-in model with a bit more flexibility, and the III is an expanded unit with digital interface and floppy disk waveform store. The capabilities of these units are too sophisticated to be described here — they literally have to be seen to be believed!

As well as the Nicolet units, Scientific Devices are also agents of the **National** division of **Matsushita,** who produce a range of oscilloscopes ranging from small portable units to a full-spec 200 MHz unit. The Panascope 5 MHz personal units are particularly interesting — they are so small they can be carried in a briefcase.

SWE-CHECK INSTRUMENTS, PO Box 218, Cheltenham, VIC 3192. (03) 95 2942. SWE-Check are agents for **Una-Ohm,** an Italian test gear manufacturer who have several oscilloscopes in their line. The G421DT is a dual-trace 10 MHz unit with 1 mV p-p sensitivity up to 20 V in 11 steps. Also available is the G404DT portable oscilloscope, which operates from rechargeable batteries.

STANDARD COMPONENTS PTY LTD, 10 Hill St, Leichardt, NSW 2040. (02) 660 6066. Standard Components handle the **Hitachi** range of four oscilloscopes in Australia. These are: the V-151, 15 MHz single trace; the V-152, 15 MHz dual-trace; the V-301, 30 MHz single trace; and the V-302, a 30 MHz dual-trace model. They say the V-152 is an ideal serivce oscilloscope, offering 1 mV/div sensitivity and 0.2µs to 0.2s sweep range.

TECH-RENTALS PTY LTD, Stanhill House, 34 Queens Road, Melbourne, VIC 3004. (03) 267 5877. It's not every day that you need a high performance oscilloscope; most of the time a perfectly ordinary machine will do the job. In this situation it may be advantageous to only hire a good CRO when you need one, instead of tying up capital in one that gets used maybe 1% of the time. Tech-Rentals stock a comprehensive range of oscilloscopes from Hewlett-Packard, Tektronix and Trio, all available for rental from two weeks up. In addition, ex-rental equipment may often be bought from them at extremely competitive prices.

TEKTRONIX AUSTRALIA PTY LTD, 80 Waterloo Road, North Ryde, NSW 2113. (02) 888 7066. Tektronix is probably the world's major manufacturer of oscilloscopes, with an extremely broad product line. Their 250-page catalogue lists all kinds of oscilloscopes, including the 7000 series of plug-in instruments and a wide range of portable oscilloscopes. The 400 series portables are of particular interest for general-purpose lab use, with models up to 350 MHz. At the lower end of the scale is the Sony/Tektronix 300 series — the 335 35 MHz dual trace delayed sweep scope, the 314 10 MHz dual trace, long term storage oscilloscope and the 305, a combined battery-powered oscilloscope and DMM.

The 200 series of miniscopes are small enough to be hand-held for service applications. Perhaps of greatest interest to the hobbyist is the T900 series of scopes; the T922, for example is a no-frills 15 MHz dual-trace scope. Also supplied by Tektronix is the **Telequipment** Range of British-made scopes.

The Tektronix range of products also includes scope-related devices such as spectrum analysers, time domain reflectometers and logic state and timing analysers, as well as graphic terminals (based on storage tubes) for computers.

VICOM, 68 Eastern Rd, Sth Melbourne, VIC 3205. (03) 699 6700. The **Leader** brand of test equipment includes a dozen oscilloscopes, including the LBO-520, a 30 MHz, 5mV/div dual-trace model with delay line, and the 25 MHz, 5 mV/div LBO-515 with delayed sweep. At the bottom end of their range, they have two 4 MHz, 20 mV/div models which are intended for the service market, as well as several models, with higher bandwidths and sensitivities, in between.

Latest in the Leader range are two high sensitivity, 10 MHz models (LBO-513 single-trace and LBO-514 dual-trace) and a 75 mm (3"), 20 MHz scope. The latter is model LBO-308 which features a sensitivity of 2 mV/div and a bandwidth from dc to 20 MHz. It incorporates a new TV sync circuit for simple triggering of composite TV signals, phase/level signal comparison and an addition/subtractor function for working with push-pull signals. The LBO-513/LBO-514 models feature sensitivity to 1 mV/div — not usually available on low-cost instruments. Both have 80 x 100 mm displays, z-axis modulation, x5 magnifier and complete trigger controls. The dual-trace unit also provides front panel X-Y operation, Ch-1/Ch-2 trigger selection and alternate/chopped display modes. ●