I have recently been asked if I would provide some information regarding the use of an Oscilloscope, so I have put together this document as a start for those who wish learn a little of the use of the instrument in Amateur radio. If you have any suggestion for improving this document then please give me a call; my addresses will appear at the foot of this page. This information is not intended as a definitive work regarding the use of Oscilloscopes, merely a little information to get you started and show some of the possibilities.

The Oscilloscope (often called simply a "scope") is nothing more than an instrument for displaying electrical signals in the TIME domain. In other words, you can view waveforms on it. Some of the uses of the scope may not be obvious but if you already possess one, then you will most probably regard it as the most useful tool on your workbench.

**CONTROLS**

A basic (and fictitious) Oscilloscope is shown below.

This is a Dual-Beam oscilloscope although most of the information presented here is also applicable to a single-beam Oscilloscope. The basic controls are:

- **BRIGHT** (Brilliance) adjusts the intensity of the display.
- **FOCUS** Adjusts the focussing of the display.
- **GRAT** (Graticule) Illuminates a scale used to measure a trace.
- **TRACE** (Channel etc.) Selects which trace is to be displayed.
- **TRIGGER** Selects a trigger source.
- **TRIGGER LEVEL** Selects the point of the waveform used to trigger.
- **TIMEBASE** Selects the speed the trace moves across the tube face.
- **INPUT LEVEL** Adjusts the input level.
- **POS** (Position) Sets the position of the trace on the display.

The Scope will also have an input socket for each input channel, situated on the front of the instrument. There will most probably be more controls on your scope, and I will try to cover some of these later on.

**BRIGHT**

This is self-explanatory, it controls the intensity of the display. It is well worth remembering that one cannot execute screen-saver programs on an oscilloscope, so leaving the scope with a high brilliance will certainly burn the trace into the tube face. If you must leave your scope switched ON for any length of time then turn the brilliance control down.
FOCUS
The focus control is also quite self-explanatory but most "scopes" seem to adjust a single spot from a short horizontal to a vertical line. A single horizontal line is therefore not the best waveform to adjust the focusing, this is best done whilst viewing a waveform.

GRATICULE
(Scale) Illuminates a scale used to measure a trace. This is usually just a clear plastic sheet placed over the tube face and shows a matrix of 1 cm squares. By comparing the matrix with the waveform, it is possible to measure such things as Frequency and voltage. If this control is turned down then the scale will not be seen.

TRACE
(or CHANNEL) Selects which trace is to be displayed. There are usually two or more selections possible:

- A - Selects trace A only (single channel).
- B - Selects trace B only (single channel).
- A+B - Selects both trace A and trace B (dual channel).
- ADD - Both channel inputs are added and displayed as a single trace.

TRIGGER LEVEL
A trace displaying a waveform without the use of TRIGGER will roll in much the same way as a TV with the horizontal hold set wrongly. Trigger action will stop the trace from starting, until a determined part of the waveform occurs. This will make each "sweep" of the tube face occur in exactly the same place and the display will appear to be stationary. The trigger level control is used to select that point of the waveform.

TRIGGER SELECTOR
Selects the trigger source. Most dual beam scopes may be triggered from either Channel A or channel B. Many oscilloscopes have the facility to trigger from an external source, in this case an extra TRIGGER input on the front panel will be provided.

TIMEBASE
The speed the spot travels across the screen of the tube may be varied by means of the TIMEBASE selector switch. This is calibrated in Seconds (S), MilliSeconds (mS = 0.001 seconds) or MicroSeconds (uS = 0.000001 seconds).

INPUT LEVEL
Adjusts the input level of each channel so that the trace display will fit on the screen. This is a switch calibrated in Volts per centimetre (V/cm).

POSITION
Sets the vertical location of the trace on the tube so that the display is positioned in a manner more comfortable to read. For example, you may wish to set zero volts to the graticule mid-position for AC measurements, or to the bottom of the tube face for DC measurements.
BASIC OPERATION

By way of example, connect a lead to CHAN-A input then hold, with your bare hand, the centre conductor
of the wire. You will see some rubbish on the screen which is the 50 Hz (60 Hz in some countries!) Mains,
which is being received by your body. Set the timebase to 10mS / Div and the CHAN-A input level to a
setting that does not go off the screen. You should see a wave-form such as is shown below.

![Waveform](image)

On the trigger input select CHAN-A. Adjust the TRIGGER control slowly and at some setting of the control
the display will become stationary. If the TRIGGER control has an AUTO position then select it and you do
not need to adjust anything.

The waveform you see will not look exactly like that shown above, as there will be loads of distortion. This
is due to many things mainly because you are picking up spurious signals radiated by household electrical
equipment such as TVs, flourescent lamps etc. All these items distort signals in one form or another.

If you look at the waveform you will see that there are two horizontal red divisions on the graticule scale
between two consecutive peaks. Since the timebase is set to 10mS/Div, it will take the spot 20mS to travel
between the two divisions. The PERIOD TIME of the waveform is therefore 20mS, (or 0.02 seconds). The
FREQUENCY of the waveform is 1 divided by 0.02 = 50 Hz.

Now look at the vertical scale. The centre-line is zero-volts and the waveform moves both 1.8 divisions
above and below the centre line, and if the input level is set to 1volt/cm the level of the input is 1.8v + 1.8v =
3.6 volts PEAK-TO-PEAK. This equates to 3.6v times 0.35 = (about) 1.2 volts RMS, as you would read it
on a voltmeter.

In this way, you can measure the FREQUENCY and VOLTAGE (AMPLITUDE) of just about any
waveform.

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OSCILLOSCOPE INPUTS

The input impedance of the oscilloscope is very high so it will not load a circuit under test. Most
oscilloscopes have an AC/DC switch at the input to each channel. When set to DC the channel trace will
move up or down by an amount proportional to the value of the DC voltage. If set to AC, then the DC
voltage component of the input will be removed allowing you to view only the AC component. This feature
is usefull for measuring the ripple that may be present on a power supply. Take for example the following
circuit diagram and test setup:

![Circuit Diagram](image)

Here, the oscilloscope has both its inputs connected to the DC output of a home-made 12v DC Power Supply
Unit. Trace B is set to 5v/cm DC and only a single is displayed. The horizontal line will have moved up the
tube face by just over 2cm, but it is straight and shows no deviations.

Trace A input is set to AC (DC block), and the input sensitivity is turned up to about 1mV/cm. The DC
component would give a deflection of 1200cm but the DC has been blocked. The low-level ripple can now be clearly seen. In practice, with the circuit shown, little or no ripple should be seen, but when a load is placed on the power supply the ripple may even become quite objectionable, depending upon the component values chosen. It is also very interesting to see that the ripple frequency will be 100Hz or 10mS between the peaks. This is because of the action of a full-wave bridge rectifier.

The TIMEBASE selector switch will most probably have an 'XY' position even on the cheapest of oscilloscopes. This can be used to for a variety of new functions, such as:

- Lisajous figures - 'pretty' frequency measurements, but very accurate.
- Other equipments - such as WOBULATORS and analysers.
- HF TX Modulation - quick and convenient.

The 'XY' timebase selector position disconnects the internal generator that moves a spot across the screen. Input B will now move the spot across the screen, but input A will still make the spot move up and down.

LISAJOUS FIGURES

By way of example, connect two leads to CHAN-A and CHAN-B inputs then hold with your bare hands the centre conductor of both the wires. You will see the same rubbish as you did before, but this time there will be differences between the two signals. This will work even better if two people each hold one of the two wires.

If the two signals were EXACTLY identical, then the spot would move UP and to the RIGHT then DOWN and to the LEFT. This would be seen as a horizontal line diagonally across the screen. A loop would be seen if the two signals were exactly the same frequency, but different wave-form or phase. If the two signals were perfect sinewaves and differed by exactly 90 degree phase then you would see the following waveform:

If you have access to an AF sinewave signal generator, then connect an RC circuits to one input and a CR circuit to the other input of the scope:

Notice how the circle slope changes as the frequency is altered.

If the phase were to constantly change (slightly different frequency) then you would see a SQUARE BLOCK formed by a moving image changing from a left -sloping line - a circle - a right sloping-line - a circle - then back to a left-sloping line again.

If the two sine-waves were to differ in frequency by EXACTLY 2:1 then you will see something like this:
Notice that in the vertical plane (Y axis = CHAN 2) there is only one peak but in the horizontal plane (X axis = CHAN 1) there are two peaks. CHAN 1 is therefore twice the frequency of CHAN 2. With other frequency combinations the waveform may become even more complex, for example 3:2 8:3 2:5 etc.

**WOBULATOR**

Many circuits have been published for wobulators. A wobulator generates a varying radio frequency that moves in sympathy with a sawtooth or triangular waveform. If the sawtooth is applied to the Y (horizontal) input of the oscilloscope, the RF signal can be applied to the X (vertical) input via a receiver IF amplifier (tuned circuit, filter etc.). The vertical axis will then give a display of the frequency response of the amplifier:

Here we can see that the left hand peak is not quite as high as the right hand peak which means that the IF response is not perfect, although it is not bad enough to be noticed by the ear.

Most single beam oscilloscopes have a TIMEBASE output which can be used to make a voltage controlled oscillator sweep through the frequencies of interest.

I will be posting a simple Wobulator circuit soon. It has been tried and tested over a number of years.

**SPECTRUM ANALYSER**

It is quite possible to build a simple Spectrum Analyser for use with an oscilloscope, in much the same way as a Wobulator. A Spectrum Analyser is a device that can display a range of frequencies 'simultaneously' (or a range of frequencies so fast that it looks continuous). If the local oscillator of a superhet receiver was made to sweep through a range of frequencies, dictated by the TIMEBASE output of your oscilloscope, and the X (vertical) axis of the oscilloscope monitored an AM detector at the IF, then you would have a spectrum analyser. A typical analyser display looks something like this:
Here we see that there are several radio signals displayed simultaneously. This would be typical of a display from 0 to 9MHz with a scale of 1MHz per division. The large spike at the left of the screen would be the 0MHz marker. This display shows a couple of small signals at about 1.5 and 1.9 MHz, 6.0MHz, 7.1MHz and 7.9MHz. Larger signals are shown at about 2.5MHz, 3.2MHz, 4.3MHz, and 5.5MHz. The baseline is cluttered with noise, often referred to as 'GRASS'.

Harmonics and other spurious emissions may be observed from an amateur transmitter. Many HF radio receivers have a narrow-band spectrum analyser built into the receiver. These are operated from the receiver IF amplifier, before the filter. In this case they are called a PANORAMIC DISPLAY, PANORAMIC ADAPTOR or something equally obscure. QRP/DX signals would be at very low signal levels 'in the grass' so a Pan.Adaptor is not particularly useful.

Above is the block diagram of a simple spectrum analyser that will cover the complete HF bands from 0 to 30 MHz. I have done some experiments with this in the past and I may post circuits sometime in the future.

MODULATION

In days of old when knights were bold and toilets were not invented, it was very easy to use an oscilloscope to check the purity of an amateur transmitter when only AM and CW was in use. All that was required was to couple the Y input of the scope to the microphone, then LOOSELY couple the X input to the antenna (just place it near the antenna coax or connect it to the transmitter chassis).

With the above setup you would see a trapezoidal waveform something like this:
CD minus AB divided by CD is equal to the modulation depth. In this example the modulation depth is \((6-2)/6\) or \(4/6 = 66\%\). The upper and lower sloping lines are straight showing that the modulation characteristic of the transmitter is linear.

CW may be monitored by LOOSELY coupling one input channel of the oscilloscope to the transmitter antenna (just place it near the antenna coax or connect it to the transmitter chassis) and set the scope timebase to (say) 100mS/Div. Send a load of DITs and observe the waveform.

Nice rounded edges are ideal, but square 'envelopes' are the sign of a badly adjusted CW transmitter. Leading spikes would render the transmitter illegal in most countries (except Saudi Arabia!). If you wish to do continuous measurements then it could be a good idea to make a multivibrator oscillator to switch a transistor in the transmitter key input. This will give a regular and continuous CW envelope for design/development of CW transmitters.

If a two-tone audio signal is connected to an SSB transmitter microphone input and the oscilloscope is LOOSELY coupled to the transmitter antenna, the following waveform will be displayed when using the scope's internal timebase:

A flattening of the peaks indicated that some stage has been overdriven, and a lack of dip between envelopes shows an excessive carrier level. This display can show quite a lot of things about the waveform, but this is beyond the scope of this page.
PROBES

Oscilloscope probes are pretty neat things, they can be armed with a plethora of clips, hooks and other assorted paraphernalia. One of the most common widgets in a commercial scope probe is a resistive voltage divider that increases the maximum voltage range of the oscilloscope. Unfortunately they use coaxial cable, even the expensive ones (although none of them are cheap!). A coaxial cable possesses capacitance, therefore this capacitance is placed across any signal fed into your expensive scope and this will have an effect on the waveform displayed. Consider a simple resistive voltage divider used with a bit of coaxial cable; A in the diagram below.

Here we see that the 100000 ohm resistor is placed in series with a capacitor (the coaxial cable) which is a simple 6dB/octave low-pass filter. A square waveform should look like A below, but with the above probe it will look more like C below. If the 100000 ohm resistor is shunted with a small capacitor, as in B above, it will correct this situation, but the value of the capacitor is quite critical. If the value is too small then the waveform will look like C below. If too large a value it will look more like B below.

If the correction capacitor is correctly selected then the waveform will look waveform A. Many oscilloscopes have a 1KHz square wave reference output for calibration purposes. The waveform is usually 1v peak-to-peak so the oscilloscope display should be one cm high using the 1v/cm input level setting. If your oscilloscope does not have a calibration output then you can easily build one using a CD4060 IC as an oscillator/divider from a 8192KHz (8.192MHz) crystal.

This circuit has the added advantage that there are also other outputs at much higher frequencies, up to 1.024 MHz, for even more accurate HF correction of your homebrew scope probe.

AND FINALLY

I hope that this short page has given you a little 'food for thought' and that even the more experienced operator has learned something. If you think I have forgotten anything basic or important then please send me E-Mail. All constructive suggestions will be gratefully received. If you have any complaints then please address them to easymoney@con.artists.inc or any other spammer who you hate (if you need suggestions then I will gladly sent you a few addresses). Have fun, de HARRY, Lunda, Sweden,