# 3-D PLOTTER

## Project Report

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1990 - 91

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## CERTIFICATE

This is to certify that the Report entitled

3 - D PLOTTER

has been submitted by

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Internal Examiner

External Examiner
27/3/91

# Acknowledgement

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We also extend our thanks to our fellow students.

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Synopsis

## SYNOPSIS

The object of this project work is to develop independent and creative thinking correlating fundamental and theoritical knowledge, we have obtained during our course of study to the practical application.

We attempted what we have learned during our course in an easy and stable manner, accompanied by detail sketch and explanation of circuits.

Our project deals with the **3 - DIMENSIONAL PLOTTER**, an electronic instrument based on linear operational amplifier and resistors, has been fabricated as an aid in plotting a function of 2 variables z = (x,y) on a CRO screen. This is an versatile attachment to a CRO or an x - y plotter will find many application in the laboratory, such as drawing 3 dimensional patterns and 3 - D curve tracing for device characteristics.

# Chapter 1 Introduction

# CHAPTER 1

## INTRODUCTION

A cathode ray oscilloscope is the most suitable laboratory instrument for studying time variation of electrical voltage or phase and frequencey relationship between two voltage signals. It has two basic mode of operations, the Y - Z mode and X - Y mode. In the latter case, ie the X - Y mode of operation the CRO is used to plot a two dimentional LISSAJOUS Figures, a semi-conductor device characteristics or in general a two dimensional curve.

The 3 - D plotter is an instrument to a CRO used in the X - Y mode or to an X - Y plotter which essentially provides a diagonal (Z) deflection input independent of the horizontal (X) and vertical (Y) inputs.

With this aid it is possible to draw a true 3 axis display in the place of the conventional X -Y plotter. In short it can be used to plot a figure in 3 dimensions (X,Y,Z) on a two dimensional screen of a CRO or a paper in case of X - Y plotter.

For understanding the use and various applications of the instruments, it is enough to treat this as a black box with 3 independent inputs, horizontal (X), vertical (Y) and diagonal (Z) and two output X and Y which are connected to a CRO. Internal circuitary processes the diagonal inputs of the CRO in the proper ratio. Fig 1.1 shows the 3 - D plotter as a black box.

# Chapter 2 Circuit Description

# CHAPTER 2

# CIRCUIT DESCRIPTION

## 2.1. Introduction:

The operational amplifier is a direct coupled high gain amplifier to which feed back is added to control its over all response characteristics. It is used to perform wide variety of linear functions and also some non linear functions and is often referred to as the basic linear or more accurately analog integrated circuit.

## 2.2. The basic operational amplifier:

The schematic diagram of the Operational amplifier is shown in fig 2.1 and the equivalent circuit in fig 2.1 (a). A large number of operation amplifiers have a differential input with voltages $V_1$ and $V_2$ applied to the inverting, non inverting terminals respectively. A single ended amplifier may be considered as a special case where one of the input terminal is grounded. Nearly all operational amplifiers have only one output terminal.

## 2.3. Ideal Operational Amplifier:

The ideal operational amplifier has the following characteristics.

1. Input resistance is infinite ($R_i = \infty$)
2. Output resistance is zero ($R_0 = 0$)
3. Voltage gain is negative infinite ($A_V = -\infty$)
4. Band width is infinitive
5. Perfect balance: $V_0 = 0$ when $V_1 = V_2$
6. Characteristics do not drift with temperature.

In fig 2.1(b) the ideal operational amplifier with feedback inpedences (Z and Z') and the positive terminal grounded. This is the basic inverting circuit. This topology represents voltage-shunt feed back.

The voltage gain $A_{vf}$ with feedback is given by,

$$A_{vf} = \frac{-Z'}{Z}$$

The operation of the circuit may be described in the following terms.

At the input of the amplifier proper there exists a **Virtual ground,** or **Short circuit.** The term virtual is used to imply that, although the feedbacks from output to input through Z' serves to keep the voltage $V_i$ at zero, no current actually flows into this short. The situation is depicted in fig 2.2, where the virtual ground is represented by the heavy double - headed arrow. This figure does not represent a physical circuit, but it is a convenient mnemonic aid from which to calculate the output voltage for a given input signal. This symbol is very useful in connection with analog computation.

## 2.4 Practical Inverting Operation Amplifier:

The equation (1) is valid only if the voltage gain infinite. It is some times important to consider a physical amplifier which does not satisfy the restrictions. In fig (2.3) the amplifier in fig 2.1(a) is replaced by its small signal model, with $|A_v| \neq \infty$, $R_i \neq \infty$ and $R_o \neq 0$. The symbol $A_v$ is the **Open Circuit Voltage gain.** The impedance shown shadded indicate the effect of Z' on the input and output of the amplifier, where use is made of the **Miller theorem.** Using these miller impedances iin place of Z' in fig (2.3). The following express for the **closed loop gain** is obtained.

$$A_{vf} = \frac{-Y}{Y' - (1/A_v)\ (Y'+Y+Y_i)} \qquad (2)$$

Where Y's are the admittances corresponding to the Z's and where the voltage gain $A_v = V_o/V_i$, taking the loading of Z' into account is given by

$$A_v = \frac{A_v + R_o Y'}{1 + R_o Y'} \qquad (3)$$

If $R_o = 0$ or $Y' = 0$ the loading in effectively removed and $A_v = A_v$; also then $A_v \quad \infty$ and,

$$A_{vf} = \frac{-Y}{Y'} = \frac{-Z'}{Z}$$

Fig (2.3) : Circuit model of the OPAMP of fig 2.1 a The shaded impedences are the miller replacements.

## 2.5 Non Inverting Opamp

Very often there is a need for an amplifier whose output is equal to, and imphase with, the input. and in addition $R_i = \infty$ and $R_o = 0$, so that the source and load are in effect isolated. An emitter follower approximates there specifications. More ideal characteristics can be obtained by using an operation amplifier having a non inverting terminal for signals and an inverting terminal for the feed back voltage as shown in fig 2.4.

We assume that, $R_i = \infty$ and $-A_V (V_1 - V_s)$ then for a finite $V_o$ it follows that $V_s = V_1$ and $A_{vf} = \frac{V_o}{V_s} = \frac{V_o}{V_1} = \frac{R + R'}{R}$

Hence closed loop gain is always greater than unity. If R = and/or R' = 0, then $A_{vf} = +1$ and the amplifier acts a **Voltage follower.**

In the analysis of non inverting Operation Amplifier circuits we shall use the facts that,

1. No current flows into either input.

2. The potentials of the two inputs are equal.

## 2.6 Operation Amplifier - Adder

Several input voltages can be added when connected to an operational amplifier as shown in fig (2.5). The summing potential at the amplifier inverting input terminal is virtually at ground potential, so

$$i_A = \frac{V_A}{R_A} ; \; i_B = \frac{V_B}{R_B} ; \; i_C = \frac{V_C}{R_C}$$

from the previous analysis,

$$I = i_A + i_B + i_C$$

and we see that, $V_o = -R'I$

$$V_o = -R' \frac{V_A}{R_A} + \frac{V_B}{R_B} + \frac{V_C}{R_C}$$

The individual signal voltages may be added with their own weighting factors $R'/R_A$, $R'/R_B$, and $R'/R_C$. This process is called scaling of the variables.

If we make $R_A = R_B = R_C = R$ then

$$V_o = \frac{-R'}{R} (V_A + V_B + V_C)$$

If R = R' then,

$$V_o = -(V_A + V_B + V_C)$$

The circuit of fig.(2.5) that of an adding circuit with a sign change

**2.7 Display System :**

**Digital Display System : -** In digital instruments, Output device indicate the value of measured quantity in decimal digits. This is done by using a digital display device. A degital display device may receive digital information in any form but it converts that information to decimal form. Thus the display device indicates the value directly in decimal digits. The number if digits correspond to the significant figures needed to respresent the value. The basic element in a digital display device is the display for a single digit, because a multiple digit display is nothing but a group of single digit displays. The below fig shows a multiple digit display consisting of 4 single digit displays.

A single digit display is capable of indicating the numbers from o to 0. This is also usually provision for a decimal point between each of the numerals. One of these is selected and actuated in accordance with the range selections controls of the instrument. Some instruments have automatic range selection commonly called autoranging. The input to the digit display is a code indicating the particular number to be displayed, or the excitation of one of the ten inputs designating the number to be displayed.

## 2.8 Digital Display Units

There are many ways of classifying the digital display units. One of the methods of classifying them is based upon the format used. The display can be planar ie the entire read out characters are in the same plane or non planar where the characters are displayed in different planes.

The planar displays may be illuminated segmental type, illuminated dot matrix type display using rear projection and gaseous discharge type segmental displays. The non planar displays include gaseous discharge tube like nixies and displays using illuminated lucite sheets.

## 2.9 Seven Segmental Display

The below fig (4.2) shows a seven segmental display. This is used for numeric display. It consists of seven segments a,b,c,d,e,f and g. A segmental display form the digit to be displayed by illuminating proper segments from the group. By illumunating the proper combination of these 7 segments numbers o through 9 can be displayed. A display is incandescent and operates on low voltage and requires about 10 to 50 MA current when using LEDs (light emitting diodes) LCDs (liquid crystal diodes) are also used for segmental displays.

The digital display circuit is used here to indicate the quadrant selected by the switches $S_6$ and $S_7$.

## 2.10 Oscilloscopes

A wide variety of electrical signals may be displayed on the face of a cathode ray tube with the Oscilloscope. An electron beam in the cathode ray tube is precisely controlled by horizontal and vertical deflection plates within the tube as voltage are applied to their terminals. The electron beam upon striking the face of the tube activates the phosphor thus tracing a visible indication.

Dual trace oscilloscopes permitt two quantity to be deserved simultaneously, such as the input and the output waveforms of an amplifier. The dual trace oscilloscope also permits comparison of phase (or) time relationships of two separate wave forms.

In our project me use this Dual trace osciloscope to draw or plot a 3 Dimensional veiw on the oscilloscope screen. Using the input node of x and y terminal.

## 2.11 Ganged Pot

This is a linearly variable device. Here two pots are ganged and hence named Ganged Pot. By using this ganged pot we can vary up to 360° of a resistances, by properly connecting the terminals of the pot.

## 2.12 Nonc Switch

The normally operating and normally closed switch are used here in this project. The operation of this switch is, when the switch is normally closed the two contacts at the closed end works and when it is 'ON' the terminal on the open end work. The fig (2.7a) shows a Nonc switch.

Fig (2.6a) show the switch in normal closed position and Fig (2.6b) show the switch in normal operating position. This switch can be used in any one mode of operation at a time.

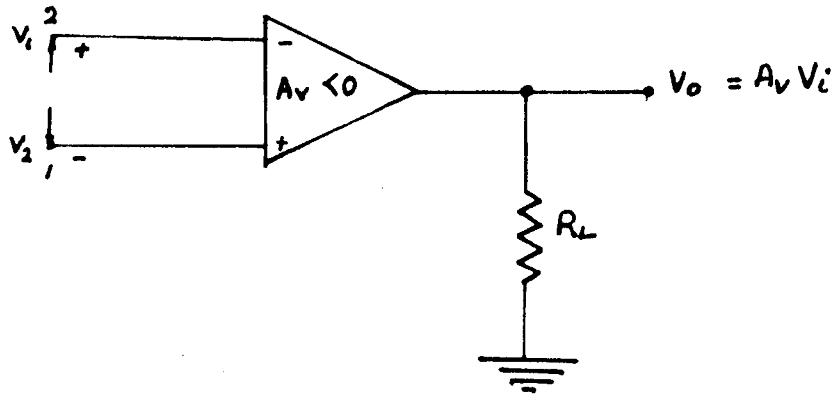
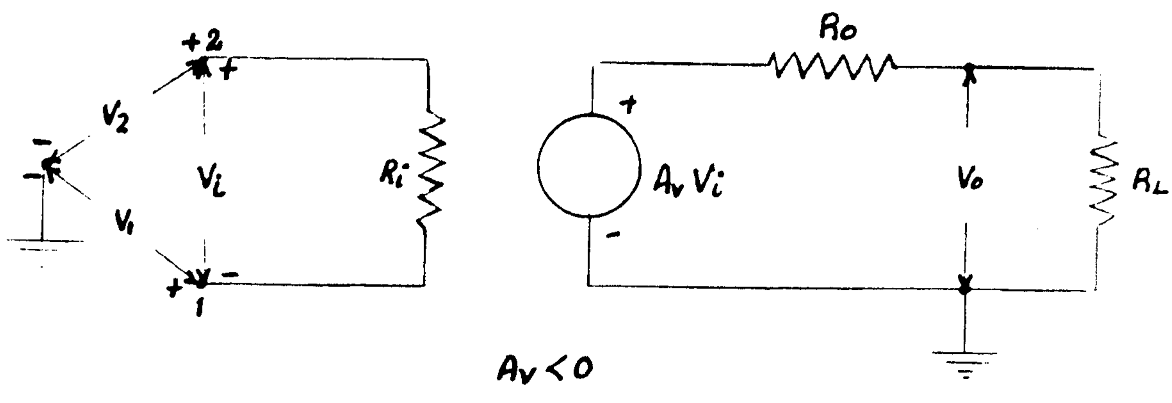



Fig 2.1 BASIC OPERATIONAL AMPLIFIER




2.1 (a) LOW FREQUENCY EQUIVALENT CIRCUIT OF OPERATIONAL AMPLIFIER

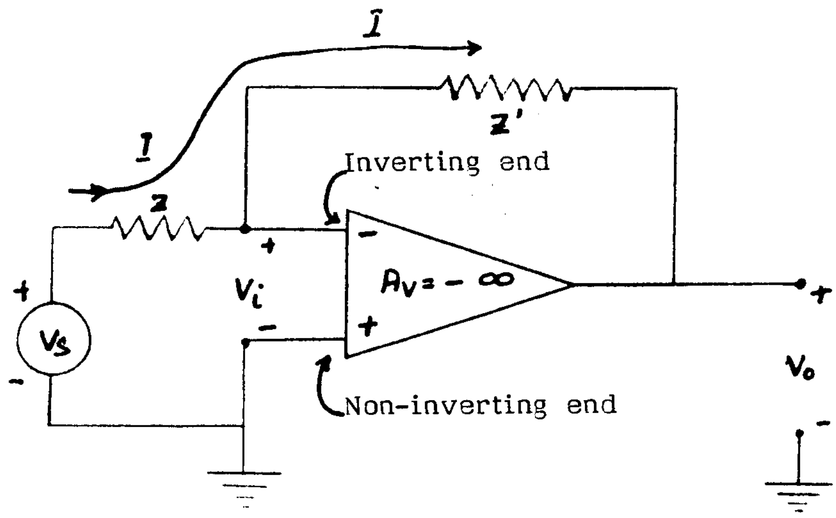



Fig. 2.1 (b) INVERTING OPERATIONAL AMPLIFIER WITH ADDED VOLTAGE SHUNT

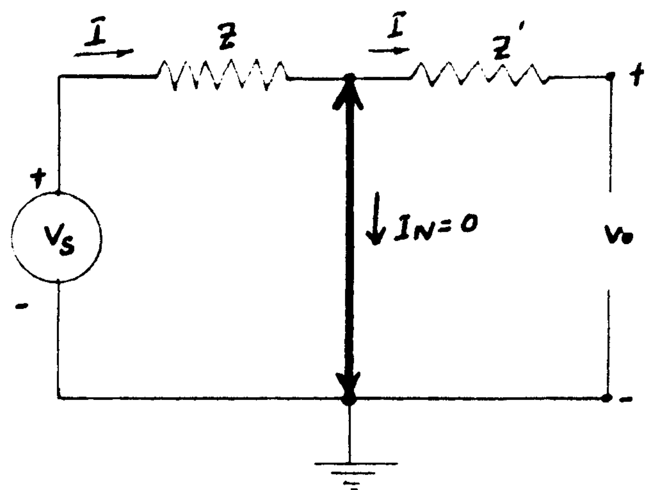



Fig.2.2 VIRTUAL GROUNDING OF OPERATIONAL AMPLIFIER

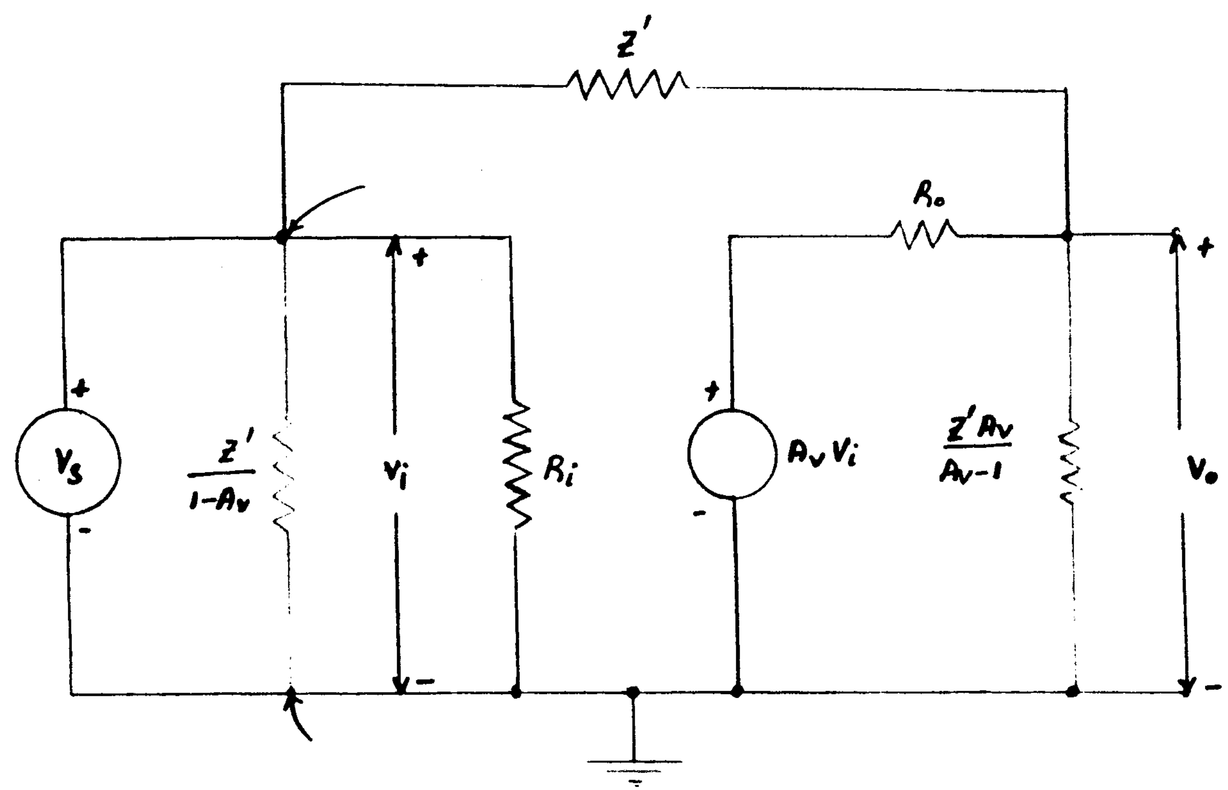



Fig. 2.3 CIRCUIT MODEL OF OPERATIONAL AMPLIFIER

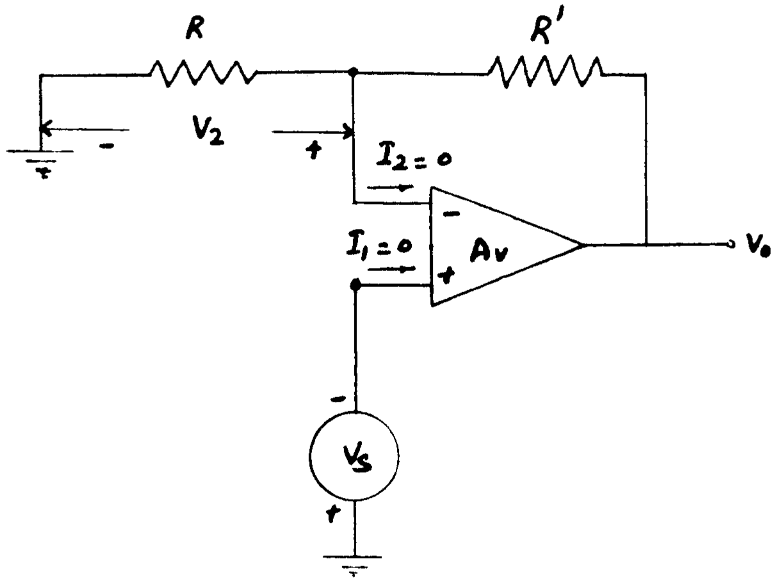



Fig. 2.4 NON INVERTING OPERATIONAL AMPLIFIER WITH RESISTIVE FEEDBACK

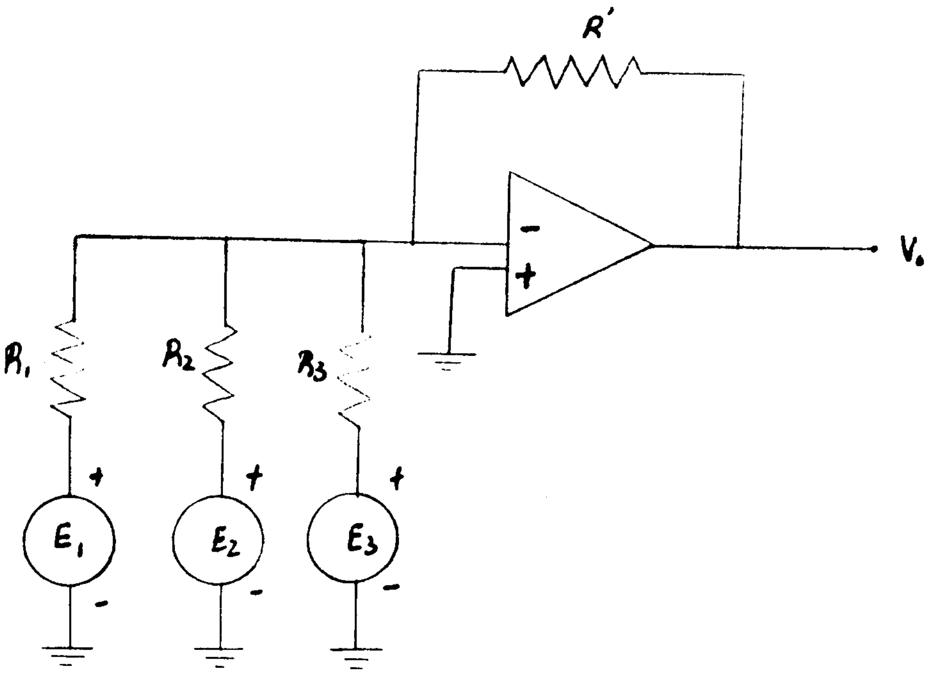



Fig. 2.5 OPERATIONAL AMPLIFIER ADDER

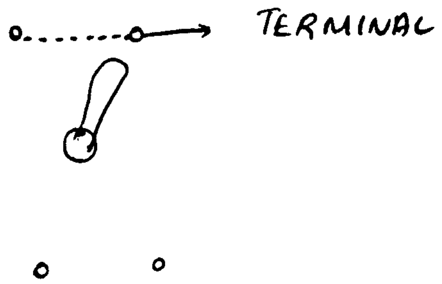



Fig. 2.6 (a) NONC SWITCH AT NORMAL CLOSED CONDITION

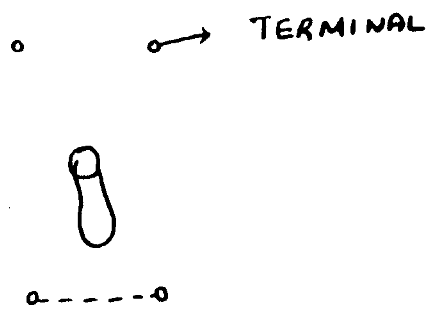



Fig. 2.6 (b) NONC SWITCH AT NORMAL OPERATING CONDITION

# Chapter 3 Circuit Diagram & its Operation

# CHAPETER 3

# CIRCUIT DIAGRAM AND ITS OPERATION:

## 3.1 Circuit Diagram and Its Operations:

Fig (3.1)a&b describes the complete circuit diagram used for the three dimensional plotter.

The analog signals (± 5 V max) applied to horizontal, vertical and diagonal inputs are prescaled with 100 kilo ohms potentiometers ($P_1$, $P_2$, $P_3$) and inverted with operational amplifiers ($A_H$, $A_V$, $A_D$). Switches ($S_2$, $S_3$, $S_4$) select either the direct inputs or inverted signals and feed to the non inverting address, ($A_{HD}$ and $A_{VD}$). However, the diagonal signal is first processed by the circuit consisting of switch $S_5$ and ganged 100K potentiometer $P_4$. In the 45 degree position of the switch $S_5$. The diagonal signal $V_D$ is applied simultaneously to $A_{HD}$ and $A_{VD}$ adders. This allows the diagonal signal to be plotted along a line at 45 degrees with respect to the X and Y axis. The amplitude of this signal $V_D$ gets effectively multiplied by a factor of 2. In the rotate position of the switch $S_5$. the potentiometer $P_4$ allows a signal of amplitude K. $U_D$ to be applied to the $A_{HD}$ adder and another signal of amplitude (1-K) x $V_D$ is to be applied to the $A_{UD}$ adder, where $0 \leq K \leq 1$.

In case when K = 0.5, once again the signal $V_D$ plotted along the line at 45 degrees with respect to X and Y axis.

However, because of the term K = 0.5, the effective amplitude of the diagonal input is divided by a factor of $\sqrt{2}$. By changing is from 0 to 1, it is possible to rotate the diagonal axis with respect to the X axis from 90 degrees to 0 degrees. Amplifiers $A_{HD}$ and $A_{VD}$ are inverting amplifiers. Quadrant selection is accomplished by switches $S_6$ and $S_7$ which select outputs of either non inverting, inverting, adders $A_{HD}$ or $A_{VD}$ or inverts $A_{HD}$ and $A_{VD}$ and couple them to the X and Y inputs of the CRO/ plotter. The four possible combinations of switches $S_6$ and $S_7$ corresponding four X - Y quadrants are displayed on a seven segmental display using a diode decoder circuit. The quadrant display circuit is shown in fig 3.2 On or OFF states of LEDs are used to indicate whether the inverted or direct input signals are being fed to non inverting adders. Non inverting adders ($A_{HD}$ , $A_{UD}$) operational amplifiers available in a single IC package LM 325. This ensures that phase shifts through $A_{HD}$ and $A_{VD}$ and similarly those through $A_{HD}$ and $A_{VD}$ are equal on account of identical operational amplifier characteristics.

### 3.2 Power Supply:

± 12 volts power supply is used for the operation of the circuits. The power supply part consists of a step down transformer. Bridge rectifier, capacitor filter and 3 pin IC regulators the circuit diagram is shown in fig 3.3.

The rating of the transfer selected is 230v/15-0-15 Volts, 1 Ampere. The secondary of the transformer is connected to the AC input of the bridge rectifier. The outputs are filtered using 470 microfarad 35volts capacitor, 2200 microfarad 25 volts capacitor. The filtered outputs are given to the input of the regulators ICs 7812 and 7912 as in fig (4.3). The outputs taken from the regulators are +12v and -12v respectively.

### 3.3 Control of Circuit

Switch $S_1$ applies AC power to the instrument and turns on the 7 segmental display. This display indicates the quadrant selected by switches $S_6$ and $S_7$. Analog signals are connecte to the 3 - D plotter with the help of input BNC sockets, labelled as horizontals vertical and diagonal inputs. These signals can be inverted with the help of interlocking switches $S_2$, $S_3$ and $S_4$. Inversion of the signals in indicated by leds $L_1$, $L_2$ and $L_3$.

Swithch $S_5$ in conjunction with potentiometer $P_4$ allows the Z axis either to be fixed at 45 degrees or to be rotated from 0 degrees to 90 degrees with respect to the X axis. Gain control potentio meters $P_1$, $P_2$ and $P_3$ allow the analog signals to be prescaled. The 3-D plotter is connected to the CRO using X and Y output BNC sockets.

### 3.4 Layout Description

The layout show in fig (3.4) is the actual size printed circuit board layout. This layout make the connection easier and simple. Just by placing the necessary component on the requried place we can get the complete circuit. On the end, the two 12 pin connectors are provided to make the connections still easier. These connection can separate the main printed circuit board whenever need for any testing. Further reduction in printed circuit board size can be made if we use quarter watt resisters (11K). Thus the layout helps in avoiding confusion in connection.

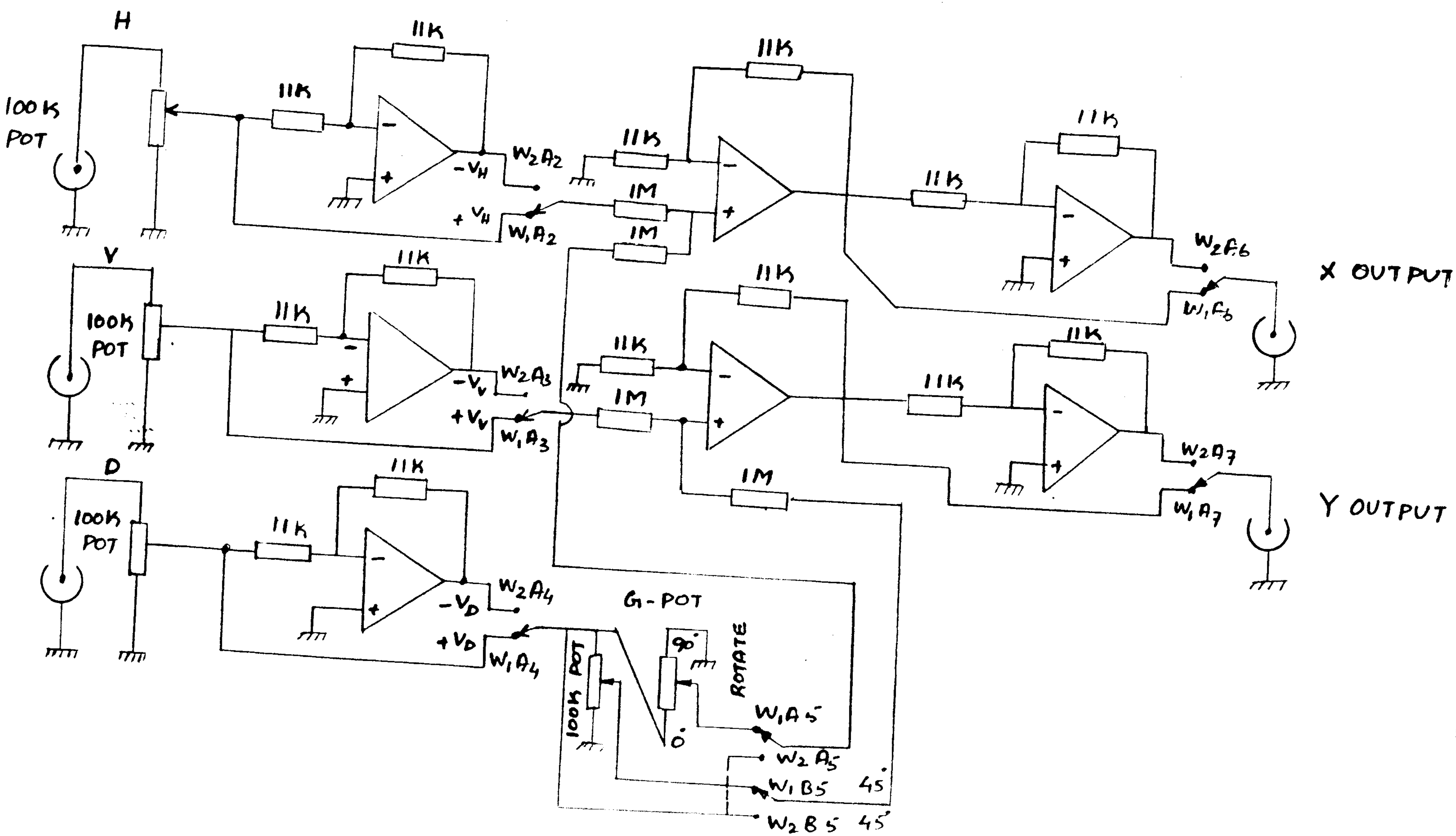



Fig. 3.1 (a) CIRCUIT DIAGRAM

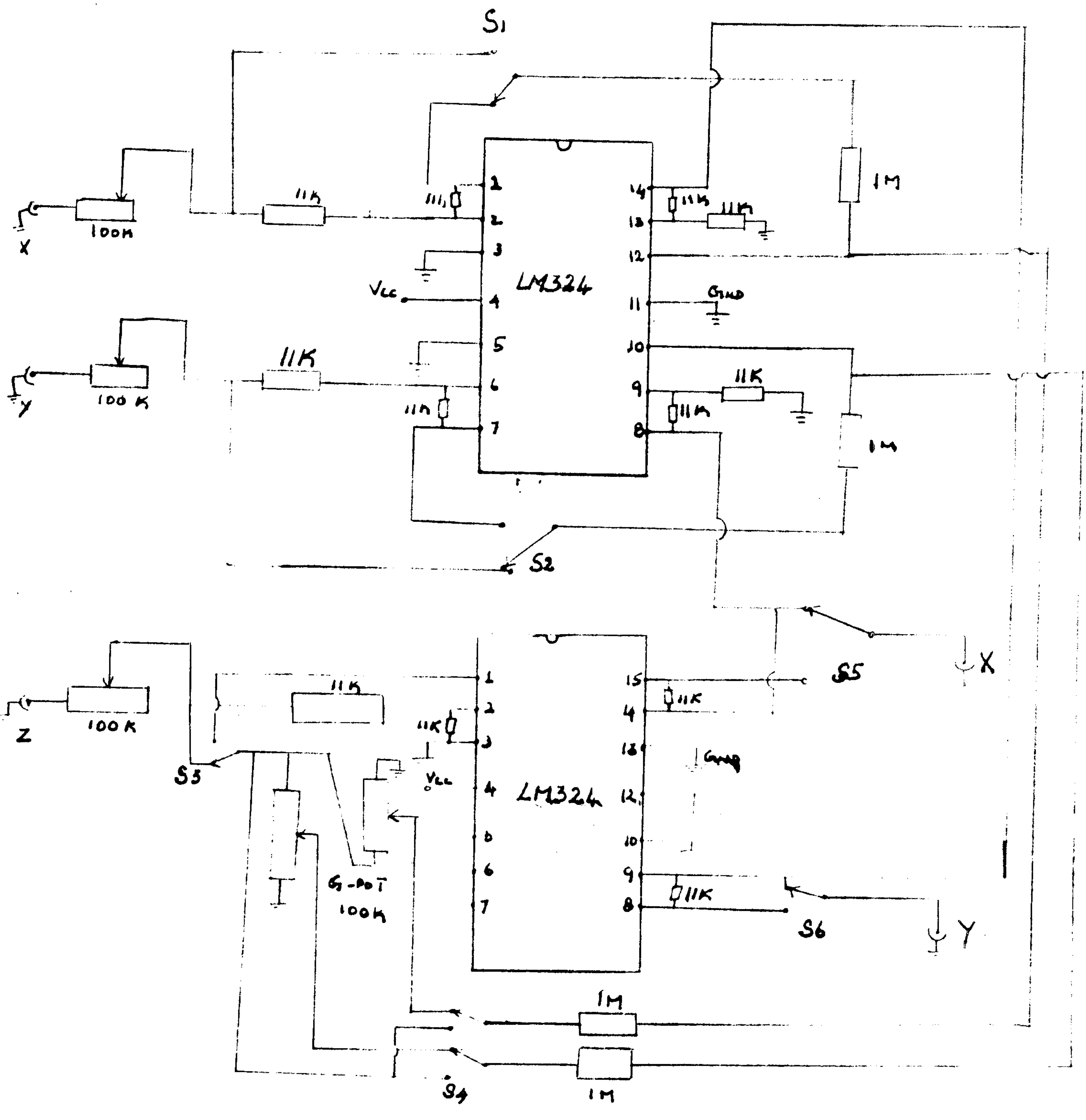



Fig. 3.1 (b) MODIFIED CIRCUIT DIAGRAM

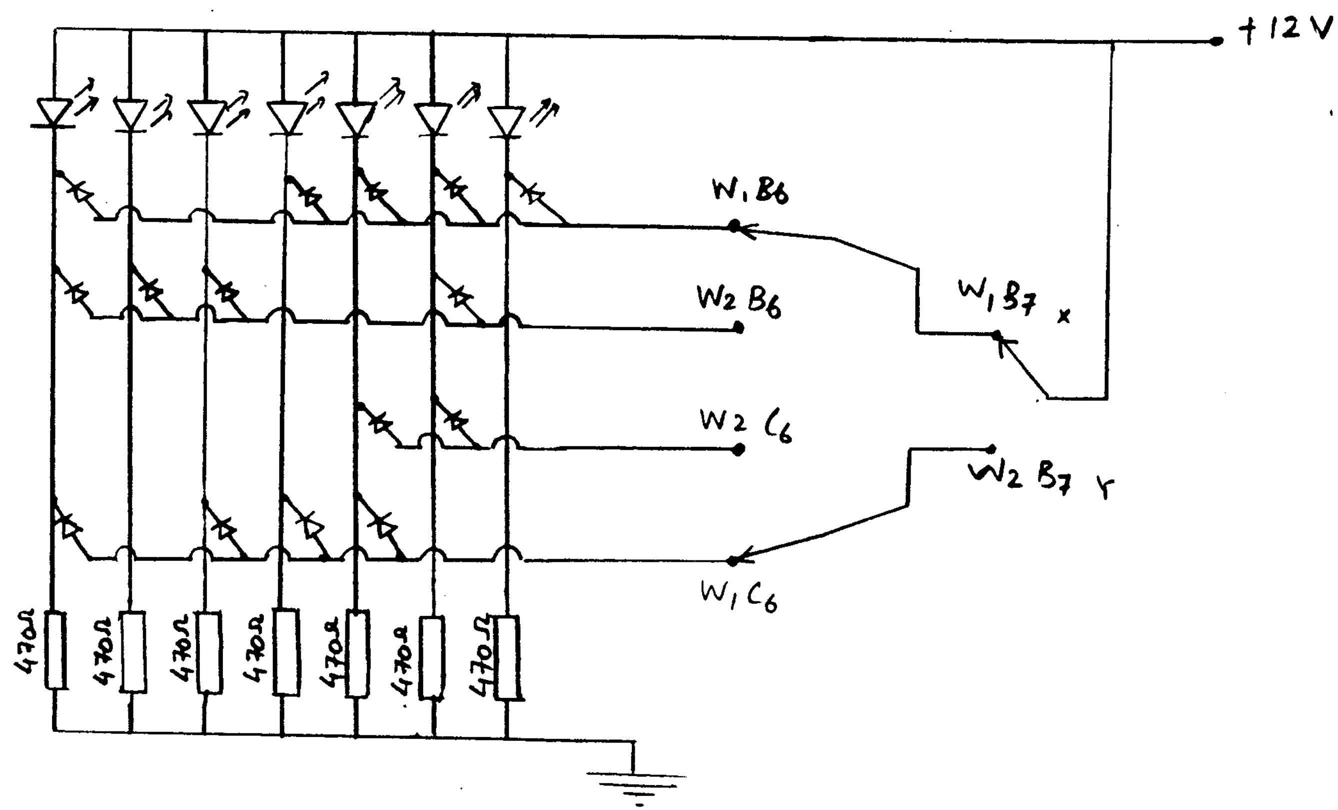



Fig. 3.2 QUADRANT DISPLAY CIRCUIT

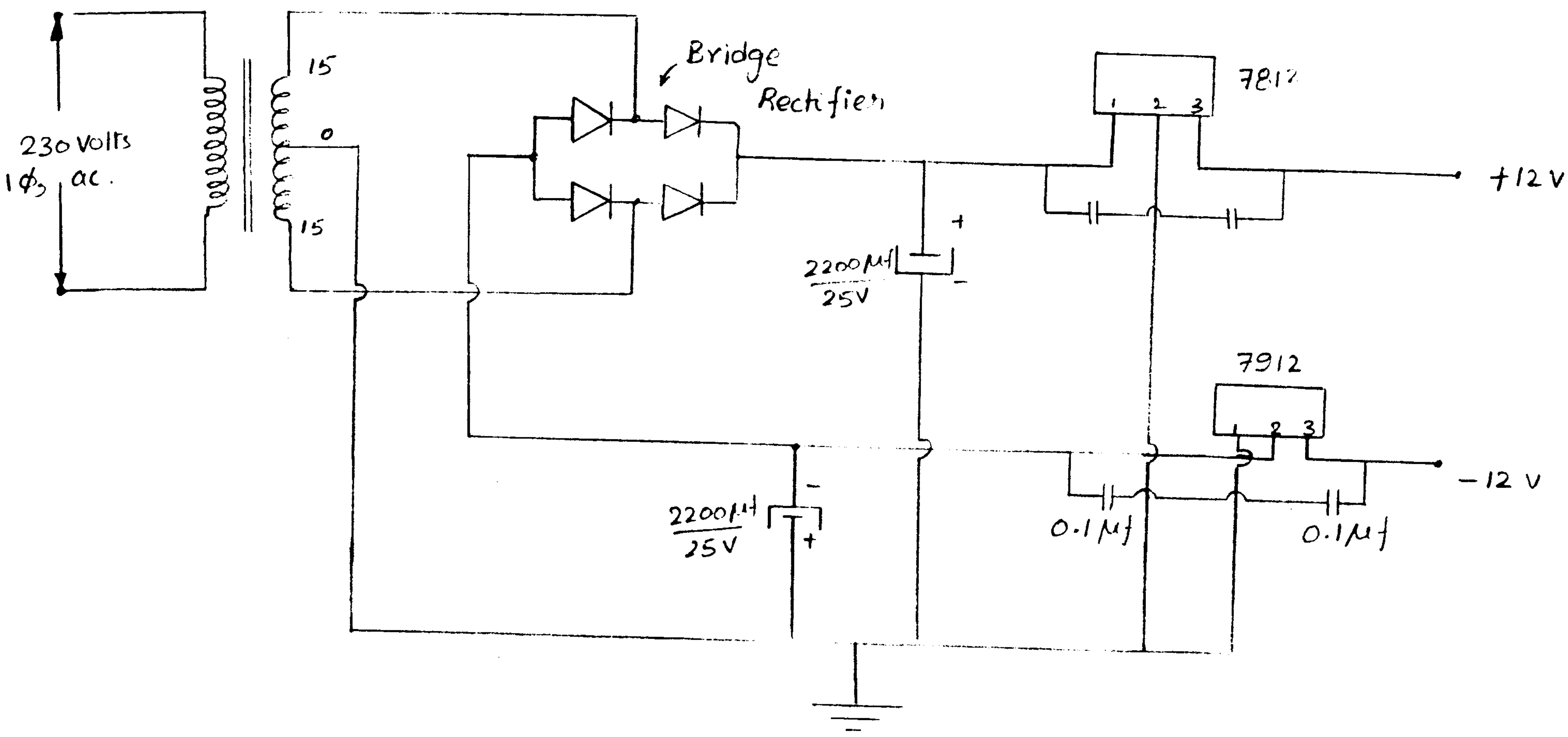



Fig. 3.3 12-0-12 VOLTAGE POWER SUPPLY

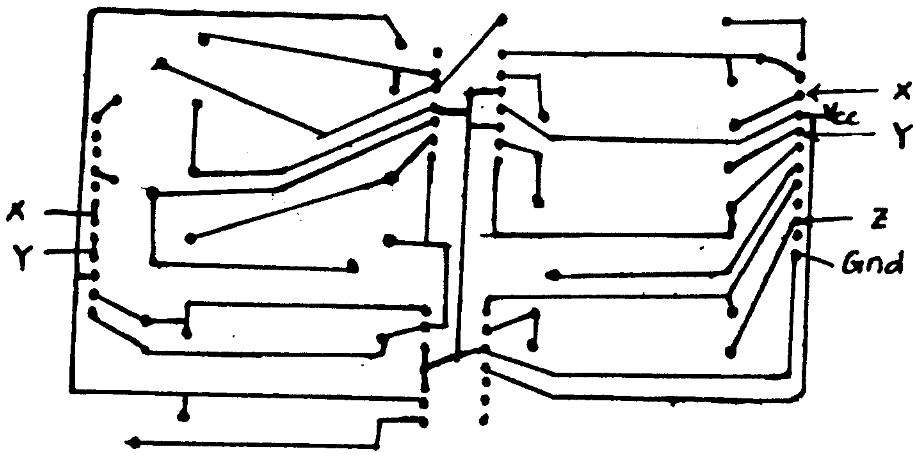



Fig. 3.4 ACTUAL SIZE LAYOUT

# Chapter 4 Description of Integrated Circuits

# CHAPTER 4

# DESCRIPTION OF INTEGRATED CIRCUITS

## 4.1 LM 324 Quad Operational Amplifier

Fig. 4.1 shows the pin details of LM 324 IC. Four internally compensated Operational Amplifiers in a single line package. Inputs bias current is both low and constant with temperature. Wide supply voltage compatability with low current drain. Available in 14 pin plastic caseing.

The LM 324 series integrated circuits contains four differential independent, operational amplifiers. Each amplifier has been designed to operate from either a single supply voltage or plus and minus voltages and features internal frequency compensation, high gain and very low supply current requirements. An additional significant advantage of these amplifiers is that when using a single supply, the input and output can be operated down to ground potential. Thus they can be powered by a standard + 5V DC logic supply and still be compatible with all forms of logic inputs and outputs.

## 4.2 FND 507 Seven Segment Display

Fig. 4.2 shows the pin details of FND 507 Seven Segment Display.

The FND 507 are Red Ga ASP single digit seven segment LED display with a normal character height. The FND 507 has common anode configrations. These display devices are for applications where the viewer is within twenty feat of the display. Each digit has a brightness code (05, 06,07) for constructing arrays with closely matcched digits. Low current requirement of typically 5mA/segment. Low voltage of typically 1.7 $V_Z$.

**Absolute Maximum Ratings:-**

Maximum temperature and humidity-25 °c to 85°c

Holder Temperature (5 seconds) 260°c

Relative humidity at 65°c 98%

Maximum voltage and currents

Reverse voltage –3.0V

Average forward current/Decimal or segment point –25mA

Darate from $25^C$ Ambient temperature –0.3mA/°c

Peak current/segment or decimal point 100 us pulse width –200mA

1000pps $T_A$ = 25°c

**4.3. Voltage regulators:**

**IC7812 - Features description and Absolute power rating:**

Fig 4.3 shows the pin details of 7812

**Details:**

1. It is a 3 terminal regulator
2. The output current is upto 1.5A
3. No external components
4. Internal thermal overload protection
5. Dicot replacements for fairchild
6. MA 7800 series and national LM 340 series
7. High power dissipation capability
8. Internal start - circuit current limiting

This series of fixed voltage monolithic integrated circuit voltage regulators is designed for a wide range of aplications. There applications include on-card regulation, For Elimination of noise and distribution problems associated with single point regulation. One of these regulators can deliver upto 1.5 ampere of output current. The internal current limiting and thermal shut down features of these regulations make them essentially immune to over load. In addition to use as fixed voltage. Regulators these device can be used with external components to obtain adjustable output voltages and currents and also as the power pass element in precision regulators.

Low input bias and offset parameters input offset voltage 2MV Type.

Input offset current 3nA Type (LM324)

Input bias current 45nA Type

Differential input voltage range equal to maximum rated supply voltage $\pm$32volt

Open loop differential voltage Amplification = 100v/MV Type

Internal frequency compensation

Input voltage +35 v

Power dissipation Internally limited

Storage temperature –65°c to + 150°c

Operating Junction temperature range 0 to + 150°c

Load temperature (Soldering 10second) +300°c

**IC7912 features Description and absolute power Rating:**

**Fig (4.3) shows the pin details of 7912**

Output voltage set internally $\pm$3%

One volt minimum input output differential

Excellent line and load regulations

Short circuit current limited

Thermal overload protection.

The 7900 series of negative regulators offer self contained, fixed-voltage capability upto 1.5 amps of load current, with four factory set output voltages (–5V, –5.2V, –12V and –15Volt) and four package options, this regulators series in an optimum complement to the SG 7800/140 line of three terminal positive regulators.

Since these regulations require only a single output capacitor for satisfactory performance and are protected from overload conditions by internal current limiting and thermal shut down protection, ease of application is assured.

Although designed as fixed-voltage regulators the output voltage can be increased through the use of sample voltage divider, the low quiscent drain current of the device insures good regulators when this method is used. Product is available in hermatically sealed to –39 to –66 and to –3 power packages and commercial product is also available in To –220

Absolute Maximum Ratings

Device output voltage –12V

Input voltage –35V

Input output differential –30V

Power dissipation internally limited operating

Junction Temperature Range –55°c to + 150°c

Storage temperature Range –65°c to +150°c

Lead Temperature –300°c

(solding 10 seconds)

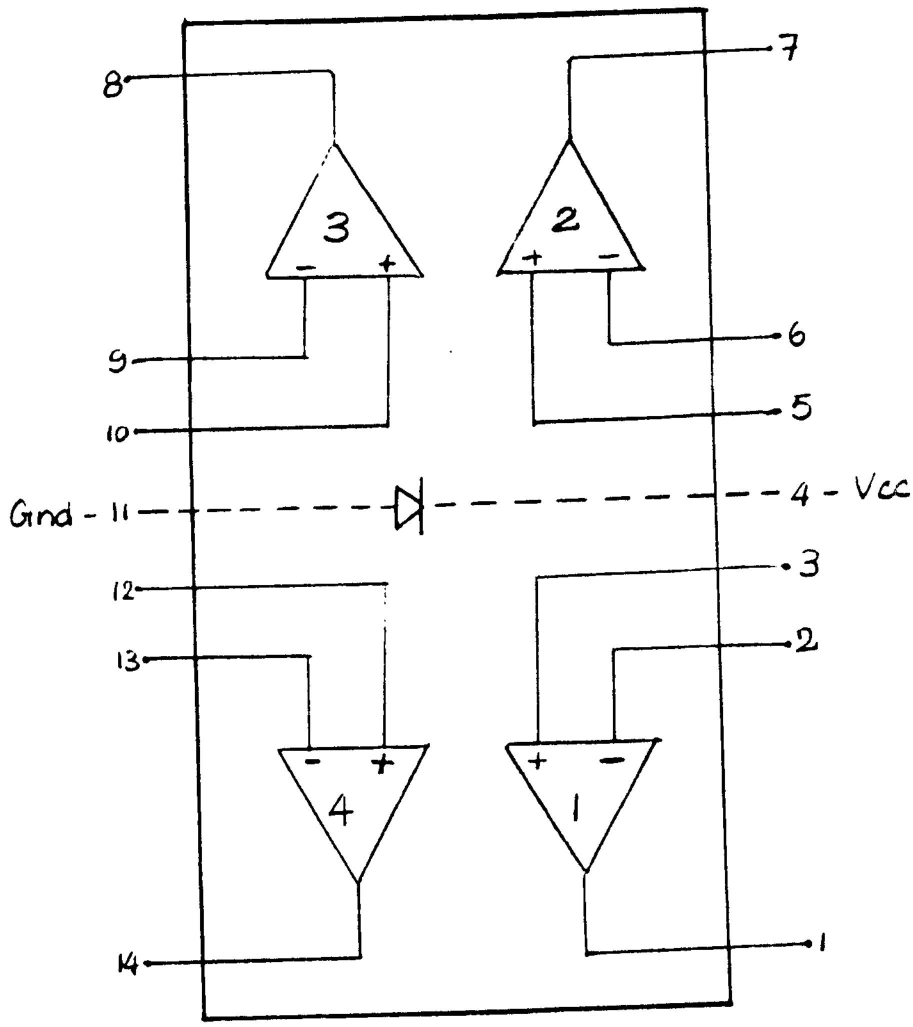



Fig. 4.1 PIN DETAILS OF LM 324

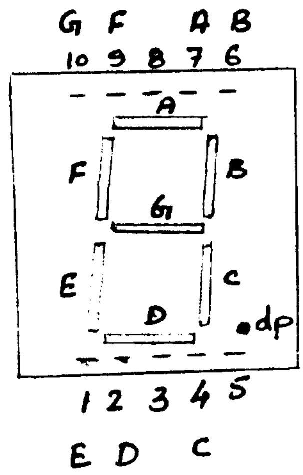



Fig. 4.2 PIN DETAILS OF FND 507

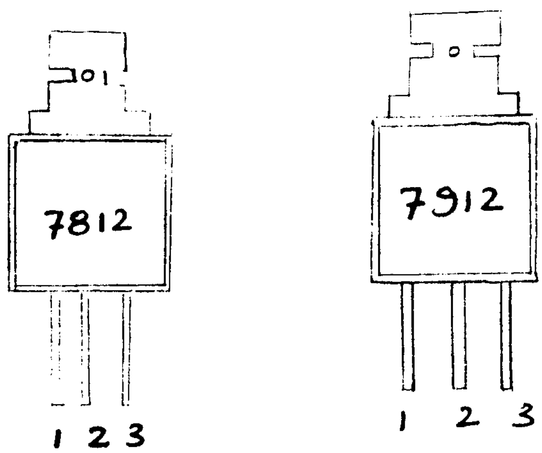



Fig. 4.3 PIN DETAILS OF 7812 and 7912

# Chapter 5 Plotters & its Drives

# CHAPTER 5

# PLOTTERS AND ITS DRIVES

## 5.1 $X_1$ - $X_2$ - Y Plotters:

The X - Y plotter is able to plot a given variable against another variable. Two servo systems must be used, one on the horizontal axis and the other on the Y - axis. The X - Y plotter the pen move in either direction Viz., X and Y. The pen is given by separate reversible balancing motor similar to that used in positioning the recording chart. The chart which are usually used are 10 Inch by 10 Inch are printed on continuous supply of rolls and are driven by geared driven rollers, which fit perforation on both edges of the chart. In this mainer a series of X - Y plots may be made by repositioning the a new chart. The addition of a second servo - actuated measuring element and recording pen to an X - Y plotter provides means for measurements of 3 variables as $X_1$, $X_2$, and Y plotter.

In X - Y plotter, the self balancing potentiometer principle is used to control both the pen carriage position on one axis and the pen position on the carriage on the other axis. Eventhough X - Y plotters are slow - speed, these are faster and more conveinent than manual curve plotting. There are large and small X - Y plotter both these X - Y plotter use solenoid operated printer which replaces recording assemply. This permit

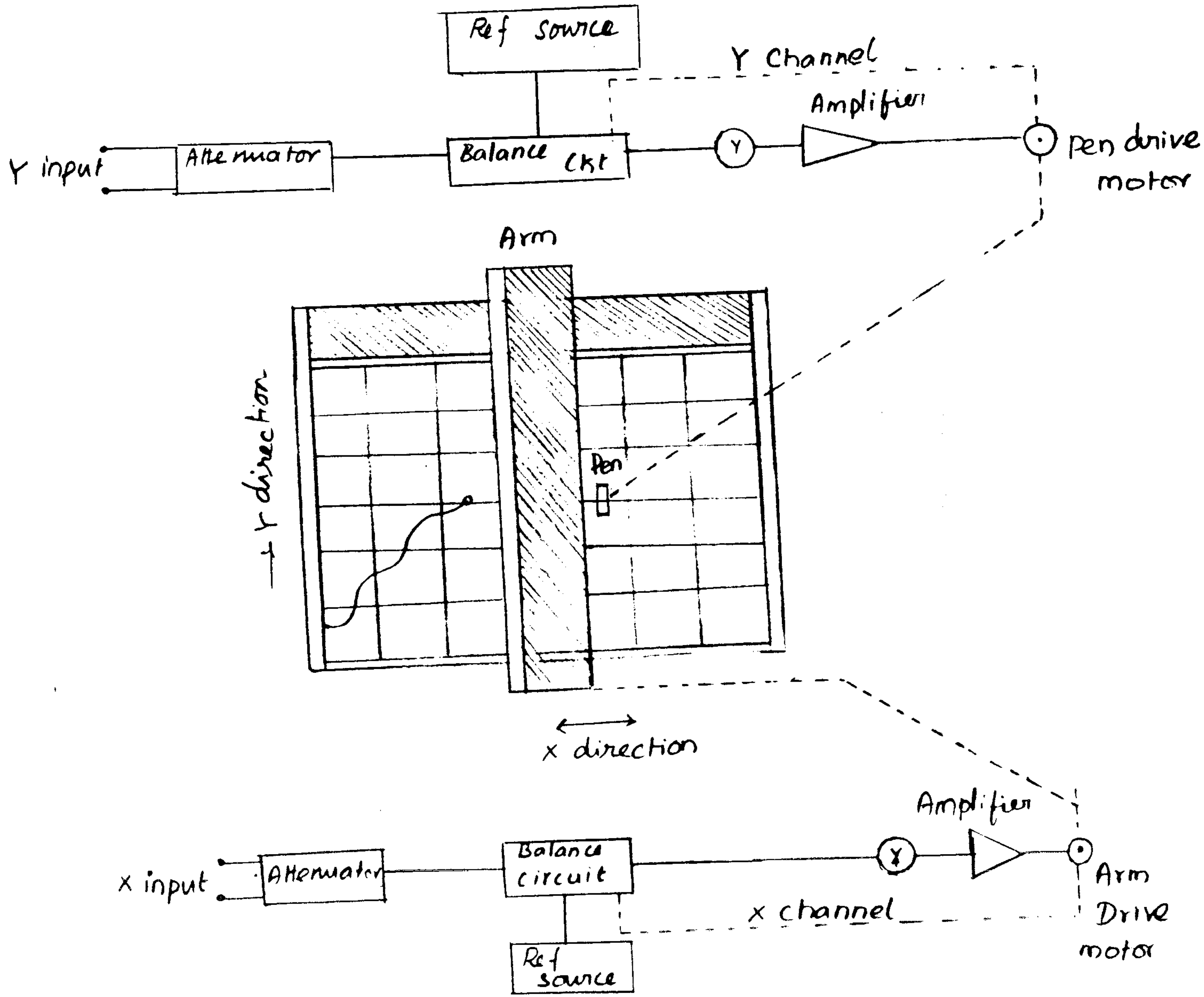



Fig. 5.1 $X_1$-$X_2$-Y PLOTTER

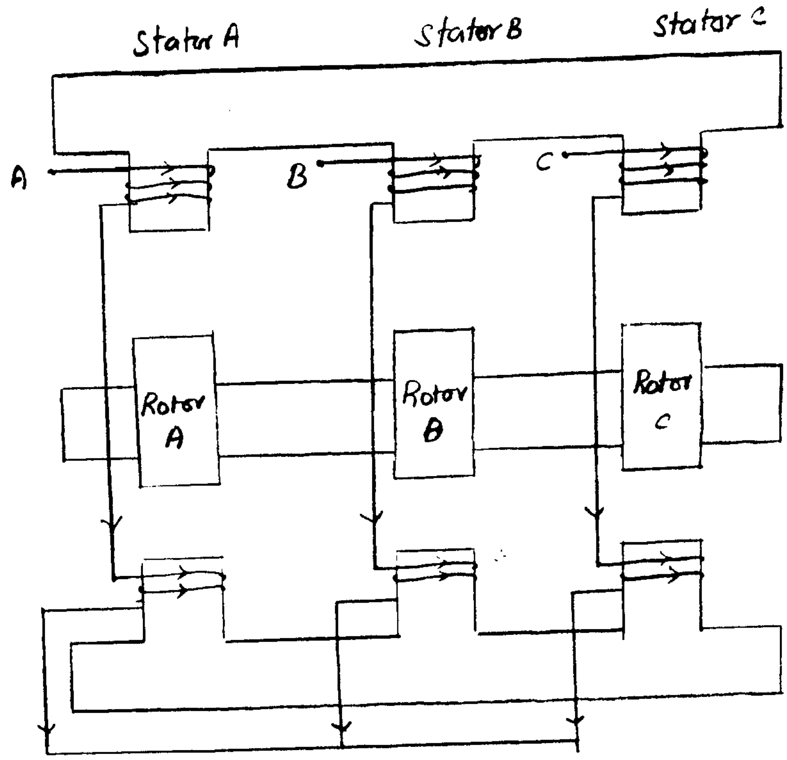



Fig. 5.2

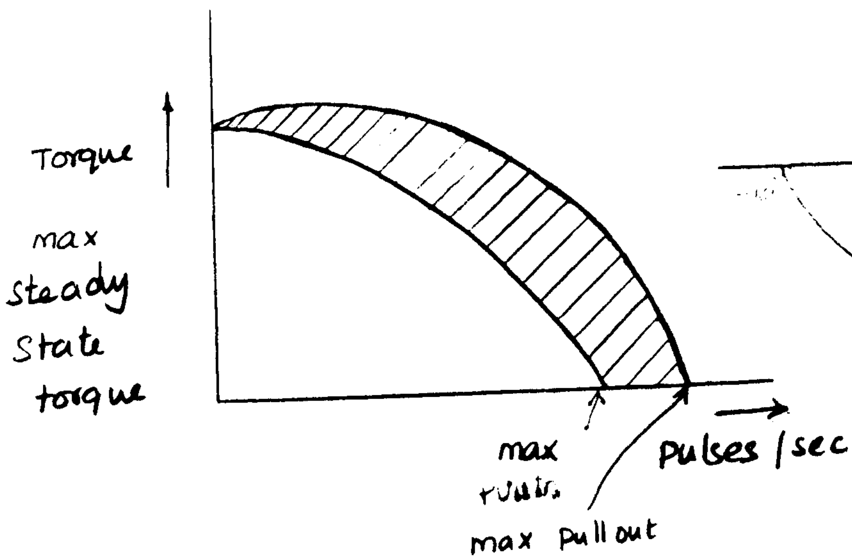



Fig. 5.3 (a)

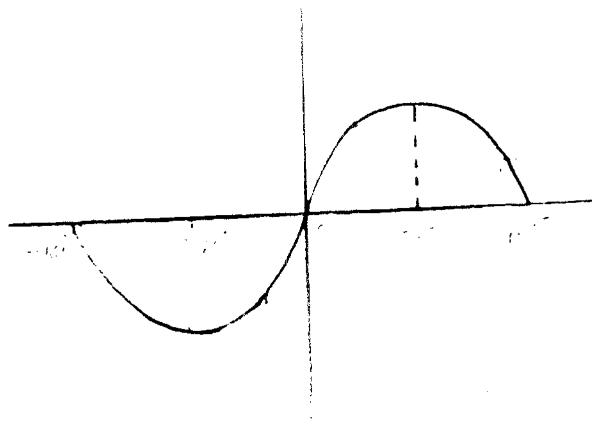


Fig. 5.3 (b)

Fig. 5.2 LONGITUDINAL CROSS SECTIONAL VIEW OF STEPPER MOTTOR

Fig. 5.3 (a) & (b) CHARACTERISTICS OF SEPPER MOTOR

# Chapter 6 Test Report

# CHAPTER 6

## TEST REPORT

The complete circuit diagram was fabricated on a Printed Circuit Board and the components were assembled on it. A 5 volts power supply was given to the three inputs respectively and tested. The outputs were taken from the output X and Y terminals and given to the CRO. We can observe the 3-D Displays of various figures such as cubes, cylinders, etc. on the CRO Screen.

# Chapter-7 Conclusion

# CHAPTER 7

## CONCLUSION

The Electronic Instrument, 3-D Plotter, based on linear operational amplifier has been fabricated as an aid in plotting a function of 2 variables Z = f(x,y) on a CRO Screen.

### Application:

Among various areas of application of the instrument are included plotting of 3-Dimensional Lissajous Patterns, 3-D Curves/surface for 3 terminal semiconductor device , computer aided 3-D graphics such as Crystellographic Structure, Geographical maps, etc. If coupled to large size X-Y display system it can be used as a very effective class room demonstration unit.

# Chapter 8 Component list & Cost Analysis

## CHAPTER 8

## COMPONENT LIST AND COST ANALYSIS

| 1) POWER SUPPLY: | RATING |
|---|---|
| Transformer | 230/15v 1Amps |
| Diode | In 4001 |
| Capacitor | 2200 f /25v |
| | 0.1 f |
| Regulator IC's | 7912 |
| | 7812 |

2) MAIN CIRCUIT :

| | |
|---|---|
| IC's (Operation Amplifier) | LM 324 |
| Pot | 100 K |
| Ganged Pot | 100 K |
| NONC Switch | |
| Resistors | 11 K / 1watt |
| | 1M. /1/4 Watt |
| Connectors | 12 Pin |

3) SEGMENT DISPLAY

| | |
|---|---|
| Display | FND 507 |
| Diode | In 4001 |
| Resistor | 470 /1/4 Watt |

# Chapter 9 References

# CHAPTER 9

## REFERENCES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