Microprocessor - Based Sub - Station Protection and Instrumentation

PROJECT REPORT

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By

M. SUDHA

P. G. SENTHAMARAIKANNAN

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Under the Guidance of

Dr. K. A. PALANISWAMY
B.E., MSc. (Engg), Ph. D., M. I. S. T. E., C. Eng. (I) FIE

Department of Electrical and Electronics Engineering
Kumaraguru College of Technology
Coimbatore - 641 006

Kumaraguru College of Technology

Coimbatore - 641 006

Department of Electrical and Electronics Engineering

CERTIFICATE

Date

Name SUDHA.M, SENTHAMARAI KANNAN.P.G. Roll No. 89EEE35, 89EEE25

Regsiter No. 8927C0031, 8927C0026

This is the bonafide Record of the

Project Work titled

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done by

Mr. M.SUDHA, P.G. SENTHAMARAI KANNAN

in partial fulfilment of the requirements for the award of

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Dr. K. A. PALANISWAMY, B.E.,M.Sc. (Engg).Ph.D.
MISTE.C,Engg (I).,FIE.,
Professor and Head
Department of Electrical and Electronics Engineering,
Kumaraguru College of Technology.
Coimbatore 641 006

Guide

Dr. K. A. PALANISWAMY, B.E.,M.Sc. (Engg).Ph.D.
MISTE.C,Engg (I).,FIE.,
Professor and Head
Department of Electrical and Electronics Engineering,
Kumaraguru College of Technology.
Coimbatore 641 006

Head of the Department

Submitted for the university Examination held on ....

Internal Examiner

External Examiner

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CONTENTS

SYNOPSIS

This project deals with the design and fabrication of circuit for microprocessor based sub-station protection and instrumentation. This scheme display line current, voltage, frequency and phase angle round the clock and simultaneously provides directional over current protection, differential protection, directional impedance protection to a typical sub-station. The data received from the sub-station are processed by a microprocessor. It gives out a try signal if there is short circuit in the system otherwise it computes phase angle and frequency and displays the system quantities.

The advantages of this scheme are self-diagnosis, realization and reduction of burden due to instrumentation.

CHAPTER - I

INTRODUCTION

The extensive use of electric power and the huge capital investment made on a "POWER SYSTEM" for generation, transmission and distribution of power have made the reliability of operation of the different parts of the system a problem of disturbance to normal operation and occurrence of faults in the system cannot be ruled out. It is the aim of the protective relays to protect the system from the danger due to faults and other disturbances.

The commonest form of disturbance in normal operation of power system equipment is excessive loading, on account of which the current may exceed the permissible safe value.

The severest faults in a power system are due to "Short circuits". The magnitude of current depends on the kind of fault, location of its occurrence and other factors involved. Occurrence of a fault shall disturb the normal operation of the power system. A part from damaging the equipment involved, it may adversely affect the voltage and frequency and consequently de-stabilize the system.

In view of the complexity involved in large scale power system due to inter connection and interdependence of the various system components, there is a strong case for the use of reliable protective devices and arrangements that will automatically isolate the faults section from the other parts of the system as promptly as necessary and possible.

The following are the advantages of the protective relaying :

1. The relays are used to cut off the supply promptly to any element of power system which undergoes short circuit or its starts operating abnormally. However, it may be understood that the relays only give a signal to the circuit breakers for tripping or isolating the faults system. The circuit breakers used must be sufficient capacity to carry the fault current momentarily and then interrupt it.

2. The protective equipment (recoup) provide a very good indication of the type of fault which has occurred.

3. The location of faults or the area in which the fault has occurred is also provided.

Thus, it will be obsérved that the protective relays help in localization of the fault and thus help in expediting repair work.

1.1 RELAYING SYSTEM :

The complete relaying of the power system can be divided in to following three groups:

1. Primary relaying which may also be called as first line of defense against short circuit or insulation failure etc.

2. Secondary relaying or back-up relaying. These relays

function only if the primary relays fail to operate, the failure of which may be due to any of the following reasons:

(a) The D.C supply to the tripping circuit fails.

(b) The current or voltage supply to the relay fails.

(c) The tripping mechanism of circuit breaker fails.

(d) The circuit breaker fails to operate.

(e) The primary protective relay fails.

3. Relays for other abnormal conditions :

This includes relays for other than short circuit conditions which very form situation to situation.

1.1.2 CLASSIFICATION OF RELAYS :

The relays consist of one or more elements which are actuated by the electric quantities of the circuits in which they are connected. The relays can also be classified according operating characteristics as detailed below.

1. **Directional over current type :**

The relay is actuated only when the direction of the current is reversed or the phase angle of the current takes up a phase displacement more than the desired value.

2. **Reverse power type :**

This type of relay is actuated when applied voltage and current attains a certain specified phase displacement. No under-voltage compensation is provided.

3. **Under-voltage:**

The relay is actuated when the rated voltage, falls below the specified values.

4. **Over current relay :**

The principle of operation of this type of relay is similar to that of under voltage, replay, but is actuated only when the voltage, current or power rises above a certain specified value.

5. **Differential relay :**

The operation of the relay is dependent on the difference in magnitude or phase of current or voltage.

6. **Distance relay :**

The principle of operation of this type of relay is dependent or voltage to current ratio or in dependent on the current carried by the relay element.

1.2 INSTRUMENTATION

The measurement of current, voltage, power, energy, flux, frequency by measuring devices is called instrumentation. They are generally named on the basis of type of quantity measured eg. ammeter, voltmeter, wattmeter, frequency meter, etc.

1.2.1. CLASSIFICATION OF ELECTRIC INSTRUMENTS :

The electric instrument may be classified in to following two groups :

(i) **Absolute instruments** are those which give the value of the quantity to measure in terms of the constant of the instrument and their deflection only. No previous calibration or comparison is necessary in their cease eg : Tangent galvano meter.

(ii) **Secondary instruments** give the direct reading of the quantity to be measured. They are first calibrated with standard instruments before putting them in use. Secondary instruments one generally used for general purpose.

Types of secondary instruments.

a) **Indicating instruments** are those which indicate the value of the quantity measured at that time on the scale. Ammeter, Volt meter, Wattmeter etc, are indicating instruments.

b) **Integrating instruments** are those which measure the total amount of either quantity of electricity (Ampere hours) or energy suppliers over a period of time. The summation given by such an instrument in the product of time and an electrical quantity under measurement. Domestic energy meter is an example of this type of instrument.

c) Recording Instruments are those which a continuous record of the variations of electrical quantity over a selected period of time. The moving system of the instrument carries an inked pen which rests lightly on a chart or graph that in moved at a perpendicular to that of the deflection of the pen. The path traced out by the pen presents a continuous record of the variations in the deflection of the instruments.

CHAPTER - II

DIGITAL PROTECTION AND INSTRUMENTATION SCHEME FOR SUBSTATION

Power and distribution transformers are generally equipped with instrumentation and protective relays in a sub-station. The engineer on duty has to observe and record qualities like current, voltage, power, power factor, frequency etc., at scheduled intervals and also trip signals whenever they occur. The performance can be assessed based on these records. This project provides protection as well as instrumentation by means of a Microprocessor based scheme which will displays voltage, current, power factor frequency at different locations.

Fig. 2.1 presents various blocks of the instrumentation scheme. CTs and PTs are connected at different part of the network and the analog outputs are taken and fed to the scheme as shown in fig 2.2. This scheme generates a trip signal and feeds to the circuit breakers during short circuit and overload conditions. Simultaneously like current, voltage, frequency and phase angle are displayed on a 7 segment 6 digit display unit. The scheme is implemented on a typical simulated sub-station conditions using a 8-bit microprocessor.

2.1 DIGITAL PROTECTION SCHEME:

The scheme provides directional distance protection, over current and differential protection. Based on the requirements of protection and measurement, the input and output of the CTs and PTs are grouped into 3 channel groups and connected multiplexer. The first group comprises of two channels namely channel 0 and channel 1 to which the V and I signals are the inputs from the feeder CTs and PTs. The second group comprises of channel 2 which corresponds to signals from CT on the secondary of the transformer. The third group comprises of channels taken from CT and PTs from the CTs and PTs from the primary of the transformer.

2.2 OVER CURRENT RELAY:

To measure a line current, a CT is connected on the line and the output is converted to a voltage signal, then rectified before being fed to the A/D convertor. This results in a microprocessor voltage to be proportional to the load current. If the load current exceeds the pickup value already stored, the microprocessor sends a trip signal to the circuit Breakers. Both instantaneous despite tripping and inverse time characteristics can be programmed.

2.3 IMPEDANCE RELAY

To realize on Impedance relay characteristic, the voltage and current are compared at the relay location. The ratio of V_{rms} to I_{rms} gives the impedance of the faulted line section. If this independence is less than the assigned allow the relay operates. The assigned impedances are stored in data locations with corresponding tripping timings. In order to obtain directional property, the microprocessor first checks the direction of current and generates trip signals only if the direction is appropriate.

1.4 DIFFERENTIAL RELAY:

Differential relay operates when a vector difference of 2 similar electrical quantities exceed a pre-determined value. Generally, in differential protection, the primary and secondary amounts of the transformers are used.

In the present realization, the instantatenous values of the primary and secondary currents are sampled and stored. The $(i_2 - i_2)$ and $(i_1 + i_2)/2$ are computed with the characteristics of the relay.

2.5 INSTRUMENTATION:

The instrumentation scheme displays voltage, current, power factor and frequency. The post record of these measurements are stored.

2.5.1 VOLTAGE AND CURRENT DISPLAY:

The voltage or current input which is to be displayed is chosen using appropriate channel through multiplexer logic. These outputs are fed to A/D converter through S/H and the sampled data in N intervals are stored and using

$$V_{RMS} = \left[\frac{\Sigma_1 x^2}{N}\right]^{1/2} \quad \ldots \quad (2.1)$$

Where X is the magnitude of the sampled quantity, V_{rms} is computed on multiplication with the CT and PT ratios the actual voltage or line currents is obtained and displayed.

2.5.2. FREQUENCY DISPLAY:

To compute the frequency of the supply the time period of one cycle is measured. For this purpose, the sinusoidal signal is converted into a square wave using voltage comparator. The software senses the transition of the rectified square wave from high to low or low to high. A decision is taken on the basis of carry and zero states whenever the transition has occurred. As soon as a transition is detected the microprocessor sets register pair as a counter and the counting stack acts and stops at the next transition. Frequency is obtained from the corresponding to the register count with the help of the look up table and displayed.

2.5.3 PHASE ANGLE DISPLAY:

The phase angle between two individual signals can be easily measured with the help of a microprocessor. The two signals of current and voltage are converted into square waves and negative transition of two signals which is the measure of the phase angle between voltage and current.

Block Diagram Of The Scheme

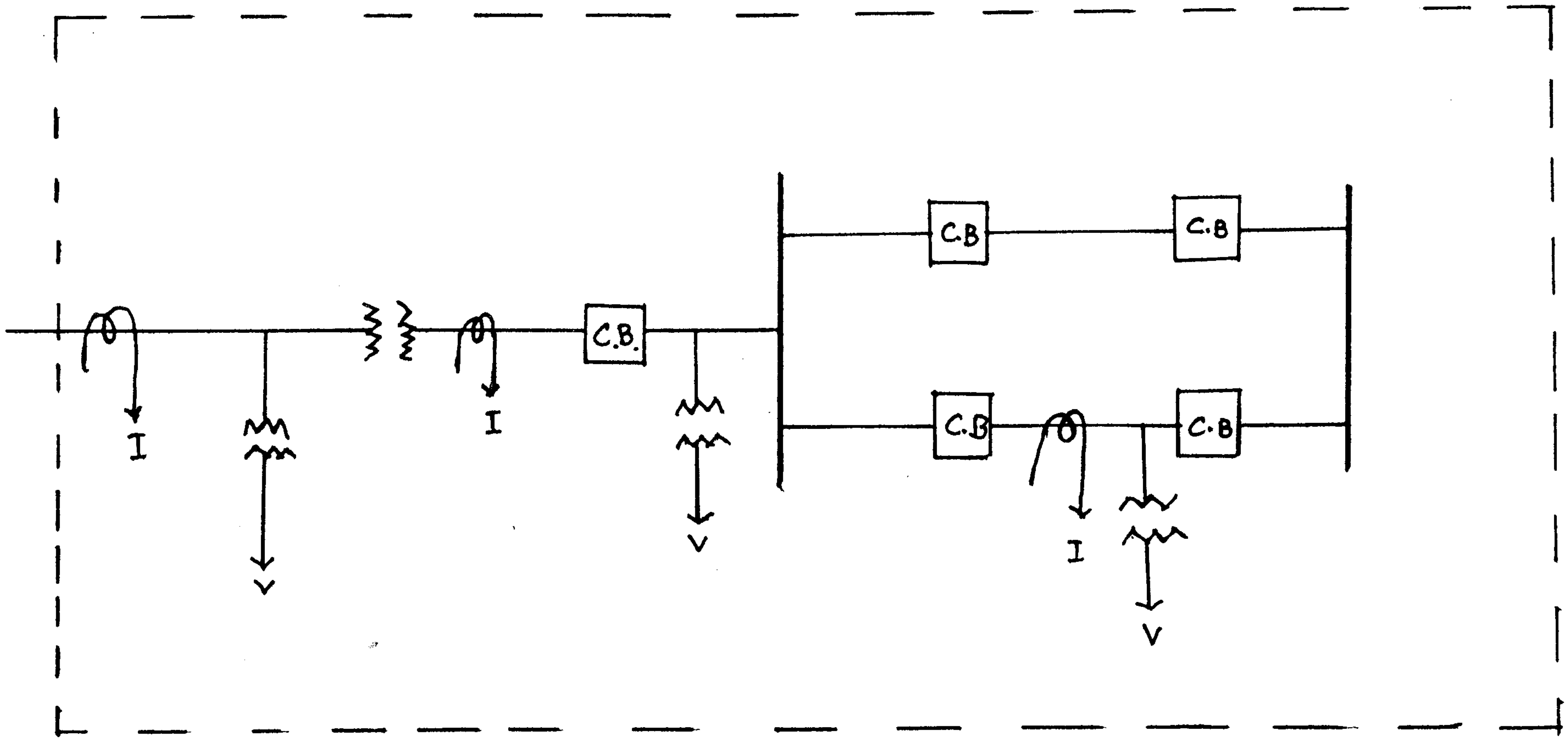


Fig (2.1)

PROTECTION SCHEME OF A TYPICAL POWER SYSTEM

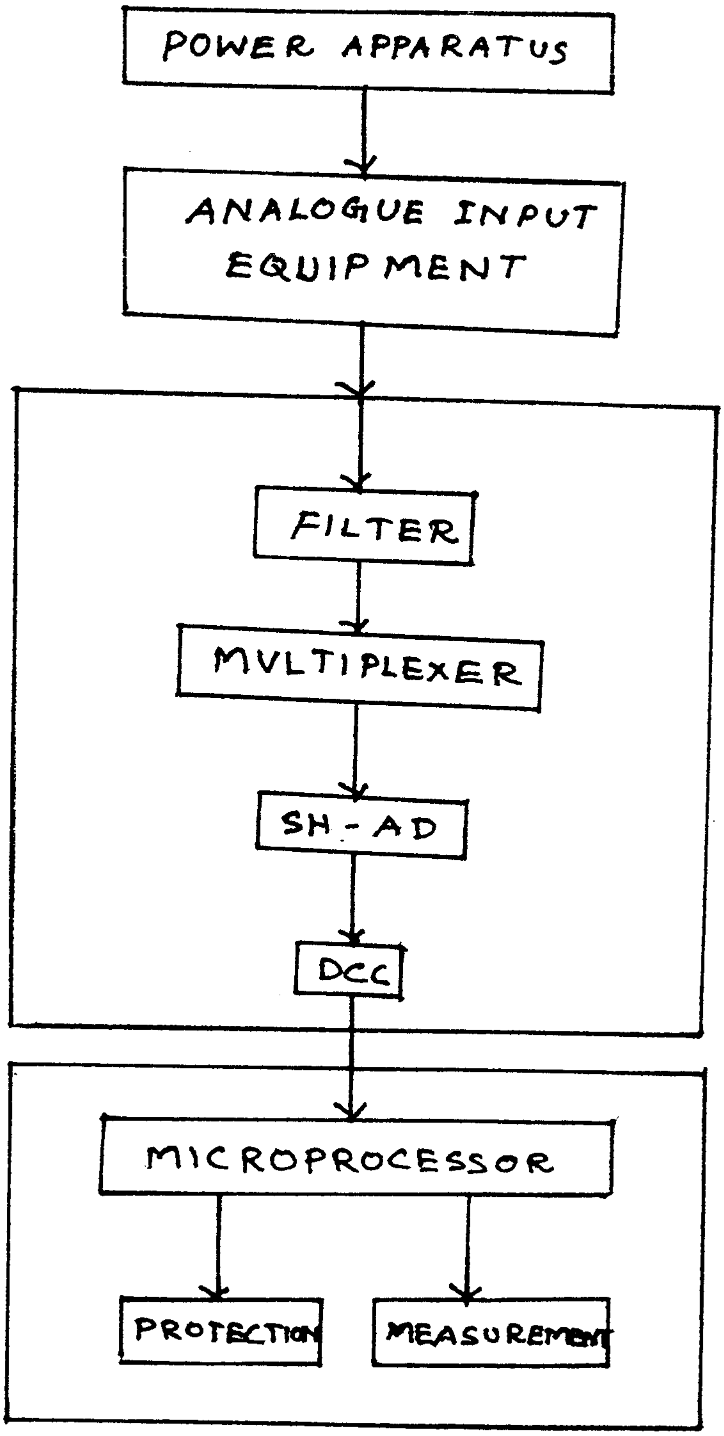


Fig (2.2)

CHAPTER - III

DESIGN OF HARDWARE

The block diagram of the digital instrumentation and protection scheme is given in fig 3.1 and the complete circuit in fig 3.2. In actual case, the first stage consists of current to voltage converters employed for the channels corresponding to current inputs. In this project the voltage signals are directly given to the multiplexers. The channel select signal is then fed to the rectifier to restrict the negative voltage level and then fed to the S/H circuit. Duration of the pulse is calculated keeping in view the ADC conversion time as the scheme is basically meant to measure at power frequency only. The Microprocessor communicates with the ADC with the help of status signals and obtains the digital inputs and performs various functions. At the same time the output of the multiplexer is fed to the conditioning circuit also, takes input directly from a particular channel prior to the multiplexer. The output of the conditioning circuit is also fed to the Microprocessor which executes the appropriate measurement routine and displays voltage, current, frequency and phase. The digital display is done on a 7 segment 6 digit unit.

3.1 CURRENT TO VOLTAGE CONVERTER:

The current to voltage converter, provides a voltage proportional to current. The current to voltage converter is shown in figure 3.3 Assuming ideal conditions,

$Vo/Vs = - Rf/Rs$

Where $Vs = Rs\ Is$ is source voltage and Rs a source resistance. In fig 3.3 it is shown in the form of current source.

Therefore $Vo/RsIs = - Rf/Rs$

or

$Vo = -RfIs$

Thus if the Vs and Rs combination is an inverting OP- is replaced a current source, the output voltage becomes proportional to the output voltage obviously, for ideal conditions Rs = Ds and in practice Rs should be very large as against the voltage source resistance.

The circuit is used in sensing current from photodetectors and in digital to analog converter applications.

Due to virtual ground V2 = 0 the current through Rs is Zero and Is flows throu the feedback resister Rf. Thus $Vo = - IsRf$.

The lower limit on current measurement with this circuit is set by bias current of the inverting input when it is used in circuit measurement applications. It is common to parallel Rf with a capacitance to reduce high-frequency noise and the possibility of Oscillators. The current to voltage converter makes an excellent current measuring instrument makes an excellent current measuring instrument since it is an ammeter with Zero voltage access the meter.

Current to voltage converter is also known as transistance amplifier.

3.2 RECTIFIER :

The fig 3.4 shows the full wave rectifier using op-amp. equal value resistors are used in the circuit. A positive going input signal reverse biases diode D2 and forward biases diode d1. Thus effectively the two amplifiers are connected in cascade each having unity gain. Thus output is in phase with input as well as its magnitude being equal to Vi. When the input signal goes negative, diode D2 is forward biases while D1 is reverse biased. Thus, there are two feedback paths to the inverting input terminal of OP_AMP A1.

Assuming ideal circuit,

$I1 = I2 = I3$

or

$Vi/R = -Vo/3R - V2/R \qquad (3)$

But $V2 = V3 = Vo \times 2R/3R = (2/3)\ Vo$

hence substituting we get, $Vo = -Vi$

But Vi is negative for negative going input hence Vo is again in phase with Vi with same magnitude.

3.3 SAMPLE AND HOLD CIRCUIT

The fig 3.5 shows the functional circuit of type LF398 and hold circuit.

The sample and hold circuit samples an i/p signal and holds on to its last sampled value until the input is sampled again. The circuit is commonly used in digital interfacing and communicates such as analog to digital (A/D) conversion and pulse modulation systems.

3.4 ZERO CROSSING DETECTORS :

Zero Crossing Detectors are used as sine to Square wave converters. The use of positive feedback in zero crossing detector improves its switching time. Fig 3.6 shows a zero crossing detector for producing symmetrical square wave with sine wave input voltage divider R4 and R5 established a reference voltage, VR at the positive input. By making the seris resistance, R1+R2 = R5, the switching condition, VR = V1, will be satisfied when Vs= 0. The positive feedback resistor, Rs is made very large with respect to R5. The resultant hysteresis established by this network is very small but it is sufficient to ensure rapid output voltage transitions. Diode, D1 is used to ensure that the inverting input terminal of the comparator never goes below approximately -100 mV. As the input terminal goes negative. D will forward bias clamping the node (between R1 and R2) to approximately -0.7v. This sets up a voltage divider with R2 and R3 preventing V1 from going below ground. The maximum negative input obver drive is limited by the current handling ability of Diode D.

Block Diagram Of Hardware

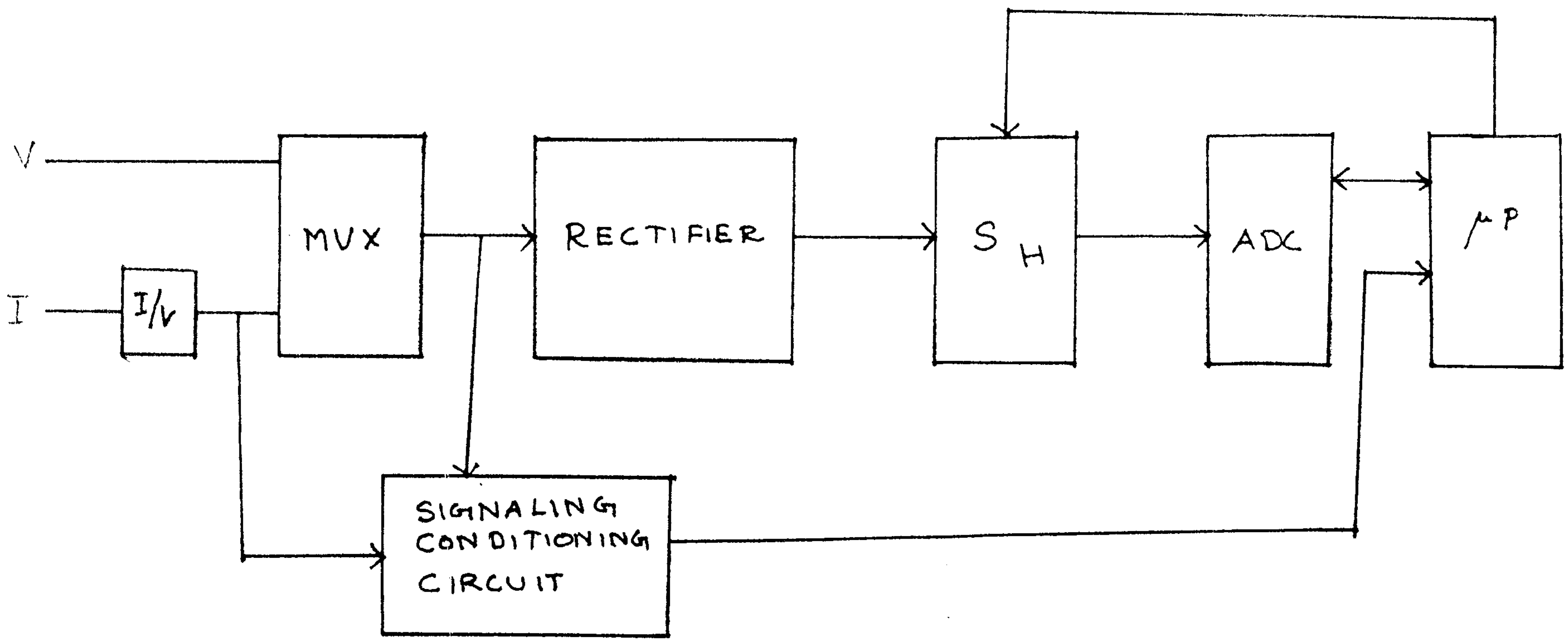


Fig (3.1)

Current To Voltage Converter

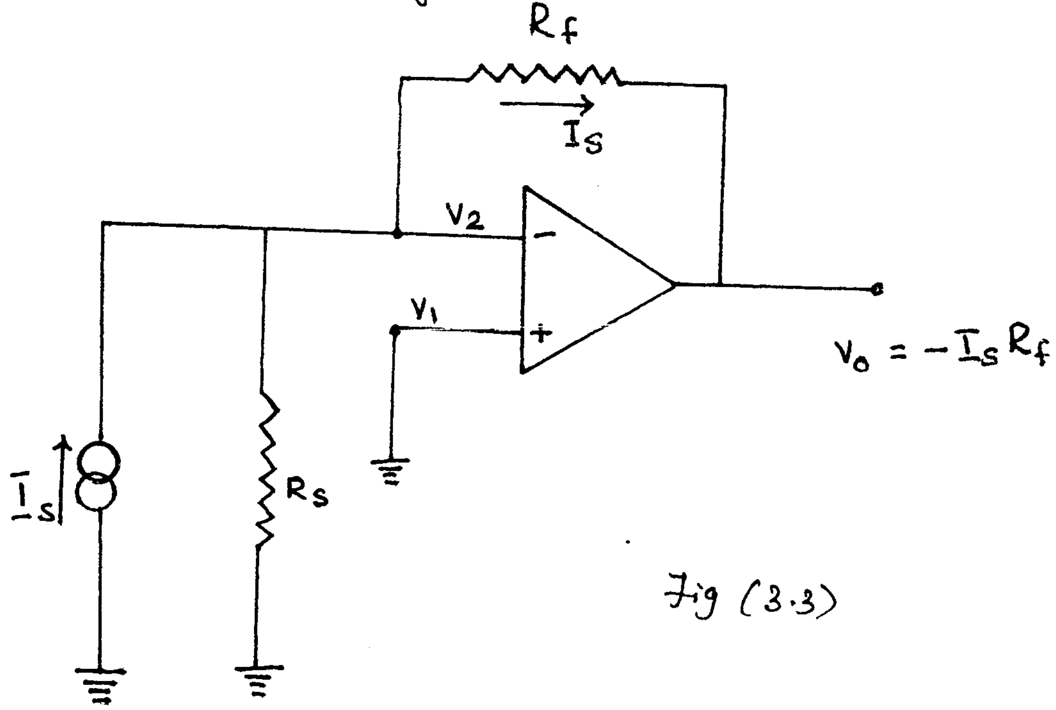


Fig (3.3)

Full-wave Rectifier Circuit Using Op-Amp

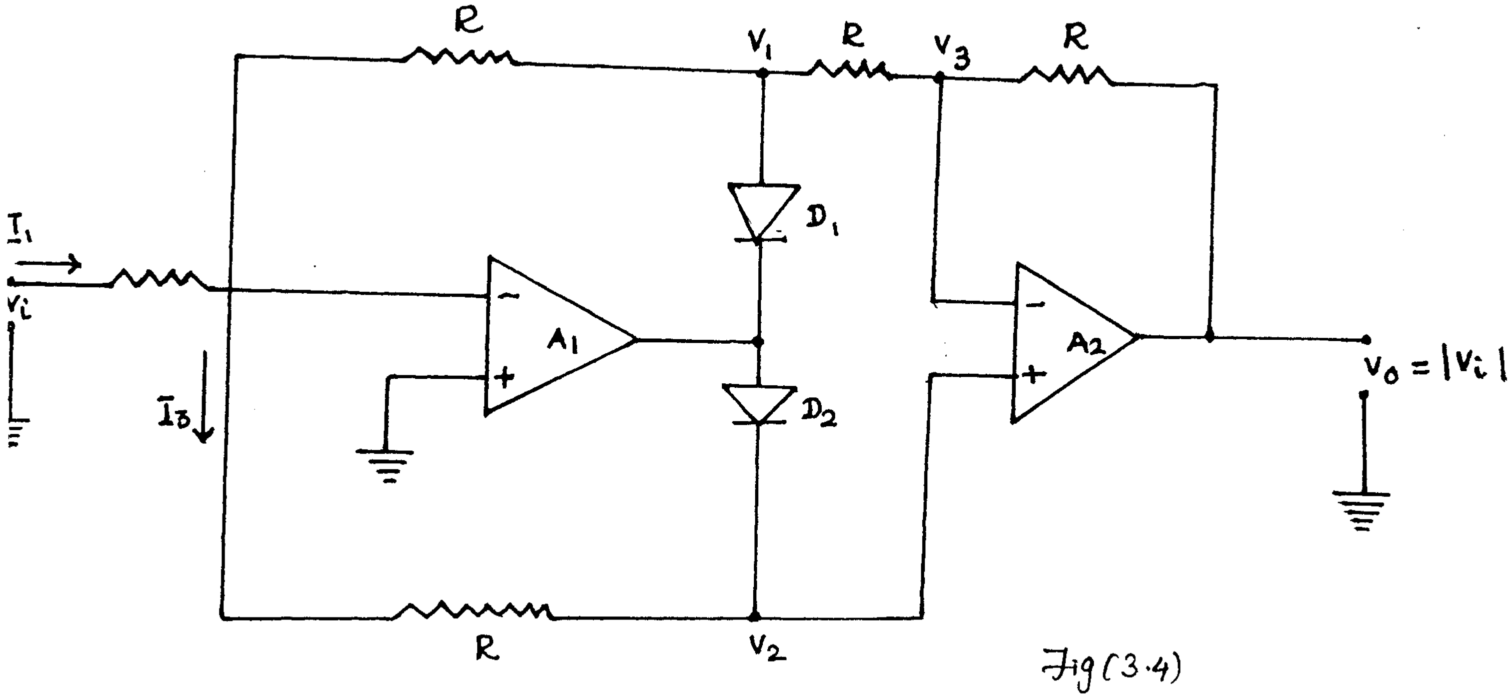


Fig (3.4)

Functional Circuit Of Sample And Hold

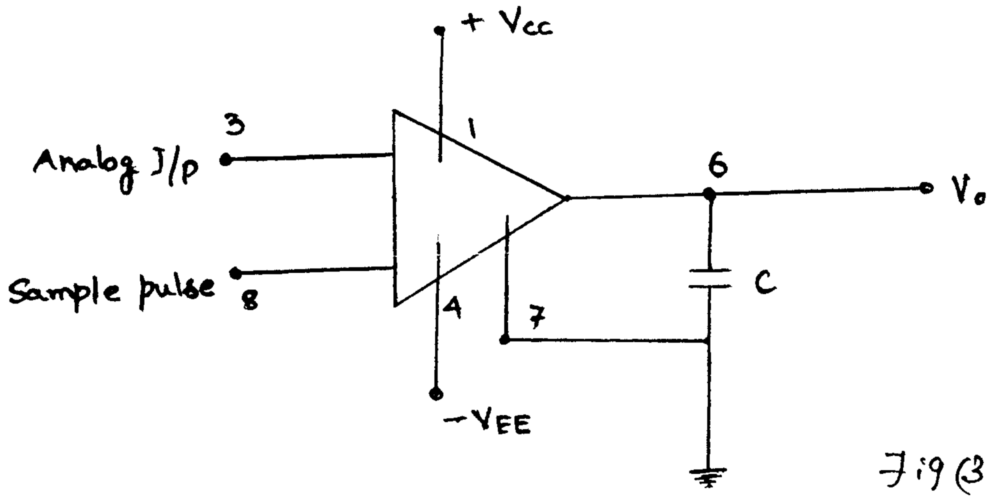


Fig (3.5)

Zero- Crossing Detector

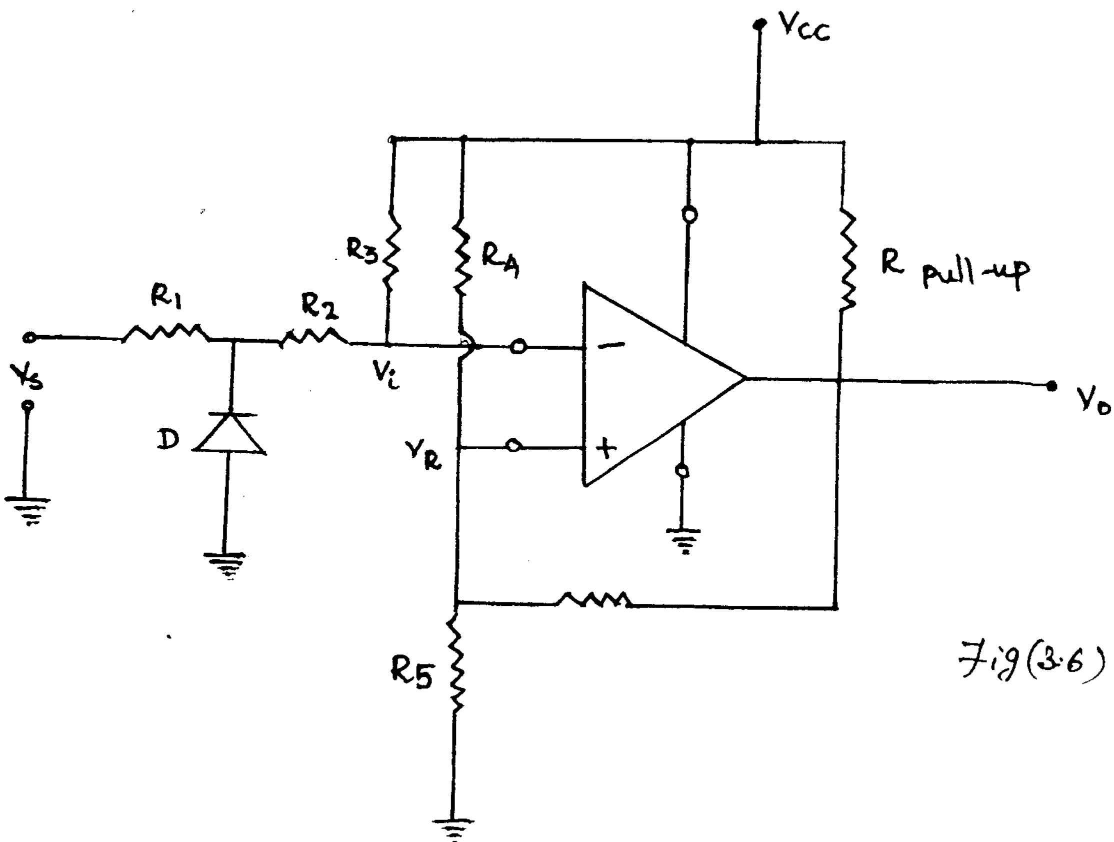


Fig (3.6)

CHAPTER - IV

MICROPROCESSOR BASED SYSTEM DESIGN

The microprocessor is a " Programmable logic device " and with reference to the field of computer. The term "Micro-processor" refers to the central processing unit of a small computer system. The Microprocessor is an electronic integrated circuit of LSI level. Although a microprocessor chip cannot function by itself, the addition of a few memories and I/O devices make a typical computer system.

4.1 MERITS OF A MICROPROCESSOR BASED SYSTEM DESIGN

4.1.1 Cost savings in Hardware : A single chip on LSI basis replaces several discrete logic gates resulting in reduction of cost as well as the size of the system.

4.1.2 Reliability : As the number decreases the probability of malfunctioning decreases. This enhances the system performance.

4.1.3 Flexibility : To modify a system one has too merely reprogram the memory elements without redesigning.

4.1.4 Expandability : Additional interfaces can be added to the system bus and software can be suitably modified too system growth.

4.2 MICROPROCESSOR ARCHITECTURE :

The 8085 is an 8 bit microprocessor available as a 40 pin DIP (Dual Inline Package). The data bus is 8 -bits wide which implies that 8 bits (1 byte) of data can be transferred to or from the 8085 parallel. There are 8 pins which are dedicated to transmit the most significant 8 bits of the memory address. The least significant 8 bits of the address are transmitted on the 8 lines on which data is transmitted. Thus, the data and part of the address are transmitted over a set of shared lines. This is known as multiplexing. Thus, effectively, the 8085 has a 16 bit address transmission capability. This implies that a total of 2^{16} (65536) memory locations can be addressed directly by 8085. Each location is a byte as 8 bits of data is transferred in parallel between the 8085 and the memory. Therefore, the 8085 can directly address 64K (1K = 1024) byte of memory.

4.2.1 REGISTERS IN THE 8085.

Inside the 8085 there are several registers which are used during the execution of a program. There is one 8 bit register known as Accumulator. It is used in various arithmetic and logical operations. There are six general purpose 8 bit registers that can be used by a programmer for a variety of B,C,D,E,H and L. They can be used individually (for 8 bit data) or in pairs (for 16 bit address). There is a 16 bit register which is used by the 8085 to keep track of the address of the instruction (in the memory) that has be to executed next. this register is called the Program Counter. The contents of the program counter are automatically updated by the 8085 during the execution of an instruction. So that at the end of execution of this instruction in the memory. There is a another 16 bit register, known as the stack Pointer. It is used by the programmer to maintain a stack in the memory. A set of 5 flip-flops, one bit registers serves as flags. These registers indicate certain condition. (eg. Carry) that arise during arithmetic and logical operations. There are address and data bus through which communication between different units is done. Interrupt Control may be utilised for interrupt subroutines.

Microprocessor based systems needs a sequence of instructions i.e., the program which is fed to the microprocessor - based system for an effective operation. A sequence of instructions designed to perform a particular task is known as Program. A set of programs written for a Microprocessor based system is known as the Software of that system. Before the microprocessor can be made to perform a task, it has to be programmed and stored in a semiconductor memory that is accessible to the Microprocessor system. Any Microprocessor based system design involves interfacing of the processor with one or more peripheral devices for the purpose of communication with external system.

4.3 THE 8255A PROGRAMMABLE PERIPHERAL INTERFACE

The 8255 is a widely used, programmable parallel I/O device. It can be programmed to transfer data under various conditions from simple I/O to interrupt I/O. It is flexible, versatile, and economical.

The 8255 has 24 I/O pins that can be grouped primarily in two 8 bit parallel ports. A and B with the remaining 8 bits as port C. The 8 bits of Port C can be used as individual bits or be grouped in two 4-bit parts C-upper (C_V) and C-lower ($_L$).

4.3.1 OPERATING MODES OF 8255.

There are 3 major modes of operation of 8255 namely mode 0, mode 1 and mode 2 which comes under the major category of I/O mode.

Mode 0 : Basic functional definitions.

Two 8 bit parts and two 4 bit parts.

Any part can be I/P or O/P.

Outputs are latched.

Inputs are not latched.

16 different input/output configuration possible. Ports do not have handshake or interrupt capability.

Mode 1: Basic functional definitions.

Two groups (group A and group B)

Each group contains one 8 bit data port and one 4 bit control for data part. The 8 bit part can be either input or output. Both inputs and outputs are latched.

The 4 bit port is used for control and status of the 8 bit data port.

Mode 2: Basic Functional Definitions

Used in group A only,

One eight bit bidirectional but port (port A) and a 5 bit control port (port C)

Both inputs and outputs are latched.

The 5 bit control port is used for control and status of the 8 bit bidirectional port.

4.3.2 CONTROL LOGIC:

The control section has 6 lines. Their functions and connections are as follows. RD (Read): This control signal enable the Read operation. When the signal is low, the Micro-processor reads data from a selected I/O port of the 8255. WR(Write). This control signal enables the write operation. When the signal goes low, the Microprocessor writes into a selected I/O port on the control register.

RESET : This is an active high signal. It clears the control register and sets all ports in the input mode.

CS,A0,A1: These are device select signals. CS is connected to decoded address and A0 A1 are generally connected to Micro-processor address lines A0 and A1 respectively.

The IS signal is the master chip select and A0 and A1 specify one of the I/O ports or the control register as given below.

Cs	A1	A0	**Selected**
0	0	0	PORT A
0	0	1	PORT B
0	1	0	PORT C
0	1	1	CONTROL REGISTER
1	X	X	8255 IS NOT SELECTED.

The port address are determined by the Cs, A0 and A1 lines. The Cs line goes low when A7=1 and A6 through A2 are at logic 0. When these signals are combined with A0 and A1 the port address range from 804 to 834.

To communicate with peripherals through 8255, 3 steps are necessary.

1. Determine the address of Port A, Band C and of the control register according to the chip select logic and address lines A0 and A1.

2. Write a control word in the Control register.

3. Write I/O instructions to communicate with peripherals through ports A,B and C.

The mode control word format and signal configuration of 8255A are given in appendix.

4.4 MULTIPLEXERS:

The multiplexer is a logic circuit that is used to select and route any one of no. of input signals to a single output. A part from input and output lines. There are some control Inputs. By applying the appropriate control inputs one can select any of the inputs to be output on the single output lines. Since the control inputs make the logic circuit to

'Select' one of the many inputs and output it, the multiplexers help to reduce considerably the repetition of similar circuitry in digital systems and thus the overall cost is reduced.

CD 4051B is a single 8 channel multiplexers. These are digitally controlled analog switches having low independence and very low 077 leakage current. CD4051B is a single B channel multiplexer having 3 binary control input A,B and C and an inhibit input. The three binary signals select 1 of 8 channels to be given and connect one of the 8 inputs as output.

4.4.2 FEATURES:

1. Wide range of digital and analog signal levels: digital 3 to 30 V, analog to 20 Vpp.

2. Low on resistance : 125 or (typ) over 15 Vp-p signal input range for Vdd - Vee = 15 V

3. High OFF resistance : Channel leakage of I 100 PA (type) Vdd-Vee = 18 V.

4. Logic -level conversion for digital addressing signals of 3 to 20V (VDD - VSS = 3 TO 20 V) to switch signals to 20 Vp-p (VDD - VEE = 20 V).

5. Matched switch characteristics : (typ) for VDD - VEE = 150

6. Very low quiescent power dissipation under all digital control I/P and supply conditions, 0.2 low (typ) VDD -VSS = VDD - VEE = 10 v

7. Binary address decoding on chip

8. 5, 10 and 15v parametric ratings

9. 100 % tested for quiescent current at 20v

10. Maximum input current of 1 at 18v over full package temperature range; 100 nA at 18v and

11. Break before make switching eliminates channel overlap.

4.4.2 ABSOLUTE MAXIMUM RATINGS :

D. C supply voltage range (VDD)	-0.5 to +20v
Input voltage range, All inputs	-0.5 to VDD + 0.5v
D. C Input current, anyone I/P	± 10 mA
Operating temp range	-55 to 125 °C
Storage temp range	-65 to 150 °C

4.5 OPERATIONAL AMPLIFIER (OP - AMP)

4.5.1 Description : The operational amplifier is a high gain, wide band, DC amplifier available in the form of an integrated circuit. The use of op-Amps first started in analog computers to perform mathematical operations such as addition, subtraction, scaling, Integration, etc.

It has two inputs and one output. The inputs are known as inverting input and non-inverting input. The output voltage depends on the difference in potential between two inputs. It also depends on external circuitry connected to it. The pin configuration of a general purpose op-Amp IC (741) is given in Appendix.

4.5.2 LM741:

The LM741 is a general purpose op-Amp which feature improved performance over industries standard. The amplifiers offer many features which make this applications nearly foolproff. Overload protection on the input and output, no latch-up when the common mode range is exceed, as well as freedom from oscillations.

4.5.3 FEATURES :

1. Internal frequency compensation.
2. Short-circuit protection.
3. Off set voltage null capability.
4. Excellent temperature stability.
5. High input voltage range.
6. No latch-up.

4.5.4 ABSOLUTE MAXIMUM RATINGS:

Supply voltage	± 22v
Power dissipation	500 mW
Differential input voltage	± 30v
Input voltage	±15v
Output short circuit duration	Indefinite
Operating temperature range	-55 to + 125 °C
Storage temperature range	-65 to + 150 °C

4.6 DUAL OPERATIONAL AMPLIFIER :

4.6.1 GENERAL DISCRIPTION :

The LM747 is a general purpose dual operational amplifier. The two amplifier share a common bias network and power supply leads. Other wise, their operation is completely independent.

4.6.2 FEATURES :

1. No frequency compensation required.
2. Short-circuit protection.
3. Wide common-mode and differential voltage ranges.
4. Low power consumption.
5. No latch-up.
6. Balanced offset null.

Additional features of LM747 are :

No latch-up when input common mode is exceeded, freedom from oscillations and age flexibility.

4.6.3 ABSOLUTE MAXIMUM RATINGS :

Supply voltage	±22v
Power dissipation	800 mW
Differential input voltage	±30v
Input voltage	±15v
O/P short circuit duration	Indefinite
Operating temperature range	-55 to 125 °C
Storage temperature range	-65 to 150 °C

4.7 ANALOG TO DIGITAL CONVERTER :

An A/D converter is used to convert analog signals in to digital force. The digital output are fed to the microprocessor for processing. The most popular method of analog to digital conversion is by successive approximation method. It has an excellent compromise between speed and accuracy. An unknown voltage Vin is compared with a function oaf reference voltage Vr. For n bits digital output comparison is made n times with different function of Vr and the value of particular bit is set to 1, if Vin is greater than the fraction of V1. The bit is set to 0, if V in is less than the set fraction Vr. This fraction is given by

$$\left[\sum_{i=1}^{n} b_i\, 2^{-i}\right] V_r$$

Where 'bi' is either 0 or 1 .

In the first step the unknown voltage is compared with 1/2 Vr. If V in > 1/2 Vr the MSB is set to 0. In the next step, Vin is compared with (1/2b1 + 1/4)Vr. b1 is the value of MSB which has already been determined. Suppose b1 = 1 , the fraction of reference voltage for second comparison becomes (1/2 + 1/4)Vr. If Vin > (1/2 + 1/4)Vr the second bit is set to 0. If the MSB is zero the second comparison with (1/2 * 0 + 1/4)Vr. If V in > 1/4 Vr, 2nd bit is set to 1.

If Vin < 1/4 Vr, the 2nd bit set to 0.

To obtain the 3rd nit of digital output Vin is compared with (1/2 b1 + 1/4 b2 + 1/8) Vr and so on.

CHAPTER V

SOFTWARE DEVELOPMENT

Microprocessor based sub-station protection of instrumentation contains phase angle measurement, frequency measurement , Impedance Reallying , Over current protection & Differential protection using V1, I1, V2, I2, V3 & I3 .

This software contains one main program and several sub-programs they are :

(i) Phase angle measurement .

(ii) Frequency measurement .

(iii) Impedance Relaying.

(iv) Over current protection.

(v) Differential protection.

(vi) Multiplication sub-program.

(vii) Division sub-program.

5.1 ALGORITHM FOR MAIN PROGRAM :

1. Initialise the ports.
2. Open the memory storage for Vs & Is & counter.
3. Switch on multiplexer-channel.
4. Sample & Hold.
5. Give some delay for acquisition time.
6. Start of conversion & End of conversion to A/D convertor.
7. Read the voltage V at port A & store.
8. Increment the multiplexer channel count.

9. To sample & Hold .

10. Give some delay for acquisition time.

11. Start of conversion pulse & end of conversion.

12. Read the current I.

13. Store I, in memory.

14. Increment the counter.

15. Goto 3rd step.

16. After reading Vs & Is call the phase, frequency, Impedance, Over current & Differential sub-programs.

5.1.1 FLOW CHART :

The various steps involved in providing protection and instrumentation are shown in the flow chart. 5.1

5.2 SUB-PROGRAMS :

5.2.1 PHASE ANGLE & POWER FACTOR MEASUREMENT

The phase angle between two sinusoidal signals can be measured by microcomputer. Signals are converted into square waves. The micro computer measure the time between positive going zero points of the two signals. fig 5.1 shows two sinusoidal signals V and I and corresponding square waves. fig5.2 shows a schematic diagram of interface for the measurement of phase angle. As the microprocessor always receives signal in the voltage form the current signal in converted in to voltage signal.

The square wave of the voltage signal is connected to PAo of the port 8255-1. The square wave for current signal is connected to PBo. The I part of the program is to find the zero instant of the voltage wave once the zero instant of the voltage wave is obtained the program moves further and reads the current signal. So long as the current signal is zero (see square waves) PBo is low. After the execution of the instruction IN 02, the content of accumulator is zero. The execution of RAR results no carry and the program jumps to the label loop. As soon as the current signal appears (see square wave) PBo becomes high. After the execution of IN 02 the content of accumulator becomes 0000010.

The execution of RAR results carry. Now the programs comes out of loop. Thus the time between the zero instant points of V and I is measured. This is proportional to the phase angle between V and I. This is in terms of count. Using look up table it can be displayed in the form of the degrees.

For the measurement of power factor first of all phase angle is measured as explained above. The phase angle is known in terms of count numbers. A look up table can be prepared to obtain the power factor. Using the look-up table PF can be measured and displayed. The alue of P.F. can also be used for control purposes, if required. If the look-up table does not serve the desired purpose and greater accuracy in required, phase angle and P.F. can be calculated from the count number.

5.2.1. ALGORITHM:

1. Get control word
2. Initialise port.

3. Read the voltage pulse.

4. Initialise H-L pair to store counts for phase angle.

5. Read current pulse.

6. After I pulse appeared store the phase angle.

5.2.3 FLOW CHART :

The flow chart for phase angle measurement is shown in fig 5.2.

5.3.1 FREQUENCY MEASUREMENT :

To measure the frequency of a signal, the time period for half cycle is measured which is inversely proportional to the frequency. A sinusoidal signal is converted into square wave using operational amplifier LM747 as shown in fig 5.3. A zener diode is used to rectify the output signal. A potential divider is used to reduce the magnitude to 5 volts.

A program has been developed to sense the zero instant of the rectified square wave. The microprocessor measures the magnitude of the square wave at two consecutive points as shown in fig 5.4. The two magnitudes are compared and decision is taken on the basis of carry and zero status flags, whether the point is at zero instant.

Various points have been shown in fig 2 at P_3 the magnitude of square wave in zero and P_4, 5 v IS LOGIC '1'. The microprocessor takes reading at P_1 and P_2 where both magnitudes are zero. Difference of the two is zero. So this is not the zero instant of the wave. At points P_5 and P_6, the difference of the zero instant of the wave. At points P_5 and $_6$, the difference of the two values is also not a zero instant point. At P_7 and P_8. The difference is non-zero but there is carry. So it is the end point of the half-square wave.

As soon as the zero instant point is detected the microprocessor initiates a register pair to count the number how many times the loop is executed. The microprocessor reads the magnitude of the square wave again and again and moves in the loop. It crosses the loop when the magnitude of the square wave becomes zero. Thus the time for half cycle is measured. The count can be compared with the stored numbers in a look-up table and the frequency can be displayed. The count which is inversely proportional to the frequency of the input signal can be used for further processing and control as designed. An interfacing circuitry is shown in fig 3. The program flow chart is shown fig 5.3 .The part A is input control word 98H.

5.3.2. ALGORITHM :

1. Detect the zero instant of the square wave.
2. Read the magnitude of the square wave.
3. Find 0,0, or 1,1point. This is the condition for the end of rectified square wave.
4. After the zero instant is detected the program moves in a loop till the square wave exists.
5. Thus the time period for half cycle is measured.

6. The count is inversely proportional to the frequency.

5.3.3 FLOW CHART :

The flow chart for frequency measurement shown in fig 5.3

5.4.1 IMPEDANCE RELAY :

To realise an impedance relay characteristic the voltage & current are compared at the relay location. The ratio of V & I gives the impedance of the line section between the relay and the fault point Vdc & Idc are proportional to Vrms & Irms respectively . Therefore, for comparison Vdc & Idc are used. For the operation of the relay the following condition should be satisfied :

$$k1\ Vdc < k2\ Idc \quad \text{or}$$

$$\frac{Vdc}{IDc} < \frac{k2}{k1} \quad \text{or}$$

$$\frac{Vrms}{Irms} < k \quad \text{or}$$

$$Z < k$$

where k1, k2 & k are constants.

The value of k for different zones of protection are calculated and stored as data to obtain the desired characteristic.

The characteristics of impedance relays are shown in fig . z1, z2 & z3, 2nd & 3rd zones of protection respectively T1, T2 and T3 are the operating times for Ist, 2nd & 3rd zones of protection respectively. From the characteristic it is clear that an impedance relay is non-directional. The operation of an impedance relay is desired only when the fault is in the forward direction. Therefore, a directional features. The microprocessor, Ist checks the direction of the fault current. Then it takes up the program for impedance relay. Too avoid complexity the connection for directions unit has not been shown

Impedance relay program flowchart in shown fig 5.4. Impedance relays are used to protect power transmission lines.

5.4.2 ALGORITHM :

1. Set a multiplier factor
2. Set a counter for reading of Vs & Is
3. Read V
4. Multiply V with K
5. Read I
6. Calculate V/I
7. If V/I < Z ref then trip the circuit if not go to increase the counter calue and repeat the above process 3 times & return to the main program.

5.4.3 FLOWCHART :

The flow chart for Impedance relay is shown in fig 5.4

5.5.1 OVER CURRENT RELAYING :

Over current relays are widely used for the protection of distribution lines, large industrial motors and equipments. The microprocessor being very fast can sense a number of circuits using multiplier and send the tripping signal to the circuit breaker of the faulty circuit. As the microprocessor receives signals in the voltage output proportional to the load current. The ac voltage which is proportional to the load current is converted in to d.c. the microprocessor receives d.c. voltage proportional to the load current. The following are the types of over current relay.

(i) Instantaneous or definite time over current relay.

(ii) Inverse time over current relay.

In definite-time over current relay the microprocessor compares the load current with the pick-up value. If the load current exceeds the pick up value , the microprocessor sends a tripping signal to the circuit breaker to isolate the faulty circuit from the rest of the system. To obtain inverse time characteristic the operating time for different values of current are noted for a particular characteristic. These values are stored in the memory in the tabular form the microprocessor first determines the magnitude of the fault current . Then it selects corresponding time for operation. A delay subroutine is started and trip signal is sent after the desired delay. Using the same program any characteristic such as IDMT, very inverse or extremely inverse can be obtained. A/D converter ADC 8700 CMOS' has been used in the interface. A program for an over current relay of inverse time characteristic is given in 4th subroutine. The microprocessor always measures the current and moves in a loop. If measured current exceeds pickup current, it compares the measured value of the current with the digital values of current given in the look-up table. Then selects corresponding count for delay time. It goes in delay subroutine and after the pre determined delay it sends trip signals to the circuit breaker.

5.5.2 ALGORITHM :

1. Initialise ports.
2. Read I1 from main program.
3. Compare with look up table.
4. If I1 is greater than pickup value, then trip the circuit.
5. Return to main program.

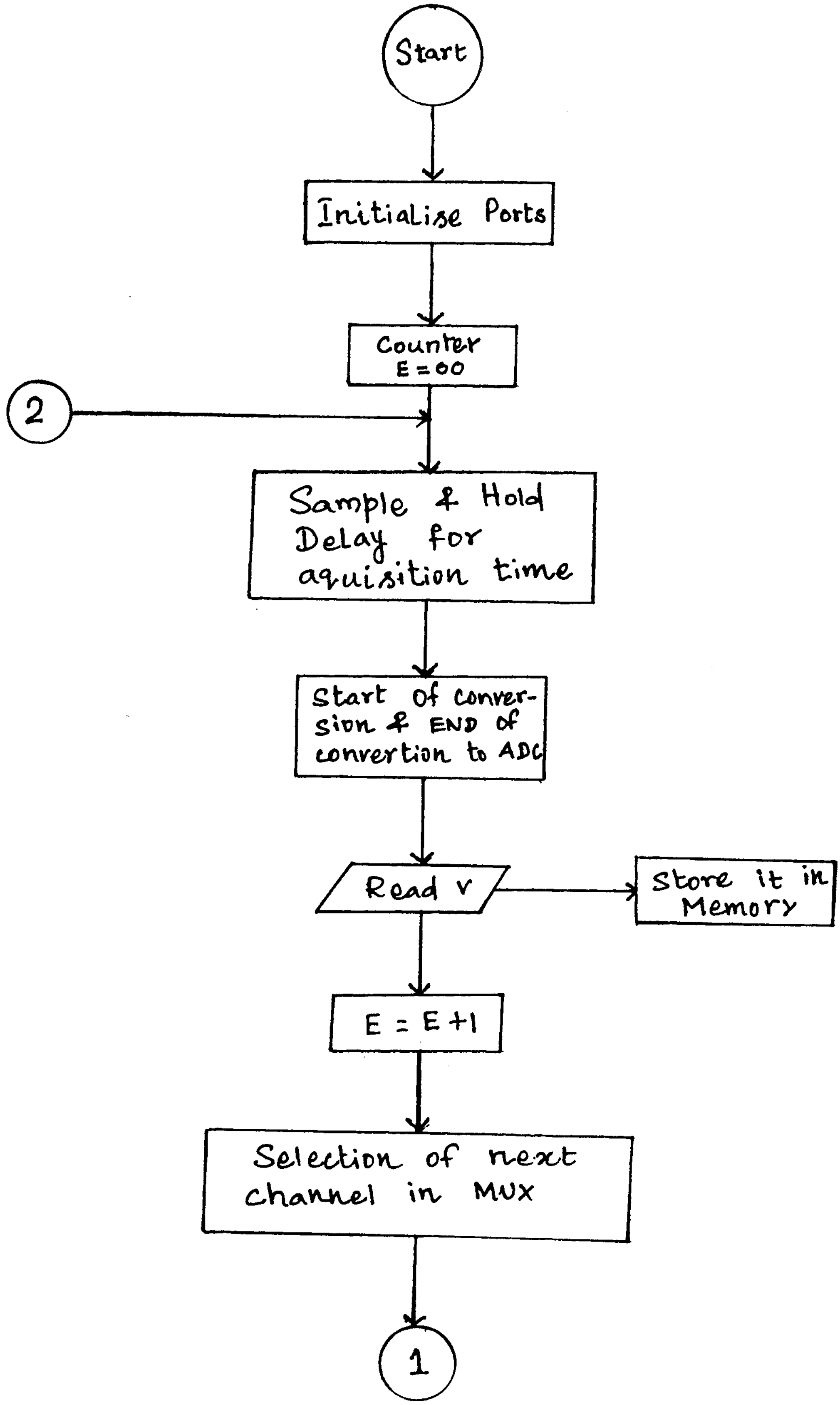
5.5.3 FLOW CHART :

The flow chart for over at relay is shown in fig 5.5

5.6.1 DIFFERENTIAL RELAYING :

Incase of differential relaying the currents from the primary (I1) and secondary (I2) of the power transformer are taken in to account. Whenever there is a fault in the transformer the trip signal is given to the CB. Differential Relay is operating during whenever a vector difference of two electrical quantities occur. The difference between currents (I1 - I2) and (I1 + I2) / 2 are calculated and compared with the characteristics of the differential Relay and trip signal is given. Here (I1 - I2) is the operating force and (I1 + I2) / 2 is the restraining force.

Main Program



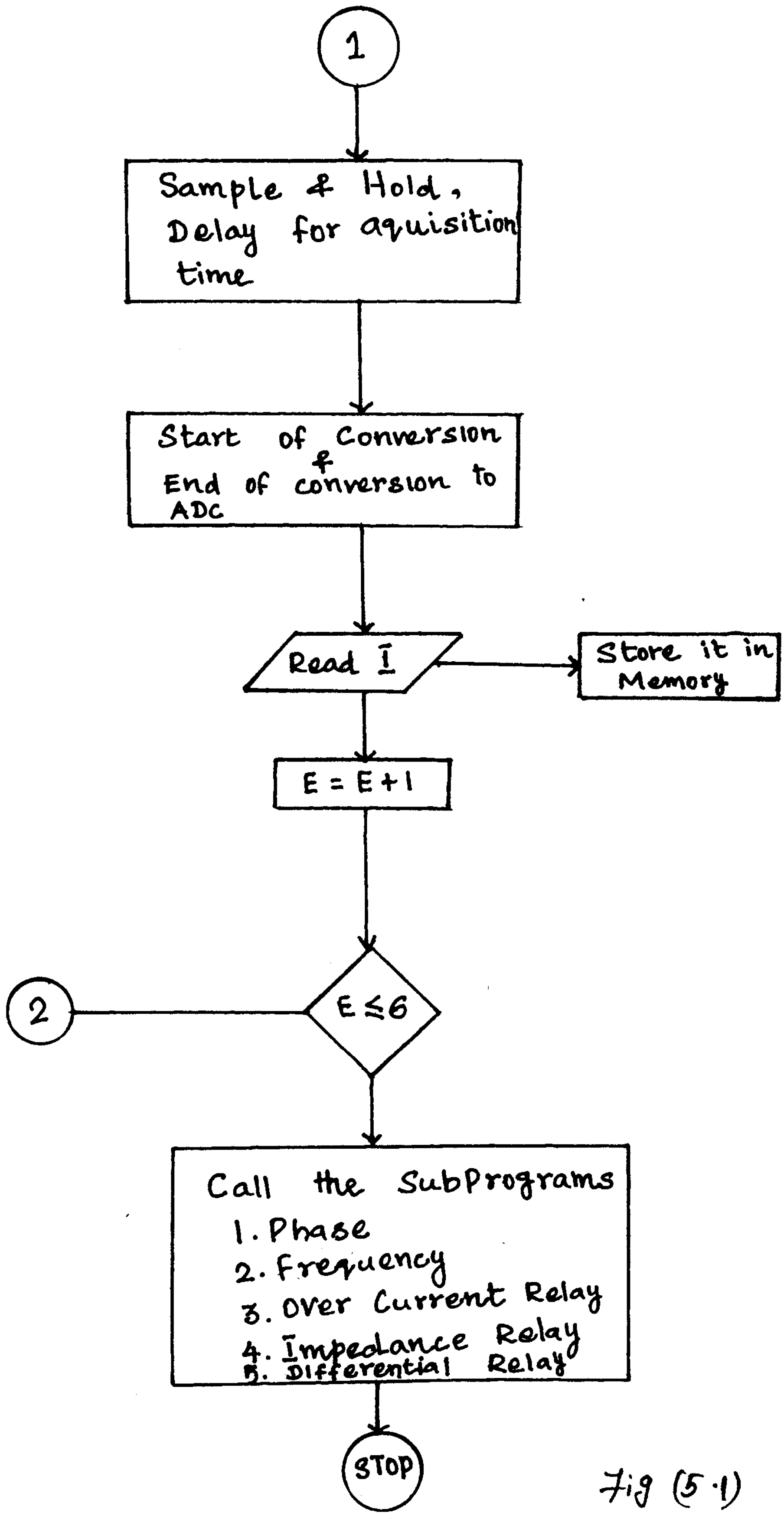

1
Sample & Hold,
Delay for aquisition time
Start of Conversion & End of conversion to ADC
Read I
Store it in Memory
E = E+1
E ≤ 6
2
Call the SubPrograms
1. Phase
2. Frequency
3. Over Current Relay
4. Impedance Relay
5. Differential Relay
STOP

Fig (5·1)

Phase Angle & Power Factor Measurement

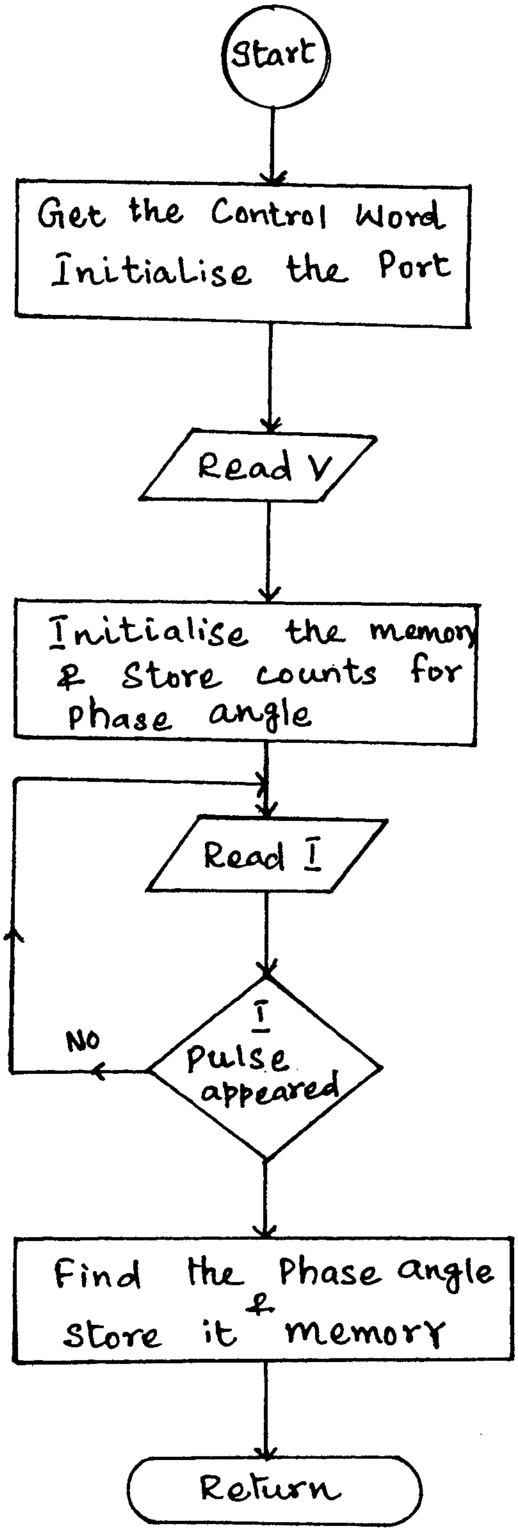


Fig (5.2)

Frequency Measurement

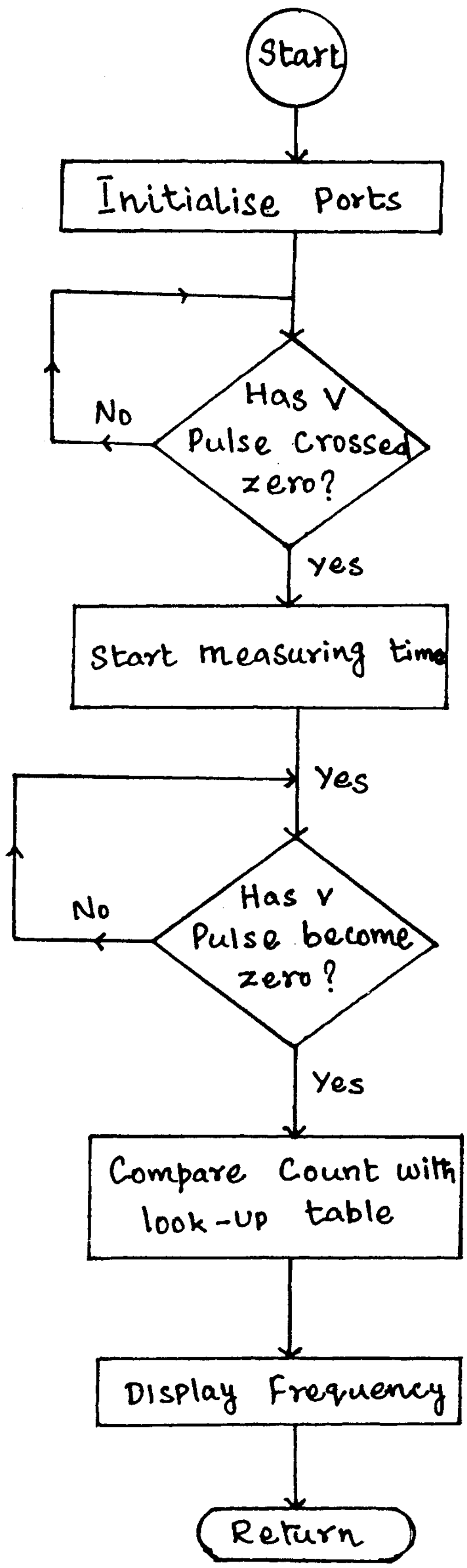


Fig (5·3)

Impedance Relay

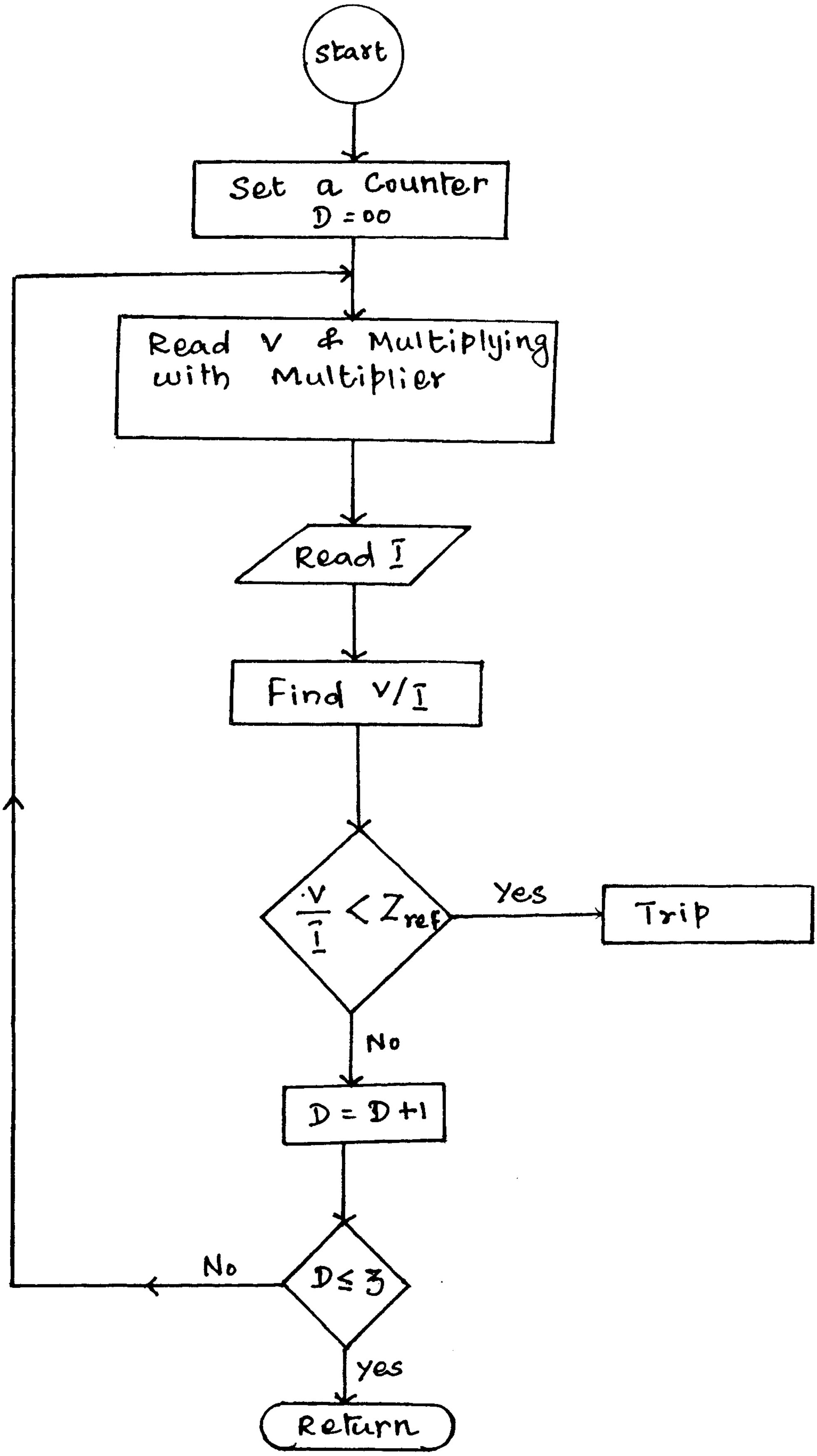


Fig (5.4)

Over Current Relay

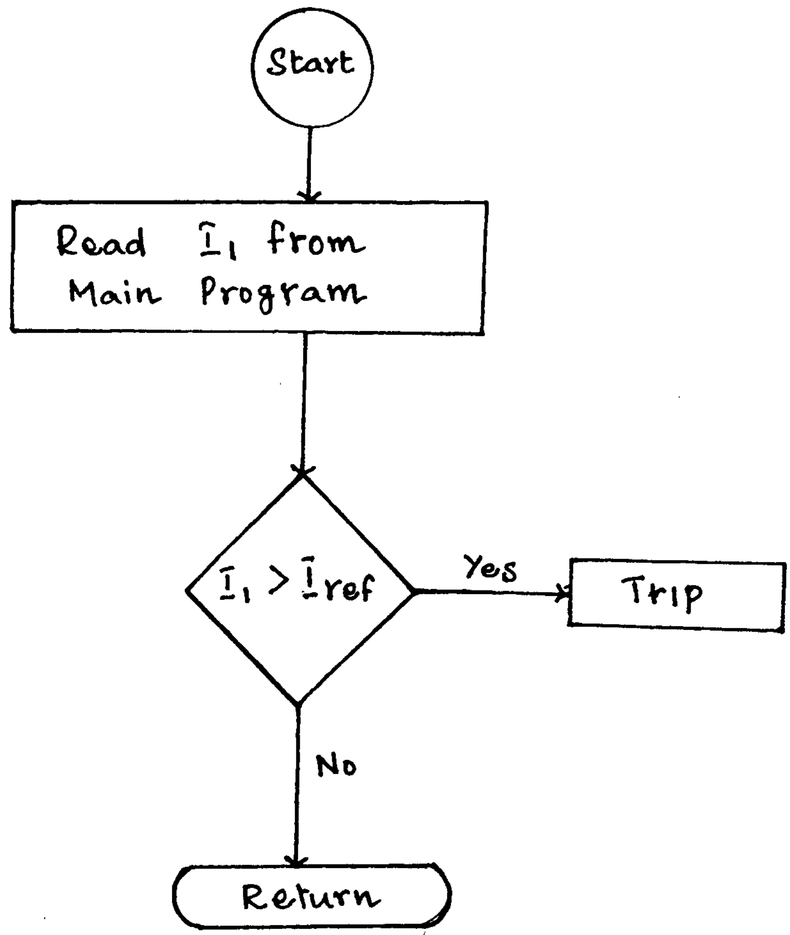
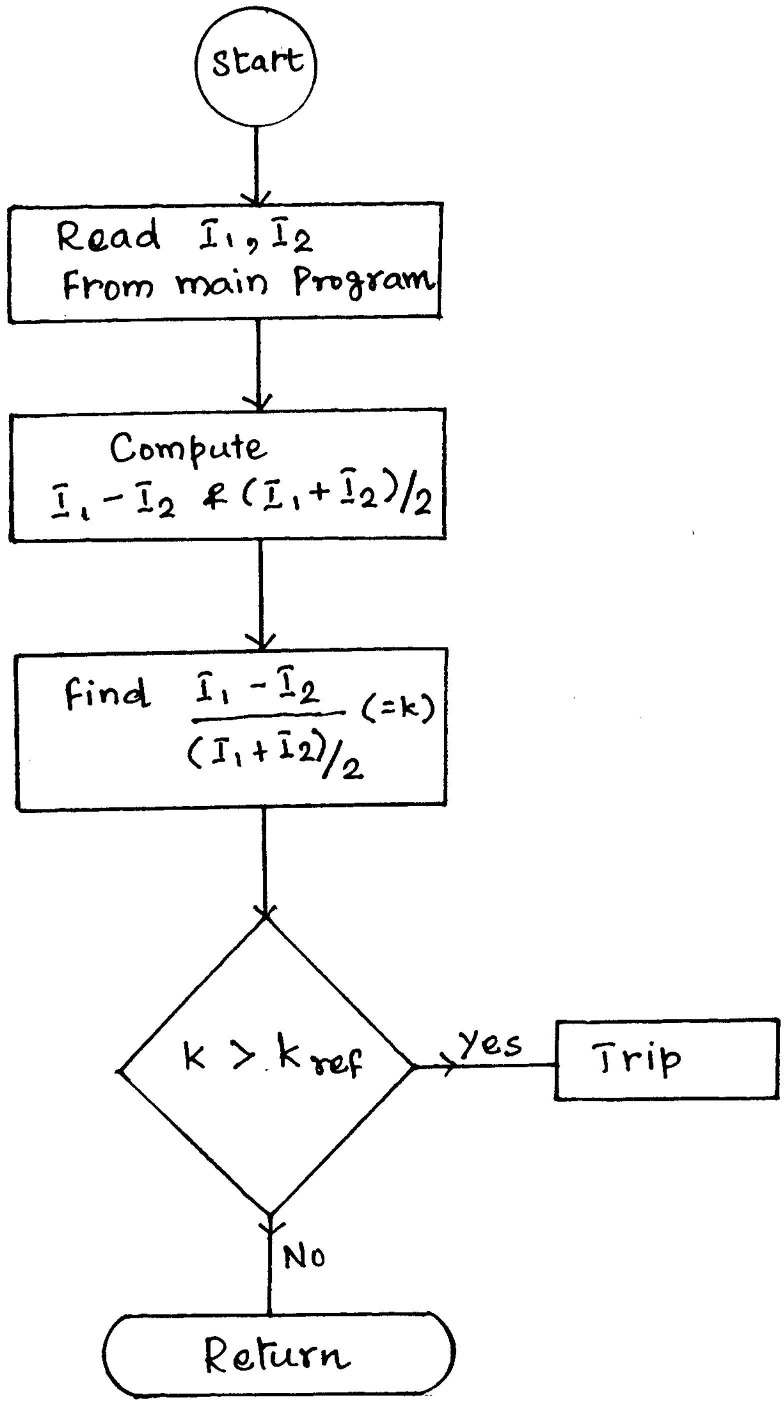


Fig (5.5)

Differential Relay



Fig(5.6)

MAIN PROGRAM

Memory Address	M/C Code	Label	Mnemonics	Operands	Comments
8000	3E 98		MVI	A,98H	Initialise Ports
8002	D3 43		OUT	43H	Control Codes
8004	21 5094		LXI	H,9450	Memory for Vs & Is
8007	1E 00		MVI	E,00	Counter
8009	7B	START	MOV	A,E	SWITCH ON MULTIPLEXER CHANNEL PORT C [8255-2]
800A	D3 42		OUT	42H	
800C	3E 80		MVI	A,80	TO SAMPLE AND HOLD [P_{B7}->HIGH]
800E	D3 41		OUT	41H	PORT B [8255 - 2]
8010	17 03	BACK	MVI	D,03	DELAY FOR ACQUISITION TIME
8012	15		DCR	D	
8013	C2 1080		JNZ	BACK	
8016	3E 00		MVI	A,00	
8018	D3 41		OUT	41H	
801A	3E 01		MVI	A,01	START OF CONVERSION
801C	D3 41		OUT	41 H	
801E	3E 00		MVI	A,00	
8020	D3 41		OUT	41H	
8022	DB 42	READ	IN	42H	IS CONVERSION OVER?
8024	17		RAL		
8025	D2 2280		JNC	READ	
8028	DB 40		IN	40H	READ V_{DC} AT PORT A
802A	77		MOV	M,A	STORE IT IN MEMORY
802B	23		INX	H	INCREMENT FOR MEMORY AND MULTIPLEXER SWITCH
802C	1C		INR	E	
802D	7B		MOV	A,E	SWITCH ON THE MULTIPLEXER FOR I_{DC}
802E	D3 42		OUT	42H	

MAIN PROGRAM

Memory Address	M/C Code	Label	Mnemonics	Operands	Comments
8030	3E 02		MVI	A,80	TO SAMPLE AND HOLD PORT B
8032	D3 41		OUT	41H	
8034	17 03		MVI	D,03	DELAY FOR ACQUISITION TIME
8036	15	GO	DCR	D	
8037	C2		JNZ	GO	
803A	3E 00		MVI	A,00	
803C	D3 41		OUT	41H	
803E	3E 01		MVI	A,01	START OF CONVERSION
8040	D3 41		OUT	41	
8042	3E 00		MVI	A,00	
8044	D3 41		OUT	41H	
8046	DB 42	SEE	IN	42H	IS CONVERSION [illegible] ?
8048	17		RAL		
8049	B2		JNC	SEE	
804A	DB 40		IN	40H	READ I_{DC}
804C	77		MOV	M,A	STORE IT IN MEMORY
804D	23		INX	H	
804E	1C		INR	E	INCREMENT FOR MEMORY AND MULTIPLEXER SWITCH
804F	7B		MOV	A,E	
8050	FE 06		CPI	06	INCREMENT VALUE IS < 6 GO TO START
8052	C2 0980		JNC	START	
8055	CD 0081		CALL	PHASE	CALL THE SUBROUTINE FOR PH,FREQ,IMP RELAY,O.C RELAY AND DIFF.RELAY
8058	CD 0082		CALL	FREQ	
805B	CD 0083		CALL	IMP	
805E	CD 0084		CALL	OC	
8061	CD 0085		CALL	DIFF	
8064	76		HLT		

SUB PROGRAMS
PHASE

Memory Address	M/C Code	Label	Mnemonics	Operands	Comments
8100	3E 98		MVI	A,98H	GET CONTEROL WORD
8102	D3 03		OUT	03H	INITIALISE PORTS
8104	DB 00	BACK	IN	00	READ VOLTAGE PULSE
8106	47		MOV	B,A	
8107	BD 00		IN	00	READ VOLTAGE PULSE AGAIN
8109	B8		CMP	B	
810A	CA 0481		JZ	BACK	
810D	DA 0481		JC	BACK	
8110	21 0000		LXI	H,0000	INITILISE H-L PAIR TO STORE COUNTS FOR PHASE ANGLE
8113	23	LOOP	INX	H	
8114	DB 02		IN	02	READ CURRENT PULSE
8116	IF		RAR		
8117	D2 1381		JNC	LOOP	HAS I-PULSE APPEARER? NO, JUMP TO LOOP &
811A	22 0090		SHLD	9000	STORE THE PHASE ANGLE
811D	C9		RET		

FREQUENCY

Memory Address	M/C Code	Label	Mnemonics	Operands	Comments
8200	3E 98		MVI	A,98H	GET CONTROL WORD
8202	D3 03		OUT	03	INITILISE PORTS
8204	DB 01	BACK	IN	01	READ VOLTAGE IN PORT B
8206	47		MOV	B,A	
8207	DB 01		IN	01	READ VOLTAGE PULSE AGIAN
8209	B8		CMP	B	COMPARE TWO READINGS
820A	CA 0482		JZ	BACK	
820D	DA 0482		JC	BACK	
8210	11 0000		LXI	D,0000	INITILISE D-E PAIR FOR COUNTING
8213	14	LOOP	INX	D	
8214	DB 01		IN	01	READ VOLTAGE PULSE
8216	1F		RAR		
8217	DA 1382		JC	LOOP	CHECK WHETHER V HAS BECOME ZERO , NO GO TO LOOP
821A	6B		MOV	L,E	
821B	62		MOV	H,D	
821C	22 5390		SHLD	9053	
821F	C9		RET		

IMPEDANCE

Memory Address	M/C Code	Label	Mnemonics	Operands	Comments
8300	01 0094		LXI	B,9400	REF Z_S ARE IN 9400 ONWARDS
8303	21 5094		LXI	H,9450	V_S & I_S ARE STORED IN 9450 ONWARDS
8306	16 00		MVI	D,00	COUNTER
8308	7E	START	MOV	A,M	READ V AND MULTPLY WITH K
8309	32 6094		STA	9460	
830C	CD 8600		CALL	MULT	
830F	24		INX	H	
83C0	7E		MOV	A,M	READ I
8311	32 0098		STA	9800	FIND V/I
8314	CD 8700		CALL	DIV	
8317	0A		LDAX	B	A <-- B
8318	5F		MOV	E,A	E <-- A
8319	3A 1198		LDA	9811	A <-- Z
831C	BB		CMP	E	Z_{REF} > Z THEN GOTO TRIP1
831D	DA 8800		JC	TRIP 1	
8320	14		INR	D	
8321	7A		MOV	AD	GO TO NEXT ZONE
8322	FE 03		CPI	03	
8324	D2 8308		JNC	START	
8327	C9		RET		

OVER CURRENT

Memory Address	M/C Code	Label	Mnemonics	Operands	Comments
8400	3A 5194		LDA	9451	READ I_1
8403	21 1094		LXI	H,9410	9410 <-- I_{REF}
8406	46		MOV	B,M	B <-- I_{REF}
8407	B8		CMP	B	I > I_{REF} ,YES
8408	DA 2184		JC	XXX	GIVE SOME DELAY THEN I > I_{REF}
840B	0E 10		MVI	C,10	THEN GO TO TRIP2
840D	16 FF	*	MVI	D,FF	
840F	15	GO	DCR	D	
8410	C2 0F84		JNZ	GO	
8413	0D		DCR	C	
8414	C2 0D84		JNZ	*	
8417	3A 5194		LDA	9451	
841A	B8		CMP	B	
841B	DA 2184		JC	XXX	
841E	C3 0588		JMP	TRIP 2	
8421	C9	XXX	RET		

DIFFERENTIAL PROTECTION

Memory Address	M/C Code	Label	Mnemonics	Operands	Comments
8500	26 00		LXI	H,00,K	
8502	3A 5394		LDA	9453	READ I_2
8505	47		MOV	B,A	B <- I_2
8506	3A 5194		LDA	9451	READ I_1
8509	90		SUB	B	A <- $I_1 - I_2$
850A	32 0398		STA	9803	
850D	3A 5394		LDA	9453	READ I_2
8510	47		MOV	B,A	B <-- I_2
8511	37		STC		
8512	3F		CMC		FIND(I_1+I_2)/2
8513	3A 5194		LDA	9451	
8516	80		ADD	B	
8517	0F		RRC		
8518	32 1098		STA	9810	
851B	CD		CALL	DIV	FIND $\frac{(I_1-I_2)}{(I_1+I_2)/2}$
851C	1A		LDAX	D	
851D	5F		MOV	E,A	
851E	3A 1198		LDA	9811	
8521	BB		CMP	E	
8522	C2 0A88		JNZ	TRIP3	
8525	C9		RET		

MULTIPLICATION :

Memory Address	M/C Code	Label	Mnemonics	Operands	Comments
8600	21 6094		LXI	H,9460	READ MULTIPLIER
8603	01 0098		LXI	B,9800	STORE THE K VALUE
8606	5E		MOV	E,M	
8607	16 00		MVI	D,00	
860A	23		INX	H	
860B	23		INX	H	
860C	78		MOV	A,B	
860D	21 0000		LXI	H,0000	
860E	06 08		MVI	B,08	
8611	29	TOP	DAD	H	
8612	17		RAL		
8613	D2 1786		JNC	LOOK	
8617	19		DAD	D	
8618	C2 1186		JNZ	TOP	
861B	22 0398		SHLD	9803	RESULT IN 9803 & 9804
861E	C9		RET		

D I V I S I O N

Memory Address	M/C Code	Label	Mnemonics	Operands	Comments
8700	2A 0398		LHLD	9803	GET DIVIDEND
8703	3A 1098		LDA	9810	GET DIVISOR
8706	4F		MOV	C,A	
8707	06 08		MVI	B,08	
8709	29	DIV1	DAD	H	
870A	7C		MOV	A,H	
870B	91		SUB	C	
870C	DA 1187		JC	AHEAD	
870F	67		MOV	H,A	
8710	2C		INR I		
8711	05	AHEAD	DCR	B	
8712	C2 0987		JNZ	DIV1	
8715	22 1198		SHLD	9811	QUOTIENT IN 9811A
8718	C9		RET		

TRIP

Memory Address	M/C Code	Label	Mnemonics	Operands	Comments
8800	3E 01	TRIP1	MVI	A,04	
8802	C3 0008		JMP	START	
8805	3E 02	TRIP2	MVI	A,02	
8807	C3 0008		JMP	START	
880A	3E 04	TRIP3	MVI	A,07	
880C	C3		JMP	START	
8810	0E FF		MVI	C,FF	
8812	16 FF		MVI	D,FF	
8814	15		DCR	D	
8815	C2 1488		JNZ		
8818	0D		DCR	C	
8819	C2 10		JNZ		
881C	D3 41		OUT	41	
881E	C9		RET		

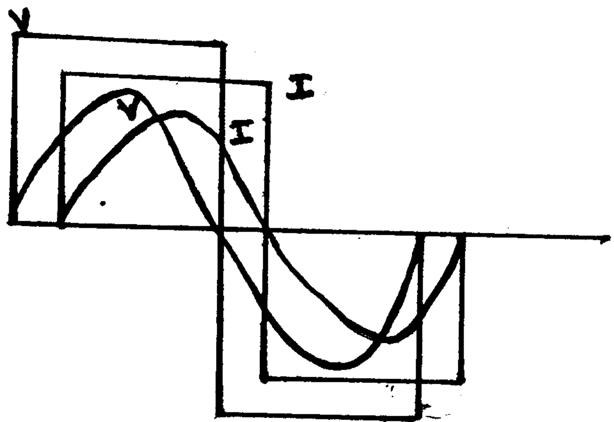


Fig (5.1)

Sine to square waves for V & I

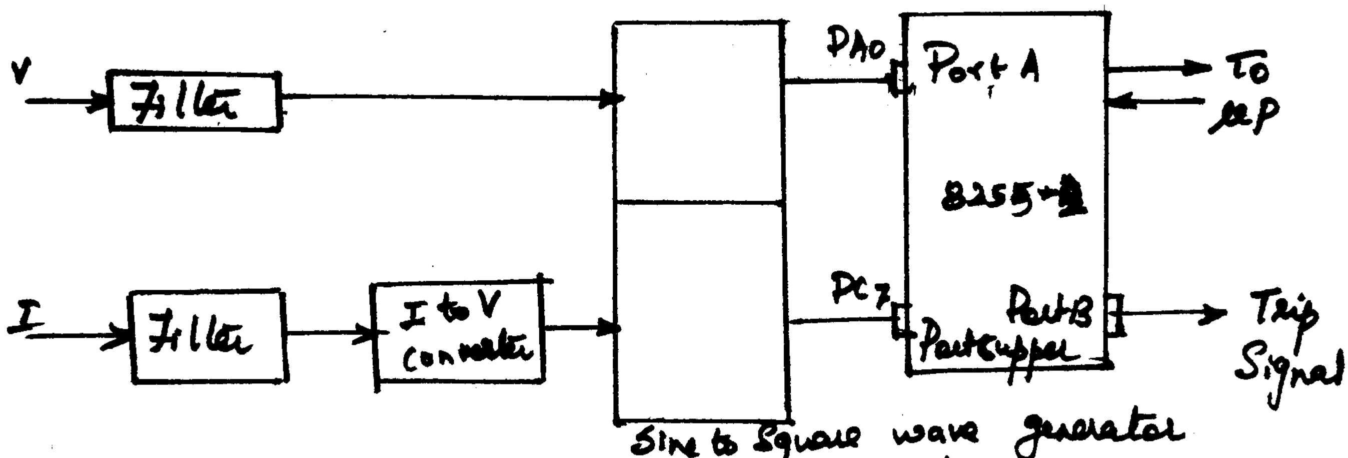
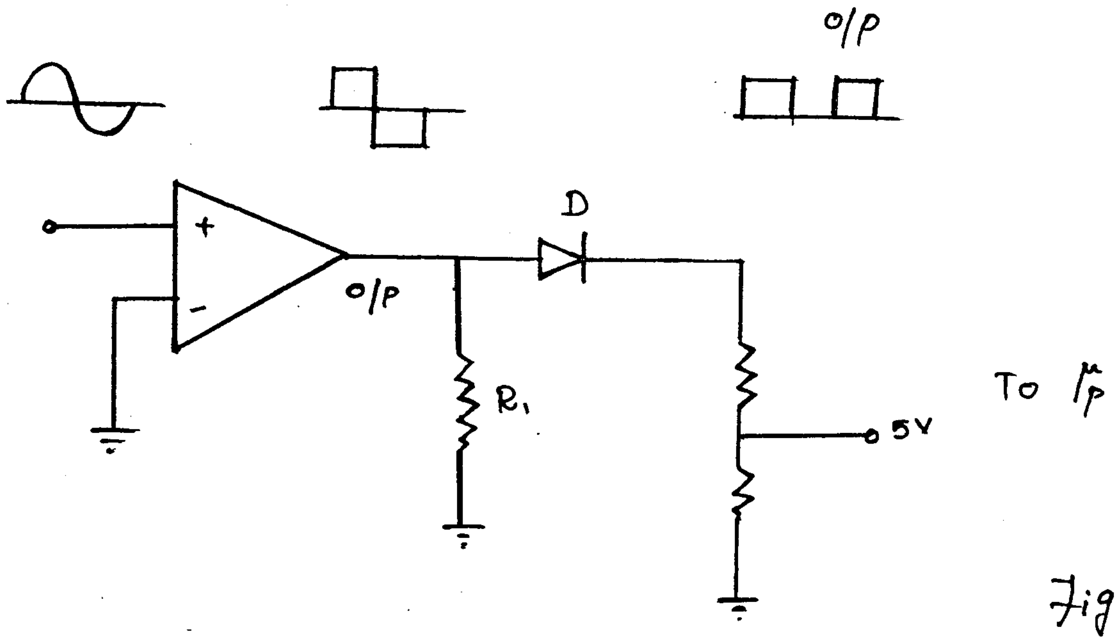


Fig (5.2) Schematic Diagram of Interface for measuring Phase Angle

Sine To Square Wave Converter



Fig(5.3)

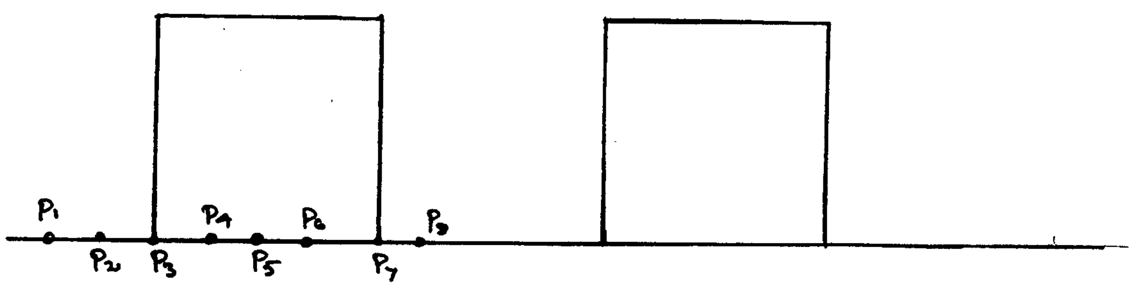


Fig (5.4)

CHAPTER VI

CONCLUSION

A combined microprocessor based sub-station protection and instrumentation scheme has been developed . The scheme is successfully implemented on a single transformer of a typical sub-station using a 8 bit microprocessor.

It can be extended to a large size sub-station where the number of transformers and buses are available. The measurements of active and reactive power can also be displayed by introducing near sub-routines. The novel advantage of the scheme over conventional methods is its minimum cost and facility to introduce a near protection and measurement functions.

REFERENCES

1. Adiya P. Mathur , "Introduction to MICROPROCESSORS", Tata McGraw-Hill Publishing company Limited, New Delhi. 1990

2. Leventhal. L.A, "Introduction to MICROPROCESSORS : Software, Hardware Programming," Prentice-Hall of India Pvt.Ltd, New Delhi.1983

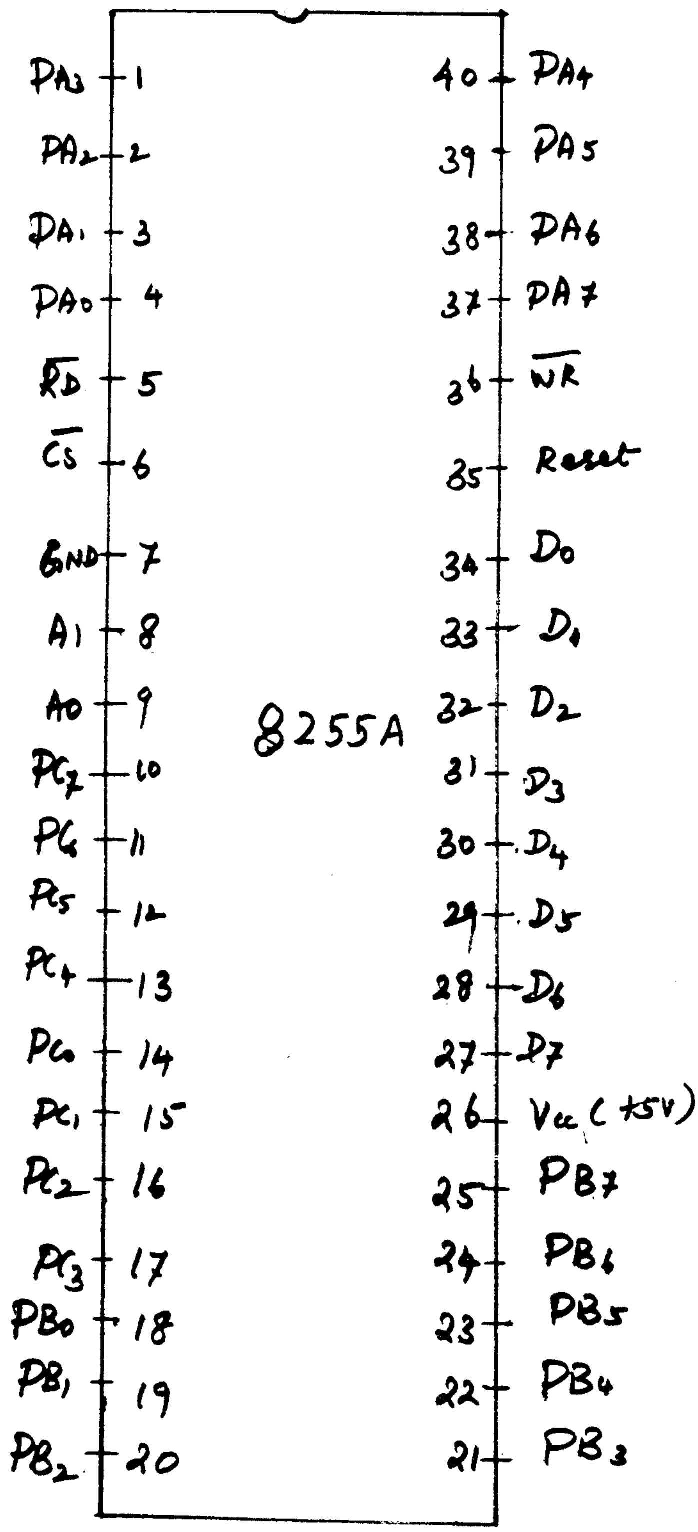
3. K.A. Gangathar, "ELECTRIC POWER SYSTEMS", KHANNA PUBLISHERS, DELHI.1992

4. G.D. Rockfeller, "Fault Protection with a Digital computer" IEEE Transactions on PAS, vol PAS-88, APRIL 1969, P438

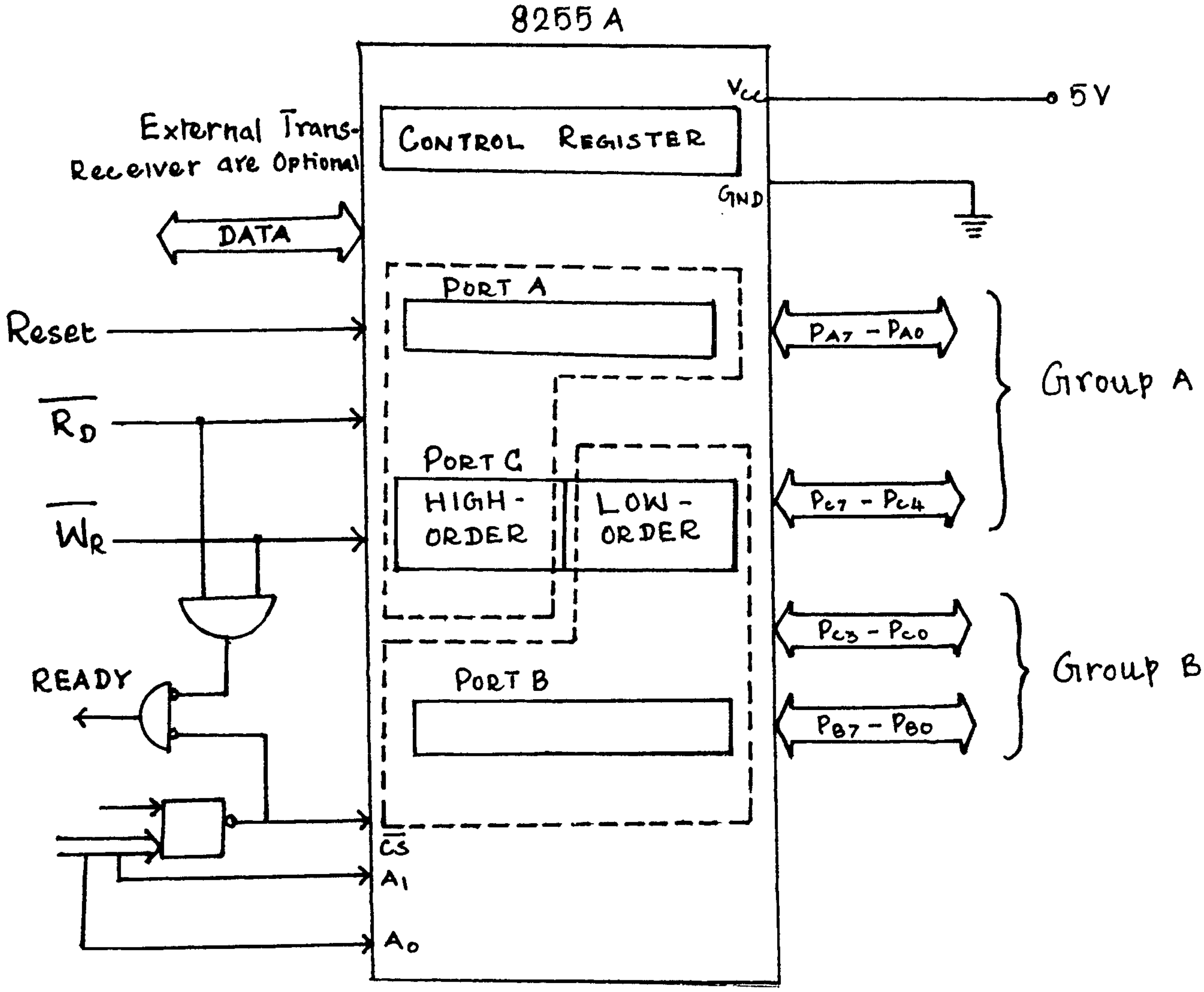
5. K. Tanaka and Kanov, " Application of Microprocessors to the on PAS, vol PAS-99 No1, Jan/Feb 1980, P344

6. Mathur, Kulsherestha, Chadha, "ELECTRONIC DEVICES APPLICATIONS AND INTEGRATED CIRCUITS", UMESH PUBLICATIONS - 1990

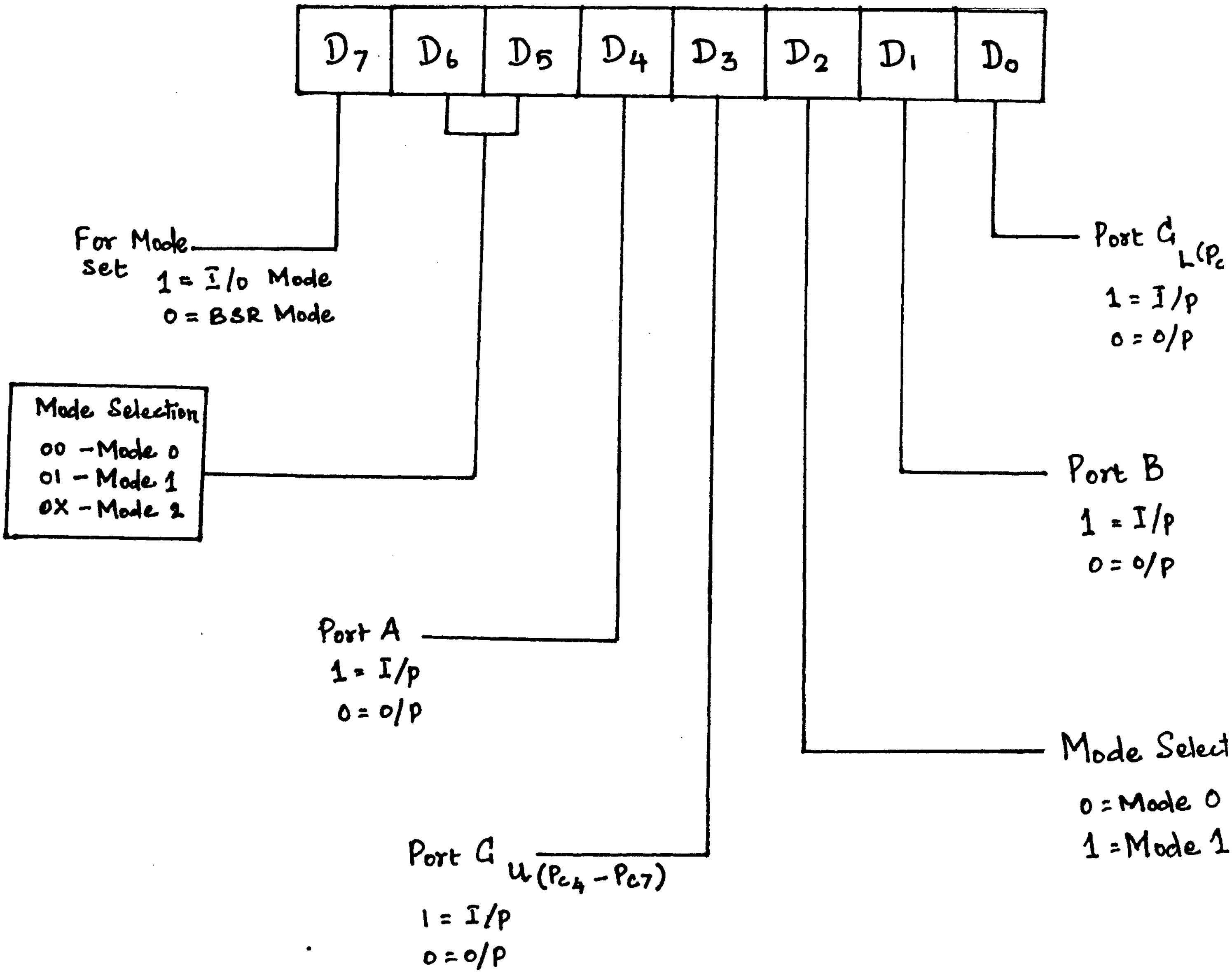
Pin Configuration of 8255A



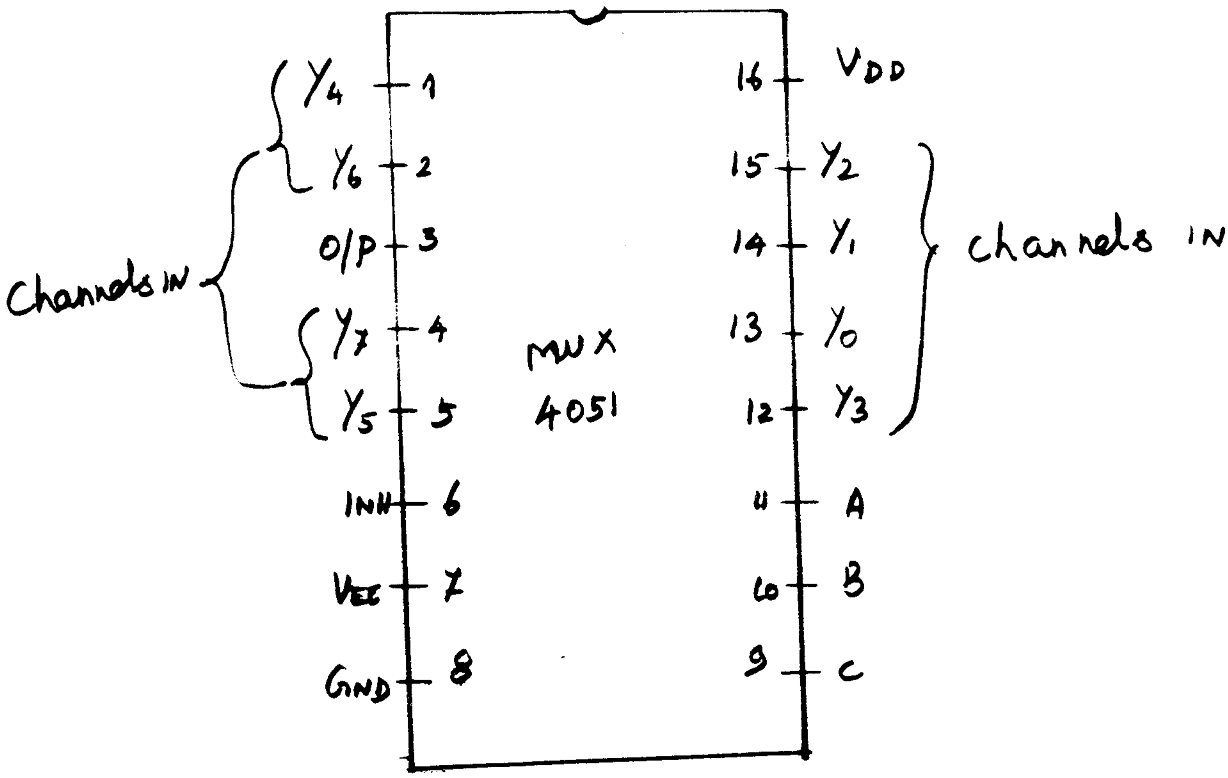
Signal Configuration Of 8255 A



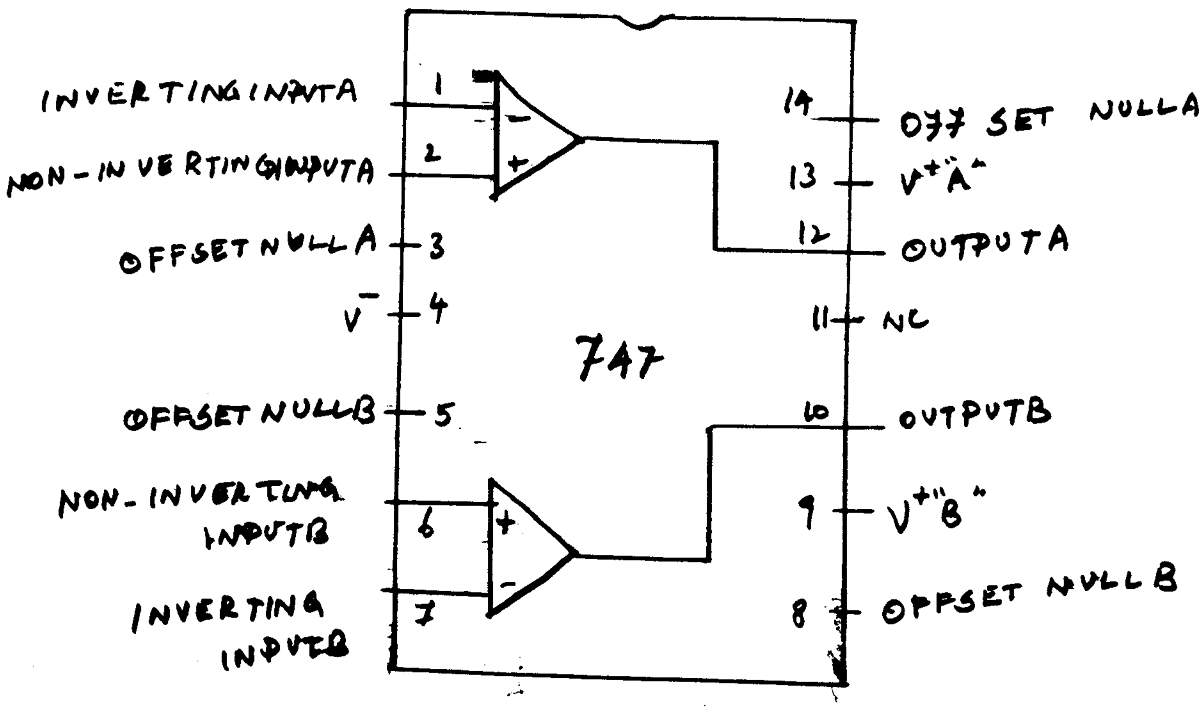
Mode Control Word Format For 8255 A



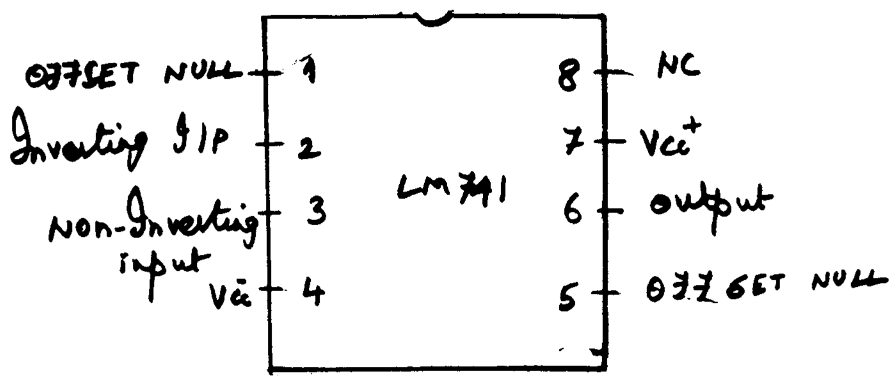
PIN CONFIGURATION OF CD4051 (MULTIPLEXER)



Pin Configuration of LM747



Pin Configuration of LM741



Pin Configuration of LF398