Oscilloscopes

By G8MNY (Updated Dec 09)
(8 Bit ASCII Graphics use code page 437 or 850)
This bull tells you about the basics of Oscilloscopes.

COORDINATES

```
  Y
 /│\ _ Z
  │  /|
  │ /
  │/
 ─┼──────>X
```

The display uses 2 coordinates Horizontal X & Vertical Y. The 3D Depth Z coordinate can't be displayed on the 2 axis system, but it is sometimes used as a brilliance input. (e.g. grid 1 voltage for TV work).

The X coordinate is usually used for time display with an internal time ramp generator (Timebase).

DISPLAY SYSTEM

Until recently this has always been a Cathode Ray Tube, usually electrostaticly deflected.

```
                 Deflection
          EHT      Plates
Phosphor  _|_        X Y
 coated  │    "~--.________________
 front   │ Glass    []─┴─ Electron│-
 screen  │  Bulb   [] ─┬─    Gun  │-
  with   │      _.--"~~~~~~~~~~~~~~~~
Graticule ~~~PDA   X   Y
```

The beam of electrons from the gun are attracted or repelled by the pair of X & Y plates, that have a differential deflection voltage across them. The more sensitive Y plates are nearest the gun. The gun voltages are usually @ -1kV to the final gun anode & deflection plates. This means some of the front panel gun controls may be @ -1kV!

The glass bulb often uses a Post Deflection Acceleration system where Extra High Tension of several kV is applied to the screen end of the bulb & a spiral high value resistance coated to the inside eventually reaches the lower votlage gun anode. The effect of this is to further accelerate the electron beam, but at the direction already set by the plates, this greatly enhances the brilliance (electron energy) without needing kilo volts of deflection voltage.

With magnetic defection types (for audio bandwidths) the plates are replaced by external coils mounted at 90 degrees to their deflection axis. Larger forces on the electron beam can be applied this way so PDA is not used & deflection angles can also be much greater (shorter tubes). However as the coils are inductive & need the drive voltage proportional to frequency & it is this that limits the usefulness for wide bandwidth scope use, as the drive circuits become a very inefficient constant current system. A TV CRT magnetic deflection has fixed scan frequencies & that can be made quite efficient.

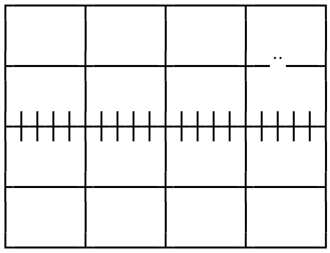
Phosphors can be any colour, but green is the brightest to the eye & blue the best for photography, so blue-green (e.g. P7) colour is common. Phosphor persistence times or afterglow can be quite slow for scope phosphors to reduce flicker & for you to follow a very slow trace. The afterglow can be a different colour!

There where more specialist CRTs that permit image storage, these are very useful for very slow events as well as fast "one offs". They use a 2nd gun to spay re-energizing electrons that are attracted to the static charge left on the screen by the 1st gun & keep the screen trace dimly lit for as long as required.

Modern LCD systems such as on PCs offer a more flexible system, but the A-D generally used is limited & the quantisation & pixilation of some of the cheaper offerings are far inferior to a good old CRT display. But different trace Colours & Storage features are a standard feature.

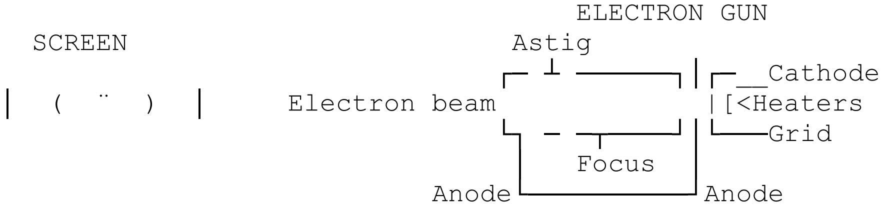
CONTROLS

Graticule. Controls a light that eliminates the etched graticule (like graph paper) engraved on the tube or just in front of it. (avoid parallax error when taking measurements)



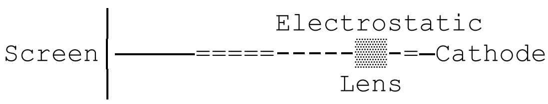
Spot is 3.0 divisions up & 3.4 divisions across from the left hand corner.

Brilliance. Alters the brightness by controlling the CRT's electron gun current too bright will burn the phosphor over time, especially if left as a bright spot or line! Blanking signals are used in the scope turn the gun off!



A bright spot will have faint rings around it due to the electron wave length effect at the voltage used in the CRT.

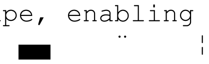
Focus. Controls the gun mid repelling (focus) tube electrode voltage (see GUN diagram above) The effect is to make a weak electrostatic lens that focuses the divergent electron beam from the cathode to a small spot on the screen.



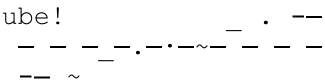
A defocused blob often shows a picture of the cathode surface!

.	¨	@
Small dim spot	Brighter spot	defocused blob

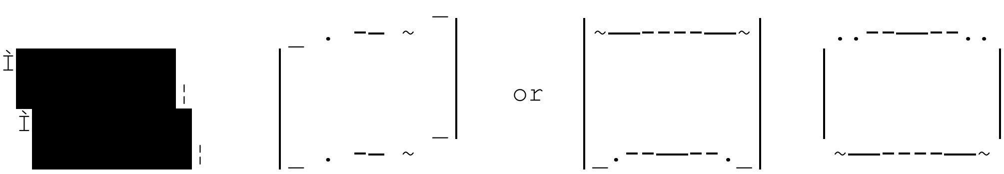
Astig. (internal) Astigmatism control is similar to focus, but applied to a pair of plates in the focus tube wall, so it causes the spot to change from a horizontal oval to vertical oval shape, enabling a really tight small round spot to be achieved.



Rotation. (internal) Controls current put on a coil around the tube that puts a small twist on the electron beam, to rotate the whole display so the X & Y axises are true to the rectangular faceplate. Round tubes you just unclamp & rotate the tube!



Geometry. (internal) Controls an additional beam plate voltage used to correct the display to make it exactly fit the graticule for perfect geometry. sometimes a pincushion shape. (a carrier will produce a rectangle)



Y Shift. Controls the standing DC on the Y plates to set the vertical beam position. Use with input grounded for display calibration. For +ve only signals set the beam to the bottom graticule, for AC or ± DC use the middle. For 2 channels either superimpose (confusing) or use a near top & bottom reference graticule.

```
 ┌───────┐       ┌───────┐       ┌───────┐       ┌───────┐
 │       │       │  /\   │       │       │       ├-------┤Y1
 │  /\   │+      ┤ │  │  ├AC    ã═══════ÁY1Y2    │       │
 │_│  │__│DC     │    \/ │       │       │       ├-------┤Y2
 └───────┘       └───────┘       └───────┘       └───────┘
```

Internal balance & bias presets may affect the shift offset position as the gain is altered. (A calibration round robin.)

Y Gain. A wide range stepped input attenuator in front of the Y pre-amplifier that through the Y defection amp drives the Y plates. Volts per division is in 10 3 1 steps or 10 5 2 1 steps per decade.

```
                                           │‾‾│  │‾‾│ good square
                               ‾‾│  │‾‾    │  │  │  │ waves have
 ┌──┐__┌──┐    ┌──┐  ┌──┐   │‾‾ │  │ ‾‾│  │  │  │  │ invisible
                  └──┘          │__│          │__│    verticals!
   10V/div       5V/div        2V/Div      1V/Div
```

There is often an off calibration variable gain control as well. A higher gain (e.g. pull for 10x) option switches come at the loss of display bandwidth (e.g. 20MHz reduced to 8MHz @ 10x)

Y Bandwidth can also non linear with small displays OK & large ones poor, due to high voltage output amp slew rate limitations.

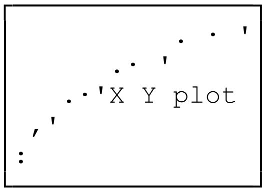
Y Input Selects input DC coupled or AC coupled that removes DC components from Y input amplifier. Note there will be a DC limit (e.g. 300V) An input grounded option is used for shift calibration.

The BNC input is normally 1MÛ//30pF (DC open circuit on AC mode), a 10:1 scope probe is designed to use this as its calibrated input load. (See ref below)

Y Select Scopes with more than one Y channel, you can select which one to use or both. Sometimes the 2 can be added or subtracted (ADD with an inverted channel).

```
      .-.                    ___
     /   \                  /   \          Subtracted
  Y1│     │             Y2 ┌┘     └┐          ┐/└┐_┌┘\┌┘‾└
AF Amp     \   /     Distorted    \___/     Distortion after gain
input 100mV '-'      AF Output 50V 4Û       adjusts cancel signal
```

X Input — This may be an option when the timebase is off. Normally fixed gain in the timebase external trigger input, or using the 2nd Y channel amp with all its gain options. Bandwidth quite a bit less than the normal Y channels.



Lissajous figures can be obtained with an X in & different but related frequencies.

```
  _ _ _       _ _        _
 (_X_X_)     (_X_)    \ to (_) to /       8

X = 3x Y    X = 2x Y     X = Y           X = Y/2
```

X Shift — This has the same function as the Y shifts but often used to move a waveform to a convenient graticule for measurement.

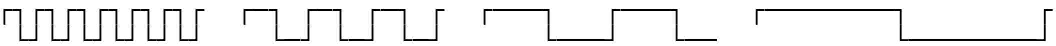
X Gain x5 — Often a fixed gain increase rather than variable. Again a higher gain will normally reduce the X bandwidth further & also make the trace proportionally dimmer. It is used to zoom in to part of the waveform.

X Timebase. This is a re-triggerable ramp oscillator that is used to scan the spot across the screen.

```
off__     ___     Gun Blanking
     |___|   |___|
 on

        /|       /|
       / |      / | Xamp input
 ramp/   |     /  |
 ___/    |___/    |___
hold off awaiting trigger
```

The time per division can be set over a large range of decade sub steps 10 3 1 or 10 5 2 1.



20mS/Div   10mS/Div   5mS/Div   2mS/Div

Off calibration speed variable usually provided to make waveforms fit the display better & for % measurement. A "hold off" control on some scopes lets you vary the free run timebase frequency without altering the sweep calibration.

During spot flyback the gun is turned off (blanked) to stop any misleading traces.

X Trigger Selected from Y channels, external input or mains line. Trigger can be DC or AC input & +/- edge trigger, Variable trigger Level or "Stability control" enables the exact height or slope to determine the trigger point.

```
                 +ve slope AC
                       .┴.     -DC Zero trigger
         +DC trigger -/   \  /
  +DC Zero trigger - |     |┘    |
                    /       \   / -DC trigger
                   -ve slope '-'
                   AC trigger/
```

An "HF mode" can help recover HF trigger signals better, as can triggers filters for line & frame TV waveforms. Some scopes allow for alternate channel triggering.

Some scopes can even show the trigger channel on screen.

Chop/Alt With 2 channels being displayed on a singe beam CRT there are 2 ways to do this. Either chop between them at a high frequency (e.g. @ 100kHz) to show low frequency waveforms, where gun blanking is done to hide the chop mode edges..

```
      _     _     Gun Blanking
 ____| |___| |____ signal
 _____       _____
  ch1 │ ch2 │ ch1  Chop Mode Astable
      └─────┘ Switch matrix control voltage
```

Or for higher Y frequencies say above 50kHz, use alternate & change ch. every timebase sweep. The timebase now triggers a bistable.

```
 _____        _______
 ch1  │  ch2  │  ch1  │ Y switch matrix
      └───────┘         control voltage
            /│      /│
           / │     / │ Xamp input
     ramp/   │    /  │
     ___/    │___/   │____
 hold off awaiting trigger
```

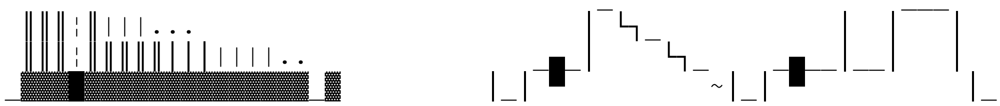
The switching is done with balanced low impedance lines with a diode matrix where only the signal currents are switched.

Simple scopes do the choice for you depending on timebase setting.

Delay Line. After the switching & before the Y display amp, fast scopes fit a signal delay line say around 20nS (e.g. 6M of 100Û twisted wire). This gives the timebase time to be triggered before the event reaches the display, so you can see it!

```
Timebase   ┌─────────────────┐  Y delay  ─────────┐ Exaggerated
delay   _  │   ┌┐_           │  >   <  ┌┐_        │ delay here!
  > <  │   │   │ └┐_         │         │ └┐_      │ But you are
 _ _█_│    │█_ │   └┐_       │ │  _█_  │   └┐_    │ able to see
|_|      │ │    Video   ~|_  │ _|       Video  ~|_│ before the
  |        │_________________│ │__________________│ trigger
Trigger     With no Y delay     With Y delay line   point!
 point
```

Dual timebase. For more advanced scopes a 2nd timebase able to run at a faster rate can be used to select a small part of the waveform. Typical example is to display one line from a TV frame waveform, e.g. a test line. Bright up highlight mode indicates the waveform section that can be expanded up. Extreme brightness is needed for this!



TV Frame 20mS   2 highlighted lines 128uS
Main frame triggered A timebase   Line triggered B timebase

Calibrate. This is usually a square wave of fixed height, sometimes at mains frequency, that is used for checking Y gain & timebase, & especially for calibrating scope probes. (see Ref. below)

```
  __|‾‾|__|  e.g. 500mV peak to peak @ 1kHz.
```

OVERALL SCOPE SYSTEM

```
   DC        _______    _______
Y1──┬─\.  │Stepped│  │  Y1   ├>Trigger         Graticule---Lamp
in  └┤├┤├─┤ Atten ├──┤preamp │                Delay
      AC  └───────┘  │x10 opt├─────┐          line_    ______
Y1gain---------------┤       │     │\___________│ │_ │  Y   ├─Y+    /\/\/
Y1shift---------------┘──────┘     │ Balanced   │_│  │output│Plates
   DC        _______    _______    │ diode matrix    │ amp  ├─Y-    \/\/\
Y2──┬─\.  │Stepped│  │  Y2   ├─────┘ switch          └──────┘
in  └┤├┤├─┤ Atten ├──┤preamp ├>Xamp   |               Rotate--Coil
      AC  └───────┘  │x10 opt├>Trigger|               Brill---CRT G1
Y2gain---------------┤       │        |               Focus---CRT A2
Y2shift---------------┘──────┘        |               Astig---CRT A3
                                ______|___   Z in--┬──────┬--CRT Anode
                               │ Chopper  │        │ CRT  │--CRT Cathode
Y Mode-------------------------┤Astable/÷2├────┬───┤ PSU  │--CRT Heaters
      Y1┐ ┌Y2        _______   └────┬─────┘    │   └──────┘--CRT EHT
Trig────  \____│Trigger│  _________ │  Blank  Y2    ______
  in           │ Gate  │ │Timebase ├┘         │ __ │  X   ├─X+    /|_/|
+/- -----------┤       │ │         │          │ /  │output│Plates  _
DC/AC----------┤       ├─┤         ├──────────┘ │  │ amp  ├─X-    \|‾\|
Level----------┤       │ │         ├────────────┘  └──┬───┬┘
TV/HF-----------┘──────┘ └──┬───┬──┘  Ramp     │      │   │
Time------------------------┘   │     X in ────┘      │   │
Variable------------------------┘                     │   │
Xshift------------------------------------------------┘   │
Xgain-----------------------------------------------------┘
```

Also see my buls on "Scope & DMM Calibrator" & "Scope Probes".

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73 De G8MNY @ GB7CIP