NEW SOUTH WALES
TECHNICAL AND FURTHER EDUCATION COMMISSION

ADVANCED TEST EQUIPMENT

NSW Module Number: 8275A

Implementation Date: 01-Jan-1996

National Module Code: NE105

½ Module, 18 hrs.

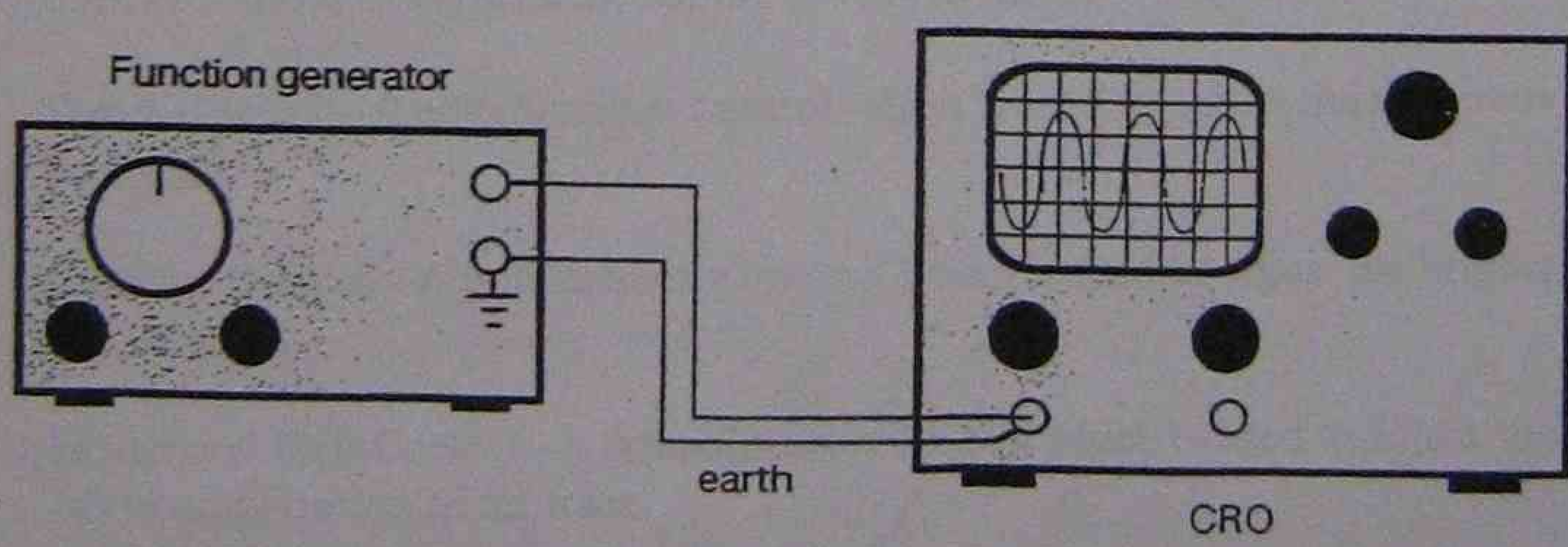
MANUFACTURING AND ENGINEERING

ELECT CONTROL & COMMUNICATIONS PROGRAM AREA

Sydney Institute of Technology

A.C. Theory

CRO Operation



TAFE NSW

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2. Construction
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1. INTRODUCTION

Alternating current (a.c.) is widely used in control systems as signals from input transducers to a source of energy to drive final control elements. A knowledge of a.c. is required to understand control systems as well knowing how to correctly uses test equipment such as Cathode Ray Oscilloscopes.

Use of a CRO and Function Generator

- The Cathode Ray Oscilloscope (CRO) is one of the most versatile instruments available and is used extensively in examining waveforms. It can be used to measure the height (in volts) of a waveform ie Vmax or Vp-p, the time period of the waveform and also shows the shape of the waveform.

- Associated with the CRO are a number of controls which permit the instrument to be adjusted for satisfactory operation.

- **General CRO controls :**

- On/Off Control - Connects the supply (240v) to the CRO.

- Focus Control - A potentiometer control which is used to adjust the sharpness of the trace.

- Intensity Control - A potentiometer control which is used to adjust the brightness of the pattern.

- Horizontal Shift Control - A potentiometer control which is used to adjust the horizontal position of the trace.

- Vertical Shift Control - A potentiometer control which is used to adjust the vertical position of the trace.

- Horizontal or Amplitude Control - A potentiometer control used to adjust the width of the trace.

- Vertical or Amplitude Control - A potentiometer control which provides a fine adjustment of the height of the pattern. (Normally placed in the "CAL" position.)

- Vertical or Attenuator - A multi-position rotary switch which provides a course adjustment of the height of the pattern.

- Horizontal or Input Selector - A switch which is used to select the source of the horizontal deflecting voltage.

- Sweep Range Selector - A multi-position rotary switch which is used to select the required frequency range of the internal sweep generator.

- Sweep Time Adjust - A potentiometer control which provides a fine adjustment of the sweep time (frequency). (Normally placed in the "CAL" position.)

- Synchronising Selector - A switch which selects the source of the signal which synchronises, triggers or locks-in the trace.

- Synchronising Adjust - A potentiometer control which adjusts the amplitude of the synchronising signal.

5. SKILL PRACTICE : USE OF A CRO

Aim: To correctly use a CRO to measure voltage and frequency.

Objectives: During this practical segment each student will be expected to :-

- To measure the period and frequency of a waveform using the CRO.
- To measure the peak to peak voltages of an A.C. waveform using the CRO.
- To measure the value and polarity of a D.C. voltage using the CRO.
- To measure the phase difference between two sine waves D.C.ng the CRO

Equipment:

- D.C Power Supply 0-30 volts, 0-2 amperes
- Function Generator
- Digital Multimeter
- Dual Trace Cathode Ray Oscilloscope (CRO)
- Resistor - 10 kΩ, 1 W
- Capacitor - 0.001 μF Polyester
- Single Pole Switch
- Connection Leads - 4 mm Banana Leads

Method 1: Oscilloscope familiarisation

In this part of the practical, you'll learn how to obtain a display on the oscilloscope screen and how to use the various controls.Remember!! If in doubt ask your teacher.

A: Obtaining a Waveform

(a) Plug in the CRO

(b) Connect a CRO probe to the channel A (or 1) input.

(c) Select this channel with the MODE switch

(d) Turn on the CRO at the power switch

(e) Check that the TRIGGER SELECT switch is on AUTOMATIC

(f) If the probe has a selector switch, set it to x 1

(g) Set the DC-GND-AC switch to AC

(h) Set the TRIGGER SOURCE switch to INTERNAL

(i) Adjust the X and Y shift controls to obtain a horizontal line across the centre of the screen. If you cannot get a trace, check the trigger select. Also, make sure the brightness control is not set to its minimum.

(j) If necessary, adjust the brightness and focus controls. The brightness should be comfortable without being too bright.

(k) Connect the probe to the CALIBRATE output on the CRO

(l) Adjust the VOLTS/DIV selector to obtain a waveform one division high.

(m) Operate the SWEEP TIME/DIV control to give a display of around three or four cycles.

(n) If the trace is drifting across the screen, adjust the TRIGGER LEVEL control until the trace is locked in position.

By now you should have a waveform consisting of three or four cycles of a square wave on the screen. If not, check each of the procedures above, otherwise ask the teacher.

B: Learning the Controls

(a) Adjust each of the following controls in turn, first fully clockwise then fully anti-clockwise and observe and record their effect on the waveform.

Table 1

Control	Effect
Vertical position (Y shift)	
Horizontal position (X shift)	
Intensity	
Focus	
Volts/Div switch	
Sweep Time/Div Switch	

Most oscilloscopes have a control, called a vernier control, associated with the VOLTS/DIV and SWEEP TIME/DIV switches. These controls can be used to 'size' the waveform - try them now....

However, if these controls are moved from their OFF position, the calibrations for the switches no longer apply. When taking measurements, *make sure these controls are OFF.*

(b) Now repeat the procedures for the other channel (Y or 2).

(c) When you are reasonably confident with using the controls, continue with the next part of the assignment.

2. Frequency and Voltage Measurement - Sine Wave

In this part of the practical, you'll learn how to measure the frequency and voltage of a sine wave using an oscilloscope. Remember!! If in doubt ask your teacher.

A: Obtaining a waveform

(a) Connect the output terminals of a function generator to channel 1 of the CRO. *The earth of the generator must go to the earth of the CRO.* Also, if fitted, make sure the CRO probe switch is set to its x 1 position.

(b) Set the TRIGGER control of the CRO to AUTOMATIC and the INPUT MODE to AC.

(c) Set the controls of the function generator so the output level is about midway and the frequency is about 5 kHz.

(d) Have the teacher check your set-up and complete the progress table before proceeding.

Progress Table 1

First Attempt	**Second Attempt**	**Teacher Assist**

(e) Switch on the CRO and the function generator then adjust the CRO to obtain at least one whole cycle across the screen. You'll need to adjust the following controls:

- Both the X and Y shift controls to position the waveform centrally
- The TRIGGER control to 'lock' the waveform
- The VOLTS/DIV switch to obtain a trace that fits vertically in the screen

- The SWEEP TIME/DIV switch to obtain around one whole cycle on the screen.

Make sure the vernier controls for the VOLTS/DIV and SWEEP TIME/DIV switches are OFF.

B: Taking Measurements

Once the waveform is correctly displayed, its peak to peak voltage and its period can be determined. Fig.1 shows a sinewave and the measurement points required.

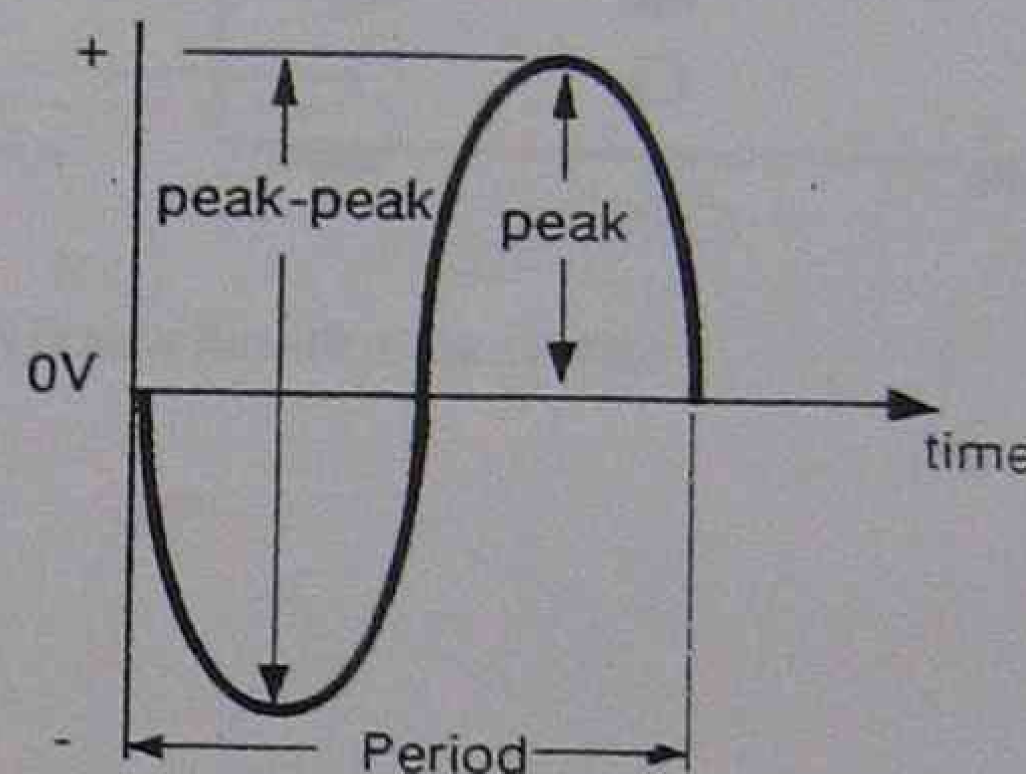


Fig.1: Voltage and time values for a sine wave

Fig.2 shows an example of how to determine the peak to peak voltage, the period and the frequency of a sinewave. The procedure is:

i. To measure the voltage, count the number of divisions and fractions of a division from the top of the waveform to the bottom. Multiply this by the VOLTS/DIV setting.

ii. To measure the period, count the number of divisions (and fractions of a division) from the left most zero crossing to the next zero crossing. Multiply this by the SWEEP TIME/DIV setting. (Note, you can also use any two similar points of the wave, such as the two peaks of the waveform)

iii. To determine the frequency, divide the period into one (reciprocal of period.)

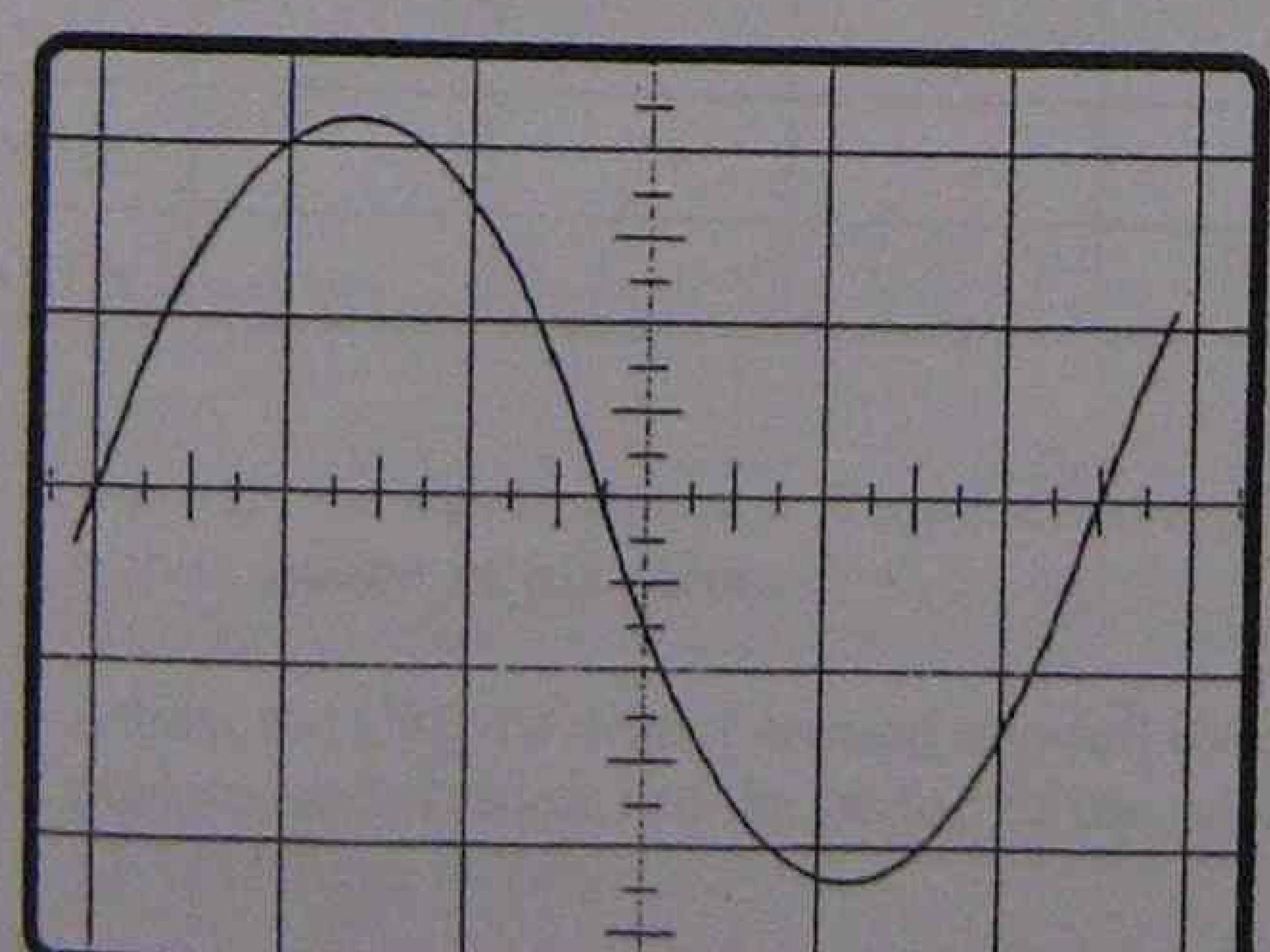


Fig.2: Measuring voltage and period using a CRO

Example

If VOLTS/DIV setting is 2V:
Volts pk-pk = 4 1/2 divisions x 2V

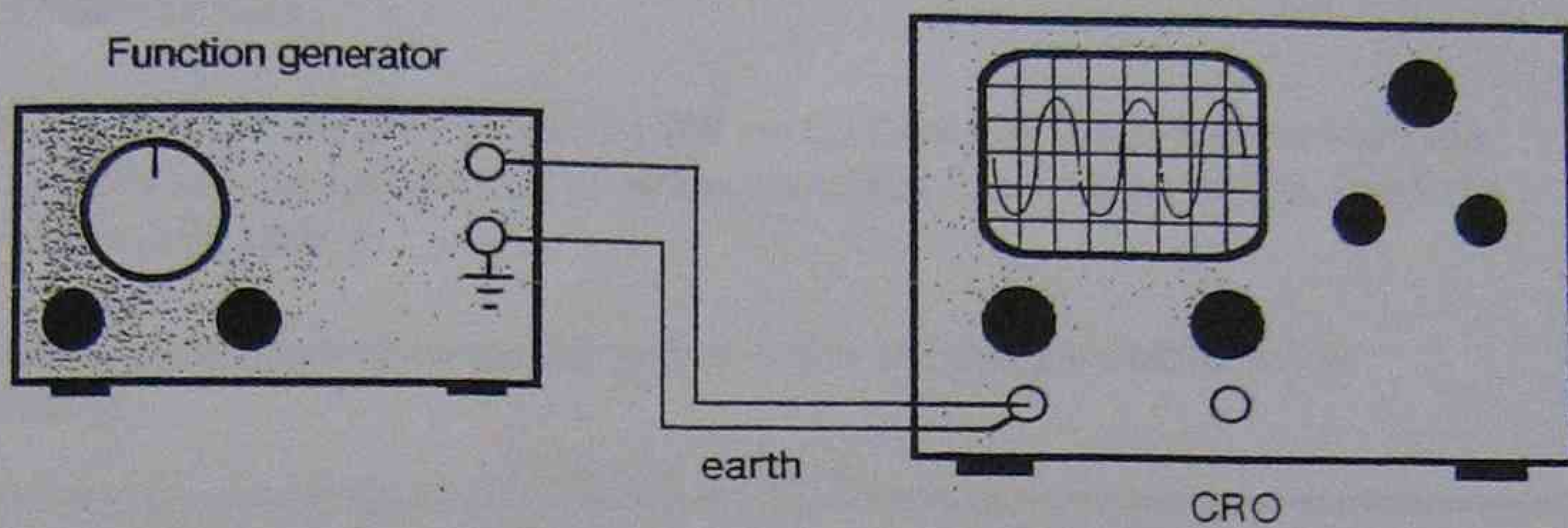
Vp-p = 9V

If SWEEP TIME/DIV setting is 50us:
period (T) = 5 1/2 divisions x 50us

period (T) = 275usecs

Therefore, because frequency $= \frac{1}{T}$

frequency $= \frac{1}{275us} = 3.64kHz$



Connecting a CRO to a function generator

(a) For the waveform you now have on the CRO, determine the peak to peak voltage, the period and the frequency. Enter these values in Table 2. Also enter the VOLTS/DIV setting and the SWEEP TIME/DIV settings. The first line of the table has been completed as an example.

Table 2

Frequency indicated on scale of signal detector	Sweep Time/Div setting on CRO	Width of Waveform Number of divisions	Measured period (T) of Waveform	Calculated frequency of waveform (1/T)	Volts/Div setting of CRO	Height of waveform. Number of divisions	Measured voltage of waveform (Vp-p)
1kHz	100μsec	9.9	990μsec	1100Hz	5V/div	1.4	7Vp-p
5kHz							
10kHz							
100kHz							

(b) Increase the signal generator frequency to around 10kHz and reduce the output level to one quarter of full output.

(c) Adjust the CRO to display around one full cycle of the waveform and measure the peak to peak voltage and the period of the waveform. Enter these results, (with the CRO settings in Table 2.

(d) Increase the signal generator frequency to around 100kHz and increase the output level to its maximum.

(e) Adjust the CRO to display around one full cycle of the waveform and measure the peak to peak voltage and the period of the waveform. Enter these results, (with the CRO settings in Table 2.

(f) Have the teacher check your results and complete the progress table before proceeding.

Progress Table 2

First Attempt	Second Attempt	Teacher Assist

3. Measuring Voltage and Frequency of a Square Wave.

(a) Leave the function generator set to 100 kHz, maximum output, but select square wave output.

(b) Adjust the CRO to obtain approximately one full cycle on the screen.

(c) Using the same procedures described for the sine wave, measure the frequency and the peak to peak output voltage of the square wave. Figure 3 shows how these measurements apply to a square wave. Record the readings and CRO settings in Table 3.

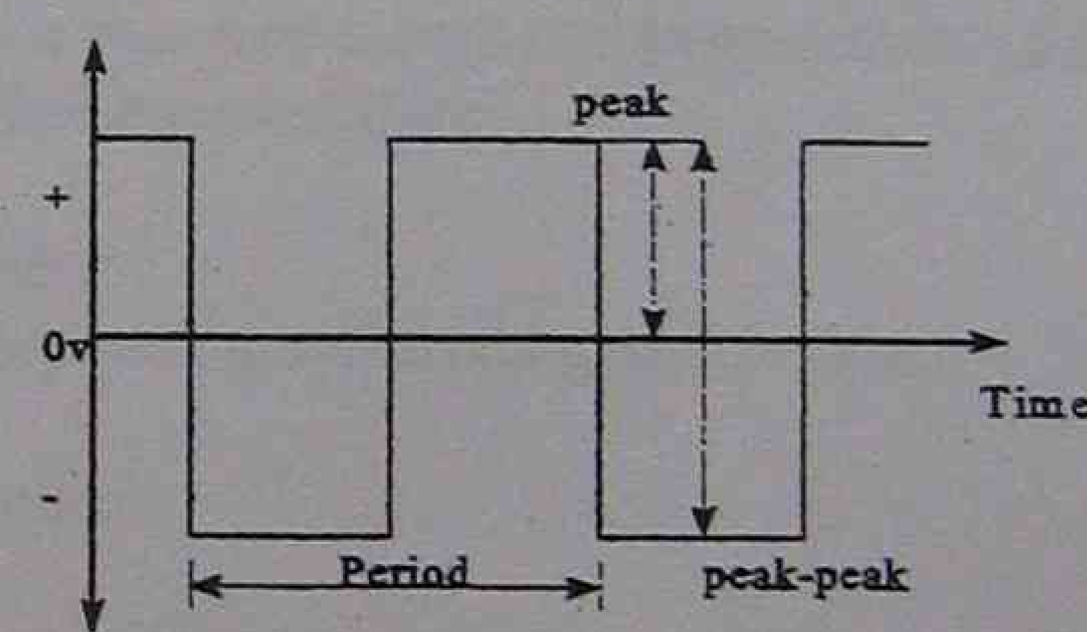


Figure 3: Voltage and Time Values for a Square Wa

Table 3

Frequency Indicated on Scale of Signal Generator	Sweep Time/Div Setting on CRO	Width of Waveform Number of Divisions	Measured Period (T) of Waveform	Calculated Frequency of Waveform (1/T)	Volts/Div Setting of CRO	Height of Waveform Number of Divisions	Measured Voltage of Waveform (Vp-p)
100kHz							
2kHz							

(d) Set the function generator to frequency of around 2kHz and adjust the output to approximately half of the output.

(e) Measure the frequency and the peak to peak voltage then record these values in Table 3.

(f) Have the teacher check your results and complete the progress table before proceeding.

Progress Table 3

First Attempt	Second Attempt	Teacher Assist

4. Measurement of DC with an Oscilloscope

In this part of the practical, you'll learn how to measure a DC voltage using an oscilloscope. Remember!! If in doubt ask your teacher.

Measuring DC with a CRO

A DC voltage has no 'shape' - it is simply a straight line when viewed on a CRO. However, the voltage value will cause the trace to move either up the screen (for positive values) or down the screen (for negative values.) The distance the trace moves is a measurement of the DC voltage. To measure DC voltages, use the following procedure:

(i) Select GND input on the MODE select switch
(ii) Obtain a trace on the CRO screen positioned over a horizontal graticule line.
(iii) Connect the probe to the DC source
(iv) Set the VOLTS/DIV switch to a suitable value
(v) Select DC on the MODE select switch
(vi) Note the distance moved by the trace. If it moves off screen, select a higher VOLTS/DIV setting, **but repeat steps (i) and (ii)**

The DC voltage is determined by multiplying the VOLTS/DIV setting by the number of divisions moved by the trace.

A. Measuring a Positive DC Voltage

(a) Disconnect the function generator, then connect the CRO probe (set to its x 1 position) to a variable DC power supply. Connect the probe tip to the positive terminal and the earth of the CRO to the negative terminal.

IMPORTANT

Make sure the power supply terminals are not linked to earth

(b) Select the GND position for the CRO input (MODE switch) and 5V/division on the VOLTS/DIV switch.

(c) Position the trace so that it aligns with the bottom line of the graticule.

(d) Adjust the power supply to approximately 15V.

(e) Switch the MODE switch to DC and observe the number of divisions the trace moves. From this determine the value of the DC input voltage where:

DC volts = number of divisions trace moves x VOLTS/DIV setting.

+ ve DC voltage = _______V

(f) Vary the output voltage of the power supply and note how the trace responds.

___

___

___

(g) Select AC input on the MODE switch and note the effect on the trace. Also note the effect when the power supply voltage is varied while the MODE switch is set to AC.

___

___

___

___

(h) Have the teacher check your results and complete the progress table before proceeding.

Progress Table 4

First Attempt	Second Attempt	Teacher Assist

B. Measuring a Negative DC Voltage

(a) Select GND on the input MODE switch and position the trace over a horizontal line at the top of the CRO screen.

(b) Select the 5V/div setting on the VOLTS/DIV switch

(c) Reconnect the CRO probe so that the probe tip connects to the negative terminal of the power supply and the earth of the CRO connects to the positive terminal of the power supply.

IMPORTANT

This is possible only if the power supply terminals are not linked to earth. If in doubt, ask the teacher.

(d) Switch the MODE switch to DC and observe the number of divisions the trace moves. From this determine the value of the DC input voltage where:

DC volts = number of divisions trace moves x VOLTS/DIV setting.

-ve DC voltage = ________V

(e) Have the teacher check your results and complete the progress table before proceeding.

Progress Table 5

First Attempt	Second Attempt	Teacher Assist

5. Phase Measurement with an Oscilloscope

In this part of the practical, you'll learn how to measure phase difference using an oscilloscope. Remember! If in doubt ask your teacher.

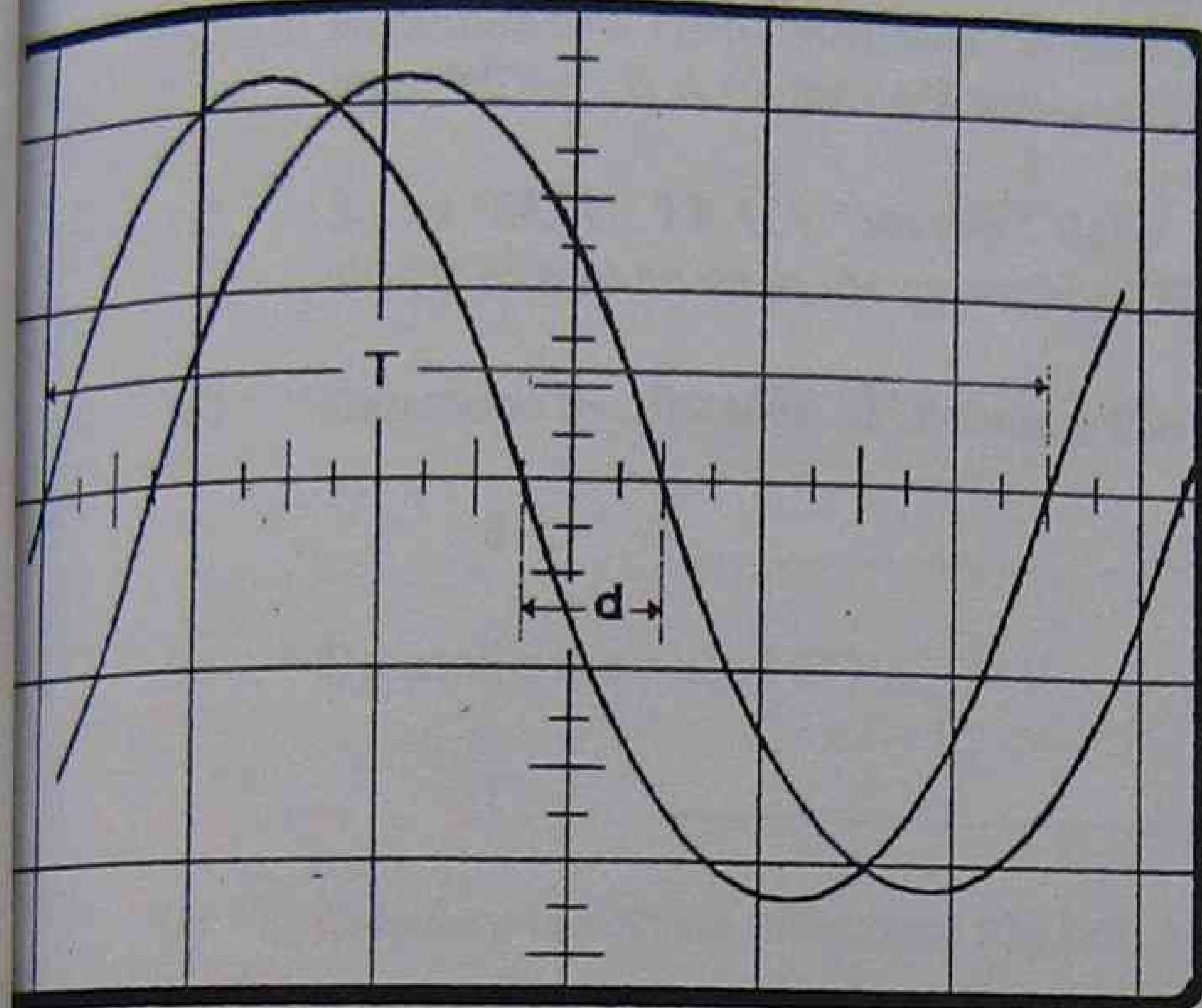
Introduction

Phase difference refers to the "distance" in electrical degrees between two waveforms. Phase difference is an important quantity and can be measured with a CRO providing the CRO is able to display two waveforms. This type of CRO is known as a "dual trace" CRO.

Fig.4 shows the type of display that will occur when two sinewaves that are out of phase are displayed on a dual trace CRO. To find the phase difference:

(i) determine the length - in divisions - of one complete cycle (T)
(ii) determine the distance (d) between the two waveforms
(iii) use the equation: phase difference (ϕ) = (d/T) x 360^0

The example of Fig.4 illustrates this method. Notice that both waveforms are positioned centrally around the middle line of the graticule.



$$\phi = \frac{d}{T} \times 360^\circ$$

$$= \frac{0.75\text{div}}{5.5\text{div}} \times 360^\circ$$

$$= 0.136 \times 360^\circ$$

$$= 49.1^\circ$$

Fig.4: Measuring phase difference with a dual trace CRO

In this practical, a resistor and a capacitor are used to produce two waveforms that have a phase difference.

(a) Connect the circuit of Fig.5. Make sure the earth of the CRO and the function generator connect together and to the bottom of the 10k resistor.

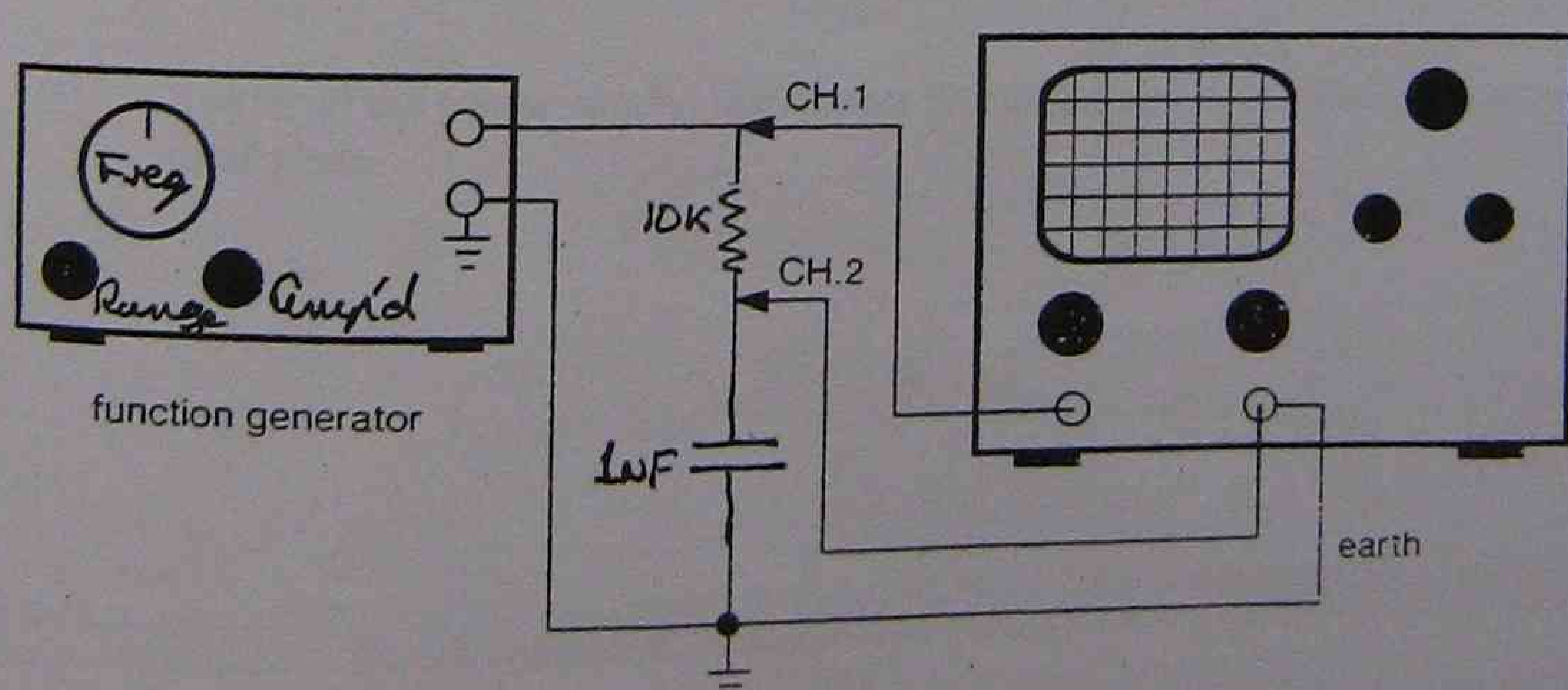


Fig.5: Measuring phase difference

(b) Set the output of the function generator to a frequency of 10 kHz. (sinewave) and the amplitude to 2Vp-p. Note that channel 1 of the CRO will show this signal and that the input MODE is A.C. for both channels.

(c) Select "DUAL TRACE" on the CRO and adjust both channels to obtain a display similar to that given in the example of Fig.4.

(d) Determine the distance "d" between the two waveforms.

d = ________________ divisions

(e) Determine the period (T).

T = ________________ divisions

(f) Calculate the phase difference (ϕ) between the two waveforms.

$\phi = \frac{d}{T} \times 360^0$ = ____________ $\times 360^0$ = ________ degrees

(g) Have the teacher check your results and complete the progress table before proceeding.

Progress Table 6

First Attempt	Second Attempt	Teacher Assist

(h) Switch off the power supply, disconnect the circuit and return the equipment to its usual place.

 Name Date

Determine the following from the display shown in Fig.1:

(a) Peak to peak voltage for both waveforms if the volts/division switch is set to:

i) 5V/div

ii) 200mV/div

iii) 40V/div

(b) Calculate the phase difference between the two waveforms and indicate which is lagging.

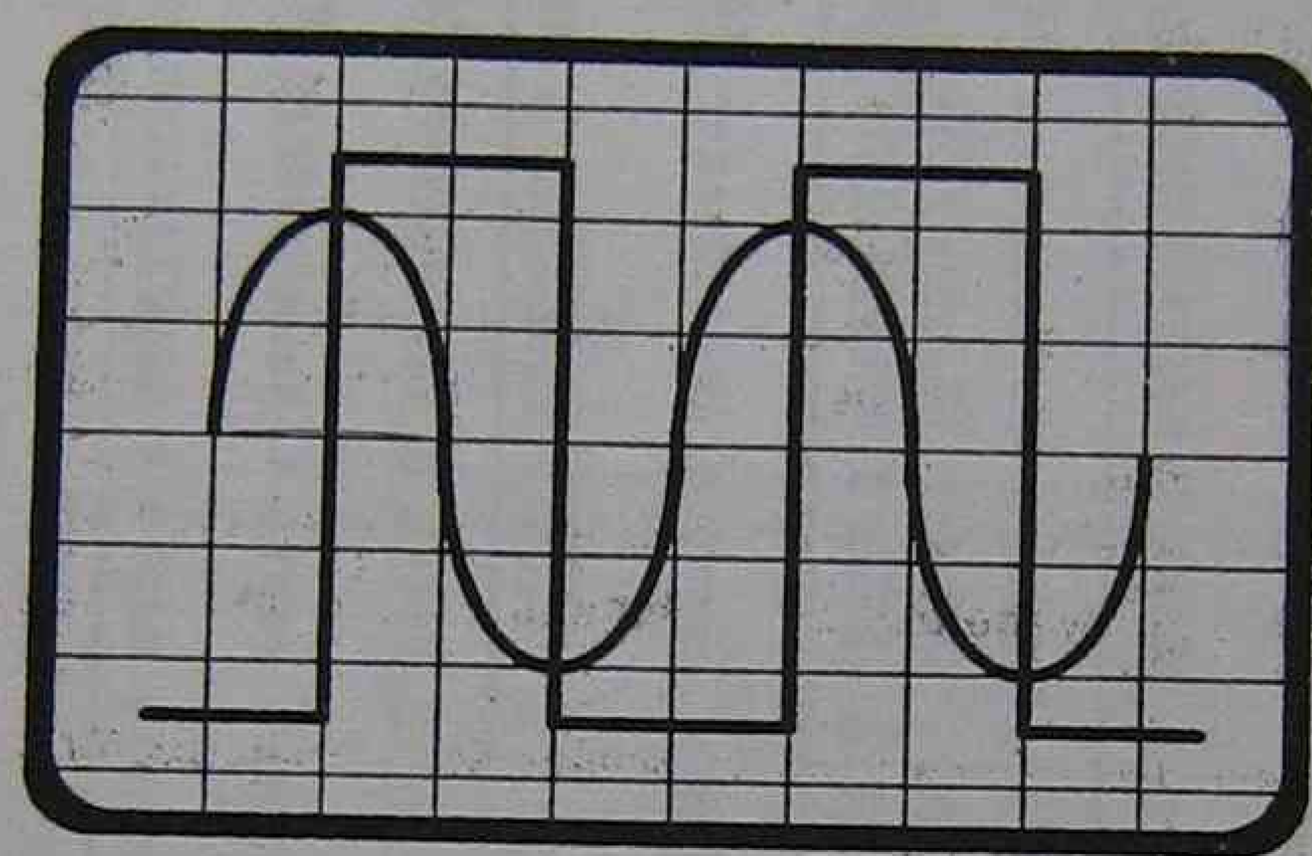


Fig.1

For the circuit of Fig.2, calculate the values of V1 and V2.

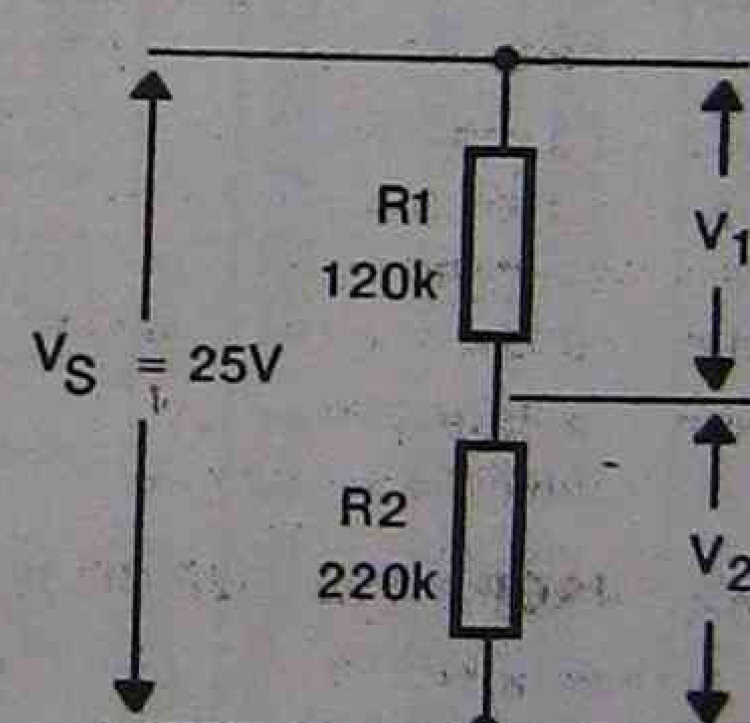


Fig.2

Calculate the voltage gain of an amplifier if a 10kHz input signal of 200mVp-p produces an output of 2.4Vp-p.

List the effect an increase in temperature will have on the base current and the collector current of a silicon transistor.

An amplifier with an output resistance of 1k produces an output signal of 20Vp-p when it is not connected to a load. Calculate the output voltage if the amplifier is connected to a load of:

(a) 1k,

(b) 100 ohms

Using the data sheet on the previous page, determine the most suitable replacement for a BC107 transistor from a choice of transistor types BC108, BC109, BC157, BC177, BC327, BC337 and BC547.

TPH 0541

Engineering Training Publication

Cathode Ray Oscilloscope Principles - ETP 0359

Issue 1, 1970

Prepared by:
Training Group.

Authorised by:
Superintending Engineer,
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Distribution Code: Selective
Filing Category: K

Telecom Australia

Telecom Australia
ENGINEERING TRAINING
210 Kingsway, South Melbourne 3205

Training
PUBLICATION
ETP 0359

CATHODE RAY OSCILLOSCOPE PRINCIPLES

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1. INTRODUCTION

1.1 A Cathode Ray Oscilloscope, more generally known as an oscilloscope or C.R.O., provides a means of 'seeing' electrical variations by the deflection of a glowing spot of light on a screen. The area of the screen touched by the spot continues to glow after the spot has moved on, and thus presents a picture or graph of the voltage variations in the form of a glowing trace on the screen.

1.2 The trace on the C.R.T. screen is used for:

- EXAMINING WAVESHAPES. The alterations to signal waveshapes produced by amplifiers and other equipment can be examined, and the information used to evaluatethe performance of the circuit, or to trace fault conditions.
- MEASURING THE AMPLITUDE AND THE RELATIVE TIME BETWEEN PARTS OF A WAVEFORM. Most modern oscilloscopes have an internal standard for accurately determining which scales to apply to the C.R.T. graph. Such an oscilloscope is called a calibrated oscilloscope and is an accurate measuring instrument with many applications in telecommunication measurements.

1.3 This paper introduces the circuit elements and controls which must be understood to effectively use a basic calibrated oscilloscope for testing purposes.

E.T.S. 12/0703

2. GENERAL.

2.1 The essential parts of an oscilloscope are:

- A cathode ray tube.
- Circuits which control the spot produced by the cathode ray tube.
- Power supplies.

Fig. 1 shows a block diagram of an oscilloscope and the interconnection of these parts. When power is connected to the cathode ray tube it produces an area of light on the screen. This glowing area will remain stationary unless circuits are provided to move it in accordance with the voltage pattern being observed. The functions of these circuits are developed in subsequent sections of this paper.

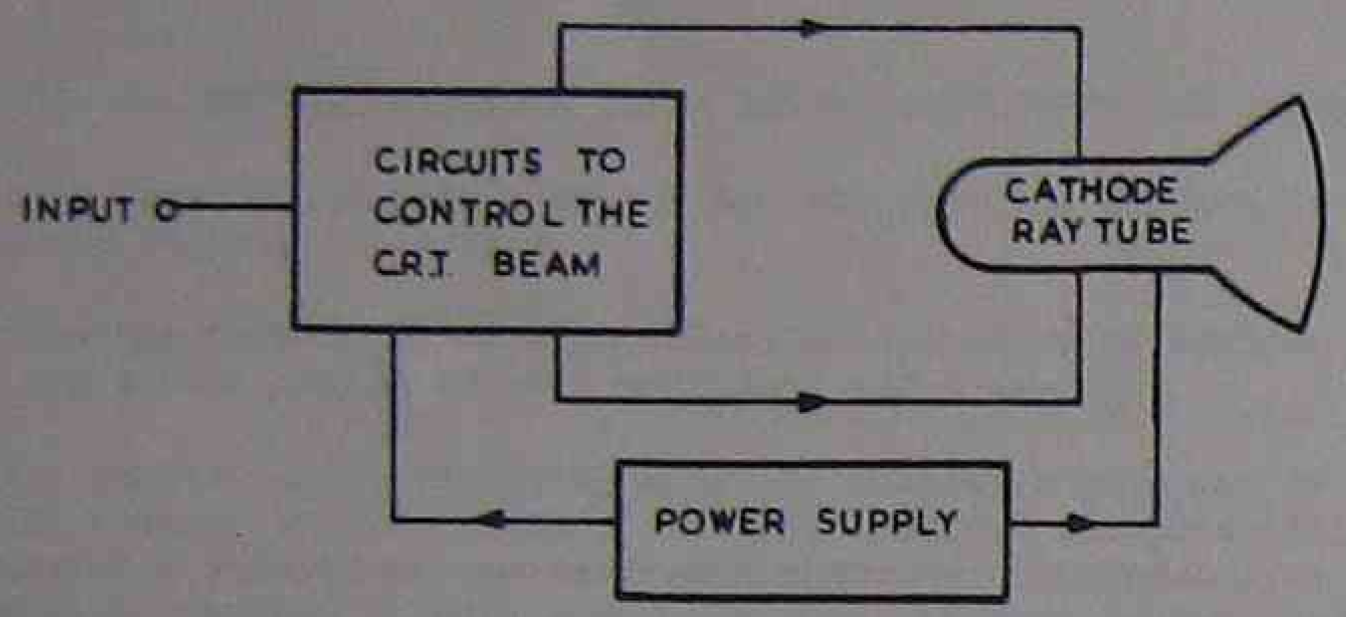


FIG. 1. BASIC OSCILLOSCOPE.

3. CATHODE RAY TUBES. (C.R.T.)

3.1 Many years ago a Physicist discovered that certain substances, called phosphors, emitted light when bombarded by electrons in a vacuum. The greater the force of the electrons the greater the light emitted from the phosphor. In cathode ray tubes a beam of electrons is directed at a phosphor coated screen to obtain a bright glowing area on the phosphor.

It was also discovered that the electron beam could be deflected (or bent) by an electrostatic or electromagnetic field. A simple cathode ray tube was created by coating the inner surface of a glass envelope with phosphor, providing a source of electrons within the envelope, and evacuating the air by vacuum pumps. The glowing trace was viewed through the glass from the other side of the coated glass faceplate.

A modern, practical C.R.T. consists of four parts (Fig. 2). These are:

- An electron source which produces an electron beam.
- A screen coated with a phosphor to convert the energy of the electron beam to a trace visible through the glass of the screen.
- A system of focusing the beam to a fine spot on the screen. The focusing grids combined with the electron source are called the electron gun.
- A means of deflecting the beam horizontally and vertically by voltage signals.

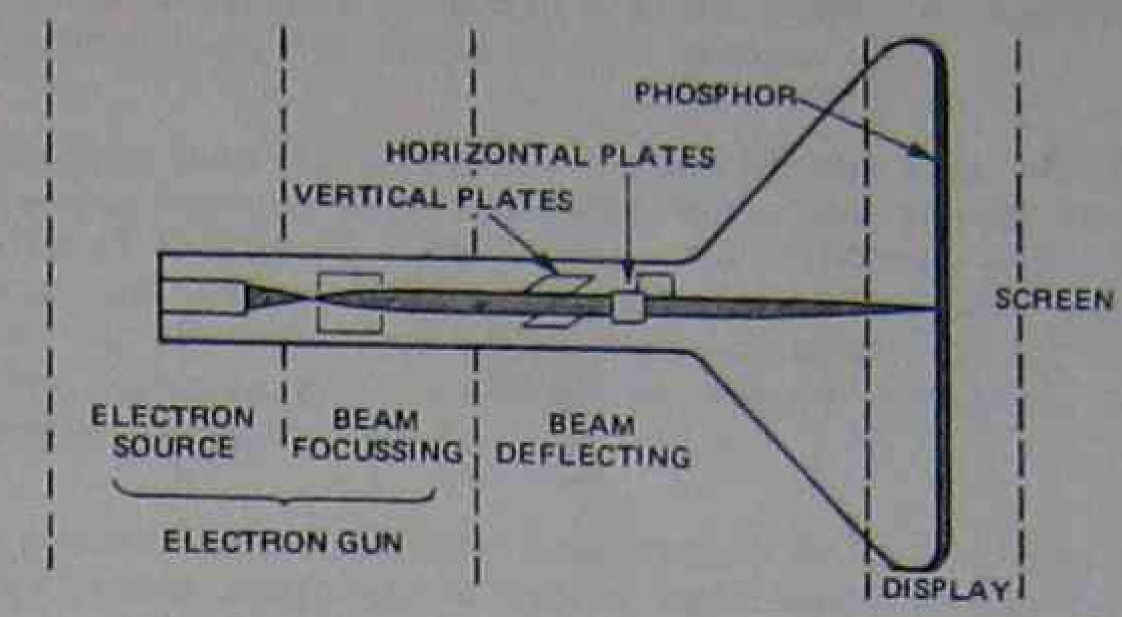


FIG. 2. FOUR MAIN SECTIONS OF A CATHODE RAY TUBE.

3.2 THERMIONIC EMISSION. The forces within the atoms of a conductor undergo changes when the conductor is heated. Some of the electrons in the outer shell of the atom collect sufficient energy to overcome the forces holding them within the atom and thus leave the surface of the conductor. Under normal atomspheric conditions, these electrons quickly lose their excess energy by collisions with molecules of air and are attracted back by the positive charge on the atom (which exhibits a positive charge when electrons are removed from it). When the conductor is heated in a vacuum, however, electrons leave the surface and are attracted towards the most positive potential acting on them. The electrons are said to be 'emitted' by the heated material, which is called the emitter or cathode. Electrons removed from the emitter are replaced from the power supply.

In a C.R.T. the phosphor is maintained at a high positive potential, relative to the electron emitter, therefore, the electrons leaving the emitter are attracted to the phosphor. The velocity of the electrons towards the phosphor is determined by the potential difference between the emitter and the phosphor. The greater the velocity of the electron, the greater the amount of light released by the phosphor at the point of impact. The emitter and power supply potentials can therefore be considered as a pump which accelerates a beam of electrons towards the screen. Surplus electrons drain back to the power supply to become part of the beam again.

3.3 THE ELECTRON GUN. This section of a C.R.T. includes:

- The cathode which emits electrons.
- The control grid to control the intensity of the electron beam.
- A number of additional accelerating electrodes, at a positive potential with respect to the cathode, to accelerate the electrons away from the cathode at a high velocity.

The actual number of accelerating electrodes varies with different types of tubes and and there may be any number from two to five. Fig. 3 represents an electron gun with three accelerating electrodes - G2, G3 and the anode. (The screen is shown but deflection arrangements are omitted).

The accelerating electrodes are sometimes called anodes - A1, A2, etc. However, the standard term for an electrode with one or more openings to permit the passage of electrons or ions is a 'grid'. The term for an electrode which collects electrons or ions is an 'anode'. In the case of the C.R.T., the electrons pass through the final accelerating grid to strike the screen and then return to the anode. In some cases, the screen itself includes a 'metallised' backing which is connected to, and forms part of the final anode.

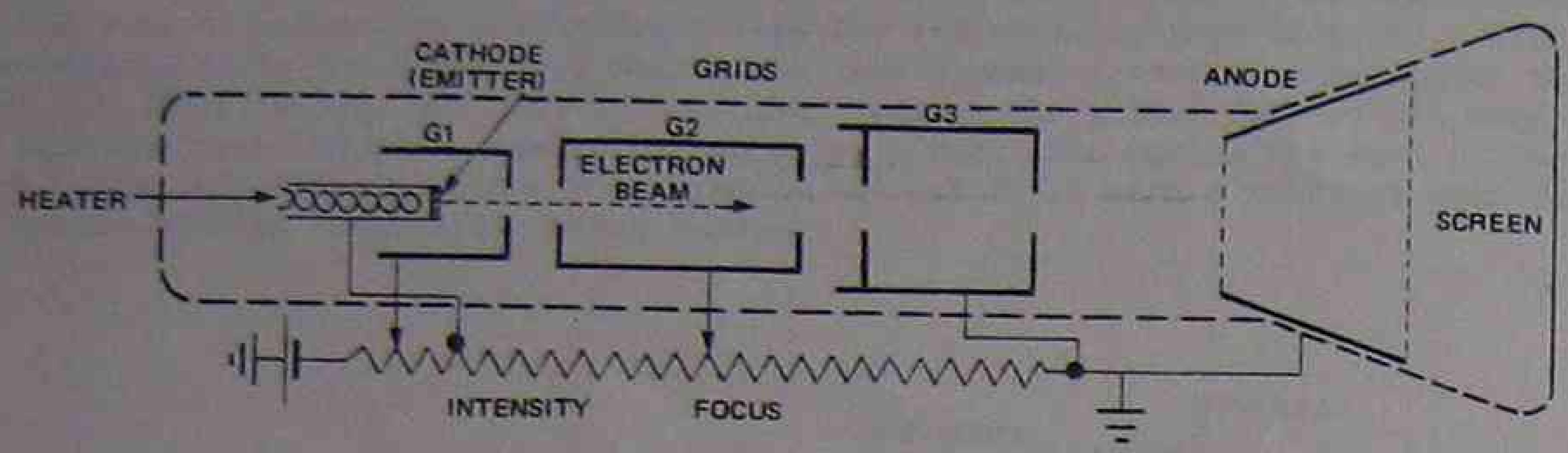


FIG. 3. TYPICAL ELECTRON GUN - BASIC ARRANGEMENT AND CONNECTION.

The cathode is usually indirectly heated and the emitting surface is confined to the disc shaped end adjacent to grid 1.

The grids take the form of discs with holes, or cylinders of various diameters and very often are a combination of both cylinders and discs.

Grid 1 is the control grid, intensity grid, or modulator grid and is generally negative with respect to the cathode. In oscilloscopes the potential of G1 is adjusted to give a pattern of the desired brightness or intensity on the screen. A varying signal is applied to this grid only when the beam is required to be interrupted or the brightness varied, such as for the black, grey and white elements of a television picture. The remaining grids are all positive with respect to the cathode and the anode is connected to the most positive potential. C.R.T.s. with large screens require very high values of voltage on the final anode. Values up to 20 kV are quite common, although most oscilloscopes are catered for with an E.H.T. (extra high tension) of under 10 kV. As the current drain of the E.H.T. is in the microamp range the problem of the energy supply is not as great as the problems of insulation. The final anode is generally a conductive coating inside the flared portion of the envelope.

3.4 FOCUSING. This is generally achieved electrostatically and is the second function of the electron gun. The shape of the grids and their position and potential in relation to each other are arranged to form an electron lens system which focuses the electron beam in a manner analagous to that of optical lenses focusing a beam of light. In fact, the phenomena has long been investigated under the name of 'Electron Optics'.

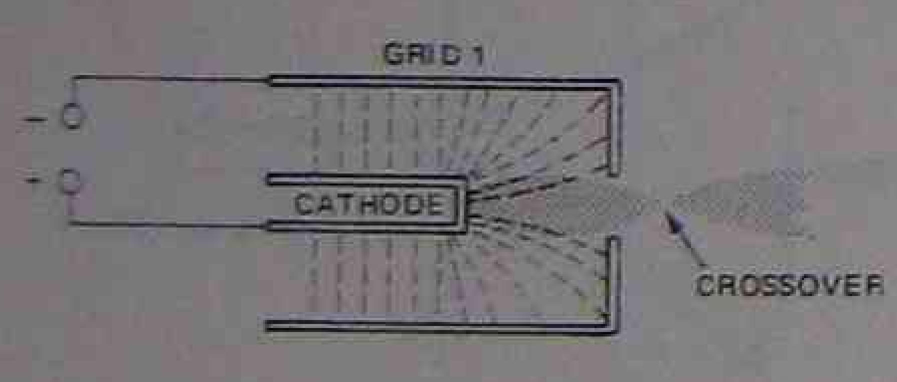


FIG. 4. FIRST ELECTRON LENS.

The electrons emitted from the cathode tend to form a diverging beam because their like charges cause them to repel each other. C.R.T's. have two electron lenses; the first is formed by the cathode and grid 1. The electric field between them (indicated by dotted line) causes the beam to converge and cross over at a point somewhere between grids 1 and 2, as represented in Fig. 4.

The first electron lens thus provides a point source at the crossover point which the second electron lens can focus on the screen.

The second electron lens is generally formed by the last two grids. (G2 and G3). The shape, spacing, and potential between these provide an electric field after the manner represented in Fig. 5. On leaving the crossover point the diverging electron paths are again bent and converge gradually on the distant screen as a small spot. The 'sharpness' of the spot (or trace when deflected) is adjusted by adjusting the potential on the focusing grid (usually the second last grid) which is G2 for the type of gun represented in Fig. 5.

It should be appreciated that this description is only a broad outline as the theory of focusing is rather complicated and of importance to the designers of C.R.T's.

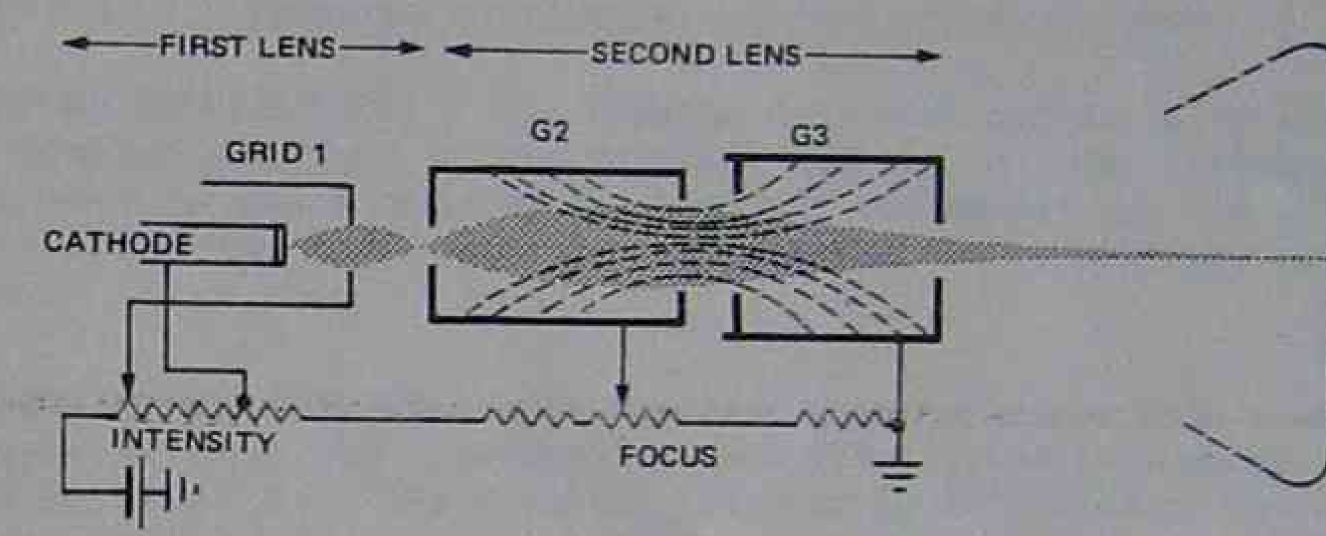


FIG. 5. SECOND ELECTRON LENS.

3.5 THE SCREEN. The end of the tube remote from the gun is coated internally with a phosphor, which emits light under the impact of the electron beam. Some phosphors continue to emit light after the beam is removed and this radiation is termed phosphorescence, or afterglow, to distinguish it from fluorescence produced only while the beam is acting on the spot. The combination of fluorescent and phosphorescence is called luminescence.

Many different compounds, or mixtures of compounds, are used for C.R.T.'s and provide a variety of colour and persistence. Persistence is the time the phosphorescence maintains a visible trace after the beam is removed. Some applications require short persistence screens while other applications require medium, long or very long persistence screens. Where the repetition rate of the sweep is low (as in radar), long persistance screens of up to a second or more are often used.

Most general purpose tubes have a medium persistence phosphor which gives a green trace. Where the pattern is to be photographed, a phosphor giving blue light is most suitable. White light emitting, medium persistance phosphors are generally used for television tubes.

4. BEAM DEFLECTION

4.1 **ELECTROSTATIC DEFLECTION** of the beam is achieved by passing the beam through two sets of deflecting electrodes called the deflecting plates (Fig. 6). With no voltages applied to the deflecting plates the spot assumes a central position on the screen, as shown in Fig. 6C. Voltages applied between the plates deflect the beam away from the negative plate toward the positive plate, thus moving the spot on the screen. The deflecting plates are located in the C.R.T. in such a position that the beam passes between them, after being focused.

FIG. 6. DEFLECTING PLATES.

4.2 **VERTICAL DEFLECTION.** The set of plates above and below the beam produces deflection up and down, that is, vertically along the Y axis. These plates are called the vertical or Y plates. Assume that the top plate (Y1) is made more positive than the bottom plate (Y2), as shown in Fig. 7. The beam deflects away from bottom plate towards the top plate and is, therefore, bent upwards by the electrostatic field. The amount of deflection depends on the potential difference between the plates and is directly proportional to this potential. For example, if a 2 volt potential difference causes the spot to be deflected 1 cm then a 10 volt potential difference produces a 5 cm deflection. Because the deflection is linear, the movement of the spot can be used to measure the applied P.D. Reversing the potentials on the plates reverses the direction of the spot movement as shown in Fig. 8.

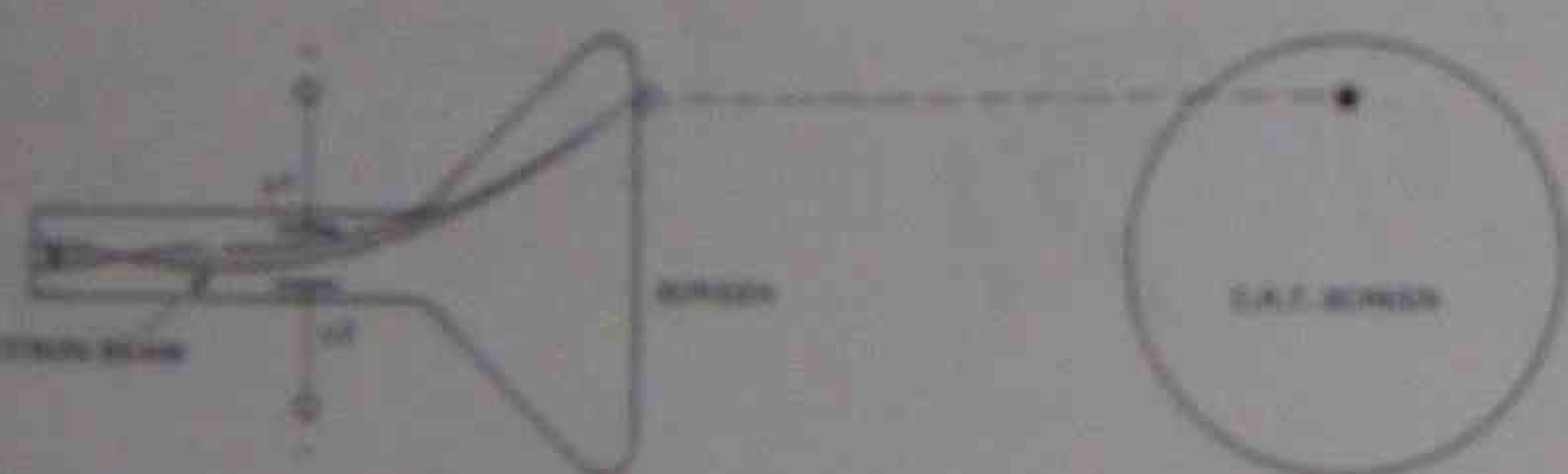


FIG. 7. VERTICAL DEFLECTION - TOP PLATE POSITIVE.

CATHODE RAY OSCILLOSCOPE PRINCIPLES

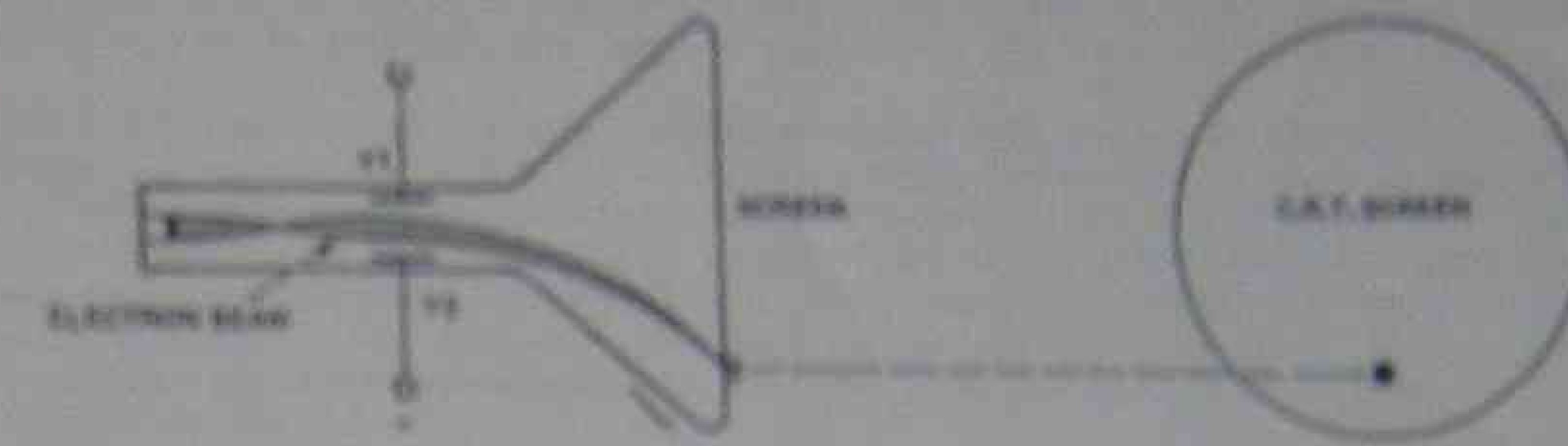
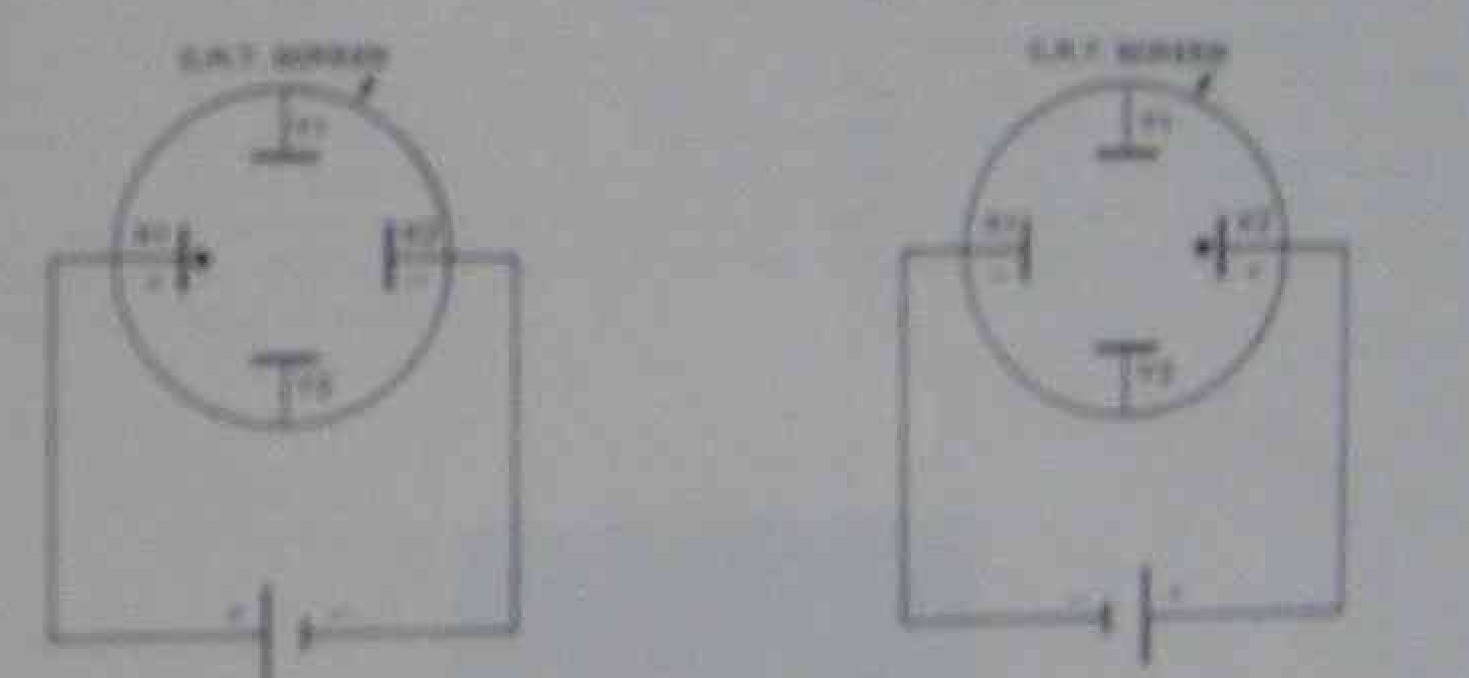


FIG. 8. VERTICAL DEFLECTION - BOTTOM PLATE POSITIVE.

4.3 **HORIZONTAL DEFLECTION.** The beam is deflected horizontally along the X axis using a similar principle to the vertical deflection. The horizontal deflecting plates are located on either side of the beam and are called the X plates. (X indicates a cross - across - and this is a useful aid to help you remember which is the X axis).

Making the plate on the left (X1) more positive than the right hand plate (X2) moves the beam towards X1 (Fig. 9a). Reversing the applied potentials moves the beam towards plate X2 (Fig. 9b). The distance the spot is deflected on the screen is directly proportional to the potential difference between the horizontal deflecting plates.



(a) X1 Positive with respect to X2 (b) X2 Positive with respect to X1

FIG. 9. HORIZONTAL DEFLECTION.

4.4 So far we have only considered the effect of a voltage applied to one set of plates at any instant. In practice, voltages are usually applied to both the horizontal and vertical plates at the same time. The beam, therefore, has two forces acting on it; one along the horizontal axis and the other along the vertical axis. The resultant spot deflection depends on the resultant of these two forces, as shown in Fig. 10.

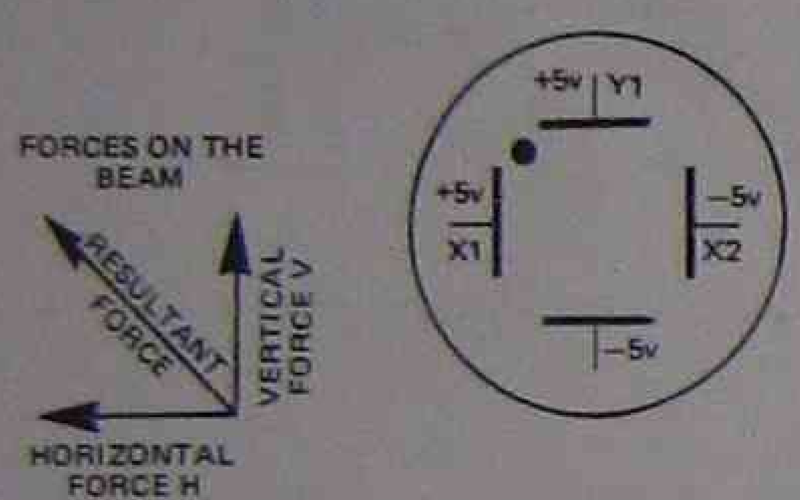
Fig. 10a shows that the beam is deflected towards the top left corner of the screen when the left hand X plate (X1) and the upper Y plate (Y1) are both positive.

Reversing the potentials on the Y plates (making Y2 positive) moves the beam towards the bottom left corner of the screen (Fig. 10b).

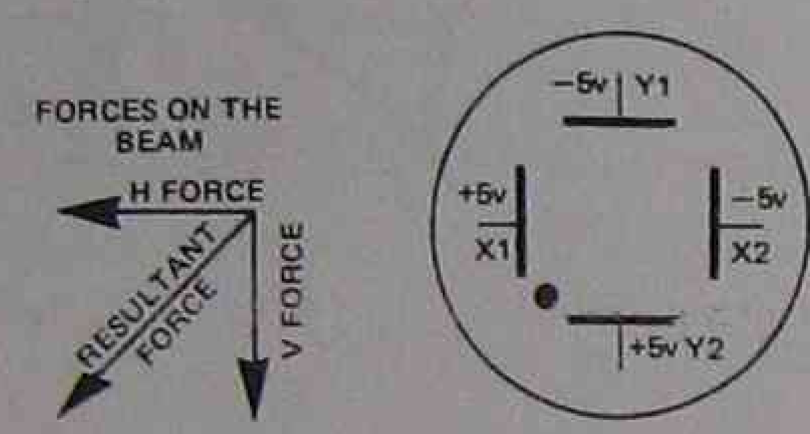
Fig. 10c shows that the beam moves towards the top right corner of the screen when Y1 and X2 are made positive.

Reversing the polarity on the Y plates, to make Y2 positive, causes the beam to be deflected towards the bottom right corner of the screen (Fig. 10d).

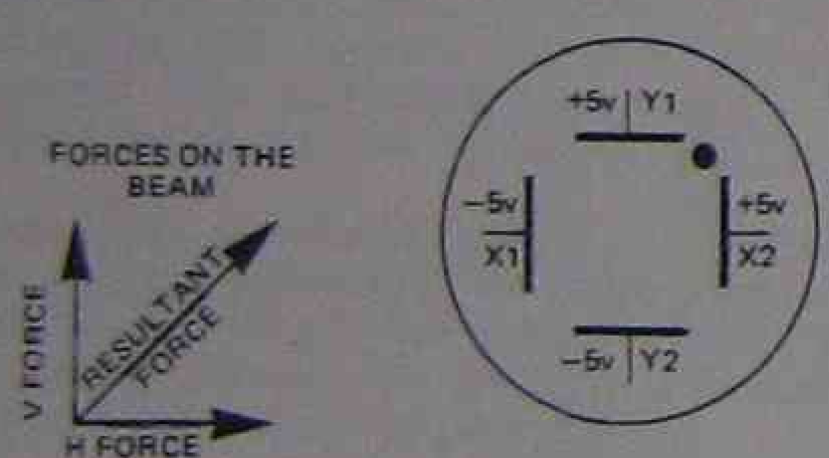
The beam can, therefore, be moved to any point on the screen by connecting suitable potentials on the vertical and horizontal plates.



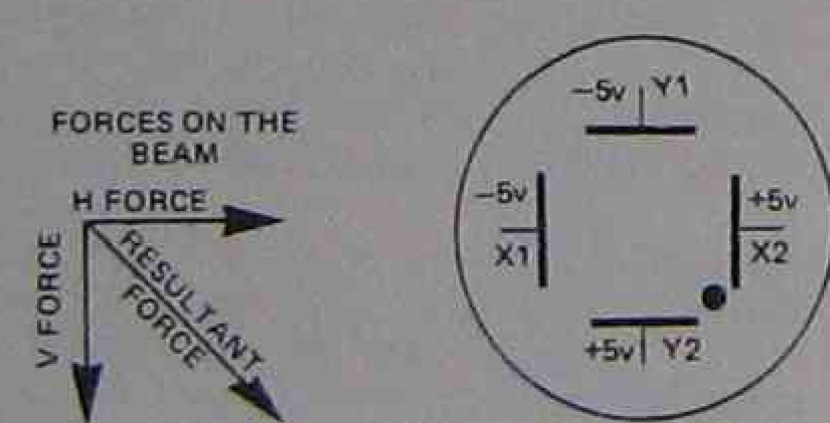
(a) X1 and Y1 positive



(b) X1 and Y2 positive



(c) X2 and Y1 positive



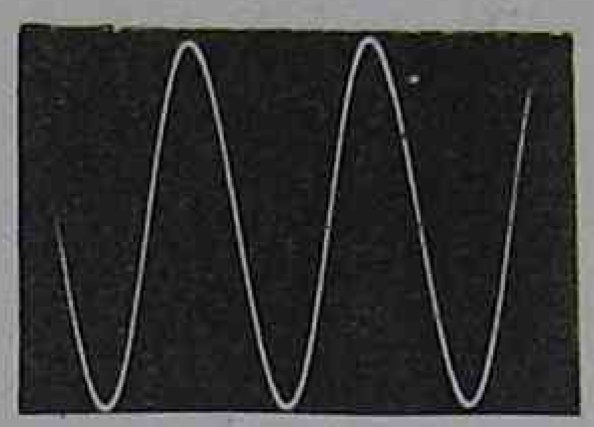
(d) X2 and Y2 positive

FIG. 10. SIMULTANEOUS X AND Y DEFLECTION.

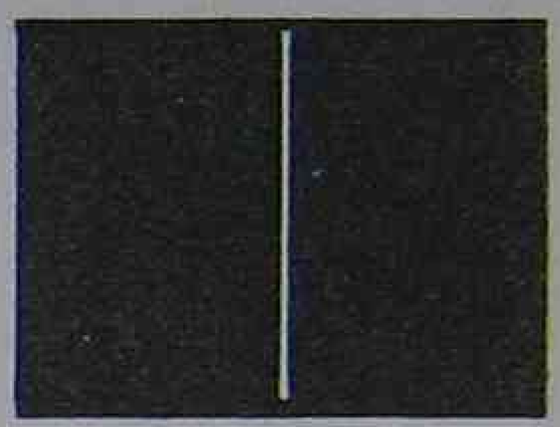
5. GENERATING A WAVEFORM DISPLAY

5.1 GENERAL. The most common use of an oscilloscope is to present the applied instantaneous voltages (applied waveform) as a graph, with the component voltages bearing the same time relationship as in the original signal. The voltages which are to be examined are usually applied to the vertical plates.

The C.R.T. pattern produced by applying a sine wave signal to the vertical plates, without a signal being applied to be horizontal deflecting plates, is shown in Fig. 11b. Since the sine wave alternatively makes each Y plate positive, and no voltage exists on the X plates to produce horizontal deflection, the spot moves up and down in a straight vertical line. This pattern is useful for determining the peak voltages of the sine wave but does not permit the wave shape to be examined. In addition, any other waveshape with the same peak voltage would produce the same display on the C.R.T.



(a) Signal on the Vertical Plates



(b) C.R.T. Display with no Horizontal Signal

FIG. 11. VERTICAL DEFLECTION WITH NO HORIZONTAL DEFLECTION.

5.2 A more useful display is obtained by causing the beam to move at a constant rate across the screen, from left to right, at the same time as the voltage variations to be examined are applied to the vertical plates. By this means, the horizontal position of the spot depends on the time which has elapsed since it started moving from the left side of the screen and the vertical position of the spot depends on the instantaneous voltage of the waveshape being examined. The combination of forces on the beam causes it to trace out a pattern which shows the voltage variations related to time. Fig. 12 shows a typical pattern produced by a sine wave a.c. signal applied to the vertical plates of a C.R.T. while a suitable signal is applied to the horizontal plates to produce a steady movement (or sweep) across the screen. The signal applied to the horizontal plates is usually called the horizontal sweep signal.

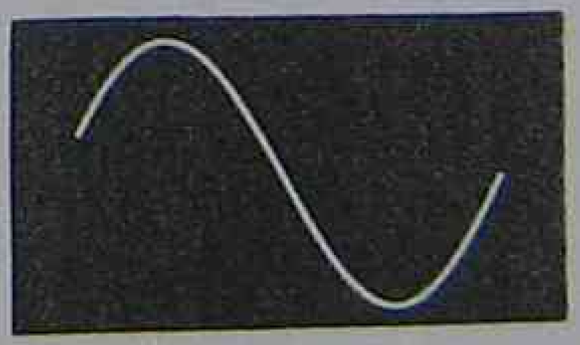


FIG. 12. SINE WAVE C.R.T. PATTERN.

5.3 HORIZONTAL SWEEP SIGNAL. This signal is applied to the horizontal plates and causes the beam to move from the left side of the screen to the right side at a constant rate and then return as rapidly as possible to the left side, ready to start the next sweep. The fast return of the beam is called the sweep retrace. The horizontal sweep voltage, and the C.R.T. pattern it produces with no voltage applied to the vertical plates, is shown in Fig. 13.

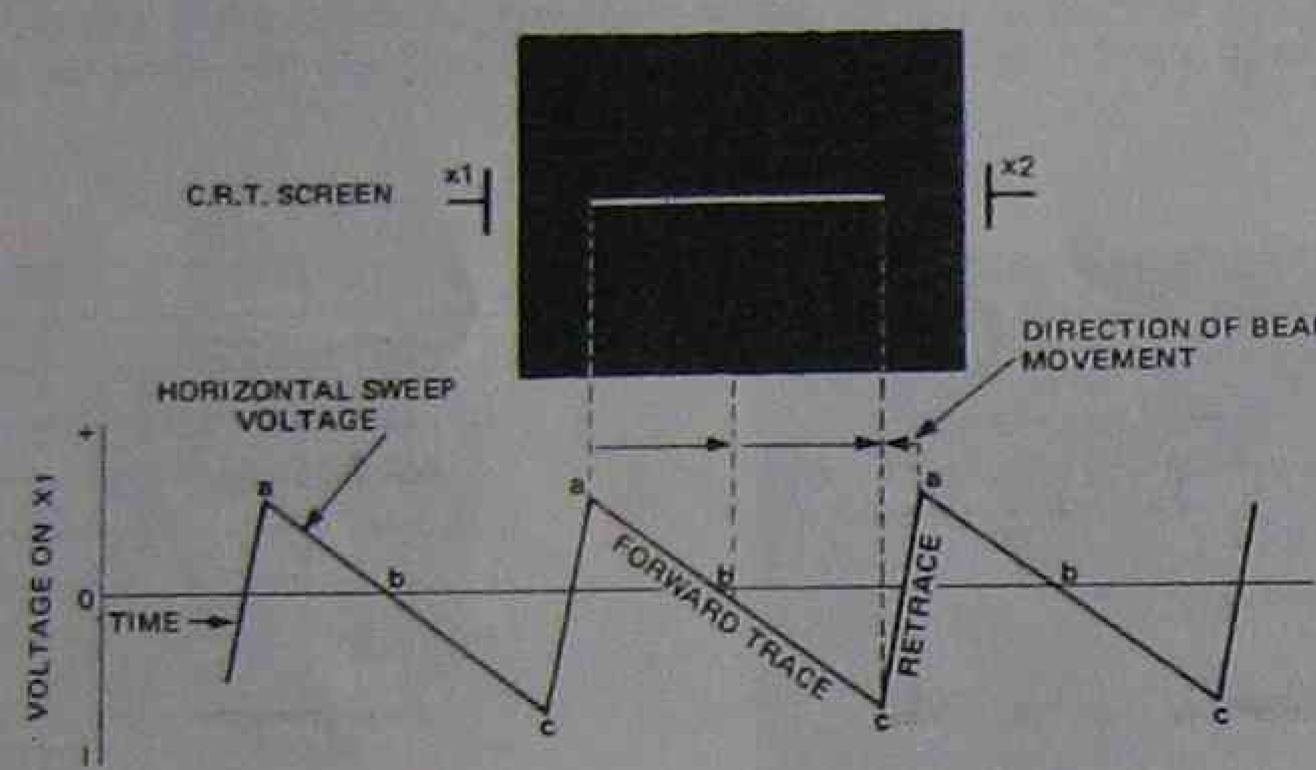


FIG. 13. HORIZONTAL SWEEP.

In order to move the spot to the left side of the screen, X1 must be positive with respect to X2 and this condition is produced when the sweep voltage is at point 'a' in Fig. 13. Steadily decreasing this potential to zero ('a' to 'b') brings the spot to the centre of the screen. Driving the potential of X1 negative with respect to X2 continues the movement of the spot towards the right side of the screen ('b' to 'c'). The rapid change of voltage during the retrace period causes the beam to return quickly from point 'c' to point 'a' ready for the start of the next forward sweep. Provided the horizontal movement of the beam is fast enough, the sweep appears as a continuous line because of the afterglow of the screen coating (phosphor). The length of time this afterglow persists after the spot has moved varies with different coating materials and is called the screen 'persistence' as explained in para. 3.5.

Because the waveshape in Fig. 13 resembles the teeth of a saw it is generally called a 'sawtooth' waveform. Sawtooth signals are produced by a special oscillator called a sweep generator. The output of this generator is generally applied to the horizontal plates, but many oscilloscopes provide facilities to connect other signals to these plates, if required.

5.4 A sinewave signal connected to the vertical plates at the same time as the sawtooth waveform is applied to the horizontal plates causes the electron beam to follow the sinewave pattern. Fig. 14 shows how the resultant movement of the beam is developed. It is assumed that the sawtooth waveform starts at the instant the sinewave is passing through zero and going positive (point 'a'). The duration of both the vertical and the horizontal waveform is the same (20m/sec. per cycle) and in each case, a 2 Volt deflecting signal causes the beam to move one division in the scale.

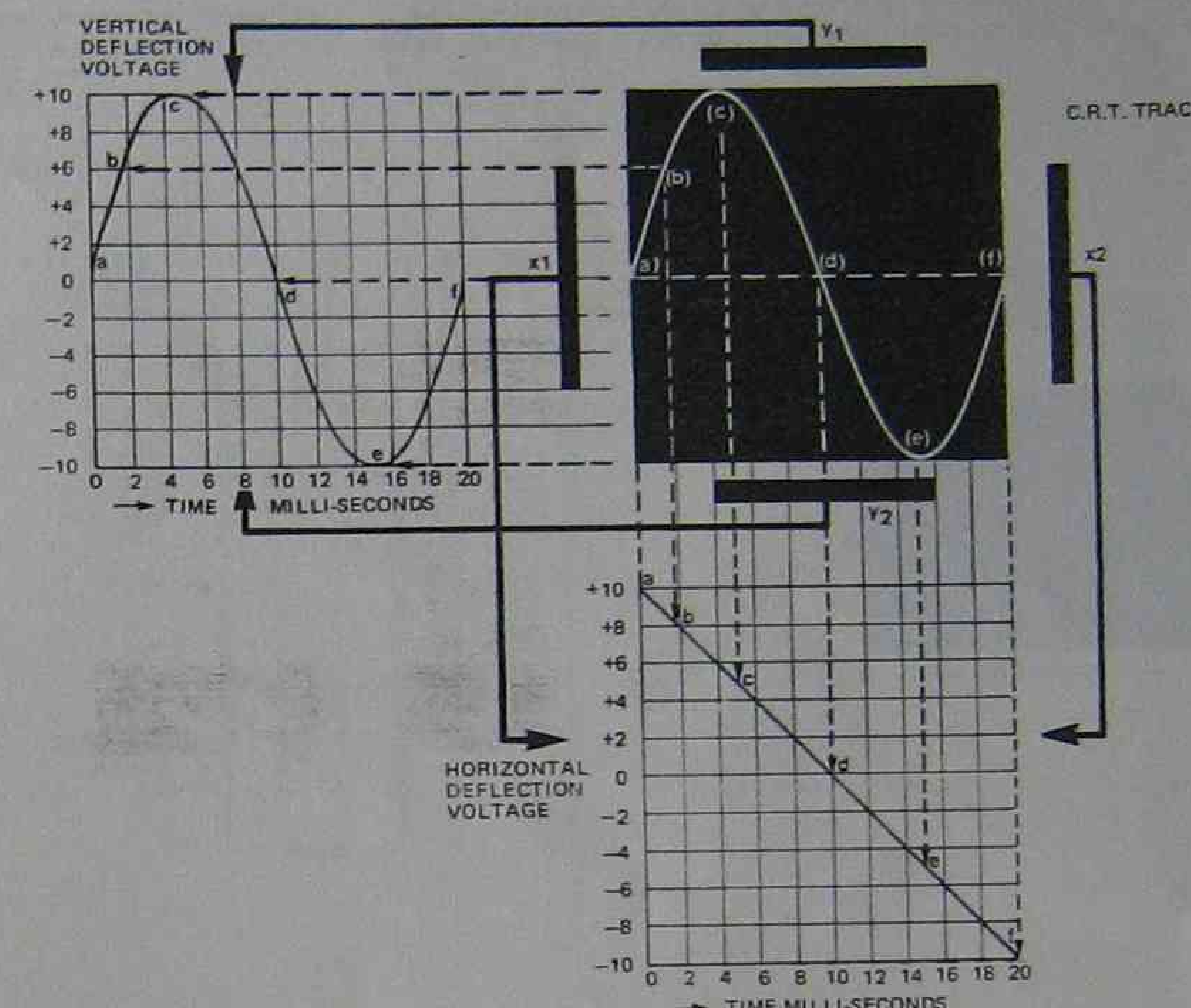
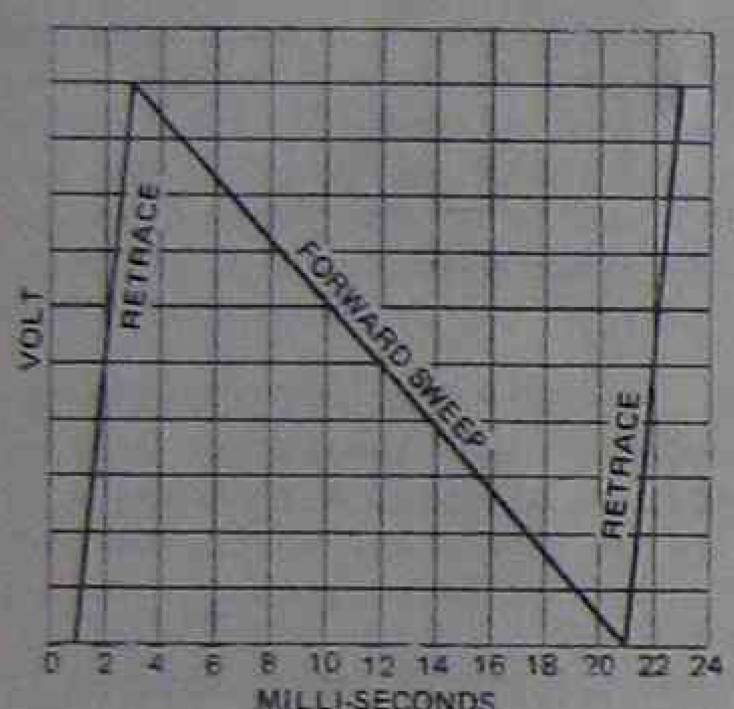


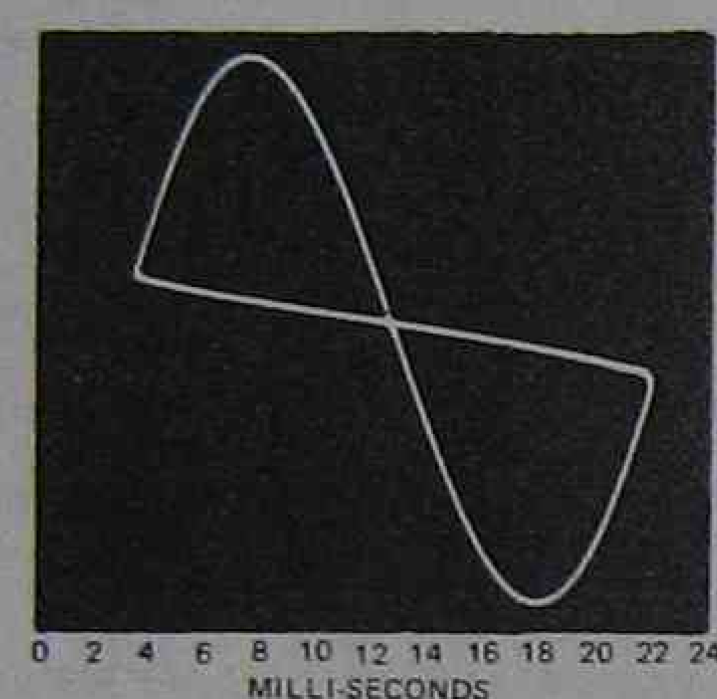
FIG. 14. CONSTRUCTION OF A TRACE FROM VERTICAL AND HORIZONTAL DEFLECTING VOLTAGES.

At the starting time (point 'a' in Fig. 14) the vertical signal is zero and the horizontal signal makes X1 10 volt positive to X2. These potentials locate the beam at the left side of the screen on the centre line. After 1.6 milli-seconds the vertical deflection voltage makes Y1 6 volt positive to Y2. The beam is deflected upwards 3 divisions. Also, at this time, the horizontal deflection voltage has decreased the potential of X1 to 8V positive. The beam is deflected four divisions left of the centre and the resultant of the two deflecting forces locates the beam at point 'b'. In a similar way the beam is located at point 'c' after 5 milli-seconds. After 10 milli-seconds both deflecting voltages are passing through zero and the spot is located in the centre of the screen (point 'd'). At 20 milli-seconds the vertical deflection voltage is again zero but the horizontal voltage on X1 is 10 volts negative and the beam is located at point 'f'. The next instant the voltage on X1 changes rapidly from 10 volt negative back to 10 volt positive with respect to X2. Thus the beam returns rapidly from 5 divisions right of the centre to 5 divisions left to the centre and is ready to repeat the trace for the next cycle of vertical deflection signal.

5.5 PRACTICAL WAVEFORM DISPLAY. The trace shown in Fig. 14 displays the full cycle of the a.c. signal applied to the vertical plates. This would only be possible if the retrace occurs instantaneously. In practice, the retrace occupies a short period of time and, as a result, some of the voltage applied to the vertical plates is not displayed on the screen. For example, in Fig. 15 the retrace occupies 2 milli-seconds, which leaves only 18 milli-seconds for the horizontal sweep. Therefore, only 18 milli-seconds of the 20 milli-seconds sinewave cycle is displayed on the screen. Some of the trace is lost because of the time taken for the beam to be returned from the right hand to the left hand side of the screen. At audio frequencies the retrace time is negligible and has little effect on the display, but at high frequencies it may account for a significant portion of the time for one cycle.



(a) Sawtooth Waveform



(b) Resultant C.R.T. Trace

FIG. 15. PRACTICAL WAVEFORM DISPLAY.

5.6 RETRACE BLANKING. In practice the beam is generally cut off during the retrace time because the retrace tends to confuse the display. One method of retrace blanking is to drive the intensity grid in the electron gun sufficiently negative to cut off the electron beam for the duration of the retrace time. Fig. 16 shows how the trace is simplified by the use of retrace blanking. Generally, a blanking pulse controlled by the horizontal sweep generator is used for this purpose.

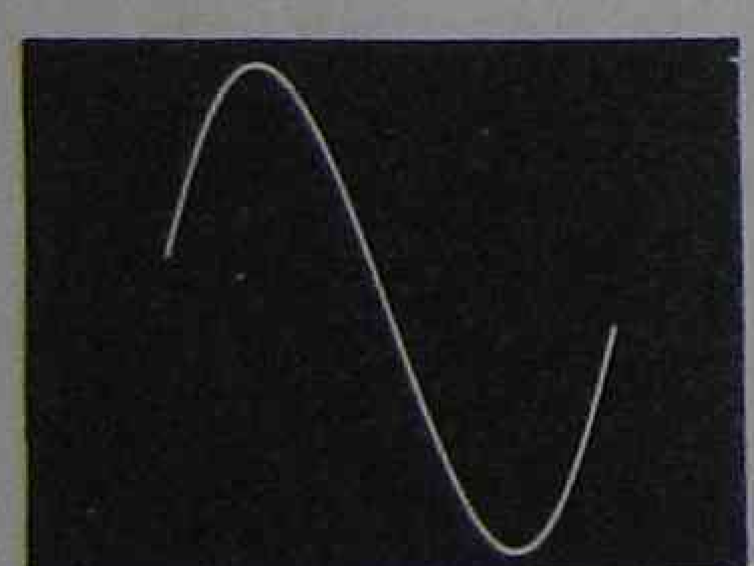


FIG. 16. RETRACE BLANKING.

5.7 MULTIPLE CYCLE DISPLAY. The sweep voltage duration is variable and by adjusting the time duration of the sweep the number of cycles which are displayed on the C.R.T. is varied. For example if the horizontal deflection voltage takes 60 milli-seconds to sweep across the screen and the vertical deflection signal completes one cycle each 20 milli-seconds, three cycles are displayed on the C.R.T. and the cycle in the centre is complete, with no time lost in retrace, as shown in Fig. 17.

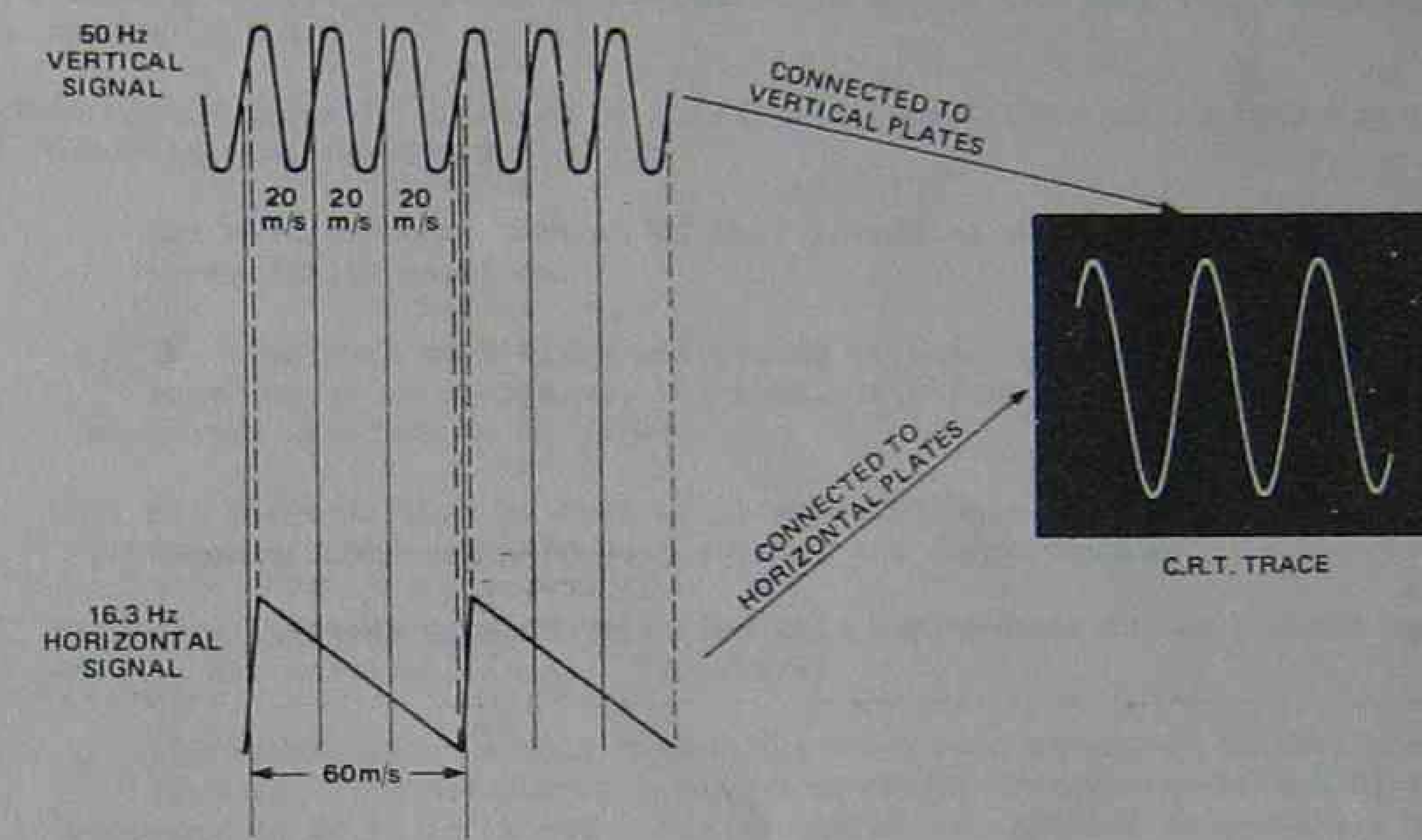


FIG. 17. 3 CYCLE C.R.T. DISPLAY.

5.8 DEFLECTION SENSITIVITY. The distance that the beam is deflected by 1 volt change in signal voltage is called the deflection sensitivity and is expressed in centimetres per volt. The voltage required on cathode ray tube plates to deflect the beam is relatively high; ranging up to 60 volt (depending on the type of C.R.T.) to deflect the beam 1 cm. The signal voltage available is seldom large enough to produce significant deflection without the use of amplifiers. Amplifiers therefore are usually connected in both the vertical and horizontal deflection circuits, as shown in Fig. 18, to increase the deflection sensitivity of the instrument.

The term deflection sensitivity is applied to the deflection in both the horizontal and vertical directions. When applied to the horizontal deflection system it is called the 'Horizontal deflection sensitivity' and when applied to the vertical deflection system it is called the 'Vertical deflection sensitivity'. In most oscilloscopes the vertical deflection sensitivity is different to the horizontal deflection sensitivity. The sawtooth sweep voltage is generated within the oscilloscope and is generally designed to produce a large enough voltage to require little amplification. However, the amplitude of the signal voltage is generally outside the control of the C.R.O. operator and, therefore, a greater range of deflection sensitivity is required for the vertical deflection system than the horizontal deflection system.

5.9 **VERTICAL AMPLIFIER.** The vertical amplifier in Fig. 18 must not introduce any noticeable distortion to the applied waveshapes. The gain must be made variable to permit different levels of signal to develop a large enough trace on the screen. Because it is much easier to design a distortionless variable attenuator than a distortionless variable gain amplifier, most oscilloscopes use a fixed gain amplifier in conjunction with a variable attenuator. The attenuator adjusts the level of the input signal so that the fixed gain amplifier produces the required output voltage for application to the vertical plates. Some higher quality instruments have a number of fixed gain amplifier stages which can be switched in or out of circuit to provide additional control of deflection sensitivity. Another function of the vertical amplifier is to provide isolation of the deflection plate capacitance from the signal source. This is necessary because this capacitance would alter the shape of the voltage waveshape and the C.R.T. display would not be a faithful reproduction of the source voltage waveshape.

5.10 The most commonly used type of vertical amplifier is biassed so that positive and negative signals are amplified by the same amount. The amplified signal is applied 180° out of phase to each deflection plate. Thus, as one plate is made more positive and attracts the beam, the other is made more negative and repels the beam. This action is referred to as push-pull deflection and produces more linear deflection for deflecting voltage changes than is obtained by earthing one plate and varying the potential on the other.

5.11 **THE HORIZONTAL AMPLIFIER.** The most common applications of C.R.O.s require voltage variations to be plotted against time on the C.R.T. and to obtain this display a sawtooth voltage is applied to the horizontal plates. The horizontal amplifier amplifies the output of the sawtooth generator to a suitable deflection voltage for the horizontal deflection plates. Some oscilloscopes are designed to have identical amplifiers in the vertical and horizontal deflection systems, but for general purposes, the horizontal amplifier does not require the same careful design as the vertical amplifier. The horizontal amplifier is usually provided with a gain control so that the voltage output can be adjusted to control the length of the horizontal trace, thus allowing it to be adjusted to fit a calibrated scale. Provision is sometimes made to disconnect the sweep generator from the horizontal amplifier to permit an external signal to control the horizontal deflection.

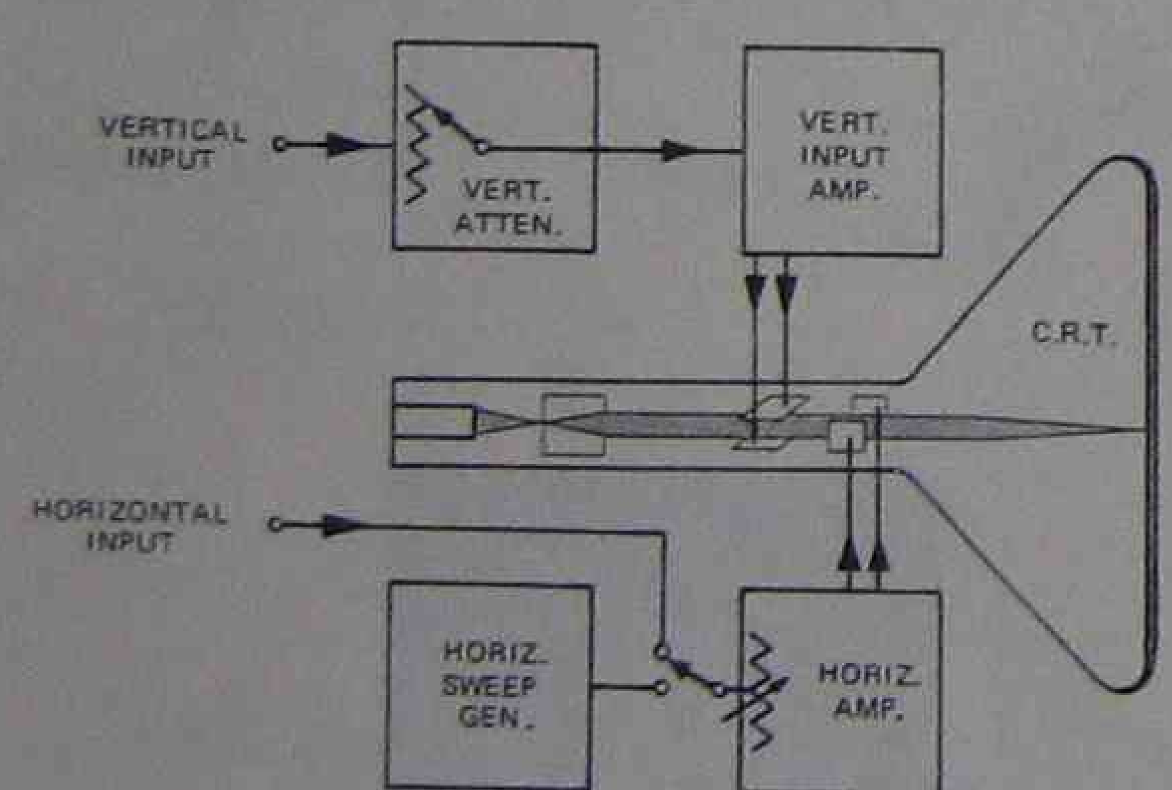


FIG. 18. C.R.T. WITH DEFLECTION AMPLIFIERS.

6. TRIGGERING THE TRACE.

6.1 **GENERAL.** At low sweep rates the electron beam is able to transfer sufficient energy to the phosphor to produce a clear, bright trace on the screen. However, as the sweep rate is increased the trace becomes less bright until it can only be viewed in a darkened room or under a hood. Some special phosphors are available which produce a trace at very high sweep rates but they are easily damaged, or destroyed, by a combination of high beam intensity and slow deflection rates. General purpose oscilloscopes generally use a more robust phosphor which has a lower light output for a given beam force.

The intensity of the trace can be increased by making the beam sweep over the same path several times.

A satisfactory trace is produced by building up the brightness in this way provided the following conditions apply:

- The waveform must consist of many identical patterns; that is, it must be a repetitive waveform.
- The time base must start and finish at exactly the same spot on each waveform to be displayed. It must, therefore, run for exactly the same time as the waveform to be viewed.
- All circuits must be free of level variations such as noise or hum voltages because these would produce a broad and fuzzy display.

6.2 There are two ways in which the time base can be made to run for the same time span as the vertical signal. These are:

- SYNCHRONISING. In this method the time base generator is free running, that is, it continuously produces sawtooth (sweep) waveshapes at the frequency to which it is set. The frequency is adjusted to produce a waveform of a slightly longer duration than the waveshape to be viewed. A voltage level on the input signal is selected to stop the sweep. When this voltage level is reached the sweep is stopped and retrace begins before the end of the normal sweep time of the generator. Thus the sweep waveshape is forced to run at the same frequency as the vertical signal and the time base generator is said to be synchronised by the vertical signal.
- TRIGGERING. In this method the time base generator does not produce any sweep voltage until the vertical signal reaches a predetermined level. When this level is reached it starts or 'triggers' the sweep. The sweep runs for its selected time then retraces to await the vertical signal once again reaching the triggering level.

Some oscilloscopes have an additional refinement which provides a triggering signal in the absence of a vertical signal. This ensures that the horizontal sweep produces a horizontal trace on the screen when no vertical signal is applied to the input.

6.3 Most modern oscilloscopes use a triggered time base rather than a synchronised one and a trigger circuit is included to ensure that the horizontal deflection starts each horizontal sweep at a selected point on the waveform to be displayed.

Fig. 19 shows the type of trace produced by triggering the time base when the signal reaches +1 volt and is rising towards a more positive voltage (positive going signal). The trigger level of +1 volt is used merely as an example. Most oscilloscopes provide a choice of trigger levels and also a choice of whether a positive going or a negative going signal is used to trigger the trace.

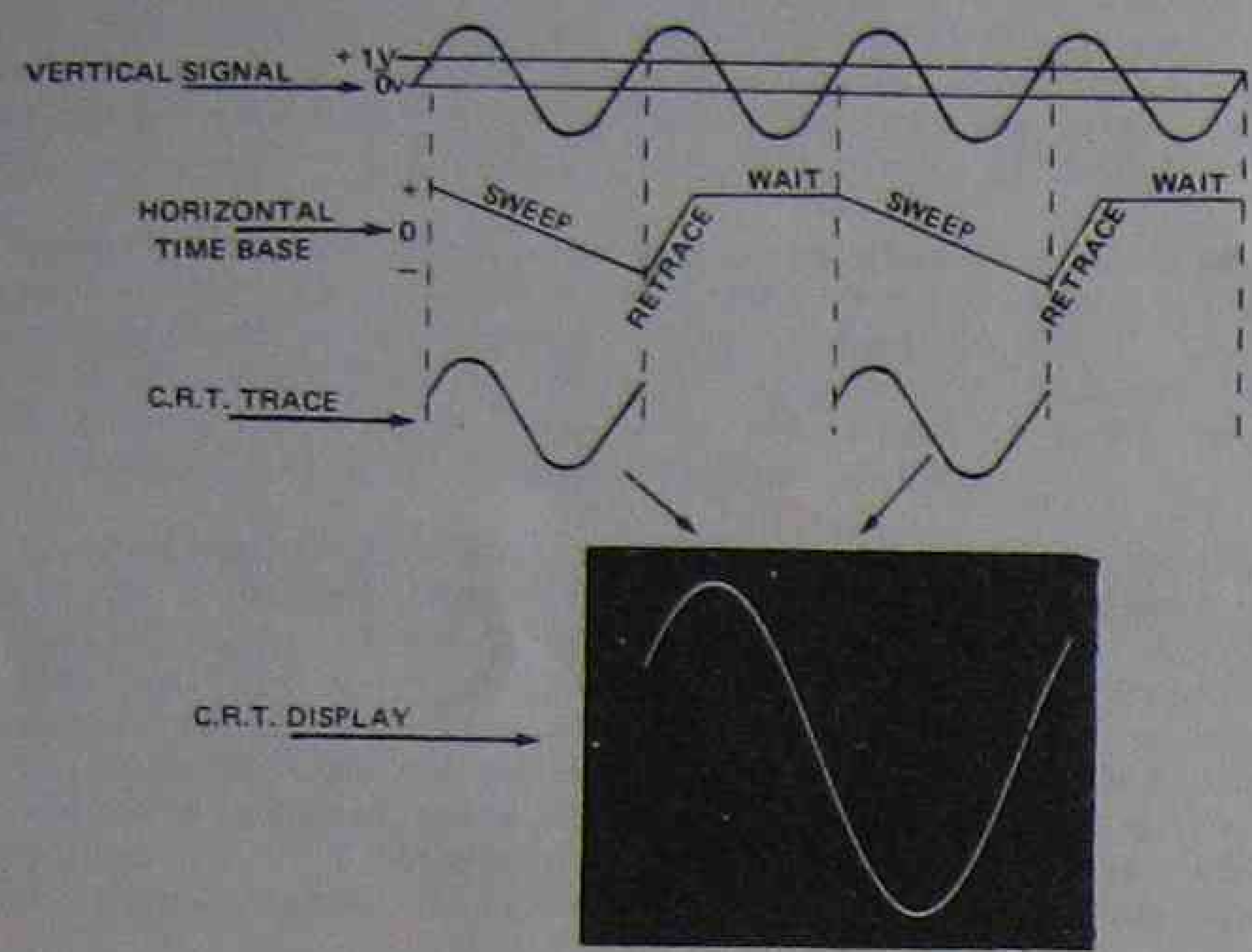


FIG. 19. HORIZONTAL SWEEP TRIGGERED BY VERTICAL SIGNAL.

6.5 The time base can also be made stable at any sub-multiple of the vertical signal frequency. For example in Fig. 20 the time base runs at about 1/3 of the frequency of the vertical signal to produce a multiple cycle trace as explained in paragraph 5.7. It should be noted that the signal reaches the triggering level during the sweep time, but once the time base is running the signal voltage has no effect on the time base. The triggering level must be received when the time base is waiting to be triggered otherwise it has no effect.

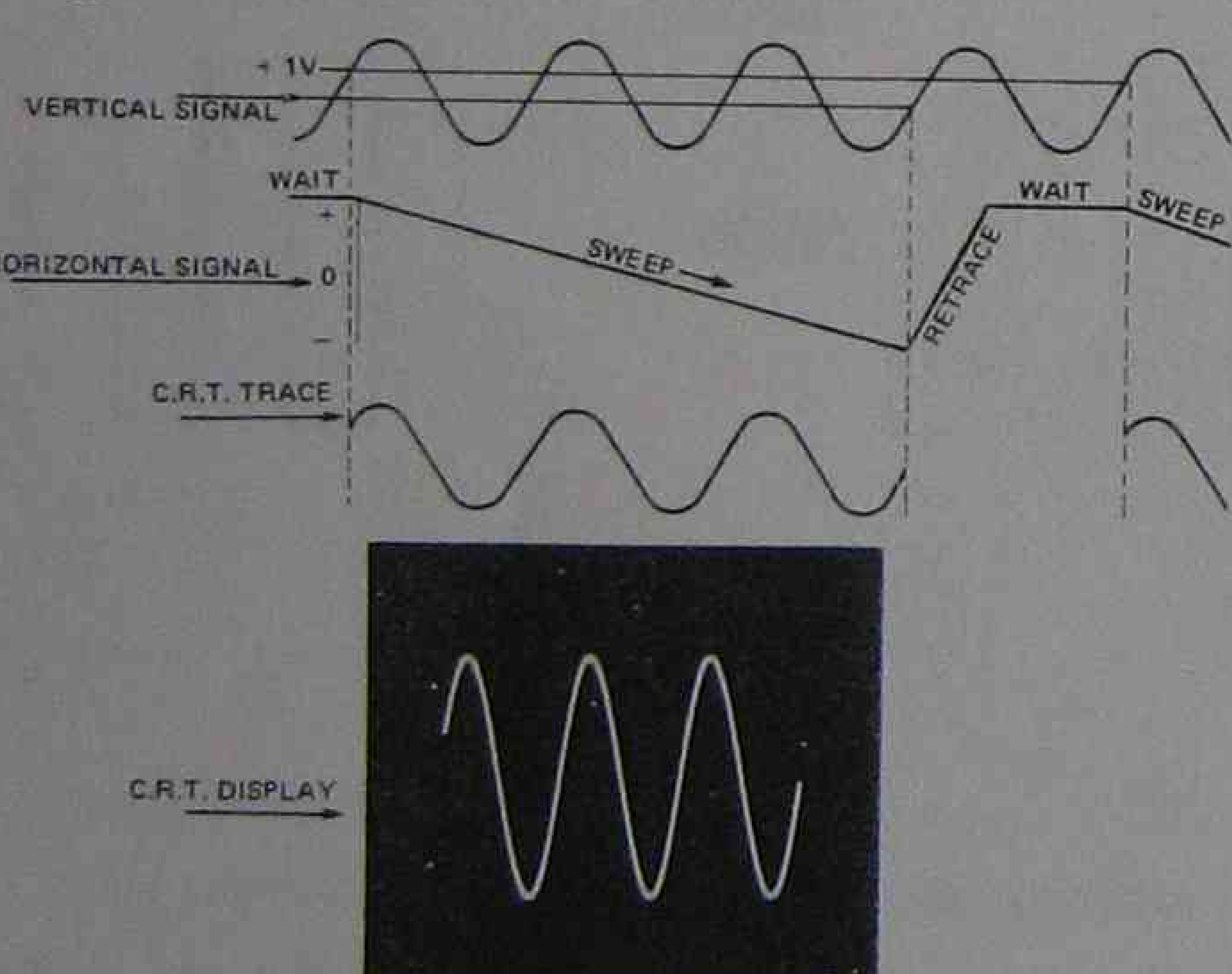


FIG. 20. TIME OF SWEEP INCREASED.

6.6 TRIGGER SOURCES. The trigger which starts the horizontal sweep is generally derived from the vertical signal but there are some circumstances which make it advantageous to derive the triggering signal from other sources. The trigger circuit is usually provided with a trigger input selector switch which gives a choice of:

- INTERNAL TRIGGERING from the signal voltage on the vertical amplifier.
- EXTERNAL TRIGGERING from some signal voltage other than that on the vertical amplifier.

6.7 TRIGGERING. The external facility is provided so that the relative phase of signals round a circuit can be determined from the C.R.T. display. To understand why external triggering is necessary, assume that a square wave signal (Fig. 21b) is applied to a common emitter amplifier (Fig. 21a). We saw in BASIC AMPLIFIERS (1) that the output voltage signals of a common emitter amplifier are inverted, compared to the input signal (Fig. 21c)

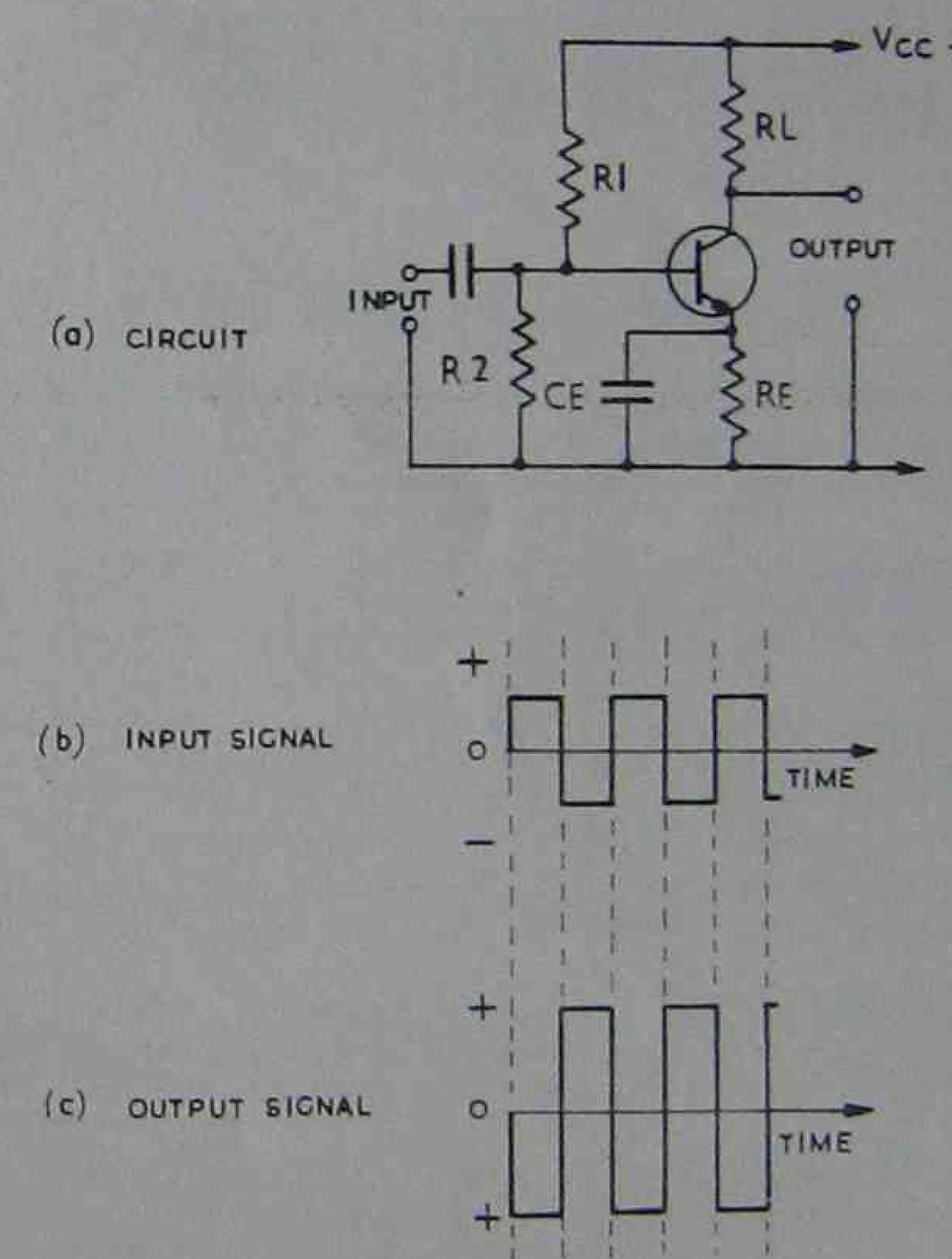
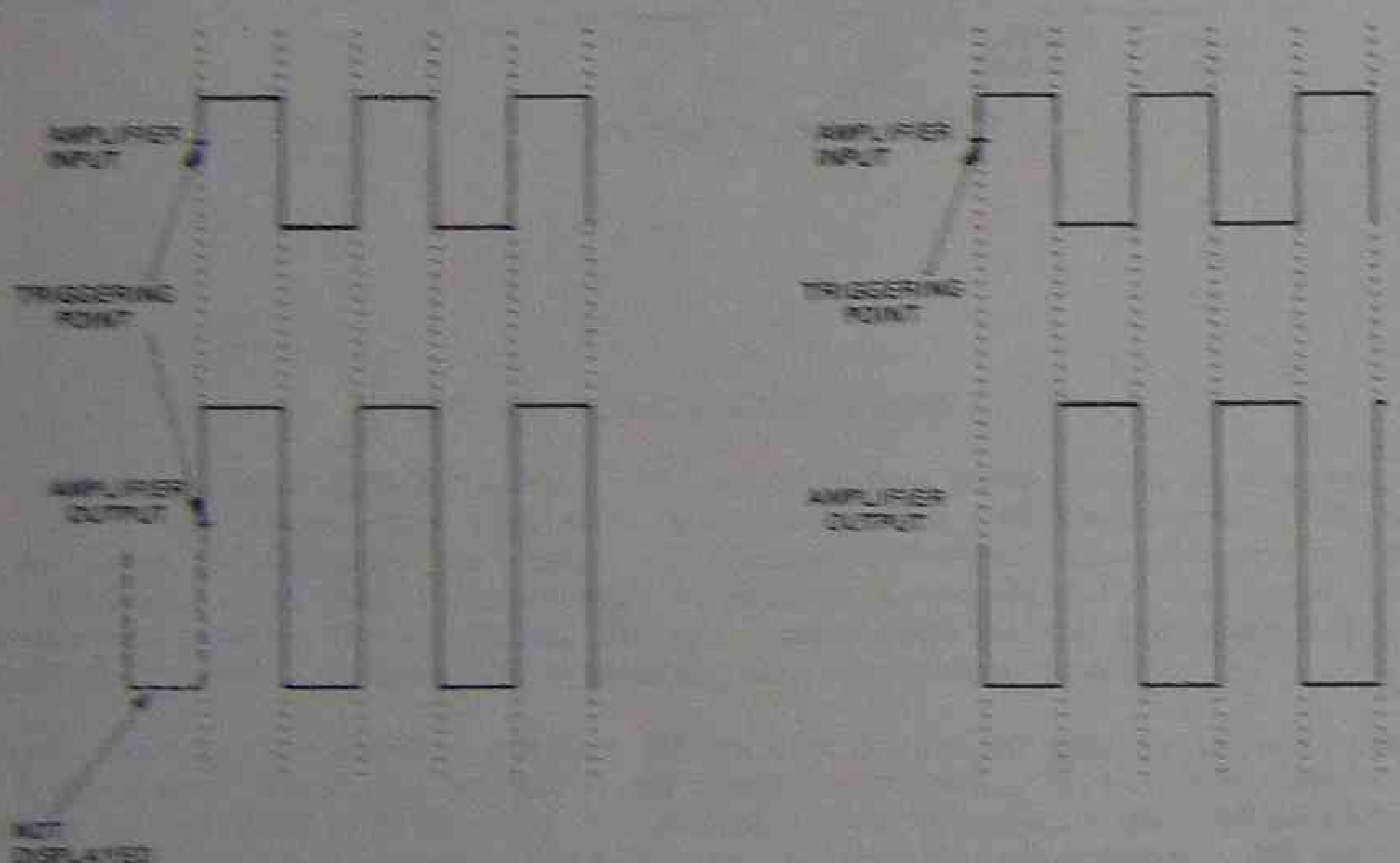


FIG. 21. COMMON EMITTER AMPLIFIER WITH SQUARE WAVE INPUT.

Assume that an oscilloscope is set to trigger internally from a positive going signal causing 2.5 cm deflection on the screen. Fig. 22a shows the trace which would be developed when the vertical input of the C.R.O. is connected first across the input and then across the output of the amplifier in Fig. 21. The trace appears to show that the input and output signals have the same polarity at the same time.

This occurs because, the oscilloscope is set to trigger to a positive going, internal trigger signal, and the trace starts at the first positive going voltage of triggering level applied to the vertical plates. Thus the C.R.T. display starts with a positive going half cycle whether the vertical input is connected to the input voltage or to the output voltage. Because of this there is no way of relating the phase of the two signals when an internal trigger is used.

In Fig. 22b the external trigger facility is used. The trigger is taken from the input signal of the amplifier under test, irrespective of which part of the amplifier circuit the vertical input of the C.R.O. is connected. When the C.R.O. is connected to the amplifier input the trace displayed is positive going. However, when the C.R.O. is connected to the amplifier output, the output voltage is negative going at the instant the input voltage reaches triggering level. The C.R.T. therefore displays the waveform negative going when the input is positive going. The relative phase relationships can thus be examined with reference to a fixed time (the time at which the input signal reaches triggering level) by the use of the external trigger.



(a) With Internal Trigger. (b) With External Trigger.

FIG. 22. C.R.T. DISPLAY OBTAINED FROM A COMMON EMITTER AMPLIFIER.

6.8 50 Hz TRIGGER. Some oscilloscopes are provided with the means of triggering the trace from the a.c. mains frequency. This provides a low frequency stable sweep (50 Hz) which is useful when irregular signals such as speech signals are to be viewed and no definite trigger point exists on the vertical signal.

7. BASIC GENERAL PURPOSE OSCILLOSCOPE.

7.1 BLOCK SCHEMATIC CIRCUIT. Fig. 23 shows how the various oscilloscope circuits are interconnected to provide the features considered so far in this paper.

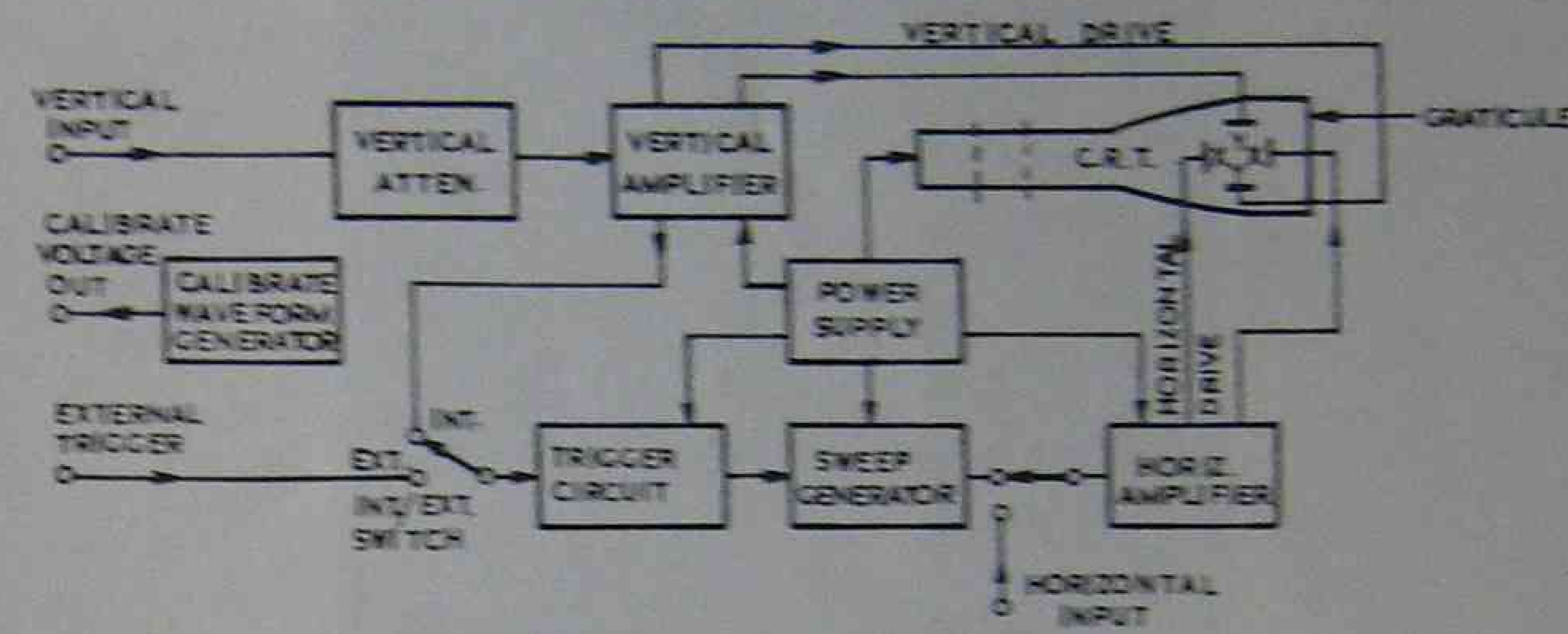


FIG. 23. BLOCK DIAGRAM OF A BASIC OSCILLOSCOPE.

The functions of the component blocks shown in Fig. 23 are as follows:

- VERTICAL AMPLIFIER. Amplifies the vertical signal, thus increasing the sensitivity of the deflection, and also isolates the capacitance of the deflection plates from the circuit under tests.
- VERTICAL ATTENUATOR. Provides a means of accurately adjusting the vertical sensitivity so that a suitable size of trace is obtained from a wide range of signal voltages. The setting of this attenuator indicates the scale to be applied to the vertical deflection.
- CATHODE RAY TUBE. Produces a beam of electrons which develops a small fluorescent indicating spot on the phosphor coating of the faceplate and also deflects this beam in the horizontal (X) axis and vertical (Y) axis by voltage differences between the respective deflecting plates.
- HORIZONTAL AMPLIFIER. Amplifies signals applied to the horizontal deflecting plates and so increases the sensitivity of the horizontal deflection.
- TIME BASE GENERATOR. Provides horizontal deflection at a constant known rate and thus provides a time reference along the horizontal axis. The setting on the time base generator indicates which time scale should be applied to the horizontal axis.
- TRIGGER CIRCUIT. Ensures a stable trace by deriving signals to control the start of the horizontal sweep. These triggering signals may be taken from the vertical amplifier, or from an external source.
- GRATICULE. The engraved scale on the front face of the C.R.T. which makes accurate measurements possible on the graph formed by the trace on the C.R.T.
- CALIBRATE WAVEFORM GENERATOR. Produces a waveshape of known amplitude which is used to check the calibration of the deflection sensitivity so that accurate measurements can be made in conjunction with the graticule.

8. MANUAL OPERATION.

8.1 GENERAL. Associated with an oscilloscope are a number of controls which permit the instrument to be adjusted for satisfactory operation. In Fig. 24 the block diagram of the basic oscilloscope is modified to show the location of the controls usually included in an oscilloscope. The purpose of the controls and the effects obtained by adjusting them are explained in the following paragraphs. The location of the controls of a typical calibrated C.R.O. are shown in the photograph in Fig. 25.

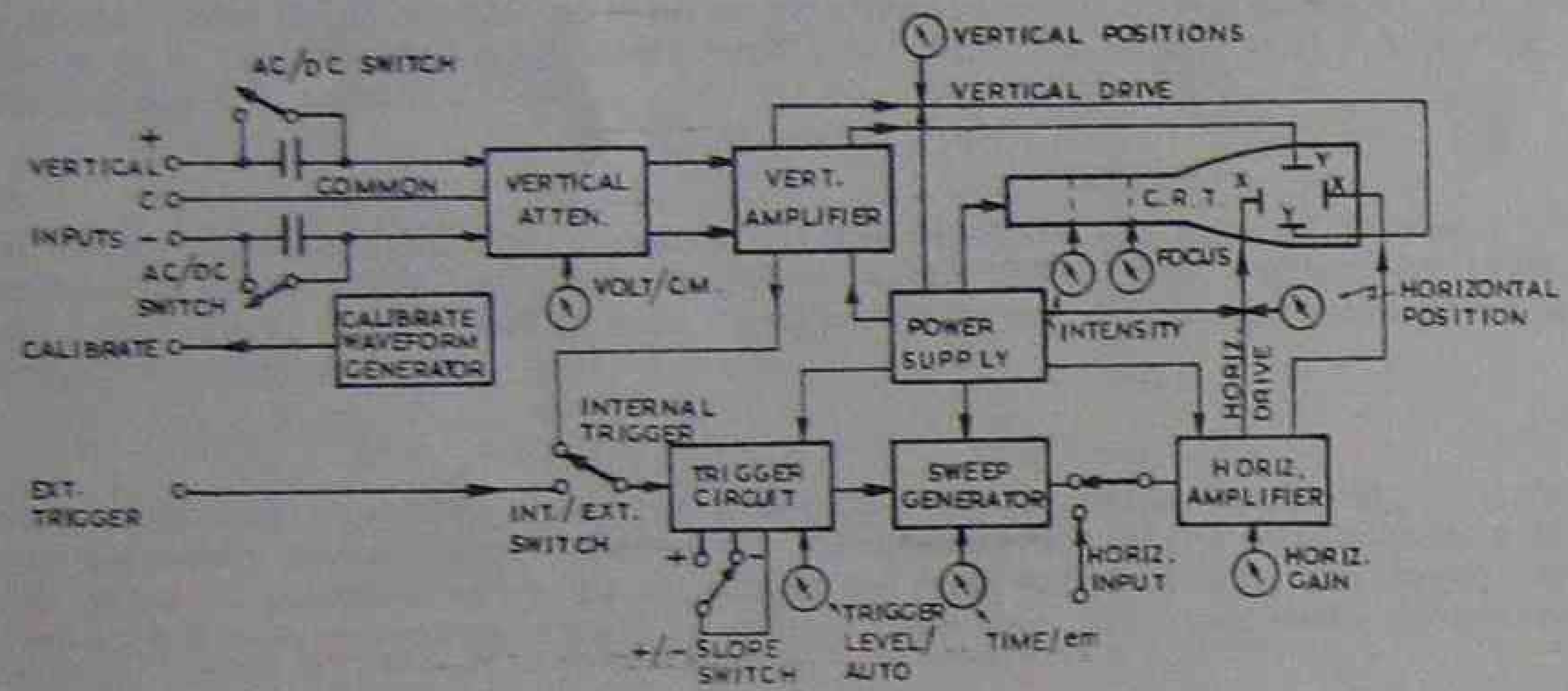


FIG. 24. OSCILLOSCOPE CONTROLS.

8.2 VERTICAL INPUT CONNECTIONS. The oscilloscope shown in the photograph in Fig. 25 has three input terminals, situated in the left hand corner. The reason for the three terminals is that this oscilloscope is fitted with two similar vertical input channels, each with its own input attenuator and amplifier. One input channel is connected between the + terminal and the common terminal and the other input channel is connected between the - terminal and the common terminal.

For most testing purposes the vertical deflection signal is applied either between the + and common terminals, or the - and common terminals. Because the common terminal is not connected directly to the oscillator chassis it must be connected to the signal return lead or earth depending on the circuit requirement. For some special testing purposes signals are sometimes connected between the + and - terminals, as described in Section 10 of this paper.

The vertical inputs are connected within the C.R.O. in such a manner that the beam is deflected upwards by the application of a positive going signal to the + terminal or a negative going signal to the - terminal. The beam is deflected downwards by either applying a negative going signal to the + terminal or a positive going signal to the - terminal. The designations + and - on the terminals are arbitary and indicate the potential which produces an upward deflection of the beam.

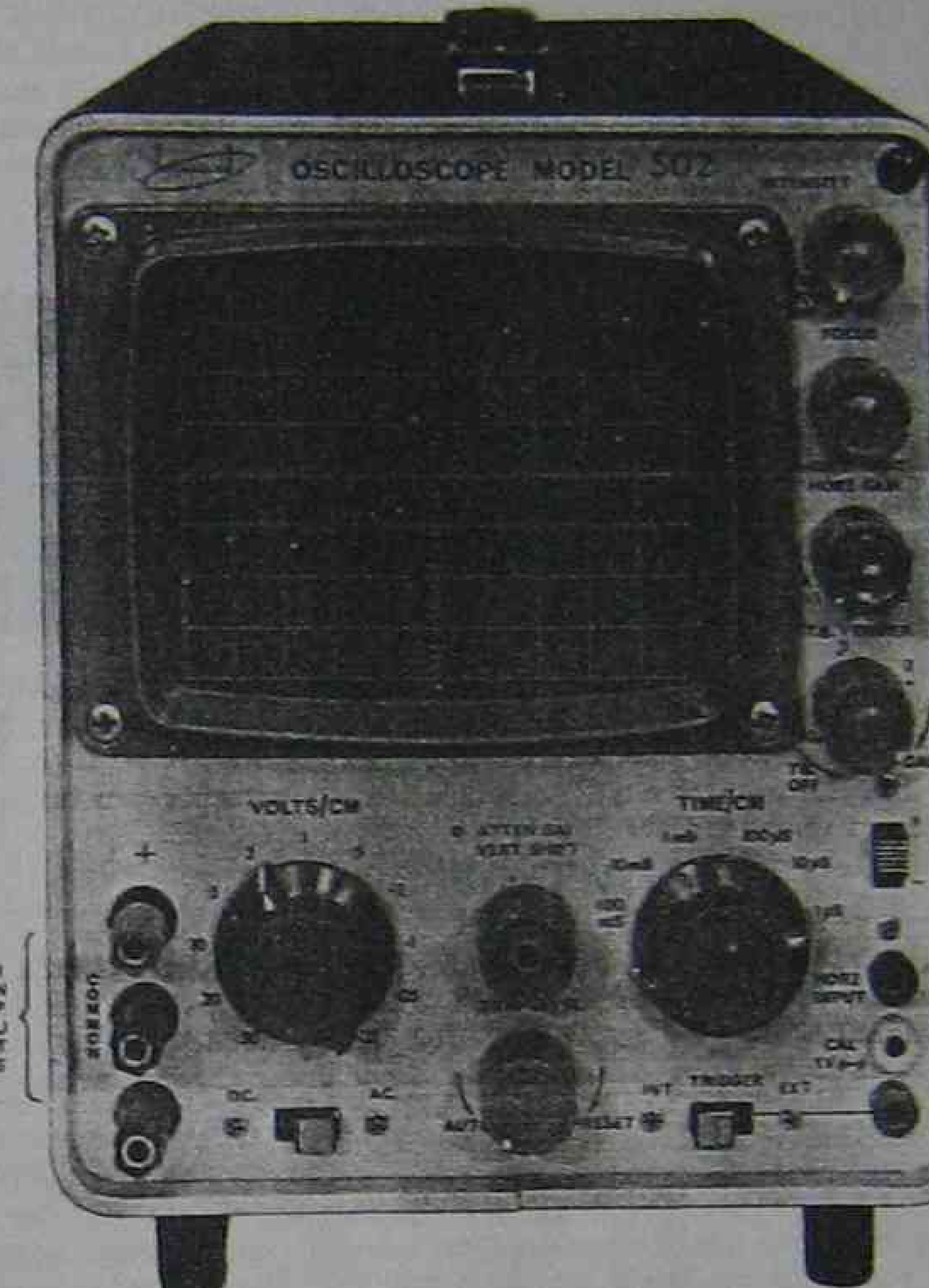


FIG. 25. CALIBRATED OSCILLOSCOPE.

8.3 FOCUS CONTROL. This control allows the operator to adjust the size of the spot and, therefore, the thickness of the trace on the screen for more accurate measurements. The focus control adjusts the relative potentials between grids in the C.R.T. and thus varies the compressing force on the beam. The photographs of the C.R.T. trace in Fig. 26 show that rotating the focus control reduces the beam size to a fine spot so that a fine trace is produced on the screen. Further rotation of the control defocuses the beam once again.

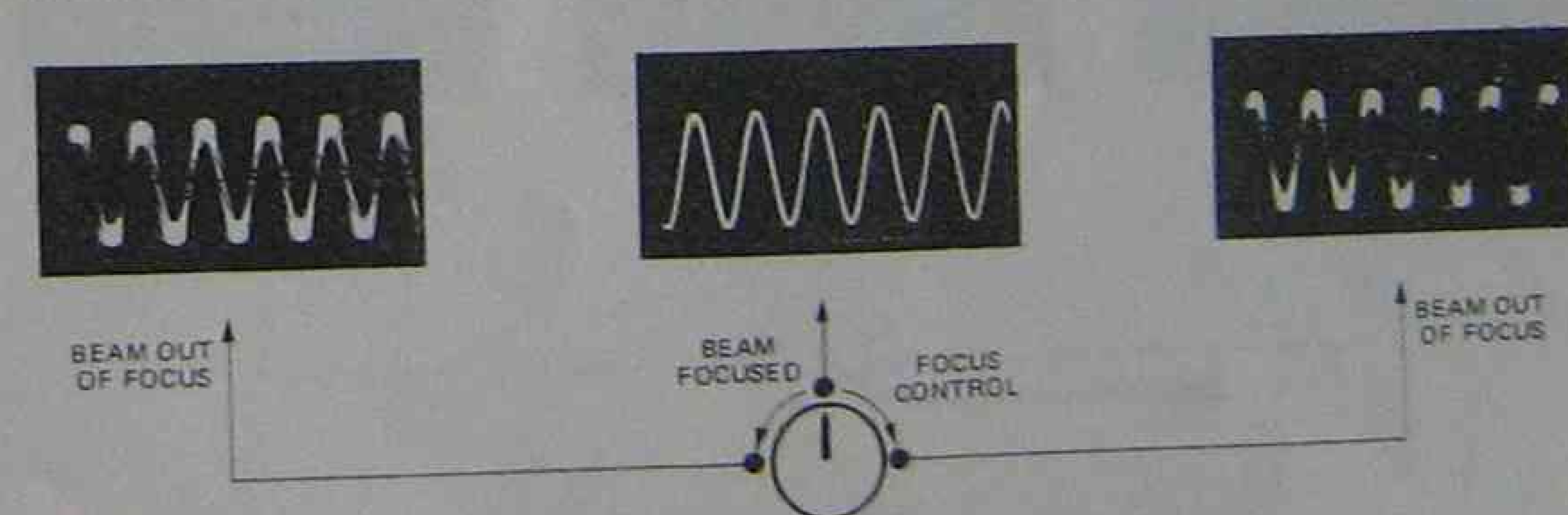


FIG. 26. VARYING THE FOCUS CONTROL.

Some oscilloscopes are provided with another adjustment which affects the focus. This is the 'Astigmatism control'. Astigmatism in a C.R.T. is caused by differences in the electrostatic fields acting on the beam and produces an oval spot instead of a round one. The astigmatism control is adjusted with the undeflected beam defocused by means of the focus control. This presents a large diameter spot on the screen. The astigmatism control is varied until the spot is as close to a circle as possible. The beam is then refocused to a small diameter by the focus control.

8.4 INTENSITY CONTROL. The intensity control provides the operator with a means of varying the intensity or brightness of the trace by controlling the number of electrons which bombard the screen. Fig. 27 shows a typical trace with three different adjustments of the intensity grid. The intensity control is adjusted to give a sharp clear trace in the particular viewing situation. For example, a C.R.O. being used in a brightly lit room would need a brighter trace than a C.R.O. being used in a dimly lit room.

Another factor which affects the intensity of the trace is the rate of movement of the horizontal sweep. The faster the movement of the sweep, the lighter the trace becomes. Therefore, the intensity must be adjusted to provide comfortable viewing at the sweep frequency used.

Excessive brightness, particularly when a static trace is being displayed, is likely to cause permanent damage to the phosphor. This damage is called phosphor burn and shows as areas of phosphor which do not fluoresce when acted upon by the beam. For this reason the beam intensity should be turned down when the instrument is not in use.

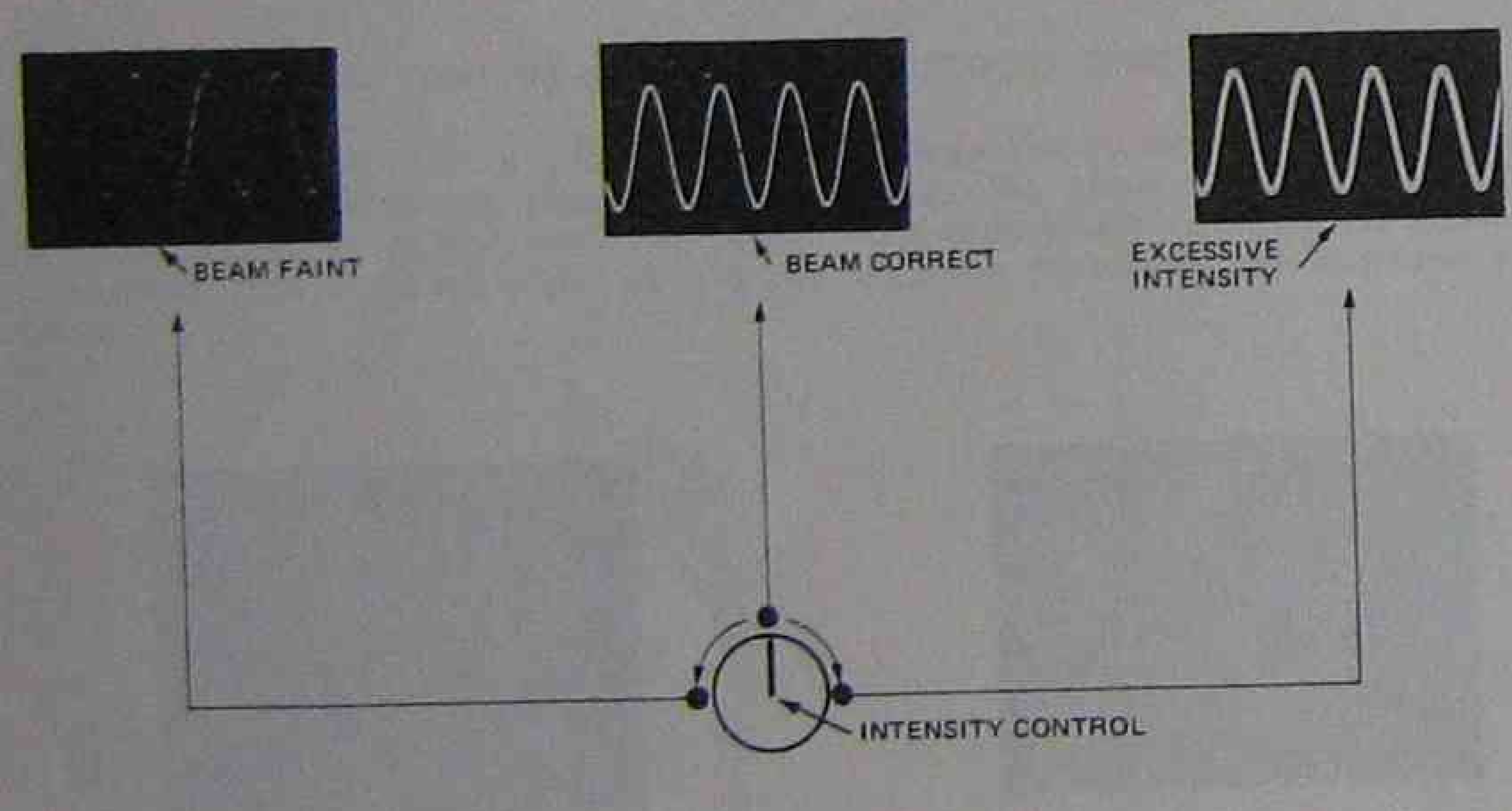


FIG. 27. VARYING THE INTENSITY CONTROL.

8.5 VERTICAL SHIFT CONTROL. This provides control over the vertical (up and down) position of the trace. In this way the trace can be placed at any required distance from the top or bottom of the screen, as shown by the photographs in Fig. 28. The vertical shift control is also used to line up the trace with the graticule when measurements are being made on the C.R.T.

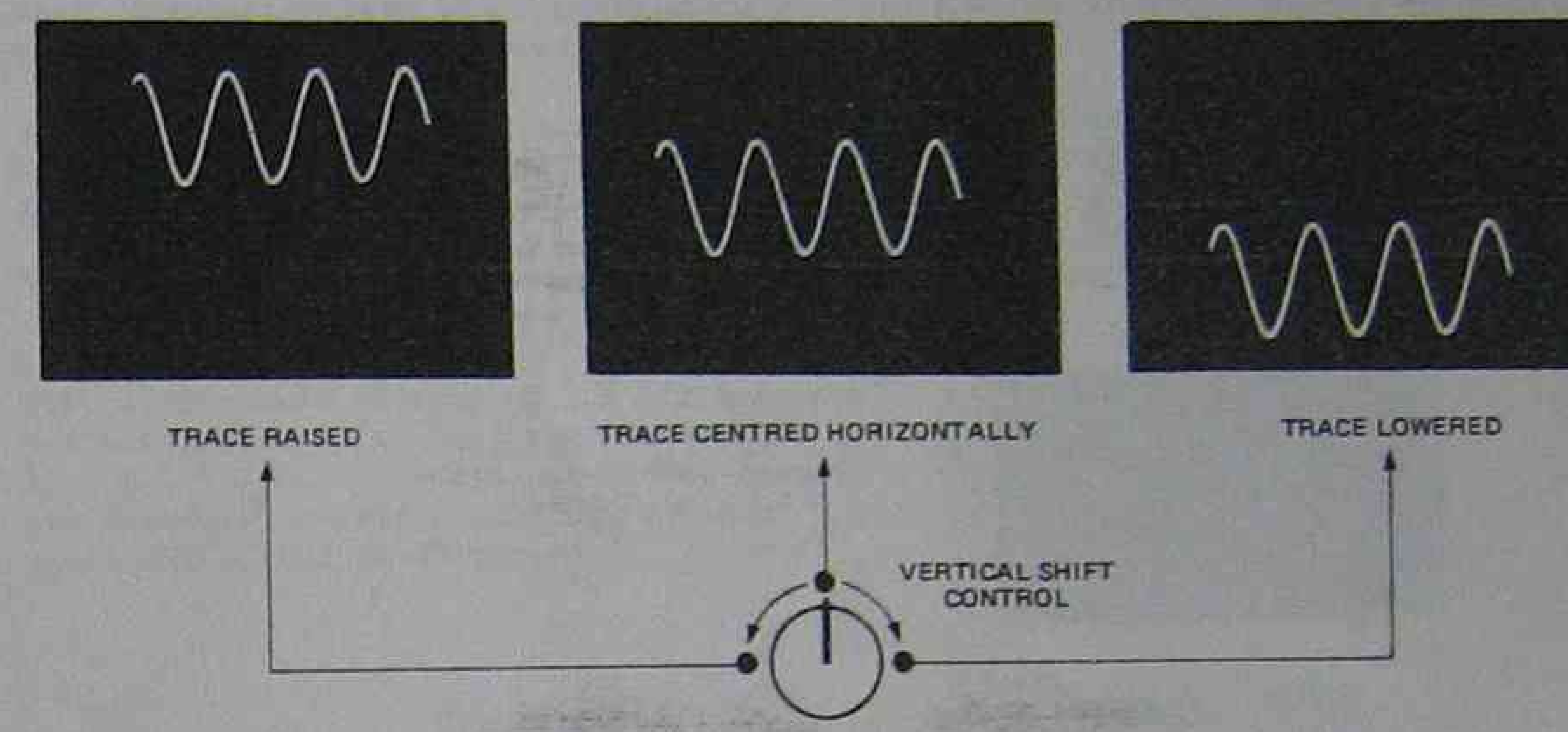


FIG. 28 VERTICAL SHIFT CONTROL.

8.6 HORIZONTAL SHIFT CONTROL. This provides control over the horizontal position of the trace and allows the start of the trace to be located at any required position across the screen, as shown in Fig. 29. The horizontal shift (or position) control also allows the trace to be lined up with the graduations on the graticule to simplify measurements along the horizontal scale of the graticule.

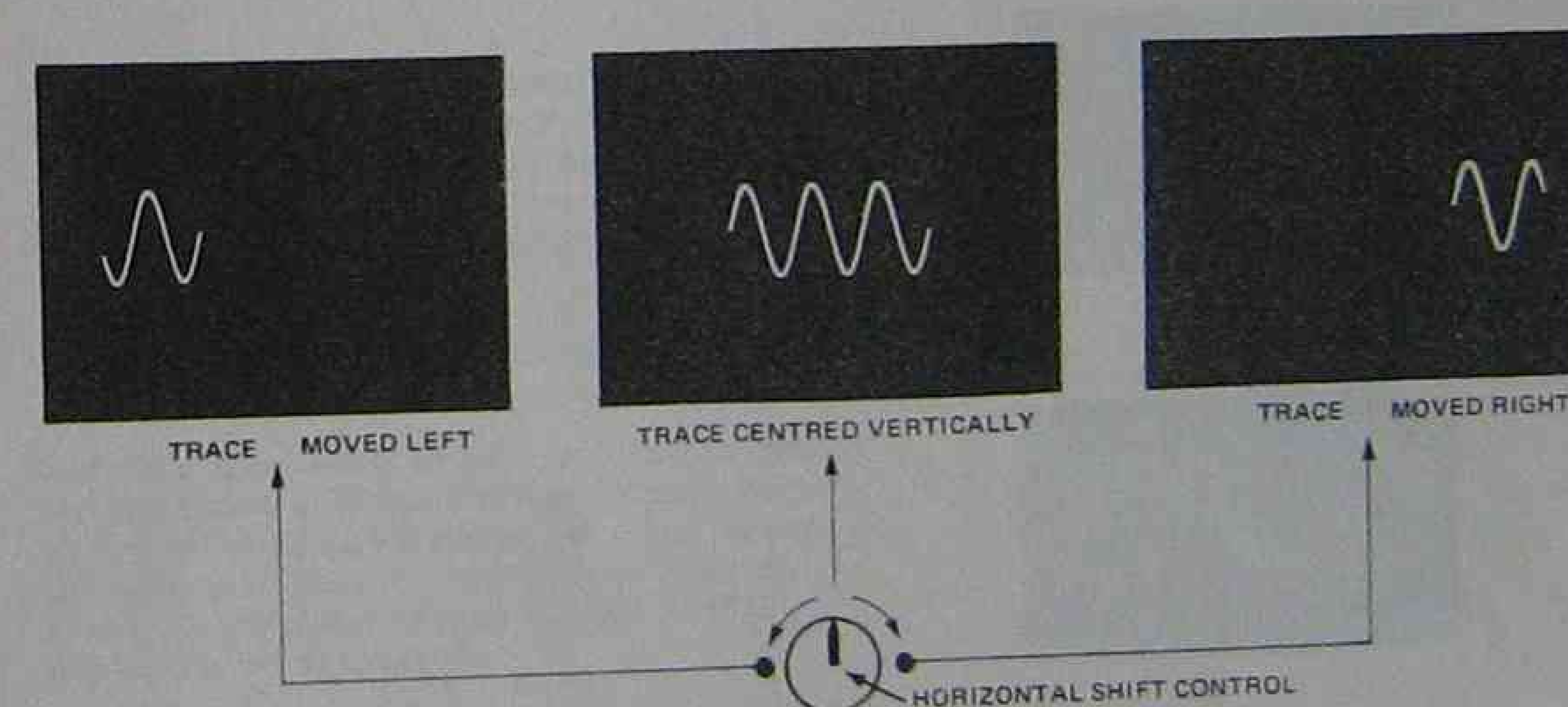


FIG. 29. HORIZONTAL SHIFT CONTROL.

8.7 VERTICAL ATTENUATOR SWITCH (volt/cm attenuator). This switch provides a means of adjusting the vertical deflection sensitivity in order to adjust the size of the trace (see para. 5.8). Accurate measurements can be made on waveforms; the degree of accuracy depends on the calibration of the instrument (5% is a typical accuracy). Readings can be made directly from the screen and the vertical attenuator setting. Fig. 30 shows a 4 volt peak to peak signal applied to an oscilloscope and the resultant patterns obtained for vertical attenuator settings of (a) 500 mV per cm, (b) 1 V per cm, (c) 2 V per cm and (d) 5 V per cm.

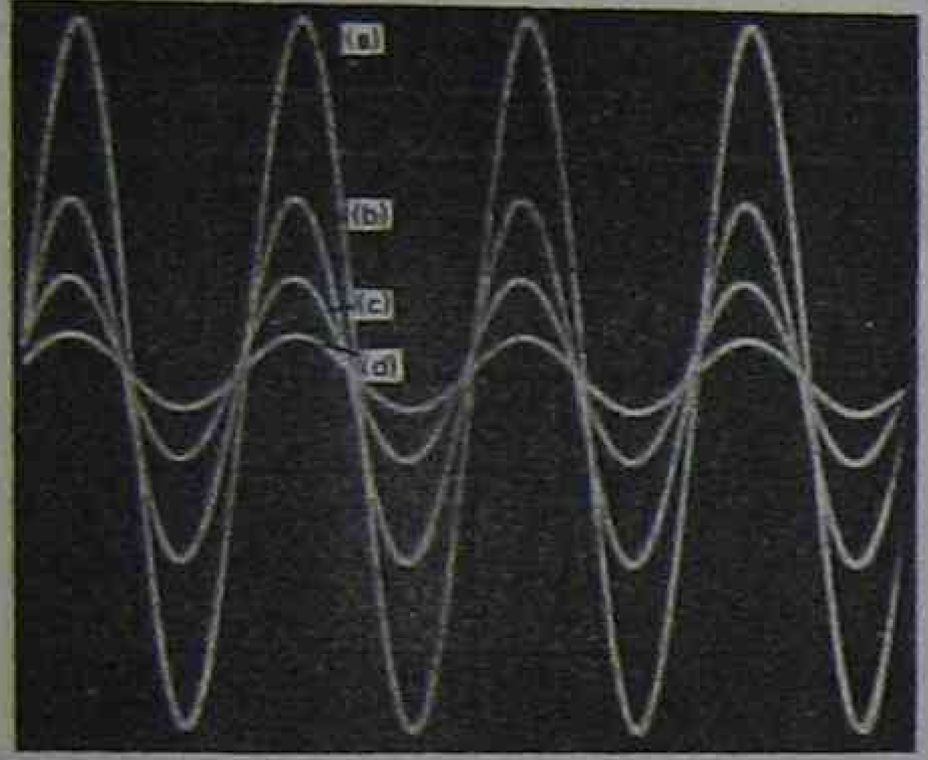


FIG. 30. VARYING THE VERTICAL SENSITIVITY CONTROL.

8.8 −/+ SLOPE SWITCH. This selects whether a negative going or positive going voltage level starts the time base sweep. Fig. 31a shows a photograph of a C.R.T. trace triggered on the positive slope. The photograph in Fig. 31b shows the trace obtained from the same input signal but with the switch in the negative slope position.

(a) + Slope Trigger

(b) − Slope Trigger

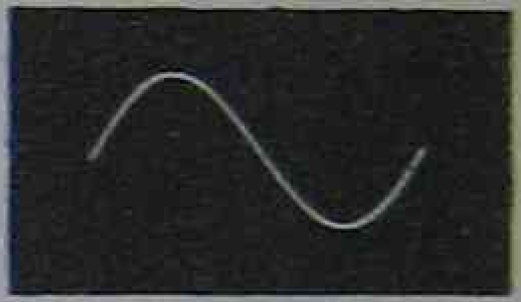
FIG. 31. C.R.T. WITH + AND − TRIGGERING.

8.9 TIME BASE (TIME/CM). This switch varies the rate of horizontal sweep and, therefore, determines the time taken for the beam to move horizontally across the screen. The control is usually in two parts; a switch calibrated in steps and a fine control which provides continuous variation between stops on the switch. There is generally an off (calibrated) position for the variable control. The sweep rate indicated by the switch position only applies to the trace on the screen when the variable control is in the calibrated (off) position. Some oscilloscopes have a small indicating lamp which glows when the fine control is operated to show that the trace is no longer calibrated.

The photographs in Fig. 32 show how the C.R.T. trace alters when an input signal of 1 kHz is displayed with the time base in four different calibrated positions and the fine control in the calibrated (off) position.

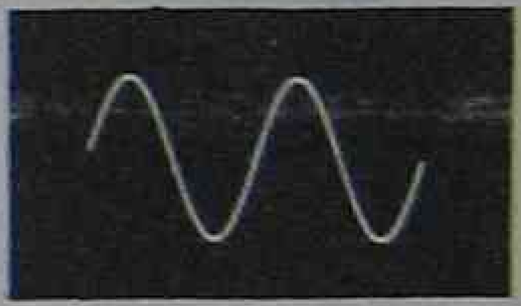
The trace on the C.R.T. in each photograph is 10 cms long and since the frequency of the signal is 1kHz, each cycle lasts 1 milli-second.

With a time base setting of 0.1 milli-second per centimetre (Fig. 24a) the trace takes 10 × 0.1 = 1 milli-second to travel across the screen. Therefore only one cycle of the 1 kHz signal is displayed.



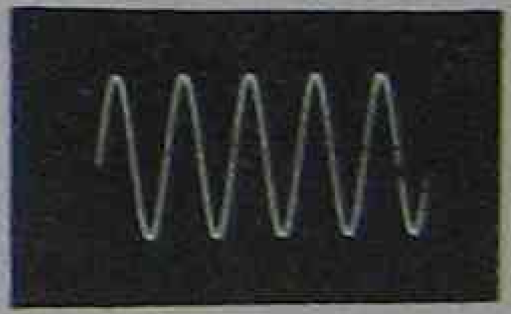
(a) 0.1 ms/cm

When the time base is set on 0.2 milli-seconds per centimetre (Fig. 24b) the trace takes 10 × 0.2 = 2 milli-seconds to travel across the screen. In this case, there is sufficient time in the horizontal sweep to display two complete cycles of 1 kHz signal.



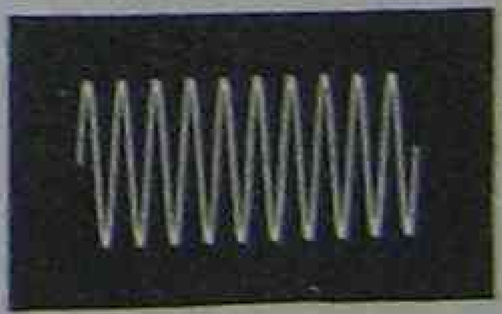
(b) 0.2 ms/cm

A setting of 0.5 milli-seconds per centimetre (Fig. 24c) causes the trace to take 10 × 0.5 = 5 milli-seconds to travel across the screen. Thus, five complete cycles of the 1 kHz signal are displayed.



(c) 0.5 ms/cm

When the time base is set on 1 milli-second per centimetre (Fig. 24d) the trace takes 10 × 1 = 10 milli-seconds to sweep across the screen. This is sufficient time to allow 10 complete cycles of the 1 kHz signal to be displayed.



(d) 1 ms/cm

FIG. 32. C.R.T. TRACES FOR DIFFERENT TIME BASE SETTINGS.

8.10 The frequency of an applied signal can be determined by measuring the time taken for one complete cycle and then calculating the frequency from this. For example, the photograph in Fig. 33a shows that one cycle occurs over 2.5 cm. The time base is set to 10 microsecond/cm (us/cm, Fig. 33b), therefore, the time taken for one cycle is 10 × 2.5 microseconds or 25 microseconds.

The signal frequency is the number of cycles which occur in one second thus the frequency of the signal displayed is calculated by dividing one second by the time of one cycle. In this example, working in microseconds:

$$f = \frac{1}{\text{time for one cycle}}$$

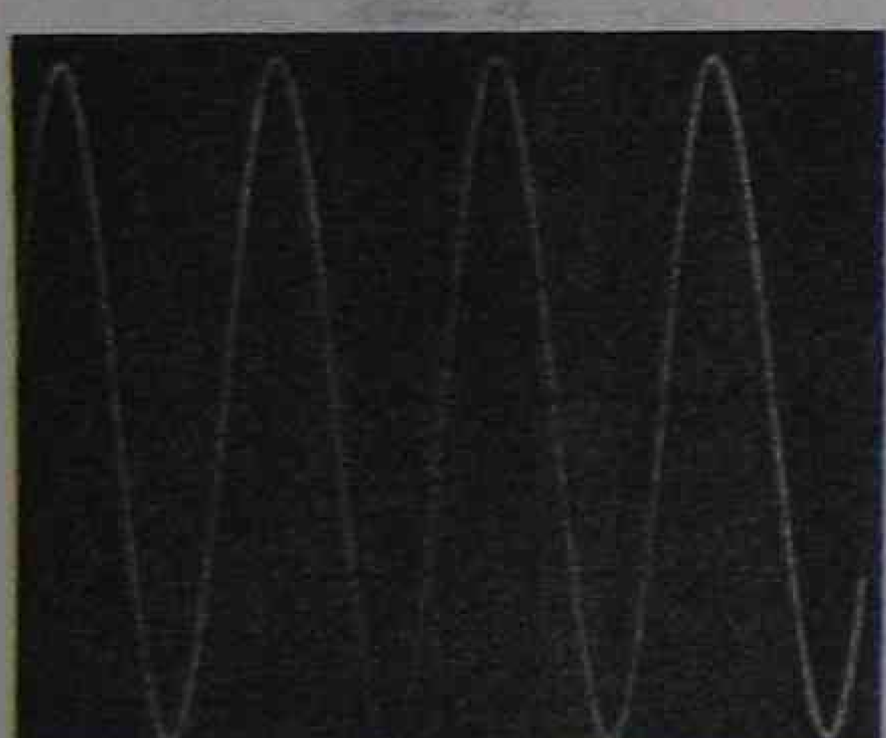
$$= 1 \div \frac{25}{10^6}$$

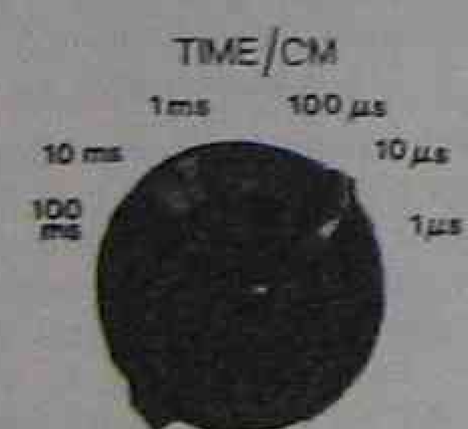
$$= \frac{1 \times 10^6}{25}$$

$$= \frac{10^6}{25}$$

$$= \frac{40,000}{1} \text{ Hz}$$

$$= 40 \text{ kHz}$$



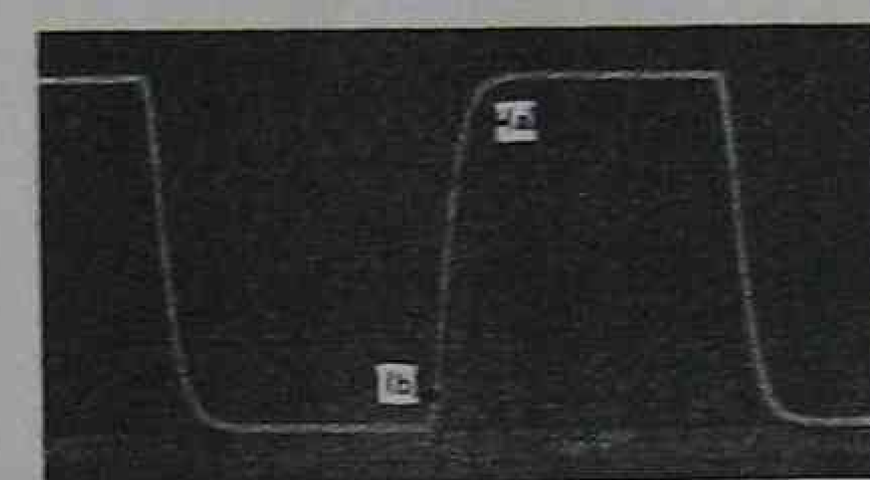


(a) Trace

(b) Time/cm Switch Setting

FIG. 33. CALIBRATED C.R.T. TRACE.

8.11 The calibrated time base switch, in conjunction with the graticule, is also used to measure the characteristics of pulses. Fig. 34a is a photograph of a pulse displayed on a calibrated C.R.T. Several characteristics of the pulse can be measured in this manner. For example, it is often necessary to know how long it takes the pulse circuit to change from one voltage level to another. This is called the rise time of the pulse. It is usual practice to express this rise time as the time taken for the voltage to rise from 10% to 90% of its final voltage. The size of the trace in Fig. 34a has been adjusted to fill 4 cm (or 40 mm) on the graticule. The graticule is divided into 2 mm divisions, thus there are 20 divisions between the two maximum voltage levels. Point 'a' and point 'b' in Fig. 34a show the 10% and 90% points, respectively, of the voltage change of the pulse. These two points are 0.4 cm apart on the horizontal graticule scale and with a time base switch setting of 1 microsecond/cm (Fig. 26b) the rise time of this pulse is 0.4 microseconds.



(a) C.R.T. Trace

(b) Time/cm Switch Setting.

FIG. 34. PULSE MEASUREMENTS.

8.12 AC/DC SWITCH. This switch connects a capacitor in the input lead to isolate the amplifier from any DC voltage present on the applied signal.

A DC coupled C.R.O. is necessary when DC measurements are made, or when it is necessary to maintain the DC component of a waveform. However, it is difficult to examine a 0.5 volt peak signal on the base of a directly coupled transistor which is at a DC level of 25 volt above earth potential. The reason for this difficulty is that then DC potential tends to cause the beam to be deflected vertically on the screen. To retain the trace on the screen necessitates the use of a low deflection sensitivity, such as 5V/cm to produce a vertical trace of 5 cm. At this setting the waveform to be examined (0.5V) is only 1/10th of a division high and is too small for detailed examination. By using the switch in the AC position the DC voltage is blocked from the plates and therefore, produces no deflection. The deflection sensitivity can be increased to produce a waveform of suitable size for measurement or examination.

8.13 INTERNAL/EXTERNAL SWITCH. This switch allows the time base to be started or triggered from the vertical signal (internal) or from an external signal (ext.) as explained in para. 6.7.

8.14 TRIGGER LEVEL/AUTO SWITCH. When the knob is turned fully anticlockwise the oscilloscope is switched to the auto position. In this position the time base is started when the vertical signal reaches a predetermined level. For example, in the B.W.D. 502 oscilloscope the time base is triggered when the input signal has sufficient voltage to produce a trace of 0.5 cm. on the screen. Also, when the switch is in the auto position, and no signal is applied to the vertical input, the time base generator becomes self triggering (free running) to produce a horizontal line on the screen.

When the knob is switched out of the auto position it moves to the variable level position. In this position the trace can be triggered by the various amplitudes of vertical trace, depending on the position of the switch (between 1 cm and 3 cms for the B.W.D. 502).

When the knob is turned to the extreme clockwise variable position the preset level is reached. In the B.W.D. 502 this level is set at 1 cm to trigger the trace.

9. PROBES.

9.1 C.R.O. INPUT. A flexible lead is generally used to connect the signal source under test to the input of the C.R.O. There are two main effects on the input which must be considered when using a C.R.O. to make measurements. These are:

- STRAY SIGNALS which are induced into the connecting lead and introduce noise into the signal being measured. This noise may broaden the trace, distort the trace, or produce erratic triggering of the trace. The voltage induced into a conductor by a moving field increases as the frequency of the field variations increases. In low frequency circuits the voltages induced by stray signals are low and cause little trouble. However, where there are high frequency circuit elements present, it is necessary to use screened wire to reduce the voltage induced into the connecting lead. Co-axial cable is extensively used as a flexible connecting lead with the outer screening layer brought out to a spring clip which must be connected to the same earth as the circuit under test.

- CIRCUIT LOADING. This is the effect that the input resistance and capacitance of the C.R.O. has on the circuit under test. In extreme cases the loading (shunting) effect of the C.R.O. input completely alters the original circuit conditions and the resultant trace bears little resemblance to the waveshape present in the circuit when the C.R.O. is not connected.

  A typical C.R.O. has an input resistance of 1 Megohm shunted by a capacitance of 35 picofarad. At low frequencies the capacitance has little effect and the input impedance of the C.R.O. is equal to the input resistance of 1 Megohm. However, at high frequencies the capacitive reactance is significant and the input impedance decreases to a value considerably less than 1 Megohm. For example, at 5 Megahertz the input impedance drops to about 900 ohms. The input impedance of a C.R.O. must therefore be considered in relation to the impedance of the signal under test. If the input impedance of the C.R.O. is not considerably greater than that of the circuit under test, the circuit conditions are altered and distortion occurs to the signal.

  In general the loading effect of the input resistance of the C.R.O. is more important in audio frequency testing, but the capacitive loading of the input is more important during high frequency testing, or when pulses with sharp transistions are being examined.

9.2 PROBES. By adding suitable circuit components on the C.R.O. input lead the input resistance and capacitance of the C.R.O. may be altered to suit circuit conditions. The extra components are generally located at the end of the flexible lead, farthest from the oscilloscope, in a housing called a 'probe'. There are many different types of probe available to provide a wide variety of input resistance and capacitance loading conditions. A photograph of a typical probe is shown in Fig. 35.

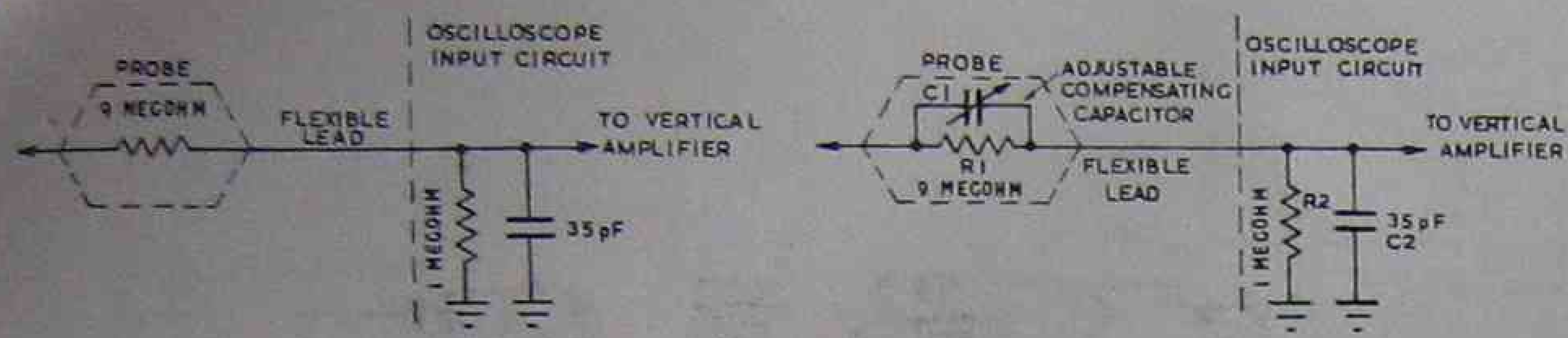
FIG. 35. TYPICAL PROBE.

9.3 1X PROBE. This is the simplest type of probe and does not alter the input impedance of the C.R.O. It provides facilities to change the tip of the probe to a spike, spring hook or spring clip, to simplify connection to the test point. This probe is usually designated 1X to indicate that the input resistance is multiplied by 1, (unaltered). It also indicates that the attenuation is unaltered.

9.4 10X PROBE. Basically, this probe contains a resistor which is connected in series with the input resistance of the C.R.O. to form a voltage divider, as shown in Fig. 36a. The designation 10X indicates that the total input resistance of the C.R.O. is increased by ten times and that the input voltage across the 1 Megohm resistor is decreased to $\frac{1}{10}$th of the value connected to the tip of the probe. The probe, therefore, has an attenuation factor of 10 because it attenuates the signal to $\frac{1}{10}$th of its original value. This arrangement is only suitable for low frequency testing where the capacitance is insignificant. Frequencies at which the input capacitance becomes significant require the use of the compensated 10X probe shown in Fig. 36b. This probe contains a variable capacitor which can be adjusted to make it effective at all frequencies in the frequency range for which it is designed. A typical compensated 10X probe reduces the input capacitance to 7.5 pF and increases the input resistance to 10 Megohm.

The correct setting for the probe capacitor is obtained by connecting the probe to a square wave signal and adjusting the variable capacitor until the trace on the screen shows a square wave with minimum distortion to its shape. The best results are obtained when the reactance of C2 is in the same ratio to C1 as resistance R2 is to resistance R1.

9.5 When a probe is used for making measurements it is necessary to multiply the volt/cm. reading by the attenuation factor of the probe. For example, a reading of 3 cm. on the screen with a 10X probe and a volt/cm. switch setting of 0.5 volt/cm. indicates an applied voltage of 3 × 0.5 × 10 or 15 volt.



(a) Basic Resistive 10X Probe (b) Compensated 10X Probe

FIG. 36. 10X C.R.O. PROBE.

9.6 CURRENT PROBES. A current probe is often used when measuring alternating currents with a C.R.O. This type of probe merely clips around the wire carrying the current to be measured, without making electrical contact with the wire. The alternating current in the wire induces a voltage into a probe, which is then applied to the C.R.O. input. A probe of this type gives very low source loading, and is generally used for specialised testing and measuring.

9.7 OTHER PROBES. Probes are available which permit the oscilloscope to be used to make measurements in high voltage circuits. The 1000X probe is an example of a high voltage probe and makes measurements possible up to 40 kV.

Probes are also available with diodes within the probe to demodulate signals for some special testing applications.

10. C.R.O. DIFFERENTIAL AMPLIFIERS.

10.1 The vertical input amplifiers in the C.R.O. shown in Figs. 24 and 25 are not isolated from each other completely, but are both connected to a common vertical deflection system. The method of interconnection is such that a signal applied to either amplifier develops signals of opposite polarity on the deflection plates to produce a more linear deflection. Fig. 37 shows a simplified input amplifier of this type without its bias arrangements. Assume that SC1 and SC2 are conducting and that a signal is applied between the + and common terminals. A positive signal applied to SC1 has the following effects:

- The resistance of SC1 decreases causing the current through the transistor to increase.
- The collector potential of SC1 becomes less positive.
- The voltage drop across R1 increases making both emitters more positive with respect to ground.
- Transistor SC2 acts as a common base amplifier and the positive signal at the emitter (the base is at ground potential) increases the resistance of the transistor.
- The collector of SC2 becomes more positive.
- Deflection plate V1 has become more positive and plate V2 less positive causing the beam to be deflected upwards.

This type of circuit is called a differential input amplifier and a change of potential at the base of either transistor affects the circuit in a similar manner by causing the potential of one collector to rise and the potential of the other to fall.

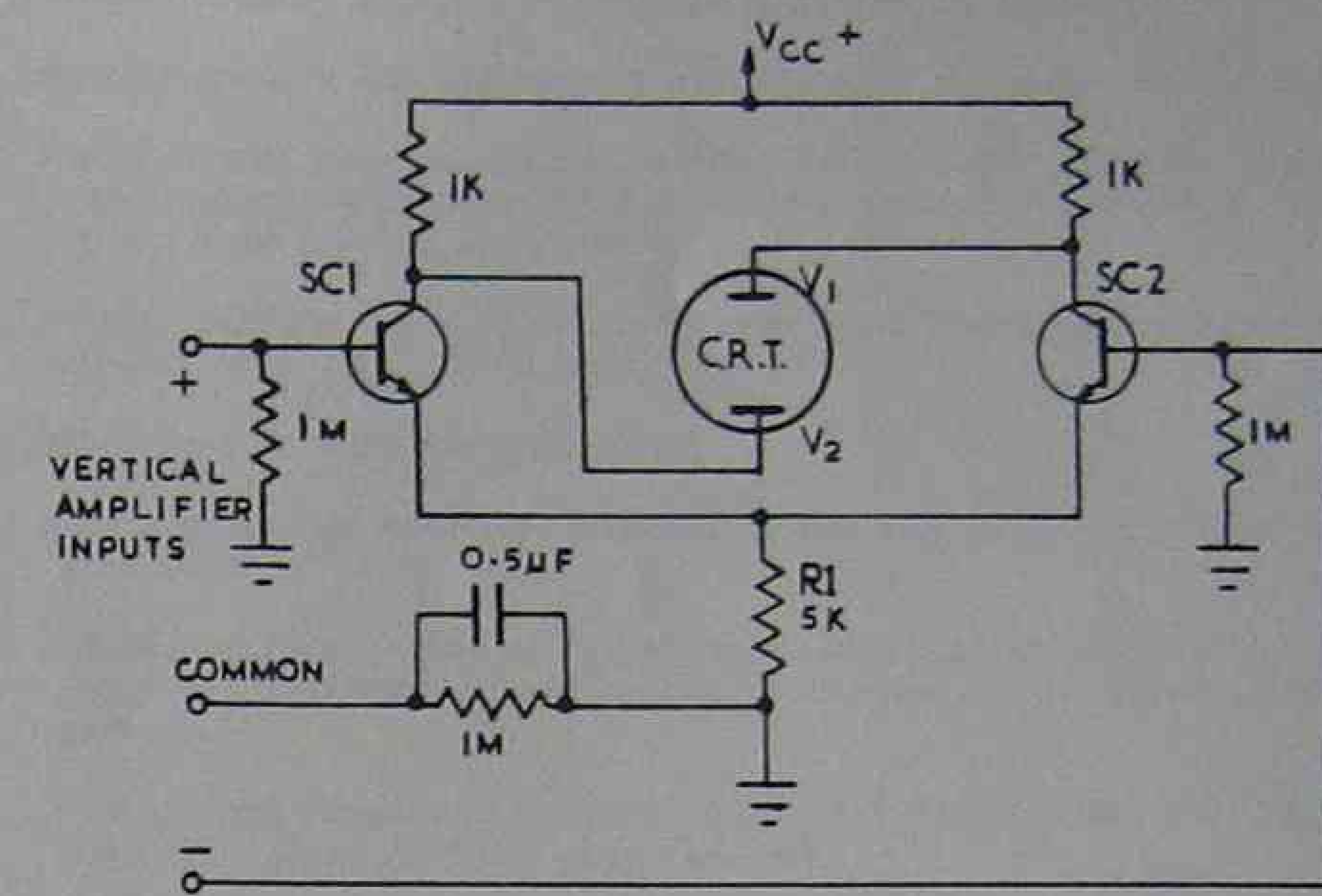


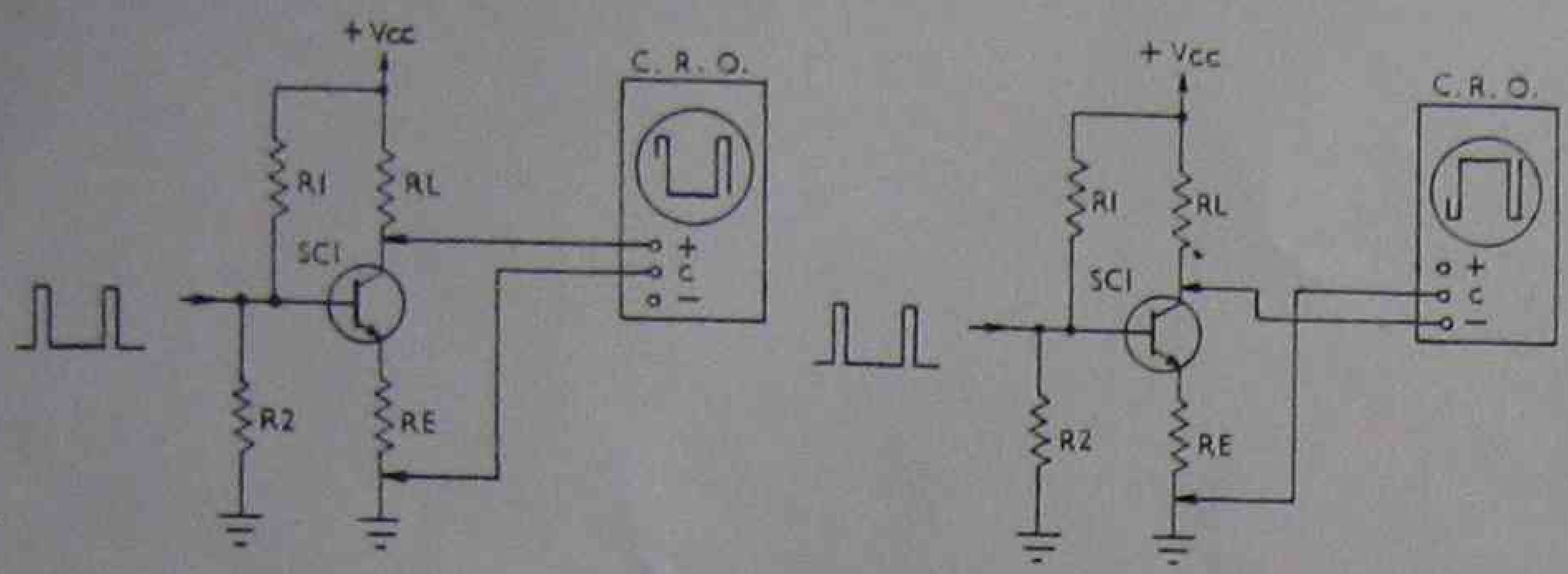
FIG. 37. DIFFERENTIAL AMPLIFIER.

10.2 An amplifier of the type shown in Fig. 37 can be used in several different ways to suit particular testing situations. The two methods most commonly used for vertical input connections are:

- UNBALANCED. A signal which produces potentials with respect to earth is applied between either the + or - amplifier input and the common terminal, as explained in para. 8.2.
- BALANCED OR DIFFERENTIAL. An a.c. signal which produces potentials between two points which are at the same relative d.c. potential to earth, is applied between the + and - amplifier inputs.

10.3 The unbalanced connections (Figs. 38a and b) are used to examine and measure signals such as those at the collector of a transistor in a common emitter configuration.

This is the most generally used method of connecting oscilloscopes. Either input can be used for this purpose but the - input (Fig. 38b) produces an inverted trace because a positive going signal drives the beam downwards. However, in all other respects both channels are identical.



(a) + Input (b) - Input

FIG. 38. UNBALANCED C.R.O. INPUTS.

10.4 Balanced connections, between the + and - terminals, are used to measure potential difference in circuits such as that shown in Fig. 39. This shows a push-pull output stage and the unbalanced connection could only be used to examine the output of one transistor at a time. The balanced connection shows the potential differences across the transformer primary and the resultant induced currents should produce a corresponding waveform in the secondary of the transformer.

The common terminal is sometimes left disconnected, but, where a large unwanted signal such as A.C. ripple is common to both inputs in may cause interference to the trace. This common interference can be rejected to a large degree by connecting he common terminal to the source of the interfering signal. Thus any ripple in the power power supply in Fig. 39 is eliminated from the C.R.O. trace by connecting the common (C) terminal to point X as indicated by the dotted line.

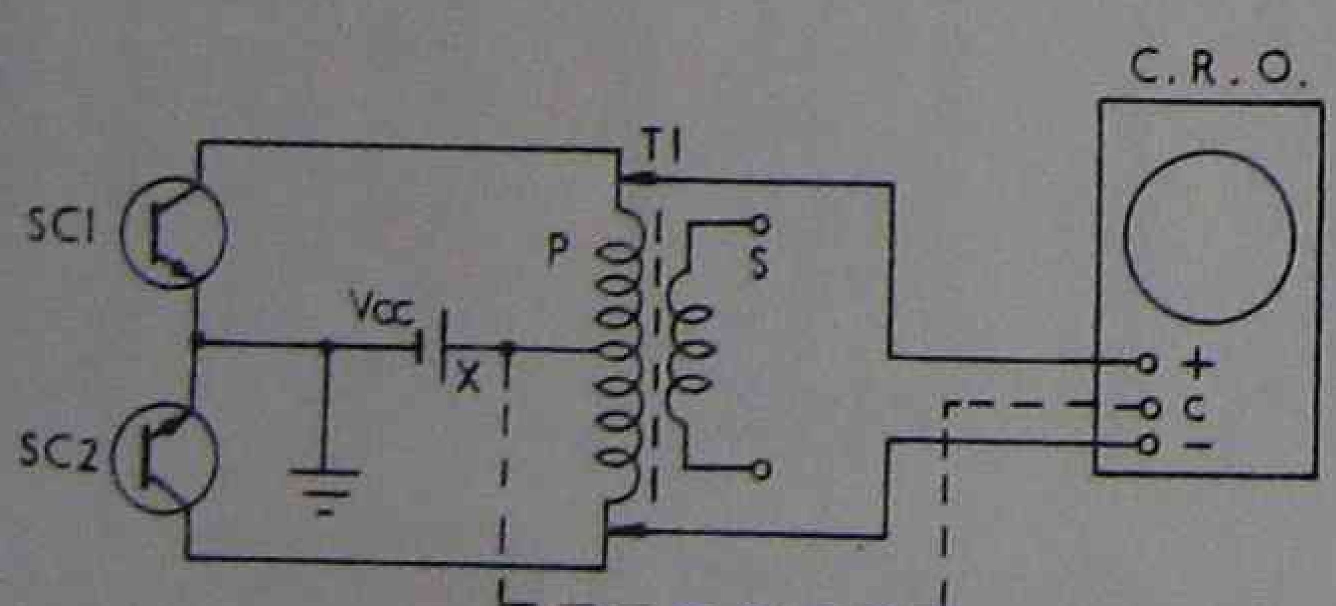


FIG. 39. BALANCED C.R.O. INPUT.

11. TEST QUESTIONS.

1. *List the 4 basic parts of a modern cathode ray tube and with the aid of a simple drawing show their relative position in the C.R.T.*

2. *Briefly explain how the beam of electrons is deflected in a C.R.T.*

3. *Why is a time base generator included in a C.R.O? Show the type of output signal which is produced by a time base generator and relate the position of the beam to this waveform.*

4a. *Briefly explain the difference between 'synchronising' and 'triggering' as applied to a C.R.O. time base.*

b. *Which type is most commonly used?*

5a. *Why is provision made for external triggering on a C.R.O. time base generator?*

b. *Briefly explain a testing situation in which an external trigger for the time base generator is preferable to the use of the internal trigger circuit.*

6. *Draw a block diagram of a basic calibrated oscilloscope and label each component block with its main function.*

7a. *Describe how adjusting the intensity control causes the brightness of a C.R.T. trace to vary.*

b. *Why is it advisable to reduce the brightness with the intensity control when a C.R.O. is not immediately in use?*

8. *How would you know when the 'astigmatism' control in a C.R.O. required adjusting?*

9. *What advantages are gained by using a 10X attenuator probe on the vertical input to a C.R.O. when measuring voltages?*

10. *Explain the function of the AC/DC switch and give an example of the use of a C.R.O. in each position of the switch.*

11. *Explain how a differential type vertical input circuit of a C.R.O. is used to display signals from the following circuit conditions:*

(a) *The signal at the collector of a transistor relative to earth potential.*

(b) *The signal at the collector of a transistor relative to the emitter when this is above ground potential.*

(c) *The signal across the primary of a push-pull amplifier output transformer.*

12. *What is blanking and why is it used?*

13. *A 5 kHz square wave signal is applied to the vertical input terminals of a C.R.O. having a trace 10 cms long and the time base set at 100 microseconds per centimetre. Sketch the pattern displayed on the screen.*

Quiz - Voltage Divider Bias of BJT's

1. The advantage of the voltage divider biasing method for BJT's is ,

a) it depends only on the supply voltage
b) only one bias supply is required to set the gain
c) the no-signal operating point is independent of h_{FE}, (B)
d) set the I/O impedances to the divider resistances

2. When using the voltage divider method for biasing BJT's it is required that,

a) the wattage of the voltage divider resistors is high for the heat dissipation
b) the voltage divider resistors draw greater than ten times I_B
c) the Q point be moved towards the zero voltage rail
d) the value of Rc is increased

3. When using the voltage divider method for biasing BJT's it is true that,

a) the resistor RE gives the circuit a wider temperature range
b) the resistors R1 and R2 must be 1% tolerance
c) circuit efficiency is increased
d) the output voltage swing is reduced

4. For the diagram below. If Vcc is 30 V, Rc = 10 k , RE =220 R and hFE = 250.

Take Vbe as 0.7V

a) State what the correct bias conditions are for this circuit, ie. value of V_C..

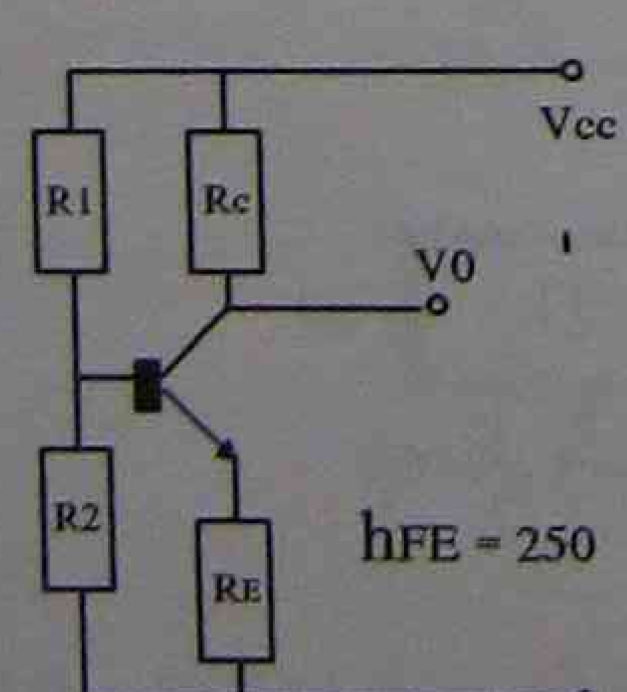
____

b) Using the rule of X10, calculate the values of R1 and R2 for the correct biasing of the circuit.State their nearest preferred 5% values.

c) Calc the value of r_e .

____

____



ADVANCED CERTIFICATE IN APPLIED INDUSTRIAL ELECTRONICS

YEAR 1 ELECTRONIC DEVICES 6016A

PRACTICAL ASSIGNMENT 4

TRANSISTOR BIASING

AIM: To examine various types of transistor biasing circuits.

EQUIPMENT REQUIRED:

Resistors:	220; 1k; 2k7; 12k; 1M; values as calculated for Figs.2 and 3; 1/4W. 1 each;.
Semiconductors :	BC547 or equivalent (3 off)
Multimeters:	Digital multimeter
Other:	Analog breadboarding system; (Power supply if required).

PROCEDURE 1: SINGLE RESISTOR BIASING

(a) Construct the circuit of Fig.1, which will be used to measure the DC current gain (β) of a number of BC547 transistors. Set the DC supply voltage to 10.6V.

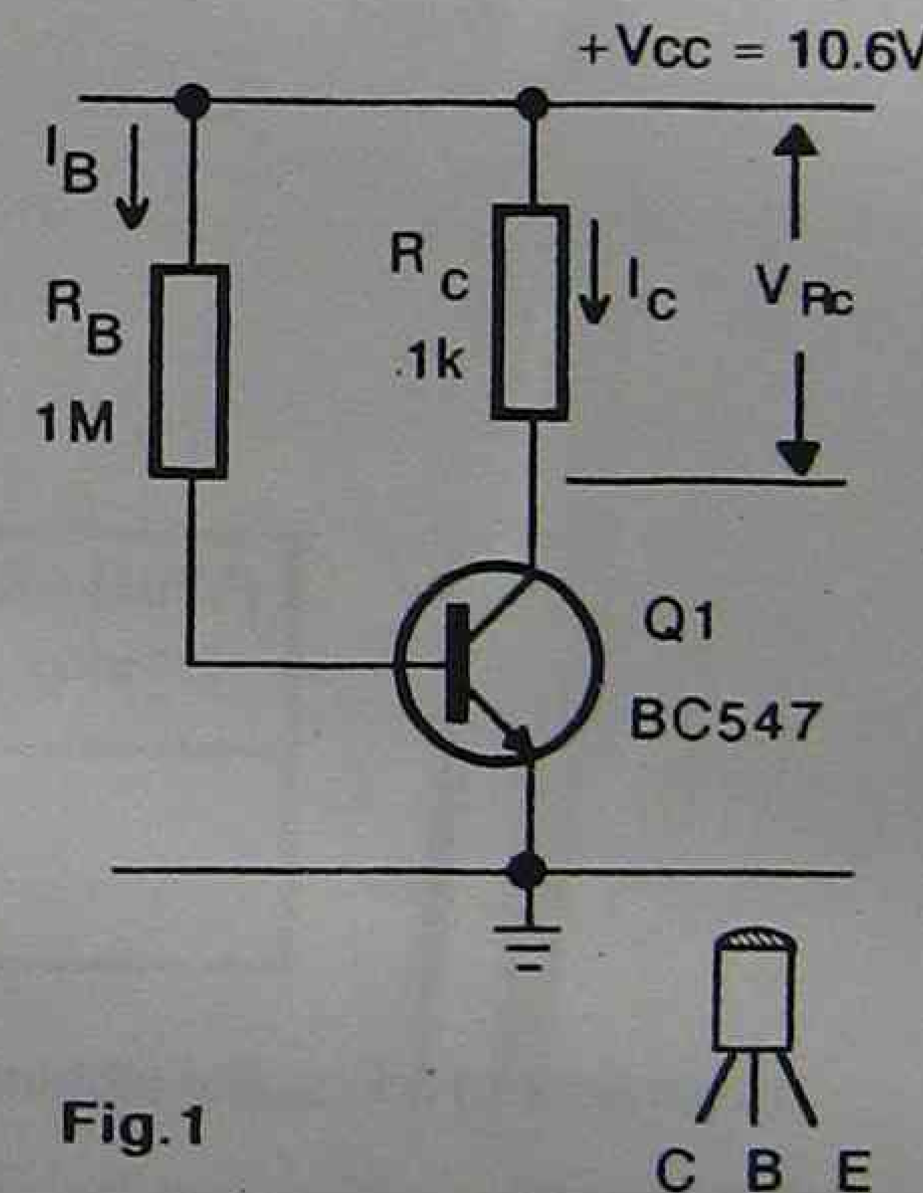


Fig.1

(b) Measure the DC voltage across Rc (V_{Rc}).

(c) Calculate the β of the transistor where:

$$I_B = \frac{V_{CC} - 0.6}{R_B} = \frac{10}{1M} = 10\mu A \;.... (1)$$

$$I_C = \frac{V_{Rc}}{R_C} = \frac{V_{Rc}}{1k} \;............ (2)$$

$$\beta = \frac{I_C}{I_B}$$

Rearranging (1) and (2) gives:

$$\beta = \frac{\frac{V_{Rc}}{1k}}{10\mu A} = \frac{V_{RC} \times 10^{-3}}{10^{-5}}$$

$$= \boxed{\square\ \beta = V_{Rc} \times 100}$$

only for this circuit

β, transistor 1: ________

β, transistor 2: ________

β, transistor 3: ________

(d) Repeat steps (b) and (c) for several BC547 transistors and record the values obtained in the space above. **NOTE**: It is important that the three selected transistors have β values that all differ by at least 20%. This may require measuring the β of a number of transistors to obtain three that meet this specification.

(e) List the transistors where transistor 1 has the lowest β and transistor 3 the highest.

ADVANCED CERTIFICATE IN APPLIED INDUSTRIAL ELECTRONICS

YEAR 1 ELECTRONIC DEVICES 6016A

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(c) Calculate the ß of the transistor where:

$$I_B = \frac{V_{CC} - 0.6}{R_B} = \frac{10}{1M} = 10\mu A \quad .... (1)$$

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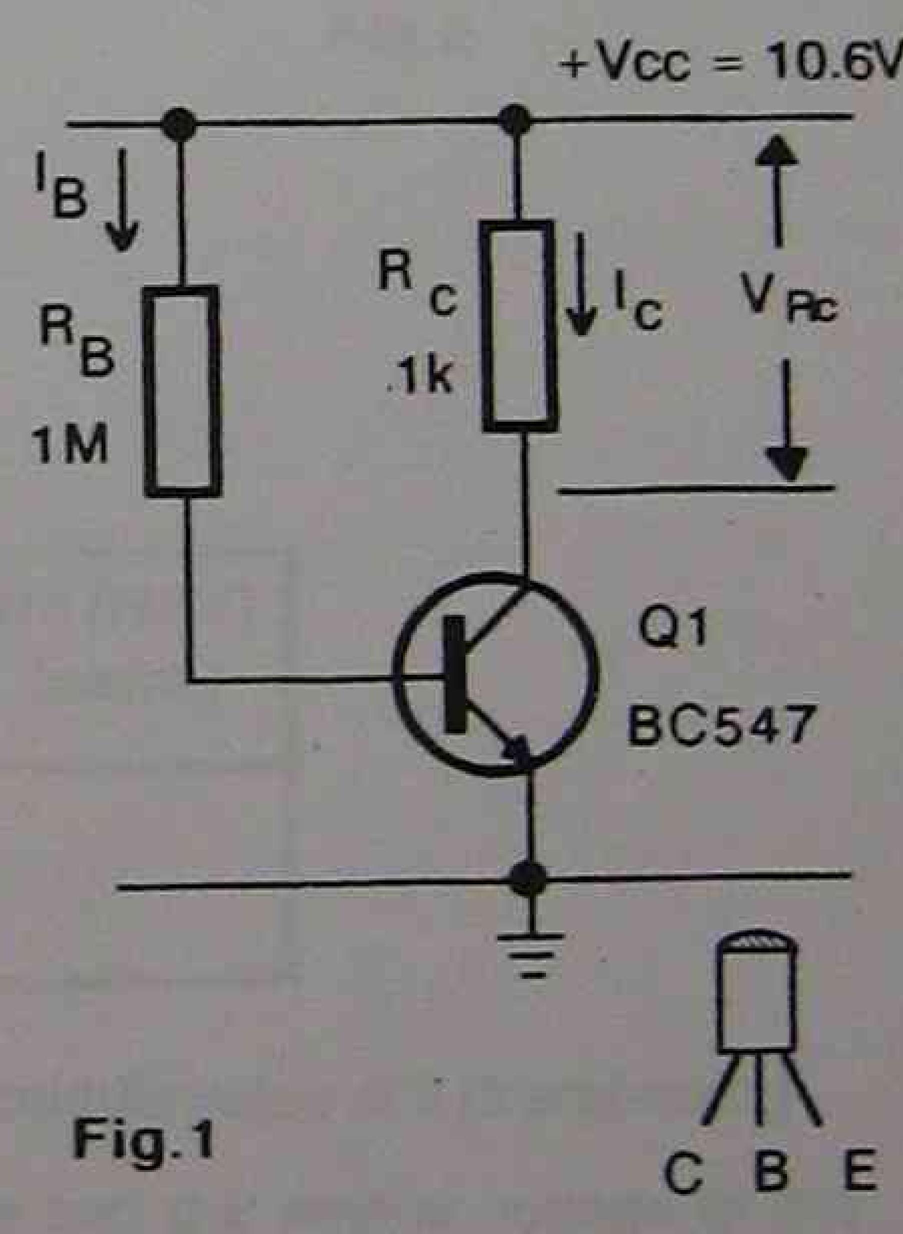

Fig.1

Rearranging (1) and (2) gives:

$$\beta = \frac{\frac{V_{Rc}}{1k}}{10\mu A} = \frac{V_{RC} \times 10^{-3}}{10^{-5}}$$

$$= \boxed{\square\ \beta = V_{Rc} \times 100}$$

only for this circuit

ß, transistor 1: __________
ß, transistor 2: __________
ß, transistor 3: __________

(d) Repeat steps (b) and (c) for several BC547 transistors and record the values obtained in the space above. **NOTE**: It is important that the three selected transistors have ß values that all differ by at least 20%. This may require measuring the ß of a number of transistors to obtain three that meet this specification.

(e) List the transistors where transistor 1 has the lowest ß and transistor 3 the highest.

(f) For the circuit of Fig.2, calculate:

- the value of the collector current to give a collector voltage (Vc) of 5V
- the emitter voltage V_E
- the base voltage V_B
- the base current I_B required to give the calculated collector current.
- the required value for the base bias resistor R_B.
- the nearest preferred value (NPV) for R_B

Enter these values in Table 1.

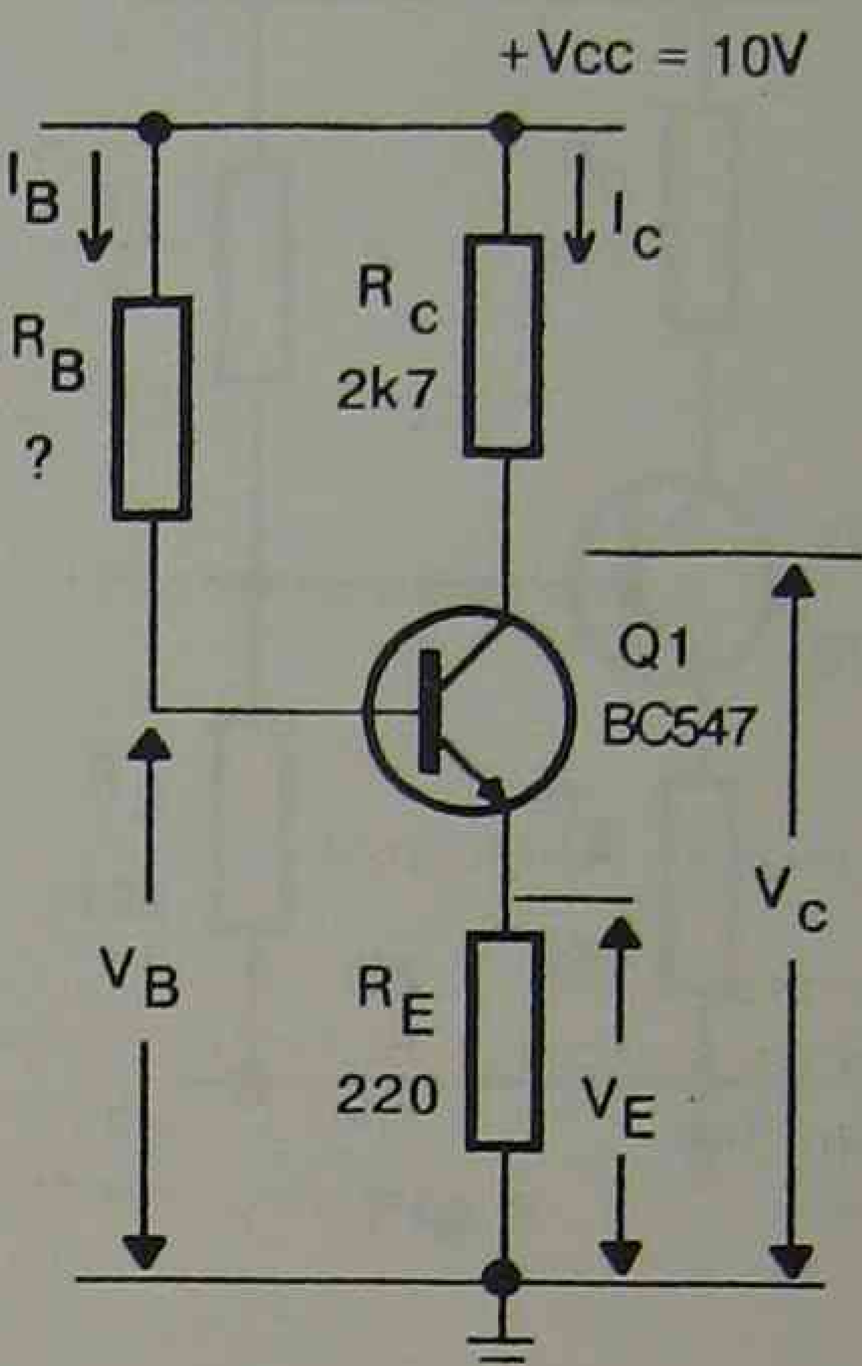

Fig.2

<u>where</u>:

$$I_C = \frac{V_{CC} - 5V}{R_C}$$

$$V_E = I_C \times R_E; \quad V_B = V_E + 0.6$$

$$I_B = \frac{I_C}{\beta}$$ (using ß of <u>transistor 2</u> [middle value] as measured in previous steps)

$$R_B = \frac{V_{CC} - V_B}{I_B}$$

<u>Table 1</u>

Ic (mA)	VE (volts)	VB (volts)	IB (μA)	RB (ohms)	RB (NPV) (ohms)

(g) Construct the circuit of Fig.2 using the transistor with the middle value of ß (transistor 2).

(h) Using a digital voltmeter, measure the collector voltage and the emitter voltage of the circuit (note that Vcc should be set to 10V). Enter these values in Table 2.

(i) Replace the transistor with one having a <u>lower</u> ß (transistor 1) and repeat step (h).

(j) Replace the transistor with that having the <u>highest</u> ß (transistor 3) and repeat step (h).

<u>Table 2</u>

Transistor	Vc (volts)	VE (volts)
Transistor 2 (middle ß value)		
Transistor 1 (lowest ß value)		
Transistor 3 (highest ß value)		

PROCEDURE 2: <u>POTENTIAL DIVIDER BIASING</u>

(a) For the circuit of Fig.3, calculate the value of R1 required to give a collector voltage of 5V. To do this, use the following steps:

- calculate the required collector current Ic for a collector voltage of 5V: $(V_{CC} - 5V)/R_C$
- calculate the resulting emitter voltage: $I_C R_E$
- calculate the resulting base voltage: $V_E + 0.6$
- use Ohm's law to determine the current in R2: $(V_B/R2)$
- use Ohm's law to determine R1, that is: $R2 = (V_{CC}-V_B)/I_{R1}$ where $I_{R1} = I_{R2}$
- Select the nearest preferred value for R1 and enter its value below.

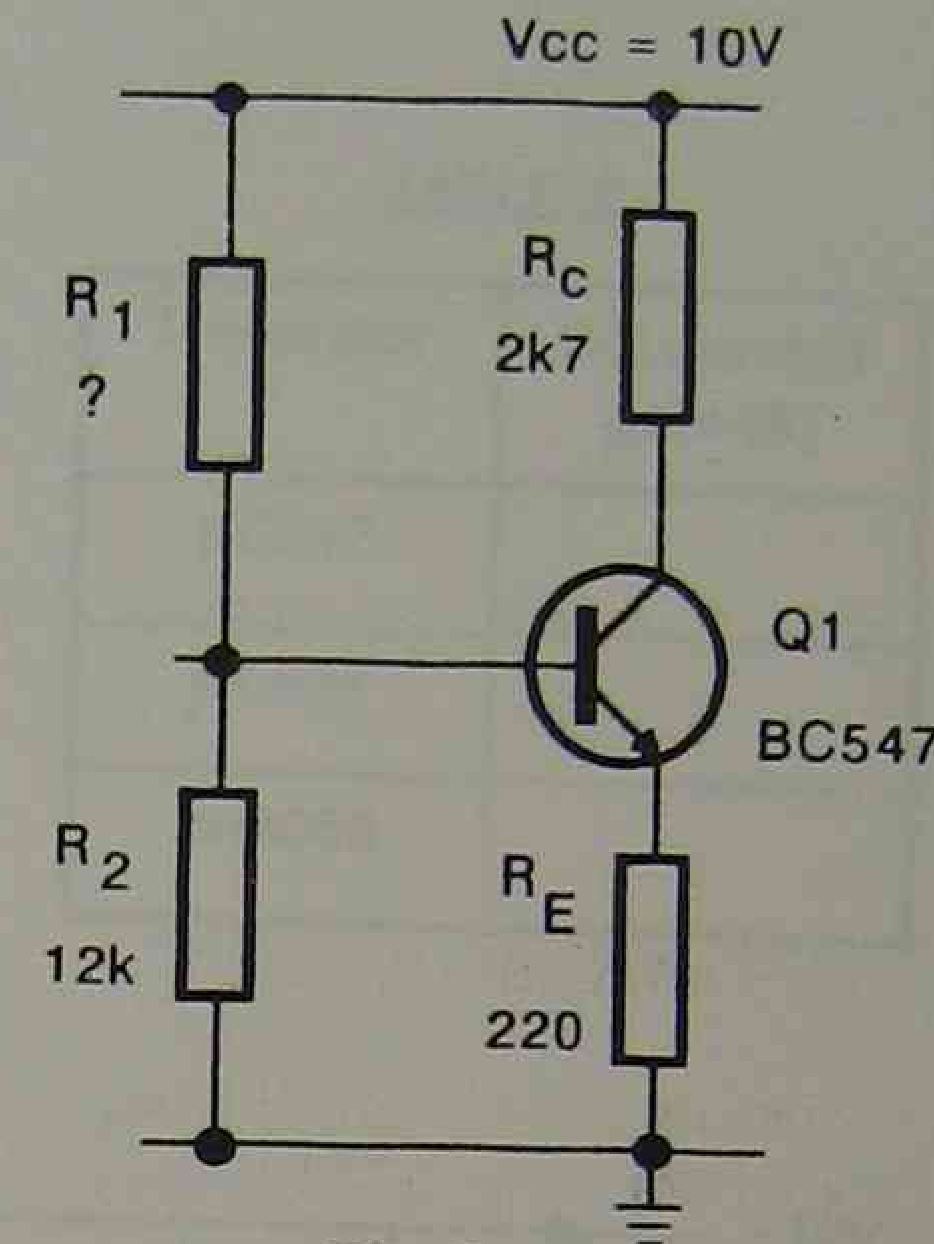

Fig.3

R1 = ________

(b) Construct the circuit of Fig.3 using transistor 2 (middle value of ß).

(c) Using a digital voltmeter, measure the collector voltage and the emitter voltage of the circuit (note that Vcc should be set to 10V). Enter these values in Table 3.

(d) Replace the transistor with one having a <u>lower</u> ß (transistor 1) and repeat step (c).

(e) Replace the transistor with that having the <u>highest</u> ß (transistor 3) and repeat step (c).

Table 3

Transistor	V_C (volts)	V_E (volts)
Transistor 2 (middle ß value)		
Transistor 1 (lowest ß value)		
Transistor 3 (highest ß value)		

<u>QUESTIONS</u>: Answer on a separate sheet of paper

(a) For the circuit of Fig.2, if the current gain of the transistor rises, identify whether the collector voltage will rise or fall. Give a brief explanation for your answer.

(b) Compare the effect on the collector voltage of replacing the transistor with one having different values of current gain for both Figs.2 and 3. Briefly explain any differences in the performance of both circuits.

(c) If the emitter resistor of Figs.2 and 3 where removed, identify the effect on the stability of the two circuits.

****

Name Date

Procedure Measuring the DC Current Gain of a Transistor

1. If available, use a DVM with the facility to measure the DC current gain (ß) of a transistor, (e.g., AWA type). Measure and record the DC current gains of each of the three transistors in Table 2.

TABLE 2

Transistor	DC current gain (ß)
BC547	
BC557	
2N3055	

2. Construct the circuit of Fig.1, which uses the BC547 transistor.

3. Connect a DVM across R_C and another across R_B, and set RV1 so that the wiper is at ground potential (0V).

4. Apply power and adjust RV1 to give a voltage across R_C of around 1V. Measure and record the voltage across R_B and also record the value of V_{RC} in Table 3 on the next page.

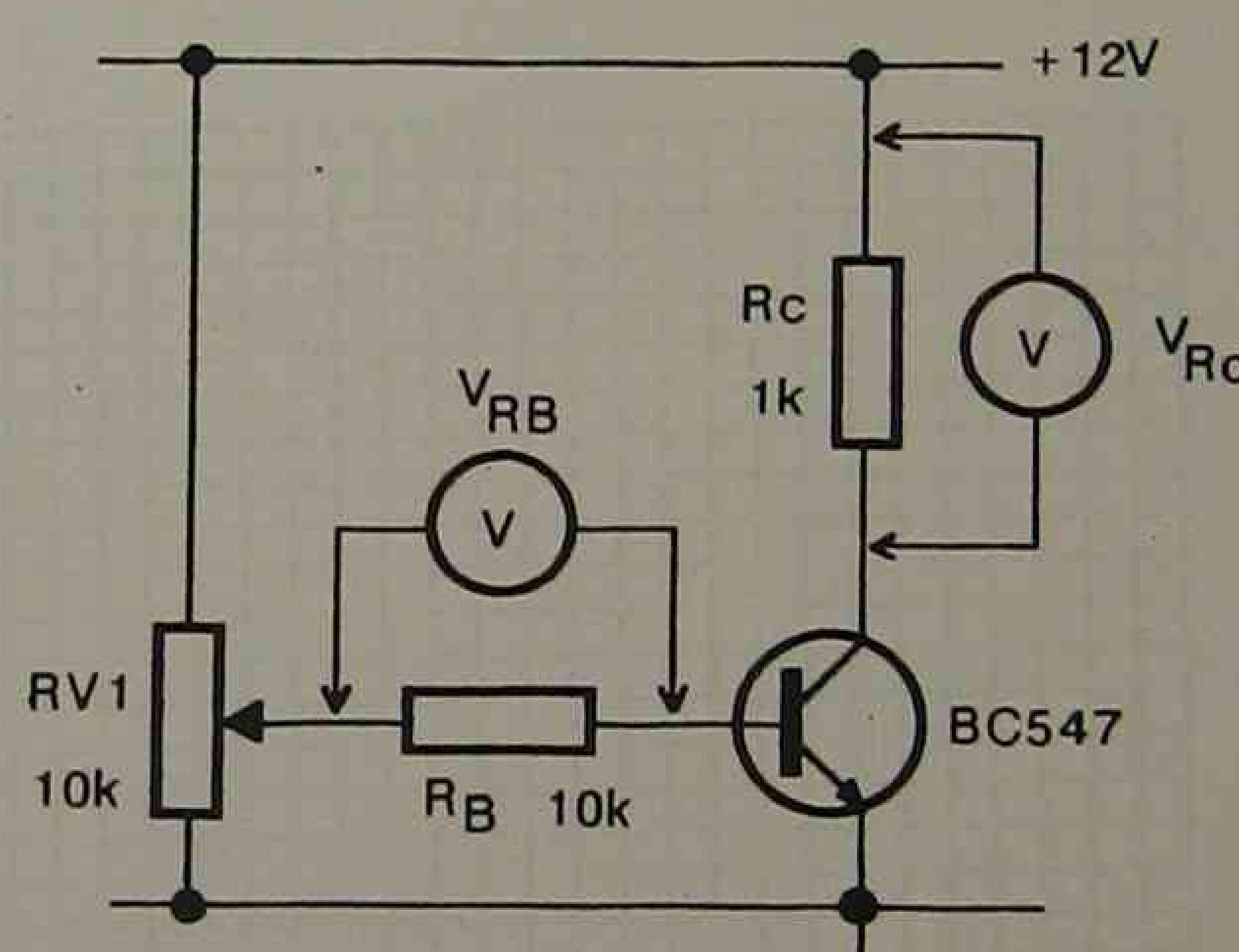

Fig.1

5. Using the previously measured values of V_{RC} and V_{RB} calculate and record in Table 3 the values of I_C, I_B and the DC current gain (ß) of the transistor where:

PTO

$$I_C = \frac{V_{RC}}{R_C}$$

$$I_B = \frac{V_{RB}}{R_B}$$

$$\beta = \frac{I_C}{I_B}$$

TABLE 3

	VRC	IC	VRB	IB	B
1.0V					
2.0V					
3.0V					
4.0V					
5.0V					
6.0V					
7.0V					
8.0V					
9.0V					
10.0V					

6. Repeat step 5 for voltages across R_C up to 10V. Adjust RV1 to obtain these voltages. Note that they need only be approximate, providing the measured values of V_{RC} are used to calculate I_C.

NOTE 1: All voltages are measured, currents are calculated.

NOTE 2: It will be noticed that the voltage across the collector resistor is relatively unstable, caused by the type of bias being applied.

Graph of Results : V_{RC} and I_C, and B against I_B