The Cathode Ray Oscilloscope

Introduction

The following should give the student some familiarisation with the function and uses of the **c**athode **r**ay **o**scilloscope (C.R.O.).

Consider a simple sine wave electrical signal from some source as in Fig. 1a. If we can arrange things so that this sinusoidal voltage is applied to two horizontal conducting plates then in the region between these plates, the electric field will be alternating with period T seconds. It will increase in strength to a maximum, decrease to zero, turn over, and increase in the opposite direction to an equal maximum, then decrease to zero again, in each period of time T.

Now, if there is a beam of charged particles (electrons) streaming between these horizontal plates, the oscillating electric field there will bend the beam first up, then down, then back to the undeflected position in each time period T.

Further, if the beam strikes a plate of material which fluoresces, one would see a spot of light on this plate (screen) which moves vertically up and down with period T.

Now consider a set of vertical plates, also straddling the electron beam. An electric field applied to these plates will deflect the beam horizontally by an amount proportional to the voltage applied across the plates. If, connected to these plates we have a circuit which generates a linear ramp voltage, periodically, with the same period T, as in Fig. 1b, then the spot on the screen would be forced to start at the left side and move linearly in time across the screen, reaching its maximum travel to the right at time T. The spot would disappear then, and instantaneously reappear back where it started at the left hand side. This "sweep" would repeat every time T. You may wonder how one can easily produce a sawtooth wave at *exactly* the frequency of the input signal (or if you don't, you should!). The answer is simple; you use the input signal to **trigger** the ramp (ie. to start it at its lowest voltage) every time the input voltage reaches a particular value going in a particular direction (ie. increasing or decreasing). In this way, if the input is periodic, then the sawtooth will have the same period, by definition.

The first set of plates, driven with the sinusoidally varying voltages will produce on the screen a spot travelling up and down in simple harmonic motion. If fast enough, it will appear as a solid vertical line. (Figure 2a)

The second set of plates, driven with the ramp signal, if fast enough, produces a horizontal line on the screen, as in Figure 2b.

A combination of both sets of plates, one with a sinusoidal driving voltage
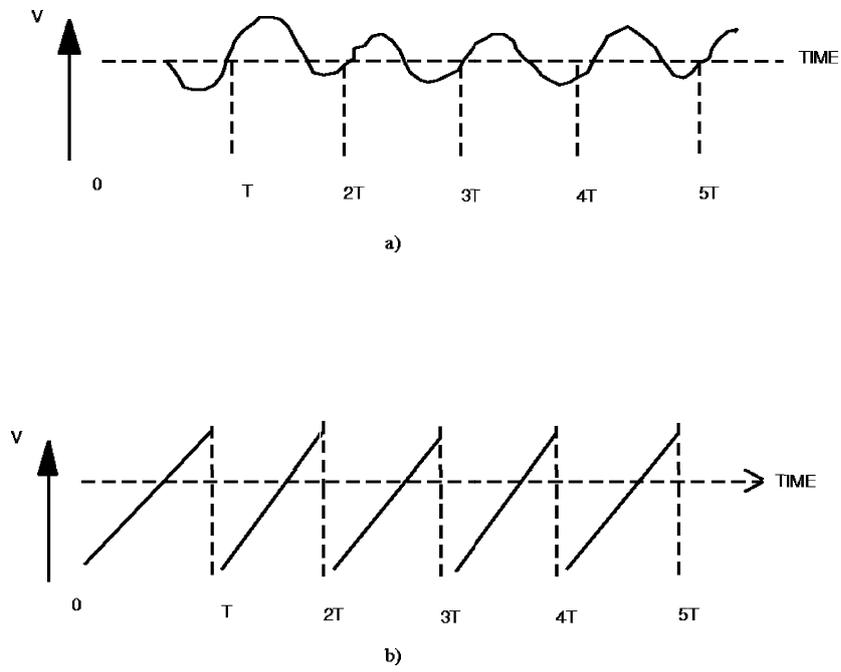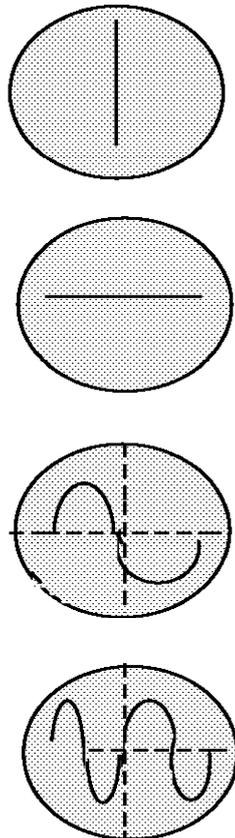
Figure 1: Periodic Waveforms
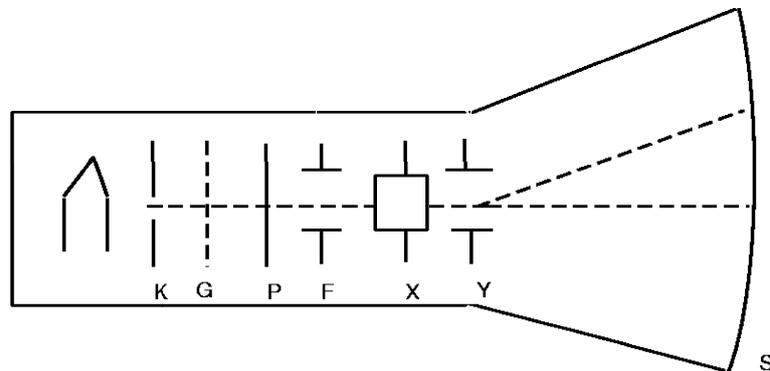

Figure 2: Different Input Signals

Figure 3: Internal Components

of period T, the other with a ramp period of period T, will produce on the screen a picture like Figure 2c, (if the two circuits are synchronised so that they start as drawn on the voltage vs. time graphs).

If the ramp period is now doubled, so that the spot sweeps across the screen in a time 2/T, on the sweep left to right the sinusoidal voltage will complete two full cycles and the picture on the screen will look like Figure 2d.

Hopefully, this introduction will have presented an idea of how the C.R.O. functions in displaying a.c. (ie. time-varying) signals on the screen.

The C.R.O. in Detail

The main part of the C.R.O. is a highly evacuated glass tube housing parts which generates a beam of electrons, accelerates them, shapes them into a narrow beam, and provides external connections to the sets of plates described above for changing the direction of the beam.

The main elements of the C.R.O. tube are shown in Figure 3.

1. **K**, an indirectly heated **cathode** which provides a source of electrons for the beam by "boiling" them out of the cathode.

2. **P**, the **anode** (or plate) which is circular with a small central hole. The potential of P creates an electric field which accelerates the electrons, some of which emerge from the hole as a fine beam. This beam lies along the central axis of the tube.

3. **G**, the grid. Controlling the potential of the grid controls the number of electrons for the beam, and hence the intensity of the spot on the screen where the beam hits.

4. **F**, the focusing cylinder. This aids in concentrating the electron beam into a thin straight line much as a lens operates in optics.

5. **X**, **Y**, deflection plate pairs. The X plates are used for deflecting the beam left to right (the x direction) by means of the "ramp" voltage. The Y plates are used for deflection of the beam in the vertical direction. Voltages on the X and Y sets of plates determine where the beam will strike the screen and cause a spot of light.

Figure 4: Front Panel

6. **S**, the screen. This is coated on the inside with a material which fluoresces with green light (usually) where the electrons are striking.

As well as this tube, there are several electronic circuits required to operate the tube, all within the C.R.O. along with the tube:

1. A power supply, operated from the 110 volt 60 cycle per second electrical "mains". This supply provides all the voltages required for the different circuits within the C.R.O. for operation of the tube.

2. A "sawtooth", or "ramp" signal generator which makes the spot move left to right on the screen. External controls for this circuit allow variation of the sweep width, and the frequency of the sweep signal. Because of the persistence of our vision, this sweep is often fast enough that what we see on the screen is a continuous horizontal line.

3. Amplifiers for the internally generated ramp signal, and for the "unknown" signal which we hook up to the C.R.O. for the purpose of displaying it.

4. Shift devices which allow us to control the mean position of the beam; up or down, or left to right.

5. The synchroniser circuit. This circuit allows us to synchronise the "unknown" signal with the ramp signal such that the resulting display is a nice clear signal like a snapshot of the unknown voltage vs. time.
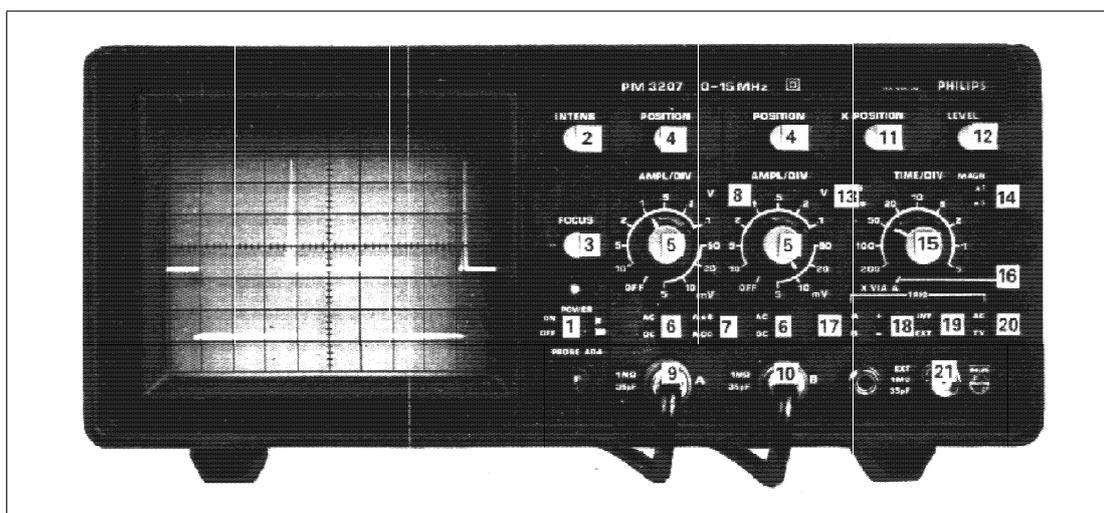

Figure 4: Front Panel

C.R.O. Operation: Typical front-panel controls

1. **On–off** switch.

2. **INTENS**. This is the intensity control connected to the grid G to control the beam intensity and hence the brightness of the screen spot. Don't run the intensity too high, just bright enough for clear visibility. Always have the spot sweeping left to right or the beam may "burn" a hole in the screen.

3. **FOCUS** allows you to obtain a clearly defined line on the screen .

4. **POSITION** allows you to adjust the vertical position of the waveform on the screen.(There is one of these for each channel).

5. **AMPL/DIV.** is a control of the Y (ie. vertical) amplitude of the signal on the screen.(There is one of these for each channel).

6. **AC/DC** switch. This should be left in the DC position unless you cannot get a signal on-screen otherwise. (There is one of these for each channel).

7. **A&B/ADD** switch. This allows you to display both input channels separately or to combine them into one.

8. **+/-** switch. This allows you to invert the B channel on the display.

9. Channel A input

10. Channel B input

11. **X POSITION** These allow you to adjust the horizontal position of the signals on the screen.

12. **LEVEL** This allows you to determine the trigger level; ie. the point of the waveform at which the ramp voltage will begin in timebase mode.

13. **ms/μs** This defines the multiplication factor for the horizontal scale in timebase mode. (See 15 below.)

14. **MAGN** The horizontal scale units are to be multiplied by this setting in both timebase and xy modes. To avoid confusion, leave it at x1 unless you really need to change it.

15. **Time/Div** This selector controls the frequency at which the beam sweeps horizontally across the screen in timebase mode, as well as whether the oscilloscope is in timebase mode or xy (x VIA A) mode. This switch has the following positions:

    (a) **X VIA A** In this position, an external signal connected to input A is used in place of the internally generated ramp. (This is also known as xy mode.)

(b) **.5**, **1**, **2**, **5**, etc. Here the internally generated ramp voltage will repeat such that each large (cm) horizontal division corresponds to .5, 1, 2, 5, etc. ms. or μs depending on the multiplier and magnitude settings. (Note also the **x1/x5** switch in 14 above.)

16. The following controls are for triggering of the scope, and only have an effect in timebase mode.

17. **A/B** selector. This allows you to choose which signal to use for triggering.

18. **-/+** will force the ramp signal to synchronise its starting time to either the decreasing or increasing part of the unknown signal you are studying.

19. **INT/EXT** This will determine whether the the ramp will be synchronised to the signal chosen by the A/B switch or by whatever signal is applied to the **EXT. SYNC.** input. (See 21 below.)

20. **AC/TV** selectors. I've never figured out what this does; find whichever position works.

21. External trigger input