MICRO PROCESSOR BASED COLD STORAGE PROCESS INSTRUMENTATION CONTROL

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By

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CERTIFICATE

Certified that the dissertation entitled 'MICROPROCESSOR BASED COLD STORAGE PROCESS INSTRUMENTATION CONTROL', which is being submitted by Mr. D.SESHAPHANI, in partial fulfilment for the award of MASTER OF ENGINEERING in MEASUREMENT AND INSTRUMENTATION of the University of Roorkee, is a record of student's own work carried out by him under our supervision and guidance. The matter embodied in this dissertation has not been submitted for the award of any other degree or diploma.

This is to further certify that he has worked for a period of six months from January 1982 to July 1982, for preparing this dissertation at this University.

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ABSTRACT

The main thrust of this work is in the direction of development of instrumentation system to measure and control different dynamic variables in a given cold-storage plant using Intel 8085 microprocessor. It is proposed to study the cold-storage plant thoroughly with a view to understand its process dynamics and to develop microprocessor controller using Intel 8085. The characteristics and the performance of the transducers in sensing the different process variables (encountered in cold-storage plant) and signal conditioning them, to be compatiable with a microprocessor controller, is a very important area of this work. Development of microprocessor based digital instrumentation, for displaying and controlling the different variables, also forms an equally important area of this work.

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D.SESHAPHANI

PREFACE

It is the purpose of this work to provide a simple and direct approach to the operation and application of microprocessor controller for cold-storage process in order to achieve automation.

The fundamental concepts employed are applicable regardless of the changes in circuit concepts and design.

Microprocessor Based Cold-Storage Process Instrumentation Control makes use of a two-fold approach conducive to learning:

1. The theory contained in this work will assure a thorough understanding of versatility in measurement of various process variables and their regulation based on applications of microprocessor the Intel 8085 for cold-storage process to achieve automation. The material is arranged to provide best continuity in learning.

2. The practical applications of the fundamentals discuss in this work may be directly implemented and partially tested in satisfactory laboratory situations.

Even though every effort has been made to relate the principles to actual application controls, this is not conclusive or exhaustive study of the constantly changing measurements and control methods employed in the field of cold-storage process. In other words it is worth to say, this work presents a few ideas on microprocessor application in cold-storage process and it is just in the beginning stage.

Upon completion of the study of this report, the designer will have benifit and confidence necessary to efficiently service and install a microprocessor controller for cold-storage process to achieve automation.

D.SESHAPHANI

REVIEW OF MICROPROCESSOR BASED COLD-STORAGE PROCESS INSTRUMENTATION CONTROL

Almost daily, measurement and control system for cold-storage process are becoming more complicated. Humidity is a curious parameter to be regulated compared to any other parameters in cold-storage process. A lot of effort has been made in this area to bring the existence of microprocessor applications in cold-storage process. To understand thoroughly and to implement microprocessor controller for cold-storage process, this report has been divided into four chapters.

Chapter-1 introduces cold-storage process principles besides giving an idea about the parameters to be measured and to be regulated in cold-storage process.

Chapter-2 leads to the approach of microprocessor controller in this area. It also presents the implementation of the transducers and controllers which are used to measure and regulate the temperature and humidity in a given cold-storage process. The transducers and control schemes developed in this work are having flexibility to extend to the microprocessor controller.

In Chapter-3, the software implementation has been presented to measure humidity using microprocessor trainer HIL 2961. Before proceeding to the hardware design, it is essential to develope the software to know how much memory is required to implement microprocessor controller in this

Afterwords slight modifications can be easily made in the software programs developed in the beginning stage to fulfil hardware requirements.

Chapter-4 presents the complete hardware and software approaches to implement microprocessor controller in this area only for regulation of temperature and humidity.

There are a few parameters to be regulated (other than humidity and temperature) using microprocessor controller,but the affect these parameters have been minimized at the initial stage of the design of the cold-storage process. A lot of effort has been made in development of instrumentation systems in this field, and to give the shape to the name suggested in this work.

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(contd.)

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CHAPTER-1

1. DESCRIPTION OF COLD-STORAGE PROCESS:

1.1 Introduction to Cold-Storage Process:

Refrigeration has for its purpose the extraction and disposal of undesirable heat; consequently refrigeration is exact opposite of heating[1]. Refrigeration application falls into two major categories, namely:

(i) Cold-Storage

(ii) Air-conditioning

The basic principles and practices for these two categories are identical. Commonly used refrigeration in most of cold-storage processes is explained in Appendix-1[1], to get conditioned air into cold-storage process.

A cold-storage process is a multi variant system. It consists of many dynamic variables (eg. pressure, temperature, flow-rate, relative humidity etc) which are interrelated and require regulation. Relative humidity and temperature are two important dynamic variables influencing very much in cold-storage process in comparision to other dynamic variables. For example, if the humidity of cold-storage plant is not carefully controlled, such food as meat , fish, vegitable may become unsalable. They will dry out, change colour, lose weight, and present an unsavory appearance. It is curious to note that here, too, the complaint is not about the temperature, but about humidity. Humidity is interdependent upon many dynamic variables. In order to reduce the complexity of its regulation, the affect of other parameters are minimized in intial stage of design of the cold-storage process. Before proceeding further, let us observe some of the typical glossaries came across in the design of the cold-storage process.[2]

1.2 Typical mechanical glossaries:

i. Latent heat:

Heat supplied or removed from a substance during a change of state is called latent heat, in distinction to heat that caused a rise in temperature of the substance to which it is supplied. It is measured in kcal/kg.°C.

ii. Sensible heat:

Heat that changed the temperature of a substance is called sensible heat, because all of man's senses gave evidence of its presence. It is measured in kcal/kg.°C.

iii. Flow rate:

It is the rate of mass flow per unit volume. It is measured in kg/cubic m per sec.

iv. Specific heat:

It is the ratio between the heat required to rise one kg of substance to one degree centigrade and heat required to rise one kg of water to one degree centigrade. It is expressed in kcal/kg per °C.

v) Wet bulb temperature:

It is provided by a thermometer which is kept damp by a wrapping of cotton wicking (No heat is added or removed externally). It is measured in °C.

vi) Dry bulb temperature:

Dry bulb temperature is provided by thermometer which is kept inside the room or room air temperature. It is measured in °C.

vii) Humidity:

It is the water vapour in the air. It is expressed in terms of grams/m^3. It is reclassified into two categories; namely

(a) Absolute Humidity and
(b) Relative Humidity

(a) Absolute Humidity:

It is the weight of water vapour per a unit of volume air. It is expressed interms of grams per cubic meter of air.

(b) Relative Humidity:

It is the amount of water vapour present in air compared with the maximum possible expressed as a percentage.

viii) Saturation point:

It is cent percent of relative humidity.

ix) Dew point:

It is the temperature at which the moisture in the air is precipitated in the form of dew, or "sweat".

1.3 Design considerations of cold-storage process:

The actual size of the compressor or machinery required for a given capacity of cold-storage, air flow over the cooling coils and refrigerant flow will depend on cooling load calculations. This job is taken into account of the following factors listed below.(1-2)

(a) Sensible heat gains in the space:

i. Heat transmission through the structure.

ii. Solar radiation.

iii. Infilteration or air leakage into the space.

iv. Heat emission from occupants.

v. Heat to be extracted from the materials or products are brought in at higher than cooling space temperature.

vi. Heat from other internal sources such as motors, chemicals and other appliences present.

vii. Heat emission from electrical lights.

(b) Latent heat gains in the space:

i. In filteration by air leakage and by vapour pressure difference.

ii. Moisture from occupants.

iii. Moisture from the materials or products in the space.

iv. Moisture from internal sources.

(c) Outside ventilation air:

i. Sensible heat gain due to temperature difference.

ii. Latent heat gain due to moisture difference.

(d) Miscellaneous items.

Cooling job calculations take account of all the above factors under worst conditions, to decide the size of compressor, air flow over the cooling coils into the cold-storage. Under these conditions, the temperature of the cold-storage space can be controlled by varying flow of refrigerant, air flow over cooling coils and switching ON and OFF action of compressor. Under these conditions, relative humidity is mainly dependent upon inside temperature of the cold-storage process. The temperature inside of the cold-storage space is classified into two categories; namely, wet bulb temperature and dry bulb temperature. Even if the temperature of the cold-storage plant is maintained constant, relative humidity may not be constant because of the following factors:

i. The heat released by preserving products inside the cold-storage is taken as constant, but it is not true. The moisture release content, heat radiation may vary from product to product of preserving material in cold-storage from time to time.

ii. Solar affect is taken under worst conditions, but it is season and time dependent.

iii. All the factors listed in design considerations are taken under worst conditions, but it is not true in actual practice.

iv. The affect of the control valve in leakage and others are neglected.

Under these conditions, with the following assumptions, the relative humidity can be computed as follows by knowing wet bulb temperature, dry bulb temperature and air velocity inside the cold-storage process[3].

Assumptions: i. The pressure of the saturated water vapour is below 800 mm of Hg.

ii. The dry bulb temperature is in the range of $-200^{\circ}C$ to $+200^{\circ}C$.

Say t_{db} is dry bulb temperature in $^{\circ}C$,

t_{wb} is wet bulb temperature in $^{\circ}C$ and

v is air velocity over wet bulb in m/sec

Saturation pressure of water vapour is given by

$$\log_c\left(\frac{225.65}{p}\right) = (7.21379 + (\alpha + \beta T + \gamma T^n)* (T - 483.16)^2 + (\frac{647.31}{T} - 1)$$

where P = pressure of saturated water vapour in kg/cm^2.

$T = {}^{\circ}K = t^{\circ}C + 273.16$

$\alpha = 1.152 \times 10^{-5}$, $\beta = -4.787 \times 10^{-9}$, $\gamma = 0$, $n = 0$

($1\ kg/cm^2 = 735.59$ mm of Hg)

By substituting in equation (1) t_{wb}, t_{db} saturation pressure of water of wet bulb temperature (P_{wb}), dry bulb temperatures (P_{db}) are calculated[4].

Partial pressure of water vapour is given by

$$PH = P_{wd} - P_b * A_v * (t_{db} - t_{wb}) \qquad .... (2)$$

where P_b = Barometric pressure

A_v = Air velocity coefficient, depends upon rate of air flow over wet bulb.

$$A_v = (65 + 6.75/v) \qquad \text{... (3)}$$

Relative humidity is given by

$$RH = \frac{PH}{P_{db}} \times 100 \qquad \text{... (4)}$$

CHAPTER-2

2. CLOSED LOOP CONTROL OF COLD-STORAGE PROCESS BASED ON MICROPROCESSOR CONTROLLER:

2.1 Schematic diagram and discussions of microprocessor control for cold-storage process:-

Temperature and relative humidity are two dynamic variable, which are essentially required for regulation in cold-storage plants. Temperature in the cold-storage plant is indirectly controlled by air flow over cooling coils or in the refrigerant space, refrigerant flow and ON and OFF control of compressor switch[5]. Normally ON and OFF control of compressor switch is well suited for air-conditioning or cold-storage plant with one cabin. Normally cold-storage plants will have many cabins, which are regulated at different temperatures and humidities (See Appendix.1).

2.1.1 Temperature regulation:

Fig.1 shows a functional block diagram of closed loop control for temperature regulation (for a simple cabin) of cold-storage process. The total number of final control elements will depend upon the capacity and number of cabins of a given cold-storage plant. Temperature in each cabin of the cold-storage plant is measured using temperature sensors. Each cabin is provided with each thermostat. A set value is selected for thermostat. This set value of the temperature is compared with measured value of the system to produce an error signal. This error signal actuates different controllers to regulate temperature. In Fig.1, three-mode controller is incorporated. Firstly, the air flow over cooling coils in the refrigerant spaces are controlled using ON and OFF Fan controllers. Secondly, refrigerant flow in the cooling coils is controlled using proportional (solenoid valve) controller. Thirdly, ON and OFF switching control of compressor is provided and it is not recommended for multi-cabinas system of cold-storage plant. ON and OFF controllers and proportional controllers are recommended for single cabin system, because of its nature (slow variations). By integrating different controllers in parallel, the desired performance can be achieved at its cost. Specifications, and wiring diagram details of the temperature controllers used in this work are given in Appendix.2[5].

2.1.2 Humidity regulation:

Fig.2 shows a functional block diagram of closed loop control for relative humidity regulation (in single cabin) of cold-storage process. It is provided with two mode ON and OFF controllers. The final control elements are humidifiers and dehumidifiers[5]. If the relative humidity of the measured value is less than set value, humidifiers will be operated. If the measured value is more than set value, dehumidifiers will be operated. Humidification or dehumidification is achieved by sending excess moisture into the refrigerant space or by removing the excess moisture content from the refrigerant space.

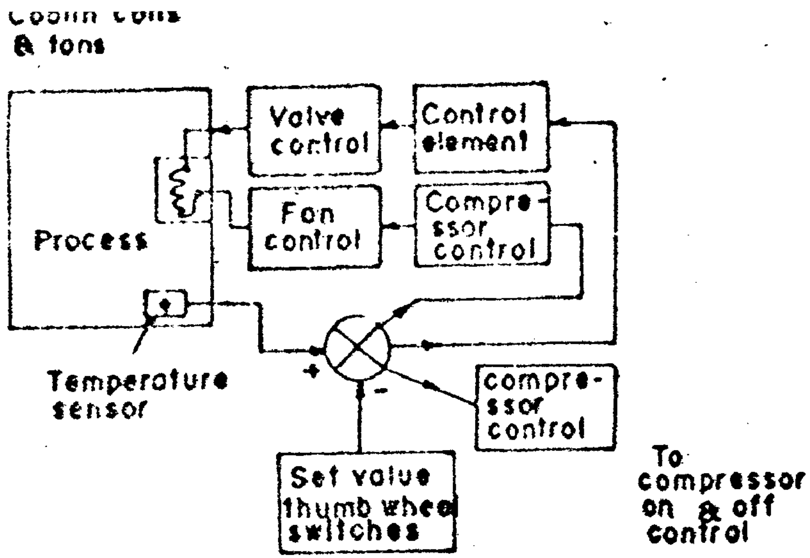


FIG. 1. BLCOK DIAGRAM FOR TEMPERATURE REGULATION

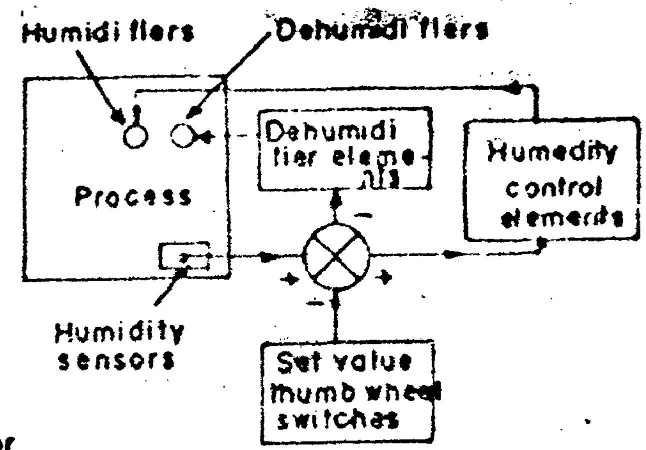


FIG. 2. BLOCK DIAGRAM FOR HUMDITY REGULATIO

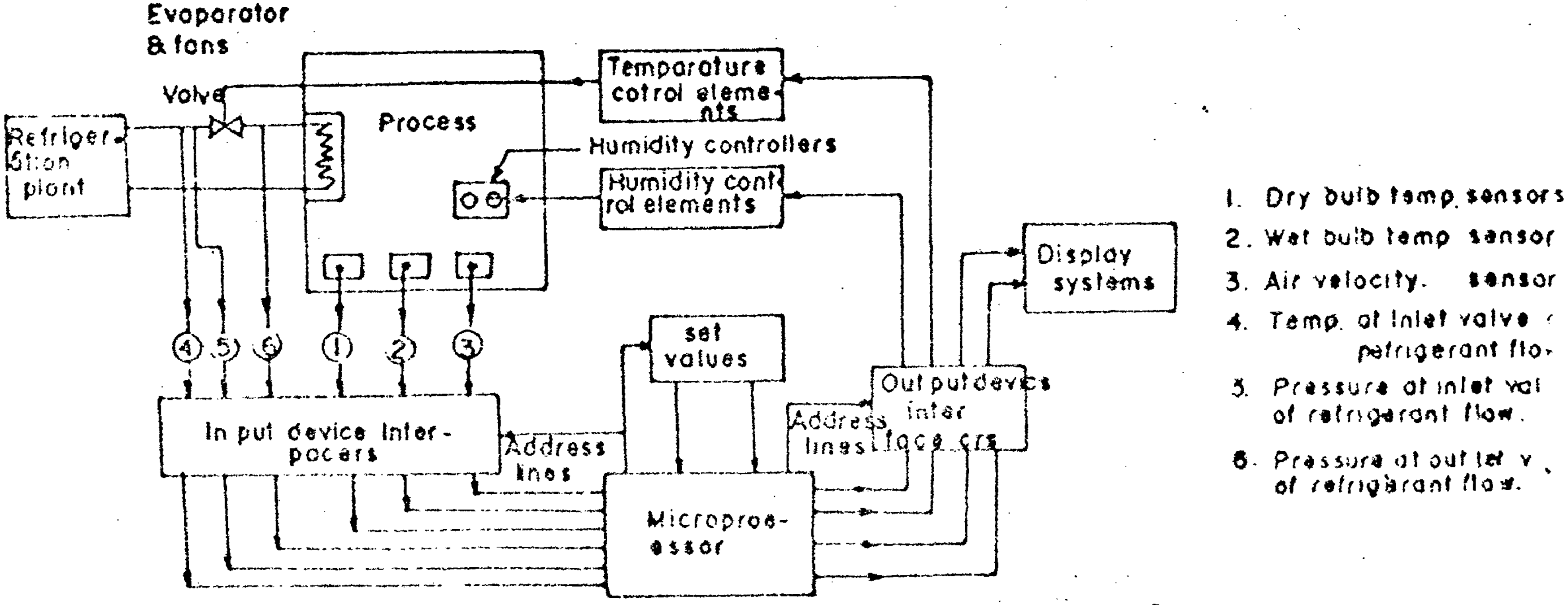


FIG. 3. BLOCK DIAGRAM FOR MICROPROCESSOR CONTROLLER COLD STORAGE PROCESS

Different methods are used for relative humidity control;namely, (i) cooling and dehumidification, (ii) cooling and humidification, (iii) heating and humidification, (iv) heating and dehumidification and (v) chemical methods[2]. Specifications and wiring diagram details of humidity controllers used in this work are given in Appendix-3[5].

2.1.3. Schematic diagram and discussions of microprocessor control for cold-storage process:

Cold-Storage process is clumsy with many controllers, which are operated continuously. For such a processes automatic controls are essential. Advances in integrated technology in recent years has resulted use of digital approach in process control applications. The movement from small scale integration to large scale integration and perticularly microprocessor removed much of economics of confining control decision to a control "all knowing" computer[6]. For multivariable systems automation is provided using microprocessors to increase the performance, to reduce cost, to replace human operator and to provide continuous regulation of different dynamic variables. Automation has been described as "the substitution of mechanical, hydraulic, pneumatic, electrical and electronics devices for human organs of observation, decision and effort, so as to increase the performance of operation, reliability, productivity, quality control and to reduce cost[7]. Fig.3 shows a functional block diagram of microprocessor control for cold-storage (single cabin) process. Dry bulb temperature, wet bulb temperature, wet bulb temperature, air velocity, differential pressures of the refrigerant at solenoid valve and its inlet refrigerant temperature signals are processed to the microprocessor via device interface selectors for controlling humidity and temperature. Set values of these variables are supplied externally to the memory of microprocessor. On processing these signals, microprocessor computes the values of the desired variables and it gives error signals to different control elements in order to meet the requirements of the process via its output device interface selectors. Fig.3 can be easily extended for controlling humidity and temperature in a multi cabin cold-storage plant on the similar lines, using microprocessor. For illustration of instrumentation system based on microprocessor control, it is proposed to select single cabin cold-storage process, at labora-tory level.

2.2 Temperature measurement:

Measurement of the temperature is quite common in industrial environments. Most of the temperature transducers are mechanical, and analog in nature. Mechanical transducers are not well suited for control applications. Hence analog transducers are most commonly used for industrial applications. Most commonly used analog transducers are thermocouples(8) and thermistors(9). Because of their non-linear characteristics, calibration of these transducers increases the number of components and cost in order to achieve greater accuracy. Hence, the advances in technology has switched over to linear analog transducers e.g. diodes, transistors, ICS etc.. Diodes are well suited for temperature measurement in cold-storage process, because of slow dynamic variations in tempera-ture(10). Though transistors and ICs have more accuracy in measurement of temperature, for slowly varying systems more than two parameters (like h_{fe}, V_{CBO}, $R_{Dynamic}$, etc.) will be affected(11-12). Hence, measurement of any one of these parameter is costlier and less accurate incomparision to diode transducer. For microprocessor applications these signals should be converted into digital signals. Digital signals are provided with all the features given by analog signals. In addition, these signals increase the speed of operation, accuracy, reduces human recording errors through visual display at low power consumption by replacing the mechanical moving parts in recording the outputs(13).

Before proceeding for measurement techniques, observe how diode is well suited for measurement of temperature. Consider a junction diode in forward bias conditions. The forward bias current characteristics are given by equation (5)(14)

$$I = I_o(e^{V/V_T.\eta} - 1) \qquad \dots (5)$$

where I_o = Saturation current at temperature T^oC

V = Forward bias voltage at temperature T^oC

V_T= Junction bias voltage at temperature $T\ ^oC$

η = A constant, depends upon material used silican or Germanium.

The dynamic resistance of the diode is equal to dV/dI. On differentiating equation (5)

$$\text{Dynamic Conductance} = \frac{dI}{dV} = \frac{I_o}{\eta V_T} \cdot e^{V/V_T\eta}$$

Since $V_T = Q/KT$ where Q & K are constants

$$\frac{dI}{dV} = \frac{I_o\ Q}{n\ KT} \cdot e^{VQ/KT\eta} \qquad \ldots (6)$$

$$\frac{dI}{dT} \quad \frac{I_o VQ}{KT^2} \cdot e^{VQ/KT\eta} \qquad \ldots (7)$$

From eq.(6) and eq.(7) $\frac{dV}{dT} = \frac{V}{T}$ ... (8)

From equation (8) one can observe that the change in diode forward bias voltage reduces linearly with increase in change of temperature. From equation (6) it is also evident that the drop in forward bias voltage is due to the change in dynamic resistance of the diode with change in temperature. For different diodes, the change in forward bias voltage with change in temperature is linear in the range from -25^oC to 100^oC.

The functional block diagram of Digital Thermometer for measurement of temperature in microprocessor based cold-storage process control is shown in Fig.4. From the comments made on equation (6) and equation (8), a wheatstone bridge is selected for signal conditioning the diode transducer to achieve temperature measurement at high sensitivity[15]. Before constructing a wheatstone bridge take a practical silicon metallic diode (BEL SD80, with sensing probe is selected in this problem)

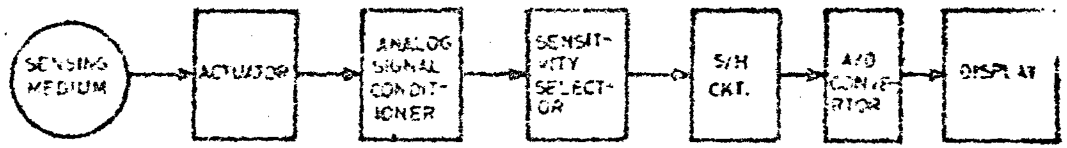


FIG. 4 BLOCK DIAGRAM OF DIGITAL TEMPERATURE TRANSDUCER

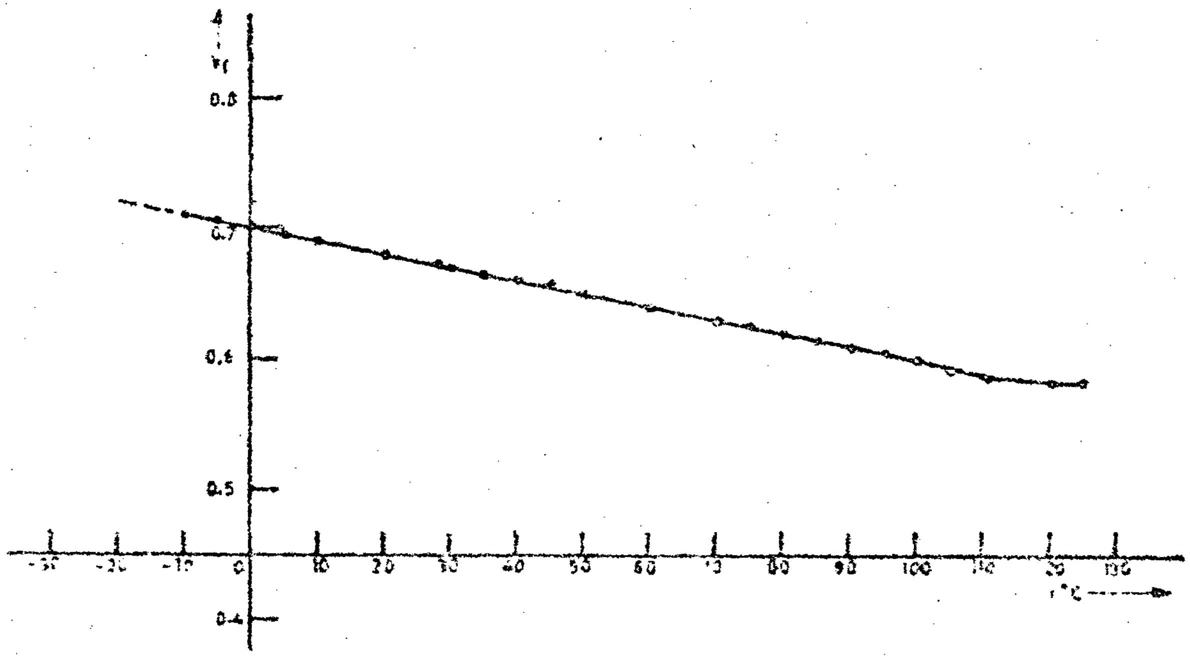


FIG. 5. TEMPERATURE (T°C) Vs DIODE FORWARD BIAS VOLTAGE CHARACTERISTICS.

and find the forward bias voltage at different temperatures. For BEL SD80, with sensor probe forward bias voltage at different temperatures are noted and a graph is plotted for temperature (T^oC) vs forward bias voltage (V_f) as shown in Fig.5. It is found that these characteristics are linear in the range of -10^oC to 100^oC. Fig.6 shows the circuit used for signal conditioning of this transducer.

For our intial analysis assume the null detector input impedance is infinite, that is an open circuit. In this case the potential difference, V between points 'a' and 'b', is simply

$V = V_a - V_b$ ... (9) where V_a & V_b are potentials of points 'a' and 'b' w.r.t. ground. The value of V_a and V_b can be found by noting that V_a is just the supply voltage V_s, divided between R_1 and R_D.

$$V_a = \frac{V_S \quad R_D}{R_1 + R_D} \qquad \ldots (10)$$

Similarly

$$V_b = \frac{V_S \quad R_4}{R_2 + R_4} \qquad \ldots (11)$$

$$\therefore \; V = \frac{V_S \quad R_D}{R_1 + R_D} - \frac{V_S \quad R_4}{R_2 + R_4} \qquad \ldots (12)$$

Initially by varying trimpot (R_4) P_1, in the circuit the null detector (voltage difference V_a and V_b) is adjusted to null deflection, by keeping the excitation voltage constant, other resistors and diodes are kept at room temperature (25^oC). Under null deflection conditions:

$$R_D R_2 = R_1 R_4 \qquad \ldots (13)$$

Hence, for construction of bridge circuit, depending upon the dynamic resistance of the diode and other resistors are selected from equation (13). Equation (13) indicates that whenever a bridge is assembled and resistors are adjusted for null, the resistor values must satisfy the indicated equality of equation (13). It does not matter, if the supply voltage drifts or changes the null is maintained[15]. From Fig.5, find the value of dV/dT, say X (is equal to 1mV/^{o}C in this problem). Say room temperature is T ^{o}C (equal to 25 ^{o}C at the time of calibration). Hence, adjust the trimpot P_1 until the potential difference is XT mvolts (25 mV).

Now, by keeping the diode in temperature bath observe the detector readings at different temperatures. From eq.(6) it is observed that the change in temperature cause the reduction of voltage across diode, cause increase in potential at terminal a, shown in Fig.6. Hence, the potential difference across the detector is increased with increase in temperature. By keeping the sensor in ice at 0^{o}C, ensure that the potential difference at terminal a and terminal b is zero volts. If not, a slight adjustment is made by varying trimpot P_1 to bring null deflection. Once this bridge circuit is adjusted in the above described manner, the excitation voltage, trimpot P_1 position and all other resistors are kept constant.

In modern applications a null detector is a very high

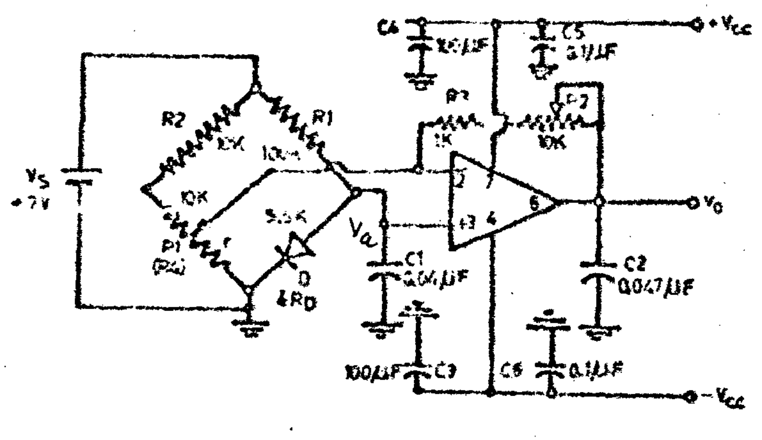


FIG.6. CIRCUIT DIAGRAM OF ANALOG TEMPERATURE TRANSDUCER.

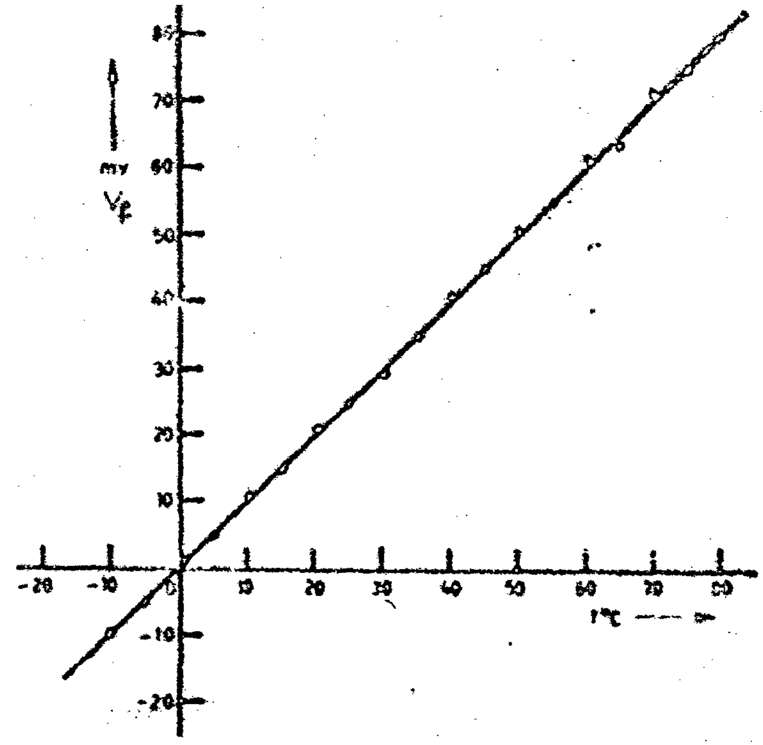


FIG.7. TEMPERATURE(T°C) Vs. DIODE FORWARDBIAS VOLTAGE (V_f) CHARACTERISTICS.

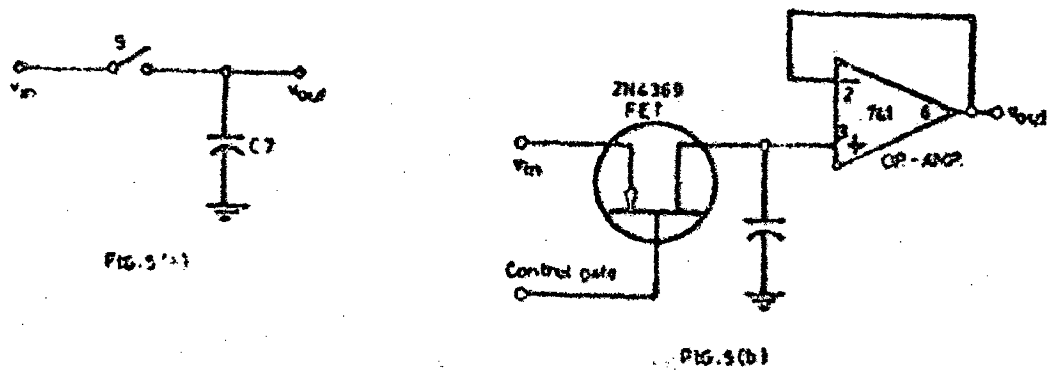


FIG.5. SAMPLE AND HOLD CIRCUIT

input impedance differential amplifier or non-inverting amplifier(15)
Hence, the detector terminals 'a' and 'b' shown in Fig.6 are connected to inverting and non-inverting terminals of a non-inverting, high input impedance operational amplifier (IC 536). A feed-back resistance (trimpot P_2) is connected at non-inverting and output terminals of an OP-AMP as shown in Fig.6. Capacitors C_1 and C_2 are used to charge to the voltage at their corresponding terminals. Now the output voltage of noninverting amplifier is given by

$$V_{out} = (1 + \frac{P_2}{r})\ (V_a - V_b) \qquad \ldots (14)$$

From equation (9) and equation (8), $dV = \frac{V}{T}\,dT$

Since V_a is constant and V_b is only varying (from Fig.6)

$$V = V_a - \frac{V}{T}\,dT \qquad \ldots (15)$$

Substituting in equation (14)

$$V_{out} = (1 + \frac{P_2}{r})(V_a - \int \frac{V}{T}\ dT) \qquad \ldots (16)$$

From equation (16), it is evident that output voltage of non-inverting amplifier varies with trimpot P_2 and temperature of the diode, while other parameters are kept constant.

Now at room temperature T °C (25°C) the potential difference of terminal 'a' & 'b' or potential at terminal 'b' is XT volts (25 mV). By adjusting trimpot P_2, shown in Fig.6, i.e. the gain of NIA set to a value of Y (say 10), the output of NIA is equal to XTY volts (250 mV at 25°C). Now, keeping the diode in temperature bath at various temperatures, the output voltage of noninverting amplifier is noted and a graph is plotted as shown in Fig.7. A high input impedance 3½ Digits Panel Meter is used to measure the output voltage of NIA. So, the temperature can be measured with an accuracy of $\pm 0.01^{o}C$. The output is connected to input terminal of sample and hold circuit. A sample and hold circuit in its simplest form is a switch S in series with a capacitor, as shown in Fig.8(a). The voltage across the capacitor tracks the input signal during time t_g when a logic gate control closes S and holds instantaneous values at the end of the interval t_g when the gate control pulse opens S. The switch may be a relay, a sampling diode bridge gate, a bipolar transistor switch or enhancement transistor controlled by gating signal. The FET makes an excellent chopper because of its off-set voltage when ON ($\sim 5 \mu V$) is very much smaller than a bipolar junction transistor. The circuit shown in Fig.8(b) is one form of sample and hold circuit(14). A positive pulse at the gate of n-channel MOSFET or FET will turn on the switch and holding the capacitor C_7 to the instantaneous value of the input voltage of the source terminal, at a time constant $R_{ON} C_7$. In the absence of a positive pulse, the switch is turned off and the capacitor is isolated from any load through μA741 OP-AMP or LM102. Thus it will hold the voltage impressed upon it. When the hold capacitor C_7 is larger than 0.05 μF an isolation resistance approximately 10 K ohms should be included between the capacitor and positive input of OP-amp. This resistor is required to protect the amplifier in case output is short circuited, or power supply is abroptly shut-down while the capacitor is charged. This circuit is incorporated to select a source signal of area of interest from many signals going to microprocessor in a given cold-storage process. The output terminal of the sample and hold circuit is fed to ADC-0800 through a sensitivity selector. The SOC (start of conversion) terminal of ADC-0800 is coming from the same terminal of sample and hold circuits control gate through a delay latch 7475. The details of ADC-0800 are given in Appendix-4[16].

The complete circuit of the digital temperature transducer for microprocessor based cold-storage process control application is shown in Fig.9. In this circuit diagram by changing gain of IA, accuracy of the measurement can be increased. By changing the gain of the sensitivity selector, the sensitivity of ADC-0800 can be increased. For example if X = 1mV/°C, Y=10, say sensitivity selector gain M = 40, the circuit diagram can be used to measure temperatures from 0°C to 25.5°C, with an accuracy of one decimal digit. Instead of M = 40, if we select M = 4, the circuit diagram can be used to measure temperature 0°C to 255°C, with an accuracy of one digit. From this it is evident increase in span cause reduction in accuracy of measurement and converse is also true. This circuit will function only if the control gate pulse is true. If the decision unit of microprocessor makes a decision to input the temperature, it issues a pulse to the control gate of sample and hold circuit. The control pulse is also applied to SOC terminal of ADC-0800 through delay latch

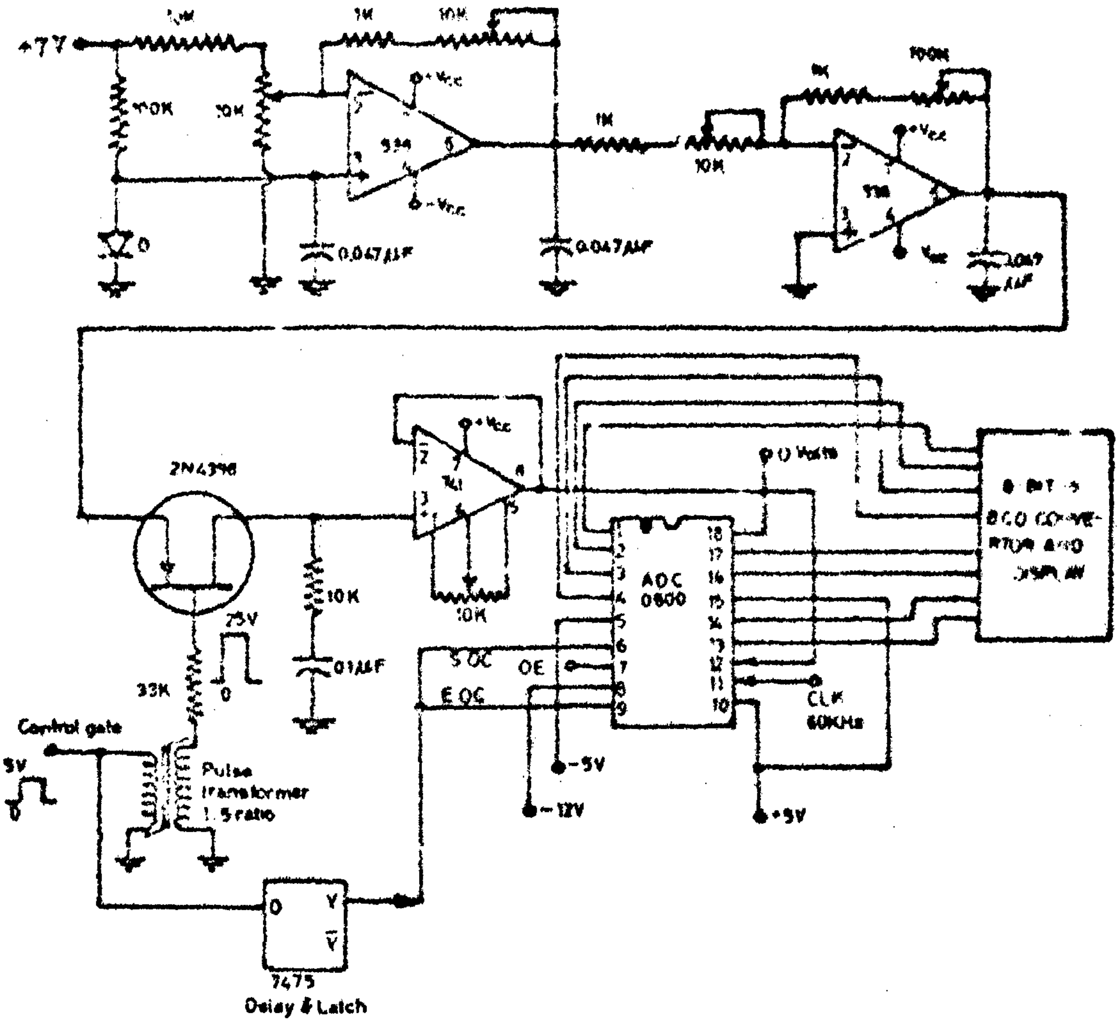


FIG.9. CIRCUIT DIAGRAM OF DIGITAL TEMPERATURE TRANSDUCER FOR MICROPROCESSOR BASED COLD-STORAGE PROCESS APPLICATIONS.

circuit ($t_g < t_d$). Hence, ADC-0800 starts conversion of analog voltage signal into its equal binary number (which gives directly the temperature of the system) with t_d seconds delay after the applying the gate control pulse. With its salient features, this is useful to input the tempera-ture data to the microprocessor in cold-storage process applications.

2.3 Humidity measurement and control:

Measurement of relative humidity plays very important role in cold-storage process applications, textile industrial applications, etc. Most of the transducers used for relative humidity measurement are mechanical in nature. Mechanical psychrometers and hygrometers are most commonly used transducers(17). These transducers can not be used for automatic controls. Among these two transducers, psychrometers are preferred to hygrometers. Hygrometers are calibrated using psychrometers, hence, less accurate and suffered with drift problems. Some chemical transducers are also available but these are less accurate in-comparision to mechanical transducers and suffered with all the drawbacks that a mechanical transducer has(17). Hence for control applications, the technology has switched over to electrical and electronics humidity measurement transducers, e.g.(18-19) capacitive, inductive, resistive, electronics psychrometers etc. Electronics psychrometers are more accurate than other electrical and electronics transducers. But it increases the cost, reduces the reliability with more number of components and increases the speed of operation. The revolution in digital instrumentation from small scale integration to large scale integration has brought application of microprocessor for relative humidity measurement and control. Before proceeding further, let us discuss one of the best electronics psychrometers used for relative humidity measurement and control, using LSI technology, to illustrate the importance of the microprocessors in the same area.

2.3.1. Relative humidity measurement and control using LSI Technology:

The functional block diagram used for relative humidity and control using LSI technology is shown in Fig.10, for (single cabin) cold-storage plant. In this circuit, Fig.9 is used for temperature measurement. Measurement of humidity is obtained by measuring dry bulb and wet bulb temperatures, under the following assumptions:

i. Two circuits used for measurement of wet bulb and dry temperatures are identical in nature.

ii. The sensor probes must have identical dimensions and mounted on the same frame in the same line, in parallel.

iii. The air velocity in the cold-storage process should be kept constant. Other-wise compution of air velocity coefficient is essential.

iv. The pressure of saturated water vapour is below 800 mm of Hg.

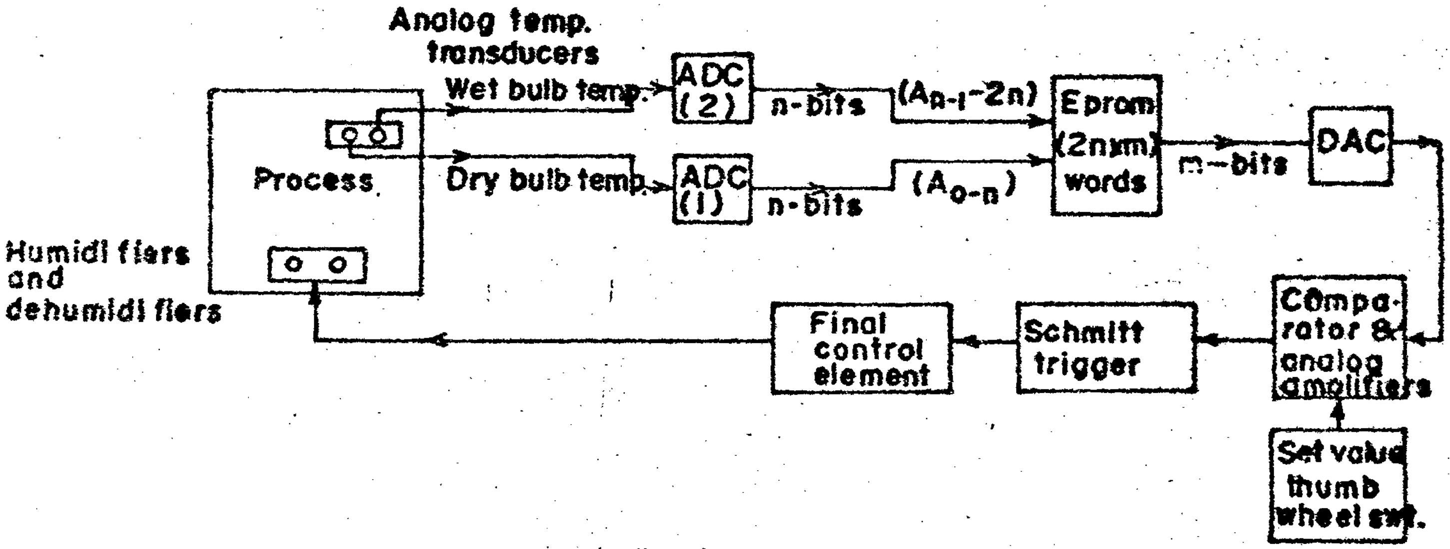


FIG. 10. BLOCK DIAGRAM OF A LOW COST DIGITAL PSYCHRIMETER AND HUMIDITY CONTROLLER

Under these conditions, the psychrometric equations (1) to (4) are valid for computation of relative humidity.

Fig.11 shows the complete circuit diagram used for measurement relative humidity in cold-storage process using LSI Technology. In this problem digital temperature transducers are adjusted to record 1°C as 1 binary digit on the output terminals of ADC-0800 (explained in 2.2 section) with an accuracy of 1°C by properly selecting the gains of NIA and sensitivity selectors. The cold-storage temperature variations are in the range of 0° to 31°C. A software is developed in FORTRAN-IV for computation of relative humidity values in the temperature range of 0°C to 31°C, by assuming constant air velocity in a given cold-storage process. The program for this is given in Appendix 5. The maximum temperature range that can be measured using these temperature transducers from -25°C to 100°C. In this problem transducers are adjusted to read only positive temperatures from 0°C to 255°C. But sensor is inefficient to measure above 100°C. Our requirement is in the range of 0°C to 31°C. Hence, in this problem first three MSB bits of ADCs (ADC-0800) shown in Fig.11, will be zeros always. Hence only first five bits of LSB of ADCs (ADC-0800) are used. In Fig.11, LSB five bits of ADC-0800(1) i.e., dry bulb temperature readings are given to MSB five bits (leaving first MSB-bit) of the memory chip Intel 2716, and LSB five bits of ADC-0800 (2) i.e., wet bulb temperature readings are given to LSB five bits of the memory chip Intel 2716. Thus

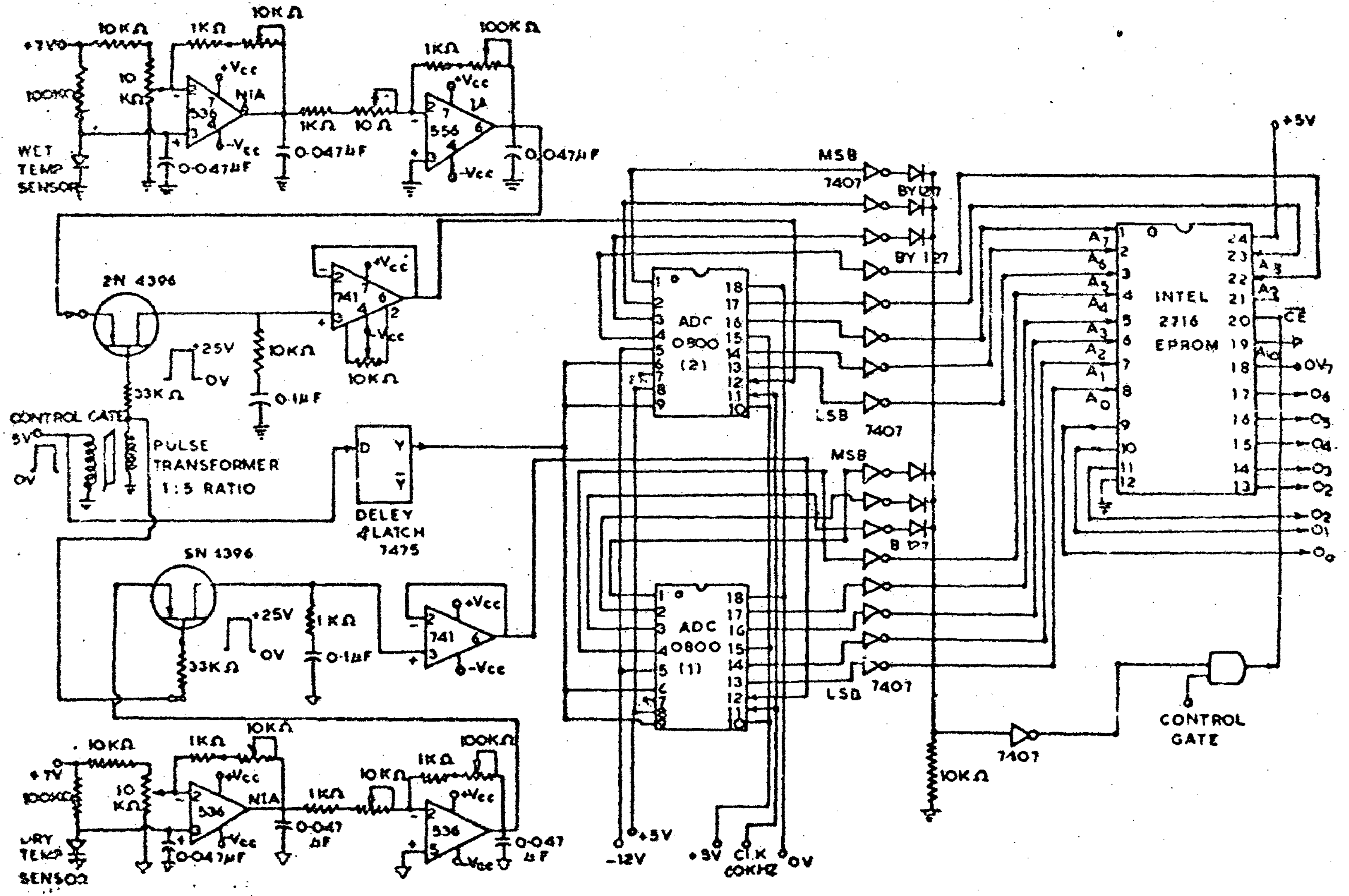


FIG.11. CIRCUIT DIAGRAM FOR HUMIDITY MEASUREMENT IN COLD-STORAGE PROCESS BASED ON LSI TECHNOLOGY.

combination of dry bulb and wet bulb temperatures will form the address of the memory chip Intel 2716. A combinational logic is build with MSB, three bits each ADC-0800 and given to the chip select signal of Intel 2716. So, the memory is selected only if the chip enable of 2716 is HIGH and also first three MSB bits of each ADC-0800 should be LOW. Each memory will contain relative humidity value corresponding to address location formed by dry bulb temperature and wet bulb temperature. The contents of memory location ie, relative humidity value and their corresponding wet bulb temperatures ie., memory address locations of 2716 are tabulated in table A.1, given under Appendix.5. The complete manual details of Intel 2716 EPROM are given in Appendix.6.[21]

In Fig.11, the chip enable signal is coming from SOC terminal of ADC-0800 (1) & (2), via a delay latch circuit. When the control pulses of S/H circuits are HIGH, the temperature equivalant analog voltages are hold at the capacitors C_7 and C_7'. These analog voltages are converted into binary form (ie., temperature directly in binary number) after t_d seconds delay. The ADC conversion will be completed within t_d seconds. Since the SOC is connected to chip select signal of Intel 2716 with a delay of t_d , the memory chip address will be selected only after the temperature data is stabilized on ADC output terminals, with a condition first three MSB bits of each ADC_s should be LOW. By keeping temperature sensors in cold-storage plant, by applying control gate pulse to S/H, the relative humidity values are measured from the output terminals of the memory Intel 2716.

The output terminals of Intel 2716, are fed to 8-bit binary to BCD convertor display circuit to display the humidity values on LED'8 in BCD form. 8-bit binary to BCD convertor display circuit details are given in Appendix.7[22].

Fig.12 shows the circuit diagram used for humidity control. The 8-bit output data of Intel 2716, is converted into analog equivalent voltage using of DAC-0800 . The details about DAC-0800 are given in Appendix.8[23]. Let the DAC has linear analog output of X volts/Binary digit. If the value of relative humidity is R (in binary), the analog output voltage of DAC-0800 is given by XR volts. ECIL Helical pot of 1 k ohms linear resistance of 1000 turns with dial counter is selected as a thumb wheel switch as shown in Fig.12. A constant potential is applied at terminal 'M', and the potentiometer P_5 is adjusted in such a way to 1P volts = XR volts, where P is set point and 1 is volts/digit. If the set point of relative humidity is P, the output of DAC-0800 is XR volts, then potential at terminal 'N' is given by (1P-XR) volts. If the relative humidity of the process value is equal to set value, the potential at the terminal 'N' becomes zero volts. The potential at terminal 'N' will become negative, if the set value is less than measured value and its converse is also true. The potential of terminal 'N' is given to a noninverting amplifier of gain $(1+R_8/R_9)$. The output voltage of NIA is fed to the schmitt trigger[14] make use of IC 741, having a gain of $(1+R_{16}/R_{15}) \sim 225$. If positive voltage is

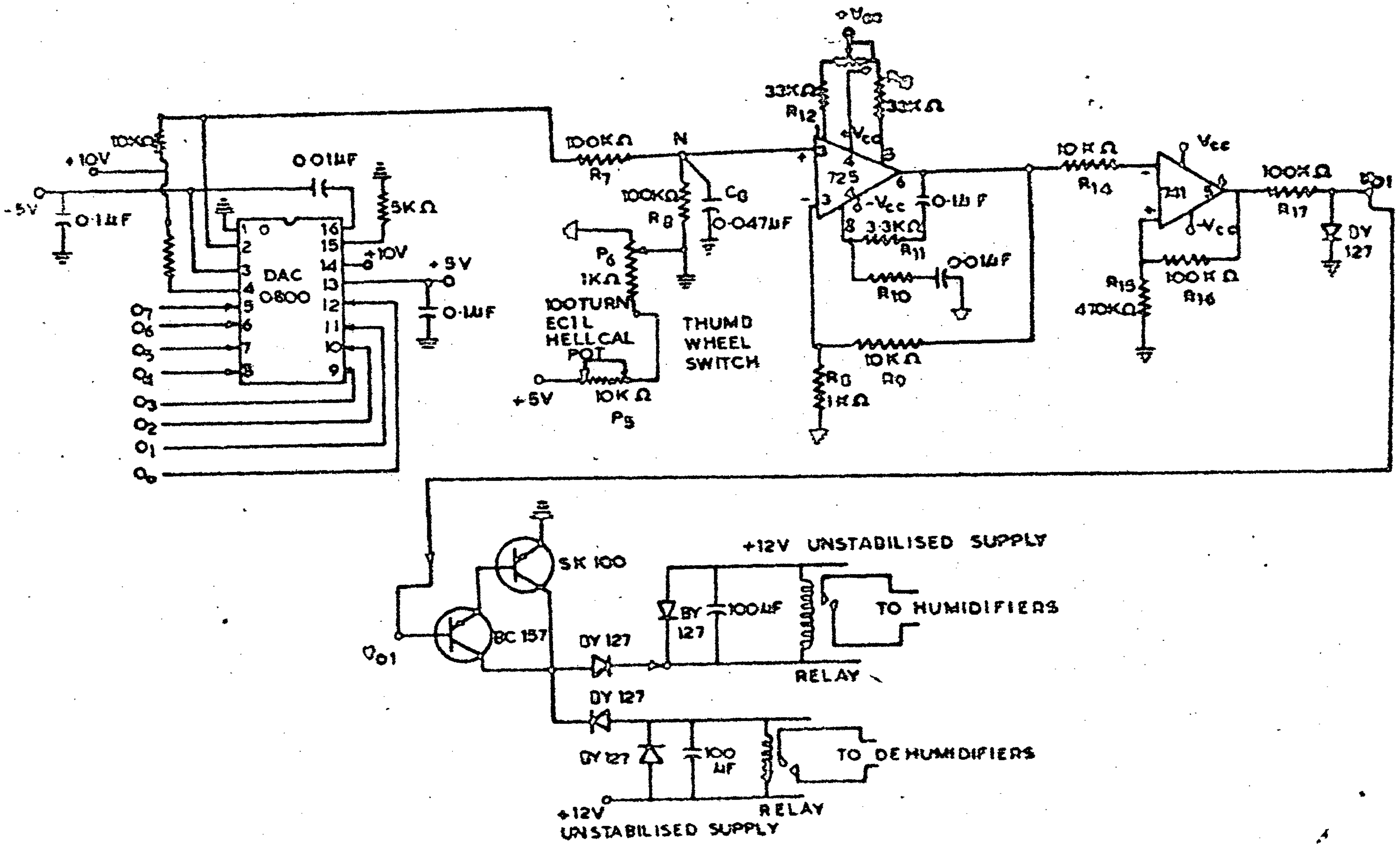


FIG.12. CIRCUIT DIAGRAM FOR HUMIDITY CONTROL

applied at input terminal of schmitt trigger it goes to positive saturation and drives current booster, relay circuit which inturn operates dehumidifiers in the process. Similarly if negative voltage is applied at the input terminal of the schmitt trigger, it goes to negative saturation which inturn drives the humidifiers in the process. In order to achieve perfect regulation two mode ON and OFF control is provided. This control system gives an accuracy of $\pm$0.5% in regulation of the relative humidity. Since, both these controllers

actuated in process are ON and OFF controllers, the rise and fall times are with in $\pm$ 5%. Since the variation in humidity is very slow, this system is well suited for cold-storage process control applications. The specification and wirings diagrams of humidifiers and dehumidifier used for this process are discussed in Appendix.3.

This method of relative humidity measurement and control achieves $\pm$ 1% of accuracy in measurement and $\pm$ 0.5% in control. The accuracy in measurement of humidity will be increased, by changing the sensitivity selector gain of the temperature transducer. At the same time the memory space will increase, causing increase of cost. The other way of improving accuracy is by changing ADC 8-bit to 16-bits or more and by increasing the memory space. Both ultimately lead increase of cost. The speed of operation of system is very high. For multi cabin cold-storage process, the number of memory chips required are increased, and at the same time cost increased and reliability is reduced. Hence, the advances in technology brought the existence microprocessor in multivariable system like cold-storage process control, textile applications etc..

CHAPTER-3

3. HUMIDITY MEASUREMENT USING MICROPROCESSOR INTEL 8085, HIL 2961 TRAINER

3.1 General introduction to HIL 2961,Microprocessor (Intel 8085) Trainer:

Microprocessor Trainer (24), HIL 2961, is used to enter program into its RAM, run them at full speed, or one instruction after another so that one can observe what happens after every instruction execution. The trainer is friendly to the operator in the sense that it warns the operator by a beep through a speaker when-ever he commit a mistake and does not destroy the programs entered by the operator. It is easy at any time to locate the fault in the program and correctly reenter the new information. The microprocessor trainer is also provided with facility to burn off the EPROM 2716 and to store information into it.

The memory map of the microprocessor trainer is shown in Fig.13. The address space assigned to the 2K ROM is 0000 to 07FF and that to RAM is 0800 to 0FFF. The whole of the ROM space is occupied by monitor program and a part of RAM space is also used by monitor program. The partial address map is shown in Fig.13,indicates clearly the space occupied by monitor program and the space available to the user to write his programs. It should be noted that not all the RAM space is available to the user program storage. Only the shaded address space (shown in FIG.13) of the map can be used by the operator to write his programs and execute them.

Now let us consider how HIL 2961 can be used to program EPROM Intel 2716. The manual details of 2716 are given in Appendix.6.[21] HIL 2961 does not provide the EPROM erasing facility. For this purpose, (i) make sure the program power switch at the rear panel is off (ii) place EPROM that has to be burnt on the EPROM socket at the top of the trainer chassis keeping in mind that pin 1 is placed next to the traingle marked on the chassis(iii) Enter the first 1k byte of data that have to be burnt into RAM locations 0C00 to 0FFF and varify using a trainer's key board. (iv) Enter the following data into RAM

Address	DATA	COMMENTS
0800	00	ROM start address LO
0801	00	ROM start address HI
0802	FF	ROM stop address LO
0803	03	ROM stop address HI
0804	00	RAM start address LO
0805	OC	RAM start address HI

(v) Now fetch the address 04F3 and execute. The display will read address 04F7 and data 2A. (vi) Now put on the programming power switch provided at the rare panel of the trainer. (vii) Press execution button. The data transfer from RAM location has begun. The operator can observe the output port of LED flicker and hear the speaker giving a cracking sound. After approximately 50 sec the data transfer is complete, the output LEDs stop flickering and the speaker stops buzzing. The address display will read 0534 and data E1. (viii) Put OFF the programming power. (ix) Enter using key board next 1k byte of data that has to be burned into the EPROM, into addresses 0C00 to 0FFF of RAM and verify. (x) Enter ROM start address and stop address and also RAM start address (just similar way of step iii). (xi) Repeat steps (v) to (viii) in sequence. (xii) Now the complete 2k location set the EPROM has been burnt.

3.2 Number Representation:

A convenient notation for representing real numbers is the floating point notation. A number expressed in this notation consisting of two parts- the mantissa and the exponent. For example, 13.2×10^{8}, $.0152 \times 10^{19}$, 1.91×10^{-29} are all in floating point notation, the mantissa for each of these numbers being 8, 19 and -29 respectively.

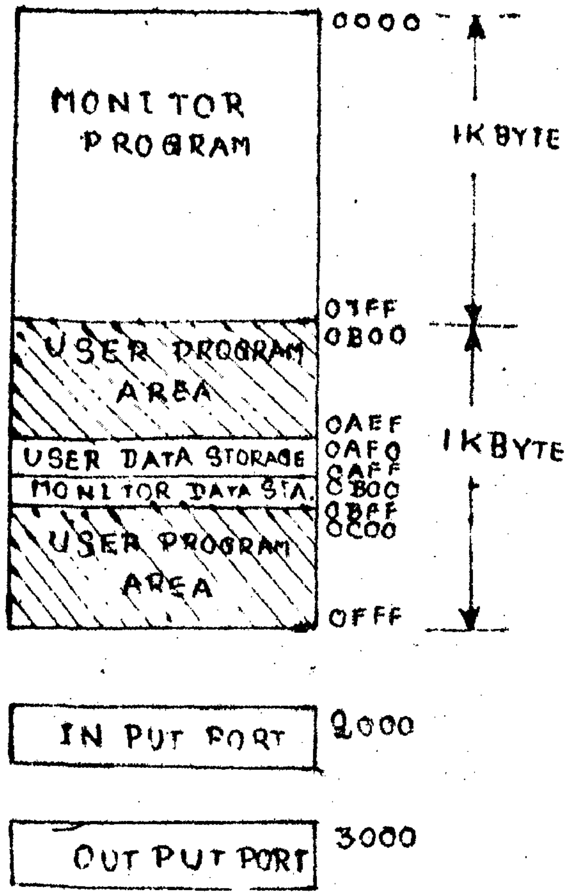
If the mantissa is between 0.1 and 1, the number is said to be in the normalized (or standard) floating point notation . The above mentioned three numbers may be expressed in normalized form as

$$13.2 \times 10^{8} = 0.132 \times 20^{10};\ 0.0152 \times 10^{19} = 0.152 \times 10^{18};$$

$$1.91 \times 10^{-29} = 0.191 \times 10^{-28}$$

In general, normalized floating point numbers are of the form $\underline{m} \times \underline{b}^{\underline{n}}$, where $\underline{m}$, the mantissa, satisfies the relation $1/\underline{b} < \underline{m} < 1$, $\underline{b}$ denoting the base of the number system, and $\underline{n}$ the exponent. A few binary floating point numbers, in normalized form, are

$$0.1101 \times 2^{12} \text{ and } 0.100 \times 2^{-10}$$



. 13 - MEMORY MAP OF HIL 2961 MICROPROCESSOR (INTEL 8085) TRAINER

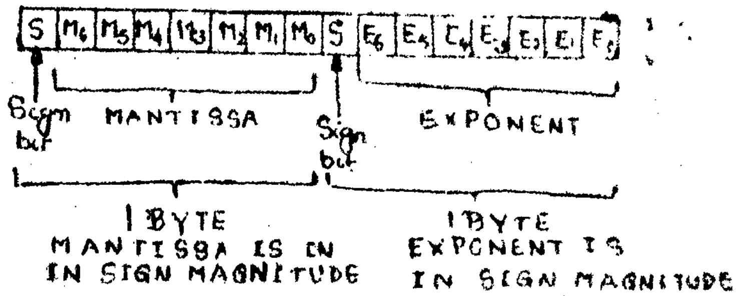
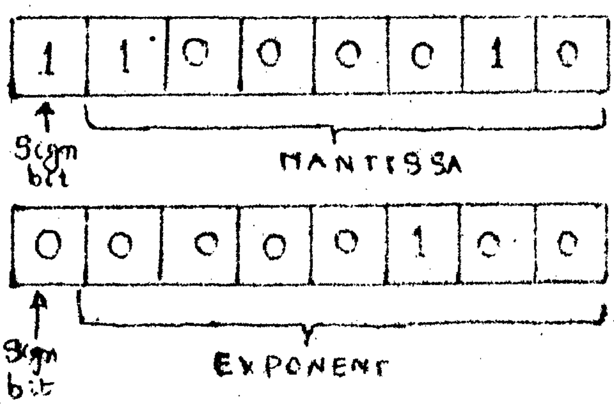


FIG.13.1 - NUMBER REPRESENTATION

EXAMPLE:

$x = -8.25 = -0.51725 \times 2^4$



However, 101.0 x 2^5 is not in the normalized form and neither is 0.001x2^7. To be in normalised form, a 1 must follow the binary point. Only in the case when the real number being expressed is 0.0 will this rule not hold.

Representation of Floating Point Numbers:

We shall assume for our discussion a particular fast arithmetic device. We shall call the format requirements of that device as the format requirement of our microprocessor, and shall represent real numbers in the memory according to this format.

We assume a device that accepts 8 bit numbers. Hence consider two BYTES, for floating point number representation. The way the floating point number is 'distributed' among these 16 bits is shown in Fig.13.1. Note that 16 bits is 2 bytes (8 bits per byte) of memory, and thus floating point numbers for a micro-processor which includes this device are stored in 2 consecutive bytes of memory.

Observe that the leftmost bit is used to indicate the sign of the mantissa, the next 7 bits are used for the mantissa and the last 8 bits for the biased exponent.

Let us understand what we mean by a biased exponent. We have seen, in some of the previous examples used to introduce floating point numbers, that exponents are negative when numbers are less than 1. One way of taking care of negative and positive values in the 8 bits reserved for the exponent would be to reserve one of the 8 bits as a sign bit and thus, in 8 bits, allow exponents to vary between -128 and +127.

Exponent and mantissa of a given number is represented in sign magnitude. An example is illustrated below the Fig. 13.1.

3.3 Soft-ware for humidity measurement:

Flow-charts for computation of relative humidity using microprocessor are given in this section. The details of memory allocation, assembly and machine languages are given in Appendix 10. The architecture, details and its instruction set of the microprocessor Intel 8085 are given in Appendix.9.[25]

The main program for computing relative humidity using microprocessor (Intel 8085) (HIL trainer 2961) contains nine subroutines; namely (i) Normalized form conversion, (ii) Normalized number multiplication, (iii) Normalized numbers division, (iv) Normalized numbers summation, (v) power of exponent calculation, (vi) Exponent value calculations (vii) Saturation pressure computation, (viii) Normalized form to integer conversion,(ix) Air velocity coefficient computation. For computation of relative humidity equations (1) to equations (4) are used.

(i) Subroutine for converting integer number to normalized form:

Using this subroutine any given integer number is converted into normalized form of binary. For this it is assumed integer numbers are in sign magnitude of 8-bit word. Its equivalent after conversion into normalized form (binary), is represented as 16-bit word in two registers. First register represents mantissa in sign magnitude and second register represents exponent in sign magnitude. Fig.14(a) represents its flow chart, Appendix. 10 contains its assembly language, machine language. This subroutine is named as 'FPCON'.

(ii) Subroutine for normalized numbers multiplication:

In this multipliers and multiplicants are represented in normalized form with 8-bits mantissa and 8-bits exponent in sign magnitude. Result of the product is represented as 16-bit mantissa and 8-bit exponent in sign magnitude. Hence, in order to take care of over-flow or under flow, the result of product exponent should not be greater than ± 127. Fig. 14.b represents the flow-chart, Appendix.10 contains assembly language and machine language. This subroutine is named as FPMUL'. Accuracy of 'FPMUL' is $1/2^7$ decimal digit.

(iii) Subroutine for normalized numbers division:

In this numerators and denominators are represented in normalized form with 8-bit mantissa and 8-bit exponent in sign magnitude. Result of the division is represented as 8-bit mantissa and 8-bits exponent in sign magnitude. In order to avoid over-flow or under-flow, the result of the division should not be greater than ± 127. Fig. 14.c. represents the flow-chart, Appendix.10 contains assembly language and machine language. This subroutine is named as'FPDIV'. Accuracy of 'FPDIV' is $1/2^7$ decimal digit.

(iv) Subroutine for summation of normalized numbers:

In this the two number to be added are represented in normalized form. It gives an accuracy $1/2^7$ decimal digit. Fig.14.d

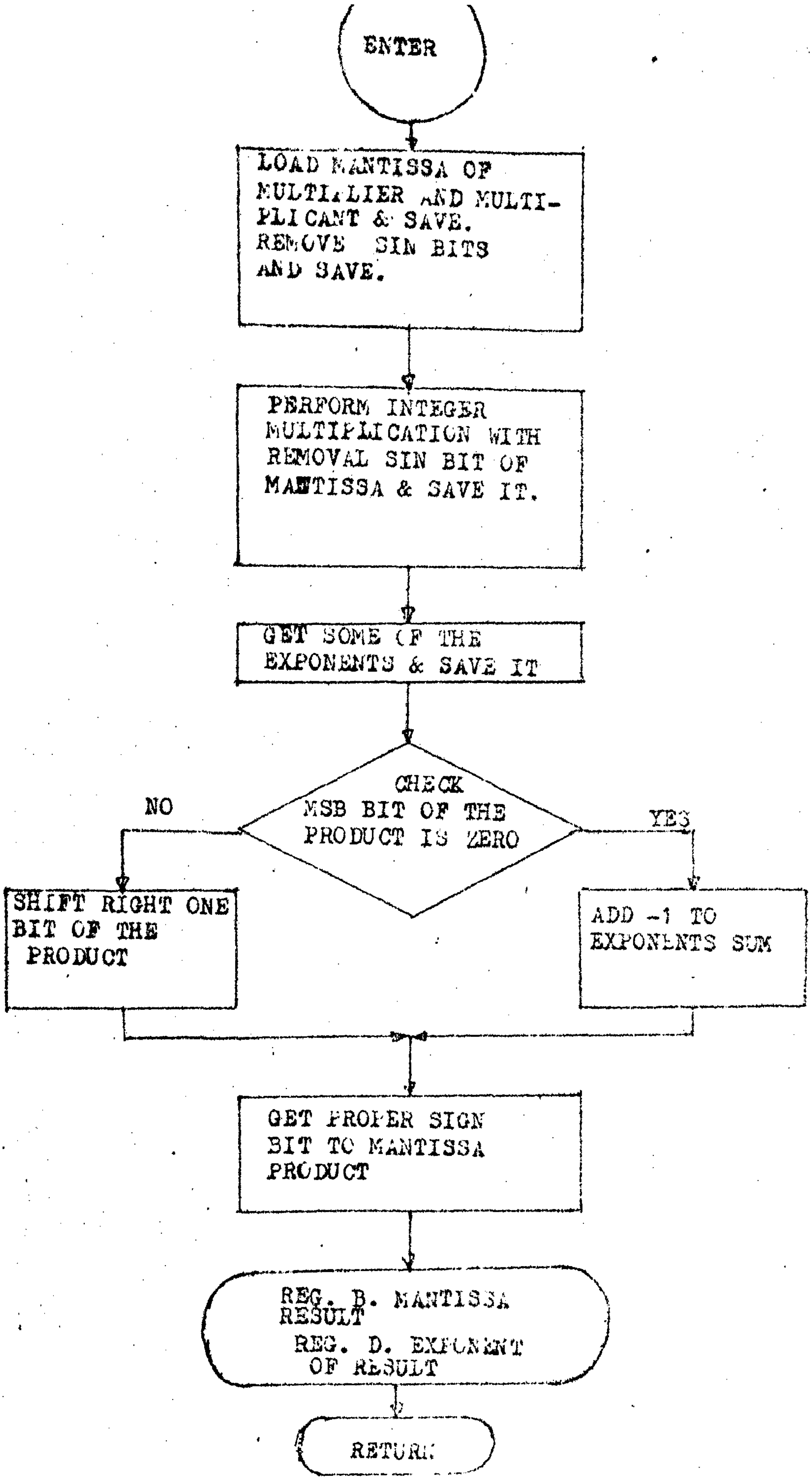


FIG. 14-B FLOW CHART OF 'FPMUL'

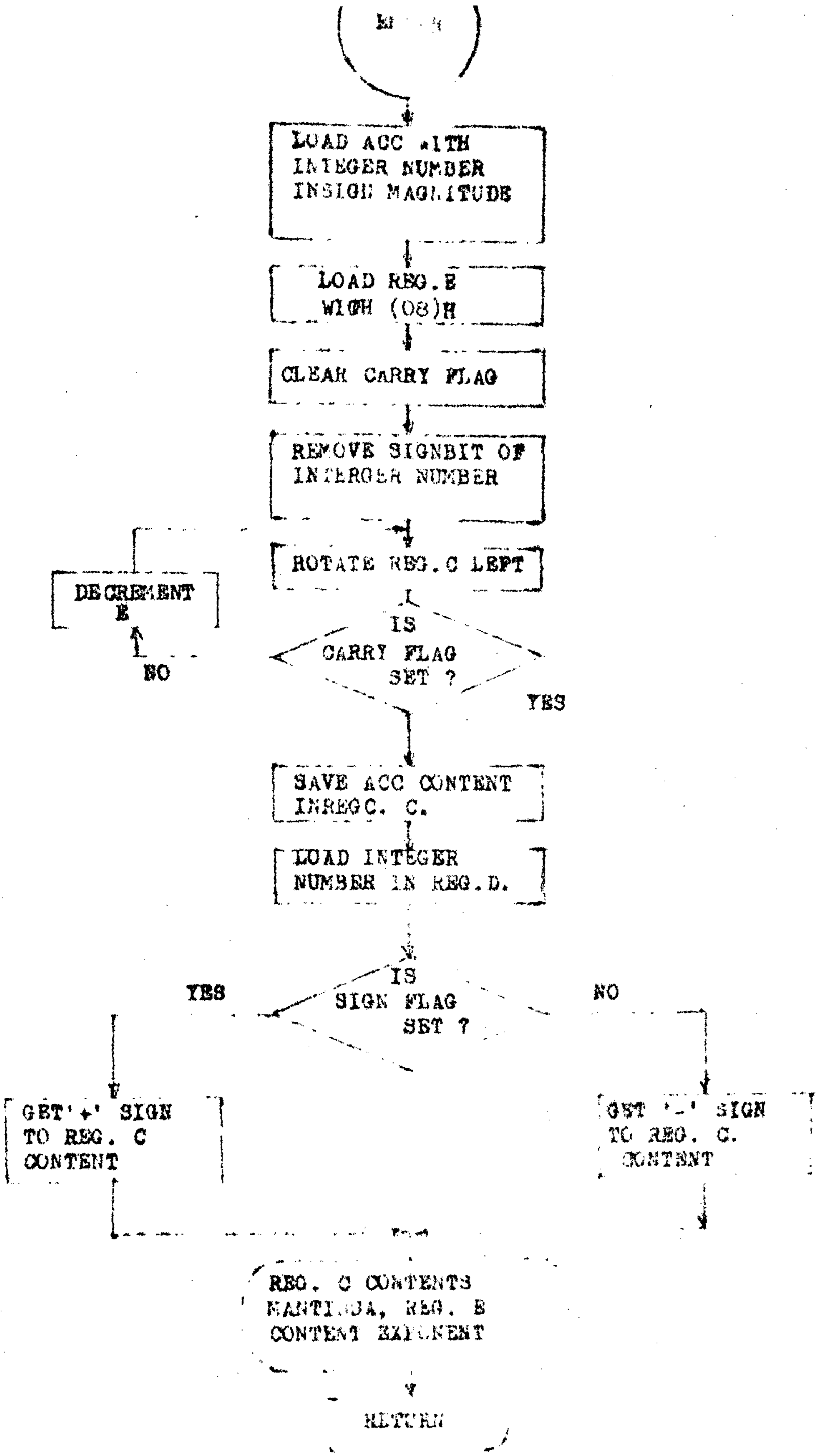


FIG. 14(a) - FLOW CHART OF 'FPCON'

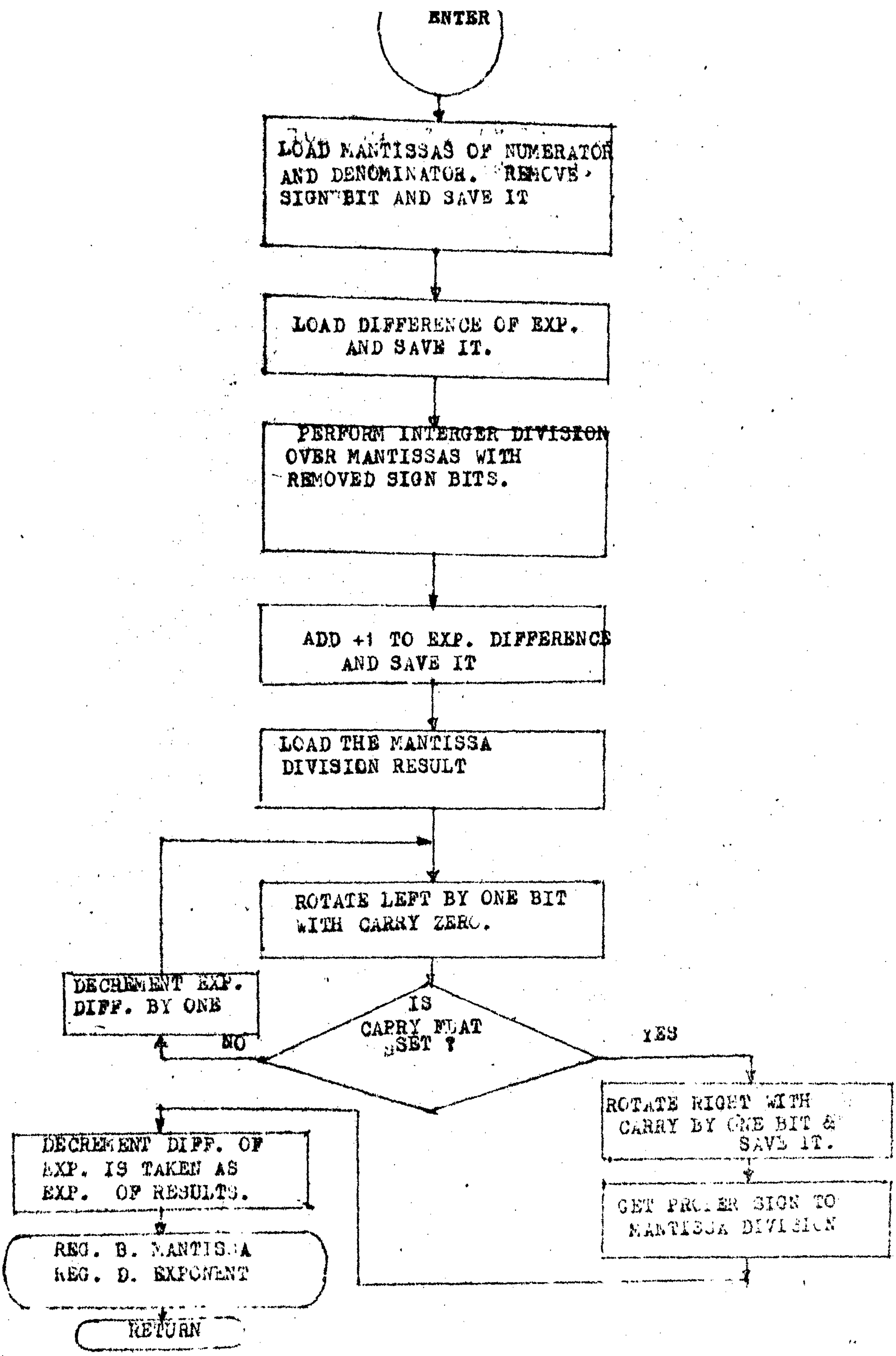


FIG. 14.c. - FLOW CHART FOR 'FPDIV'.

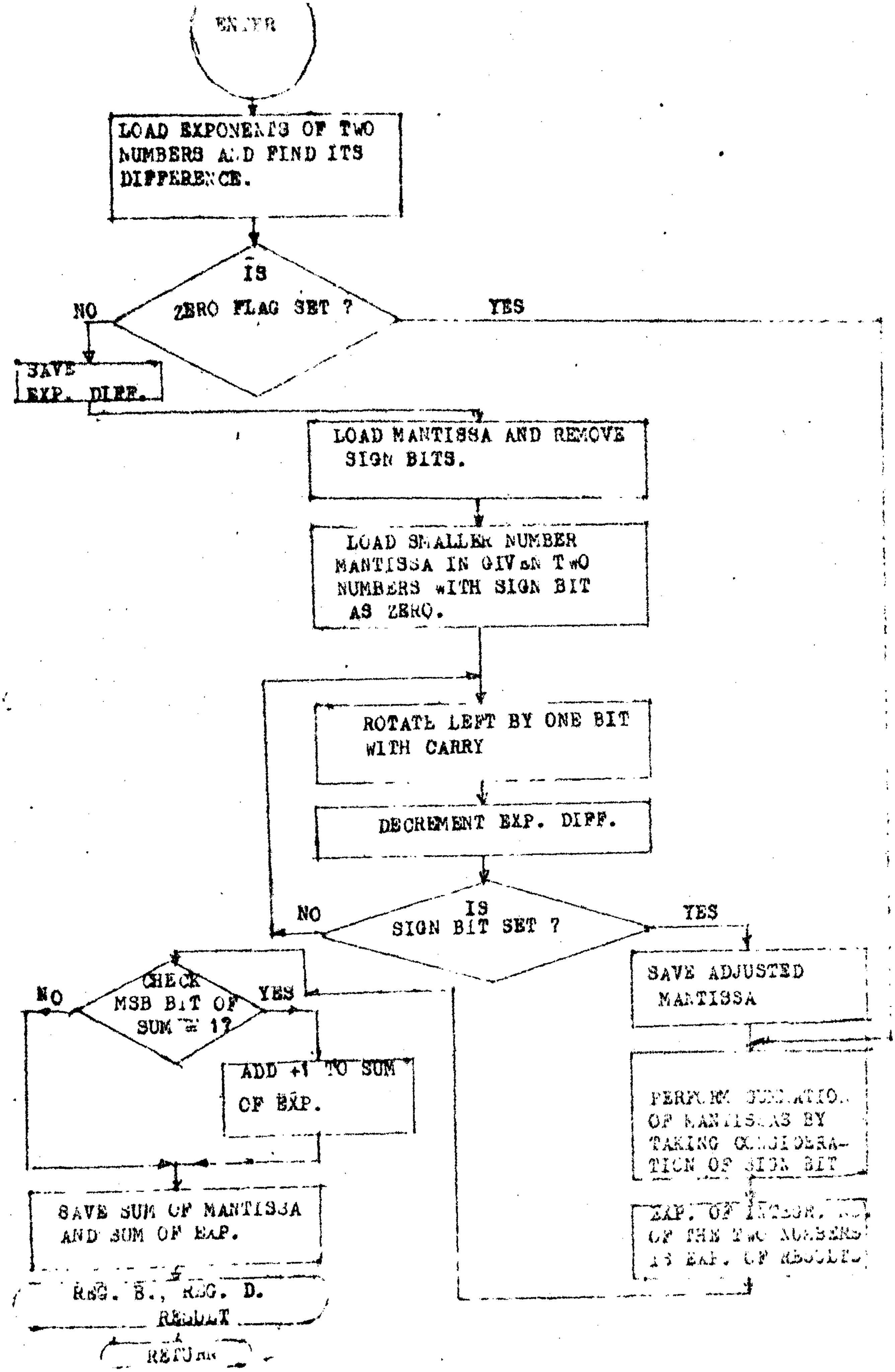


FIG. 14.d. – FLOW CHART FOR 'FP SUM'.

shows the flow-chart, Appendix.10 contains assembly language and machine language. This subroutine is named as 'FPSUM'.

(v) Subroutine for calculation of power of exponent value to compute saturation pressure:

This subroutine is useful to compute power of exponent value for calculation of saturation pressure. In this (ii) to (iv) subroutines are called wherever necessary for computation. This is developed to make easy to evaluate equation (1) on micro-processor Intel 8085, HIL Trainer 2961. Its flow-chart has shown in Fig.14.e. From equation (1) power of Exp =(P+(A+(B*TD))*(TD-Q)*(TD-Q)*(R/TD-1).

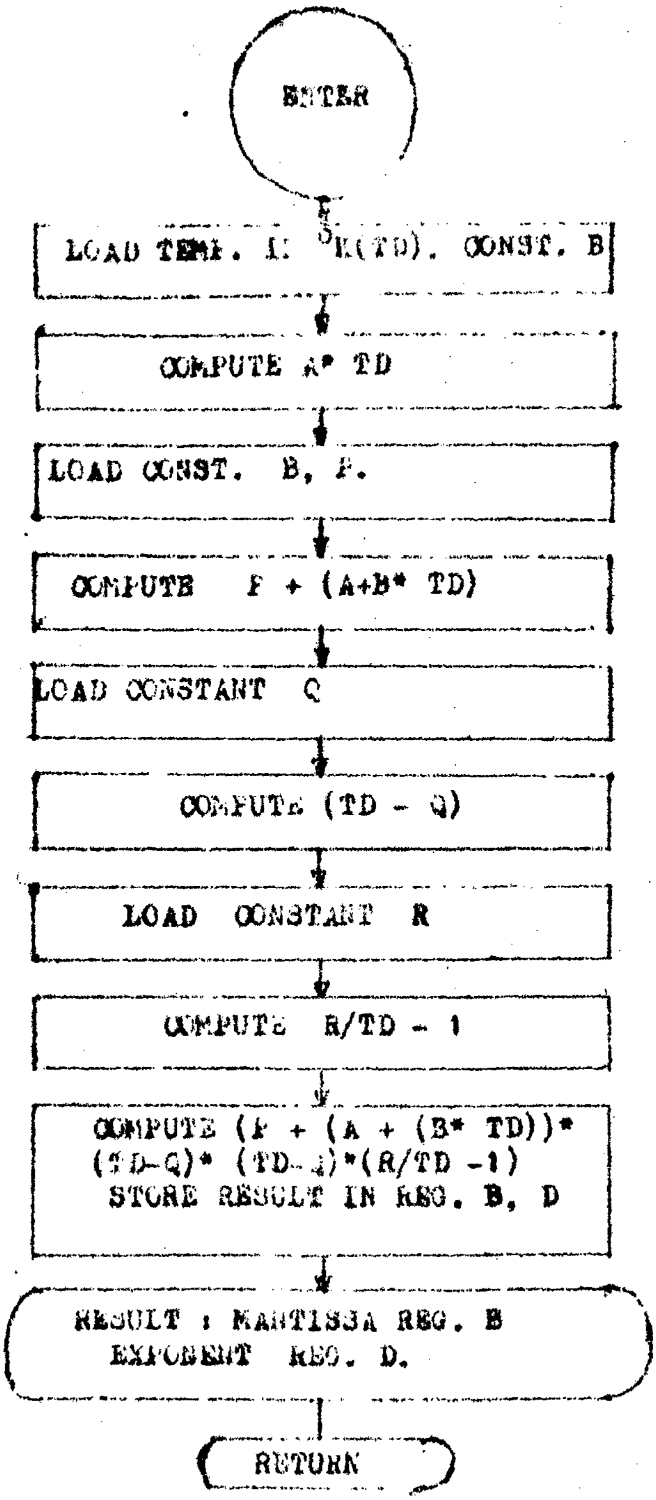
The details of all constants and variables are clearly specified in Appendix.10. Fig.14.e shows its flow-chart. It is precaution, argument should placed proper before calling subroutines in this subroutine named as 'POEXP'.

(vi) Subroutine for exponent value calculation:

In this problem power of exponent is varying from 7 to 10 with three decimal digits, accuracy. In this range exponent value can be computed using the following formulei:

$$e^x = 1 + x + \frac{x^2}{2} + \ldots + \frac{x^n}{n}$$

This formulae accuracy will depend upon the value of n. To achieve more accuracy we can select many terms in series. This subroutine is named as 'EXPVA', and its assembly language, machine languages are given in Appendix.10.



4.6. FLOW CHART 'POEXP'

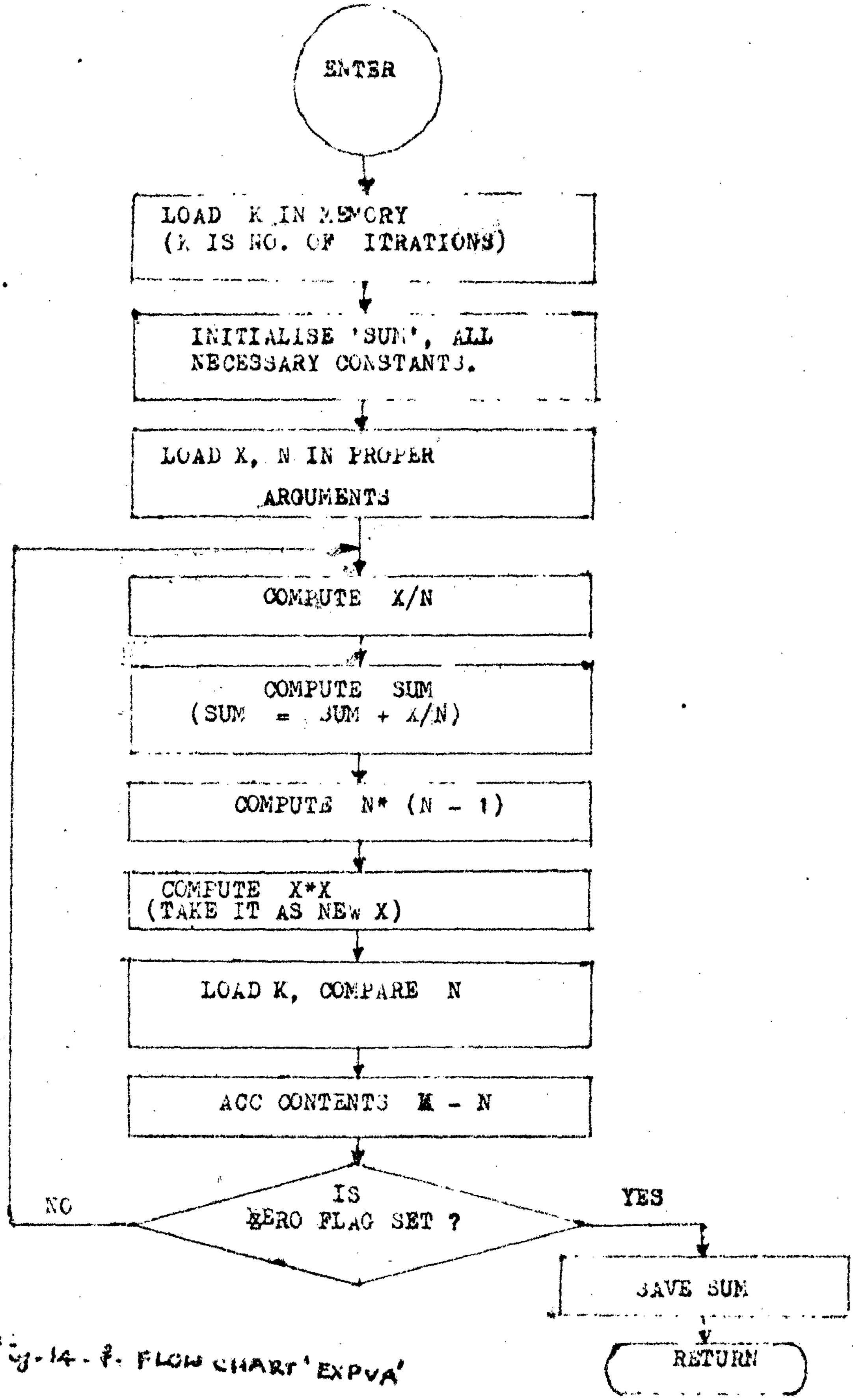


Fig. 14. 7. FLOW CHART 'EXPVA'

(vii) Subroutine for saturation pressure computation:

This subroutine computes saturation pressure of water vapour at a specified temperature in ^{o}C. It is named as 'SATPR'. Its flow-chart is shown in Fig.14.g, machine language and assembly language are given in Appendix.10. This computation is obtained by make use of equation (1) and its conversions.

(viii) Subroutine for Integer conversion from normalized form:

This subroutine is used to convert normalized number to integer form. For this normalized numbers should be represent in 8-bit mantissa in sign magnitude and exponent should also have sign bit as positive, ie., it is only useful for conversion of positive numbers in the range from 1 to 127 integer numbers, ie., exponent should not be greater than + 7 and should not be less than +0. It is named as 'INCON'. It's flow-chart is shown in Fig.14.h, machine language, and assembly languages are given in Appendix.10.

(ix) Subroutine for air velocity computation:

This subroutine is used for computation of air velocity coefficient. It is named as 'AIRVE', its flow-chart is shown in Fig.14.i, assembly language and machine languages are given in Appendix.10. It is computed from the equation (3).

MAIN PROGRAM:

This program is used to compute relative humidity value from equation (1) to (4), for a given dry bulbtemperature, wet

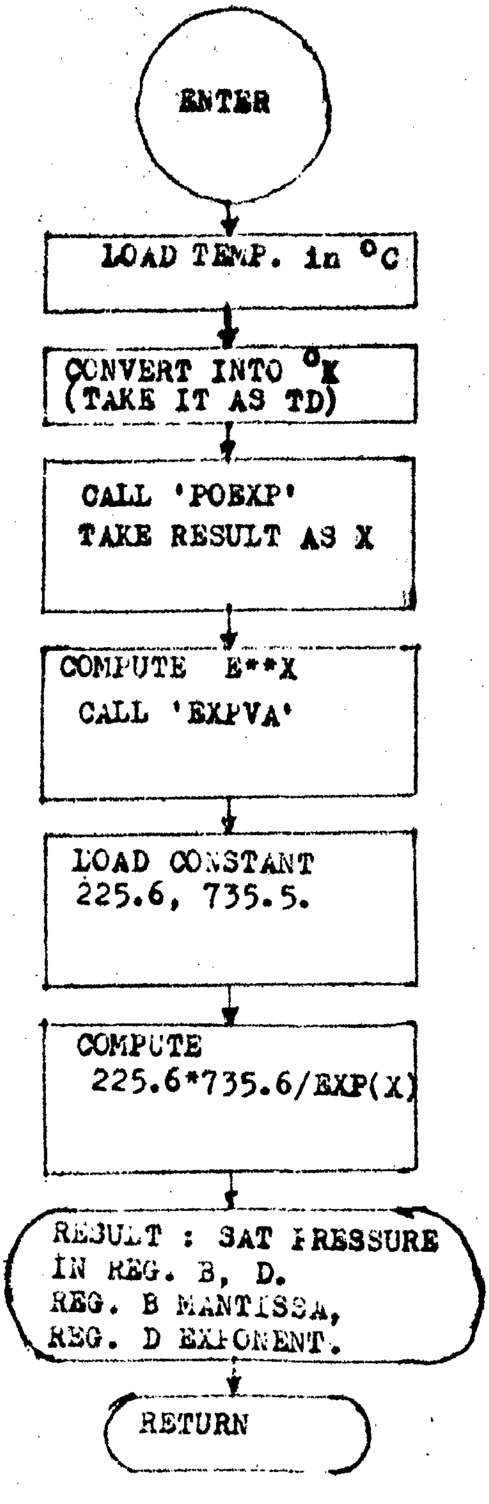


FIG. 14.g - FLOW CHART FOR 'SATPR'

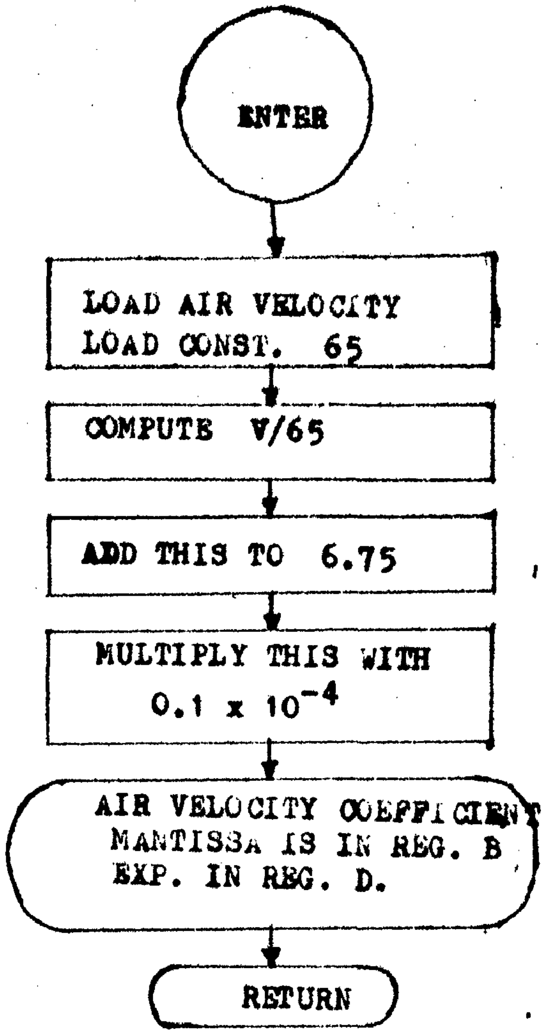


FIG. 14.f. FLOW CHART FOR 'AIRVE'

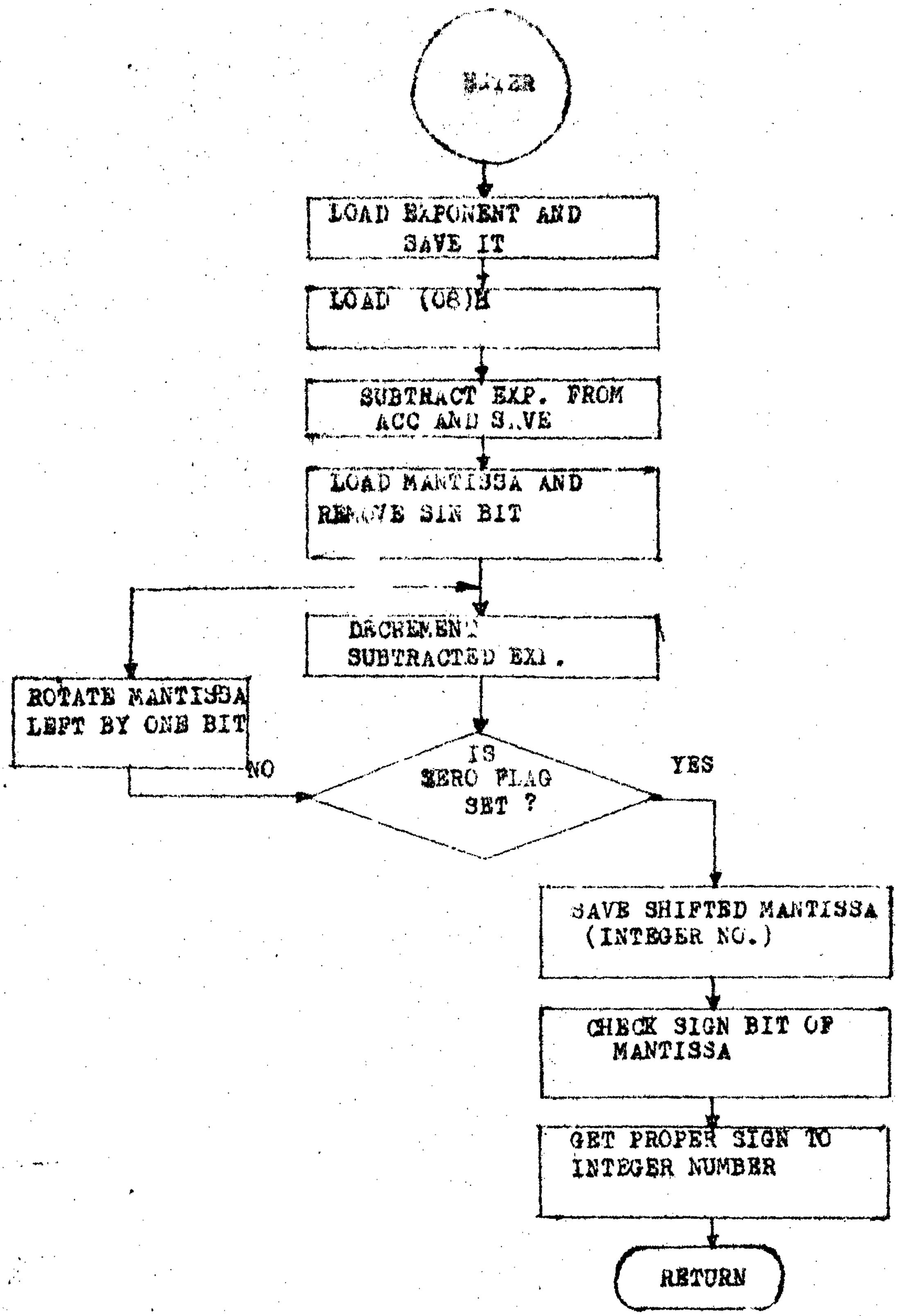


FIG. 14.h – FLOW CHART FOR ' INCON '

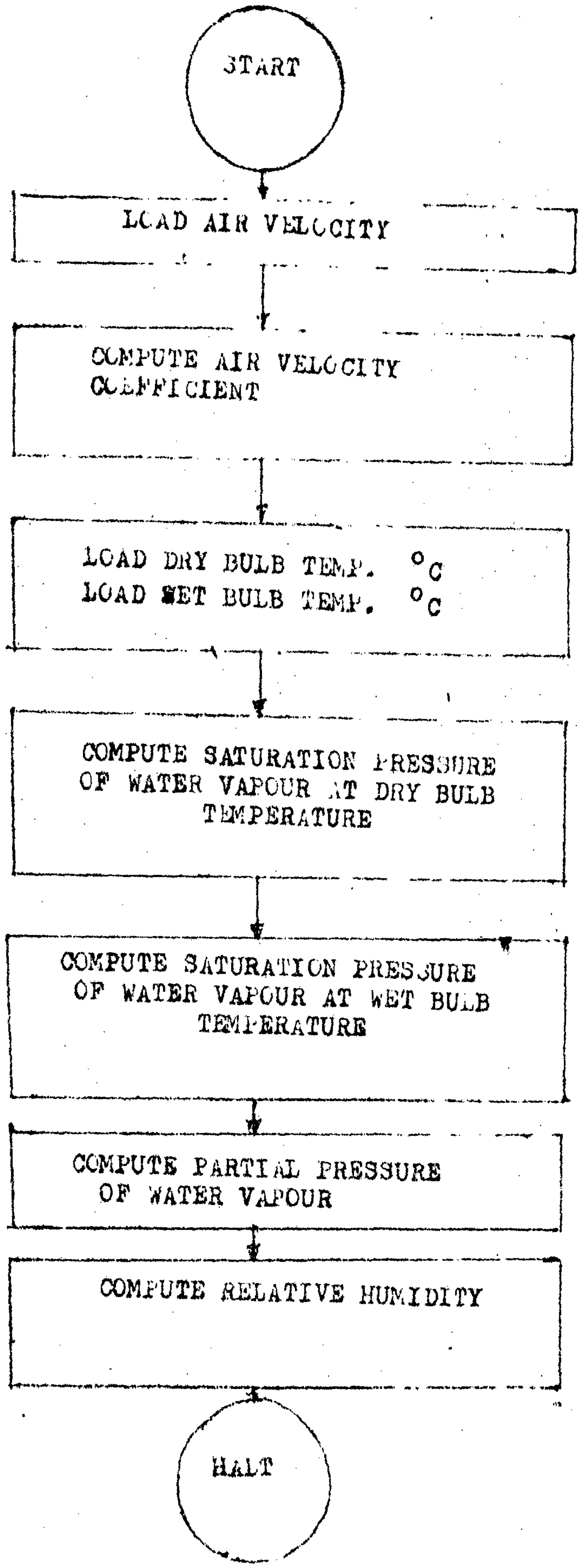


FIG. 14 - MAIN PROGRAM FOR COMPUTATION OF RELATIVE HUMIDITY

bulb temperature and and air velocity. Since the expotential values in calculation of these equation varies from 10^{-26} to 10^{28}, a special normalized form arithmetic has been developed in order to avoid over flow or under flow in computation of this value. At present, in this program it is assumed that dry temperatures, wet bulb temperatures and air velocities datas available in the memory locations of the microprocessor. Relative humidity value is available in one of the registers after completion of the computation. In the preceding chapter it is discussed how to input these variable to the microprocessor, output the computed results to display and to achieve control of different parameters. Fig.14.j shows the flow-chart of the main program, assembly language and machine language programs are given in Appendix.10.

3.4 Comparision of Microprocessor based humidity measurement with that of using LSI Technology:

In section 2.4 a method of humidity measurement using LSI technology has been described. In the previous section the same is achieved with microprocessor Intel 8085. The comparisions of these two methods are discussed below:

Humidity measurement using Intel 8085 microprocessor	Humidity measurement using LSI Technology.
1. Using this method a wide range of temperatures can be selected, using less than 1k-BYTE memory space.	1. For the same, it requires 64k bytes of memory space.
2. Accuracy is improved by improving the complexity of the soft-ware program.	2. Accuracy is less

(contd.)

3. It can be computed with different air velocities over wet bulb temperature.	3. Here air velocity should be assumed constant. And its affect is neglected. Hence accuracy will be reduced.
4. It reduces the hardware complications by taking least number of components.	4. It increases hardware complications.
5. Reliability increases.	5. Reliability reduces.
6. For multivariable systems, it reduces the cost. Of, course for single variable it is costly. For example, using this method 256 parameter can be regulated.	6. For multivariable processes it increases the cost.
7. The speed of operation is slow. But it is matched for cold-storage process application.	7. The speed of operation is very high.
8. Hardware can easily modified.	8. Hardware once developed it does not have expandability.

From the above discussions, for a cold-storage process of multivariable system, it is suggested to select microprocessor in this area. To develope instrumentation systems at laboratory level, it has been considered for a single cabin cold-storage plant. But in actual practice, it consists of many rooms which are to be regulated at different humidities and temperatures. So, to reduce complexity of this system, it is essential to provide automation using microprocessors to increase the performance of operation, reliability, productivity, quality control and to reduce cost. The next chapter presents the external hardware selection and slightly modified software (developed in this chapter) to provide wide flexibility to interface input, output devices for measurement and control applications.

CHAPTER-4

4. DEVELOPMENT OF MICROPROCESSOR CONTROLLER FOR COLD-STORAGE PROCESS

4.1 Introduction:

Since the advent of the microprocessor in 1971 its application domain has been continuously expanding. One of the applications of the areas of microprocessor is process control. In a typical process control application, the microprocessor continuously monitors one or more process variables, performs the suitable computations on these to generate control variable values and outputs to the electromechanical elements which in turn control the process variables is known as closed loop control. The microprocessor outputs the control variables to human operator via displays, which inturn apply the necessary control inputs, then control the strategy is known as open loop control. In chapter-3, it has been discussed how to use microprocessor (Intel 8085), HIL Trainer 2961 for computation of the relative humidity values by assuming the necessary input processes variables stored in the memory of the microprocessor. This chapter presents the interface circuits to input the process variables namely dry bulb temperature, wet bulb temperature and air velocity; to output the process variables namely relative humidity, wet bulb temperature and dry bulb temperature; and it also includes closed loop control circuit for controlling relative humidity and temperature in a given single cabin cold-storage process. Once the system has been developed for a single cabin cold-storage process control application, it can be easily extended by incorporating the similar circuits and controllers with little modifications of its soft-ware.

To reduce the complexity of the software and complications in development of hardware at the time of repair, it is suggested to provide individual channels, displays to monitor the each process variable at its cost. In such cases, the trouble shooted at one channel will not affect the other channel at the time of repair. This type of instrumentation system is very useful for cold-storage (multi-contains) process control applications.

4.2 Over all system design:

The complete system can be decomposed into three distinct subsystems:

i. Processor and memory subsystem.
ii. Input subsystem
iii. Output subsystem

It is decided to use the Intel 8085 microprocessor as the controller processor. To design input and output subsystems, it is decided to select the Intel 8155 RAM chips. The Intel 8155 is a programmable peripheral interface provided with three I/O ports and a timer. The complete details of Intel 8155-RAM are presented in Appendix.11.[26]

The input subsystem:

In order to satisfy the design requirements, the following variables should be fed to the microprocessor:

(i) Dry bulb temperature,

(ii) Wet bulb temperature,

(iii) Air velocity in the surroundings of the wet bulb thermometer,

(iv) Set limits of the air temperature and relative humidity.

The input process variables dry bulb temperature, wet bulb temperature, air velocity in the surroundings of the wet bulb thermometer are converted to an analog voltage by means of suitable transducers and these transducers outputs applied to ADCs. The output of ADC may be read by the microprocessor when it is desired. In this the provision to interface (the process variable) air velocity is provided and its transducer part is ignored, a constant value has taken for it from the memory location for computations. There are several ways to provide the set limits. In this, thumb wheel switch are selected to provide set limit for air temperature and relative humidity values. The thumb wheel switch produces an analog voltage proportional to its set value and this voltage is applied to ADC to give the set value in binary form on the output terminals of ADC. The output ADCs may be read by microprocessor, when desired.

Output subsystem:

In order to satisfy the design requirements, the microprocessor should output the following variables:

(i) Relative humidity value of the process,

(ii) Dry bulb temperature,

(iii) Wet bulb temperature,

(iv) Error signal of the air temperature,

(v) Error signal of the relative humidity,

The relative humidity, wet bulb temperature, dry bulb temperature and error signals values are displayed on the operator pannel board. So that operator can have the cross check on the displayed values with the help of set limit values of the thumb wheel switches. For example, let the set limit value is 80% on thumb wheel switch dial, the process monitor value of the relative humidity is 90%, then the error signal must monitor +10% on its error display. In this at low cost, individual displays are provided to cross checkover the monitored values to the operator.

Timers:

The timer (available with 8155) is used to provide delay of 15 sec, whenever the error signals are given by the processors.

The output ports, which corresponds to error signals are given to DAC-0800 to convert these error signals to equivalent analog voltages. These analog voltages are given to amplifiers, current booster and to relay circuits which inturn drive final control elements in the process to increase or decrease its affect depending upon the values of error signals.

The complete block of microprocessor controller for cold-storage process is given in Fig.15.

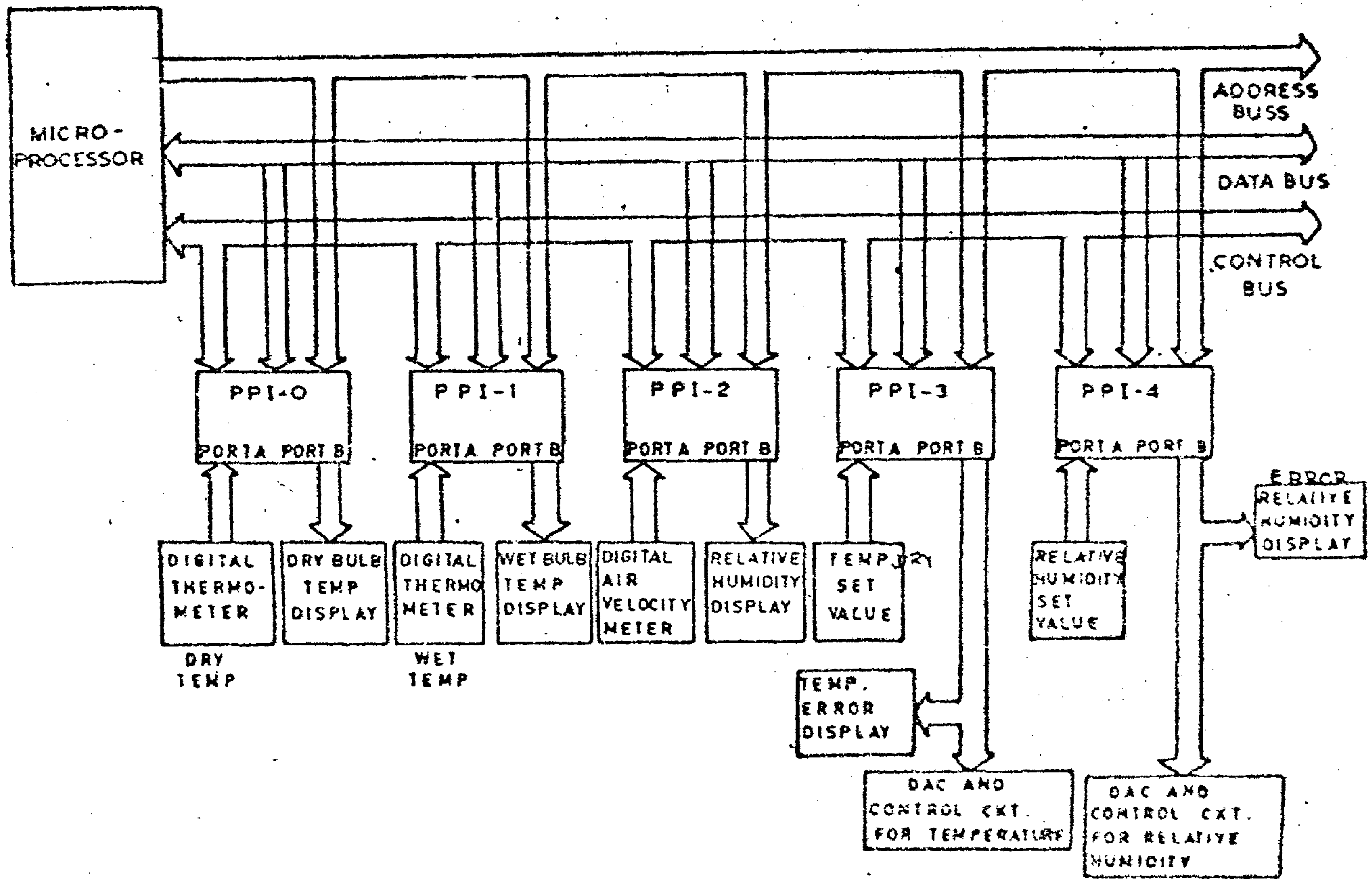
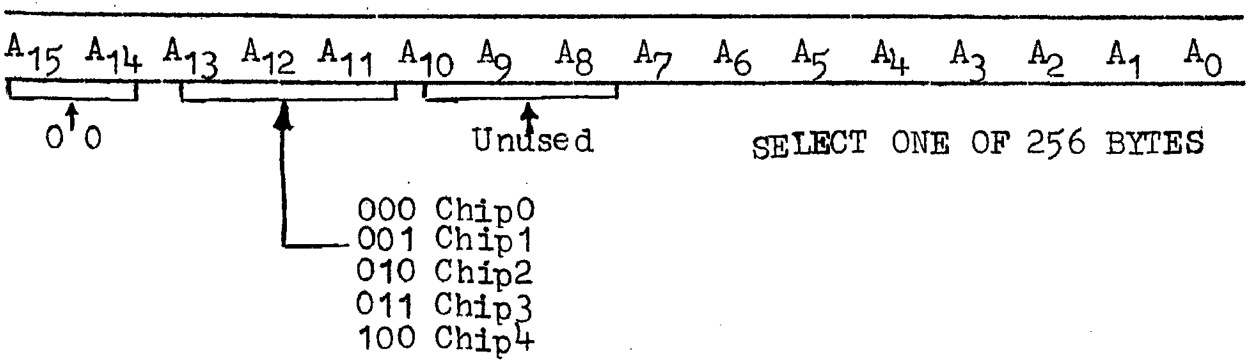


FIG. 15 BLOCK DIAGRAM OF MICROPROCESSOR CONTROLLER FOR COLD STORAGE PROCESS INSTRUMENTATION

4.3 Hardware design:

Let us begin the detailed hardware of the system. To begin with the designer has assumed that he does not require more than (1280x8) words of RAM or 1¼k BYTE RAM. Since this problem is involved with slight modifications of software developed in chapter.3, the designer has assumed it does not require more than 1¼k BYTE RAM. Thus, a total of five 8155 RAMs are selected to provide the required memory space. These five chips may be assigned the addresses as shown in table.1. These chips have been selected by the address bits A_{11}, A_{12} and A_{13}. This assignment is shown below:



Address assignment for RAM, I/O ports and timers.

With this assignment, the chip select signals can be generated using an 8205 decoder[26] as shown in Fig.16, Note that A_{15} and A_{14} must be 00 in order that the decoder be enabled. This reduces the number of multiple addresses per byte.

TABIE:1

8155 RAM Chip Address Assignment

Chip No.	RAM/ I/O port Portion	Address(es) (Hex)
0	RAM	0000-00FF
0	C/S-Register	0000
0	Port A	0100
0	Port B	0200
0	Port C	0300
0	Timer	0400 & 0500
1	RAM	0800-08FF
1	C/S-Register	0800
1	Port A	0900
1	Port B	0A00
1	Port C	0B00
1	Timer	0C00 & 0D00
2	RAM	1000-10FF
2	C/S-Register	1000
2	Port A	1100
2	Port B	1200
2	Port C	1300
2	Timer	1400 & 1500
3	RAM	1800-18FF
3	C/S-Register	1800
3	Port A	1900
3	Port B	1A00
3	Port C	1B00
3	Timer	1C00 & 1D00
4	RAM	2000-20FF
4	C/S-Register	2000
4	Port A	2100
4	Port B	2200
4	Port C	2300
4	Timer	2400 & 2500

Input/Output subsystem design:

To input and output data from the process variables (digital signals) to the microprocessor and to the monitor system, the ports available in 8155 are used. Table.2 shows the list of all ports assignment. The timer of chip-0 has been used to provide 15 seconds delay whenever the microprocessor outputs the error signals to the controllers in a given process. Fig.18 shows the design of I/O subsystem.

TABLE:2

Port Assignment

Chip No.	Port No	Input or output	Function
0	Port A	Input	Dry bulb temperature input port
0	Port B	Output	Dry bulb temperature display
0	PC 0	Interrupt Port A (to S/H ckt)	To input Dry bulb temperature
1	Port A	Input	Wet bulb temperature input
1	Port B	Output	Wet bulb temperature display
1	PCO	Interrupt port A (to S/H ckt.)	To input wet bulb temperature
2	Port A	Input	Air velocity input port
2	Port B	Output mode	Relative humidity display
2	PCO	Interrupt port A(to S/H Ckt.)	To input Air velocity
3	Port A	Input	Temperature set value input
3	Port B	Output	Temperature error signal output to display DAC
3	PCO	Interrupt port A	To input set limit of Air temperature (S/H ckt.)
3	PB_7	Output	To control ckt of S/H
4	Port A	Input	Relative humidity set value input
4	Port B	Output	Relative humidity error signed to output to display & DAC
4	PCO	Interrupt port A	To input set limit of the relative humidity.
4	PB_7	Output mode	To control ckt S/H control gate pulse
0	Timer-1		To provide 15 sec delay

In Fig.16 shows (as its part) the pin connections of chip-0,RAM 8155. On the similar lines all other are connected to their respective I/O devices as assigned in table.2.

The complete circuit diagram of over all system is shown in Fig.16.

Timer Outputs:

The timer-in pulse of RAM 8155 chip-0 may be connected to the clock output of the 8085. The timer out of chip-0 is connected to RST 5.5, via an invertor 7407. Recall that RST 5.5 is a high level sensitive interrupt that forces the microprocessor to branch to location (5.5 x 8). Fig.16 gives the over all view of the hardware design for cold-storage process control application. How to develope software for it is described [redacted] in section 4.4.

4.3.1 Hardware circuit description:

The complete circuit diagram of microprocessor based cold-storage process instrumentation and control is shown in Fig.16.

Temperature measurement: From the discussion so for made, it is evident that for measurement of temperature; this process consists of two temperature measuring devices; namely Dry Bulb Digital Thermometer and Wet Bulb Digital Thermometer. The circuit diagrams of these thermometers are shown in Fig.16(a) & 16 (b). These two circuits are identical and their descriptions are presented in chapter-2. The only difference is that wet bulb thermometer sensor probe consists a cotton wick of 2.5 cms diameter. The detail description of mounting procedure is also given in section 2.3.

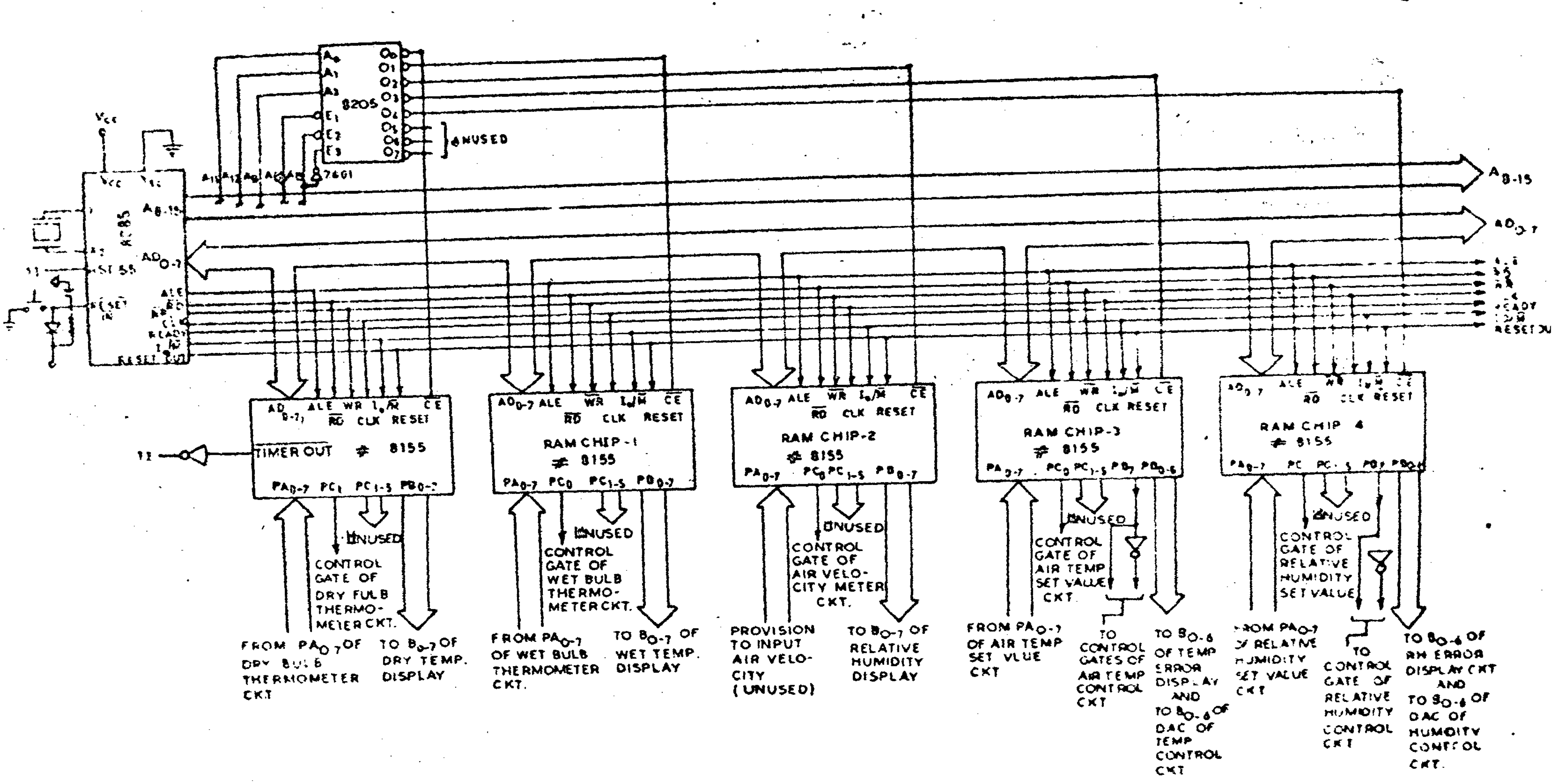


FIG. 16 COMPLETE CIRCUIT DIAGRAM OF MICRO PROCESSOR BASED COLD-STORAGE PROCESS INSTRUMENTATION CONTROL

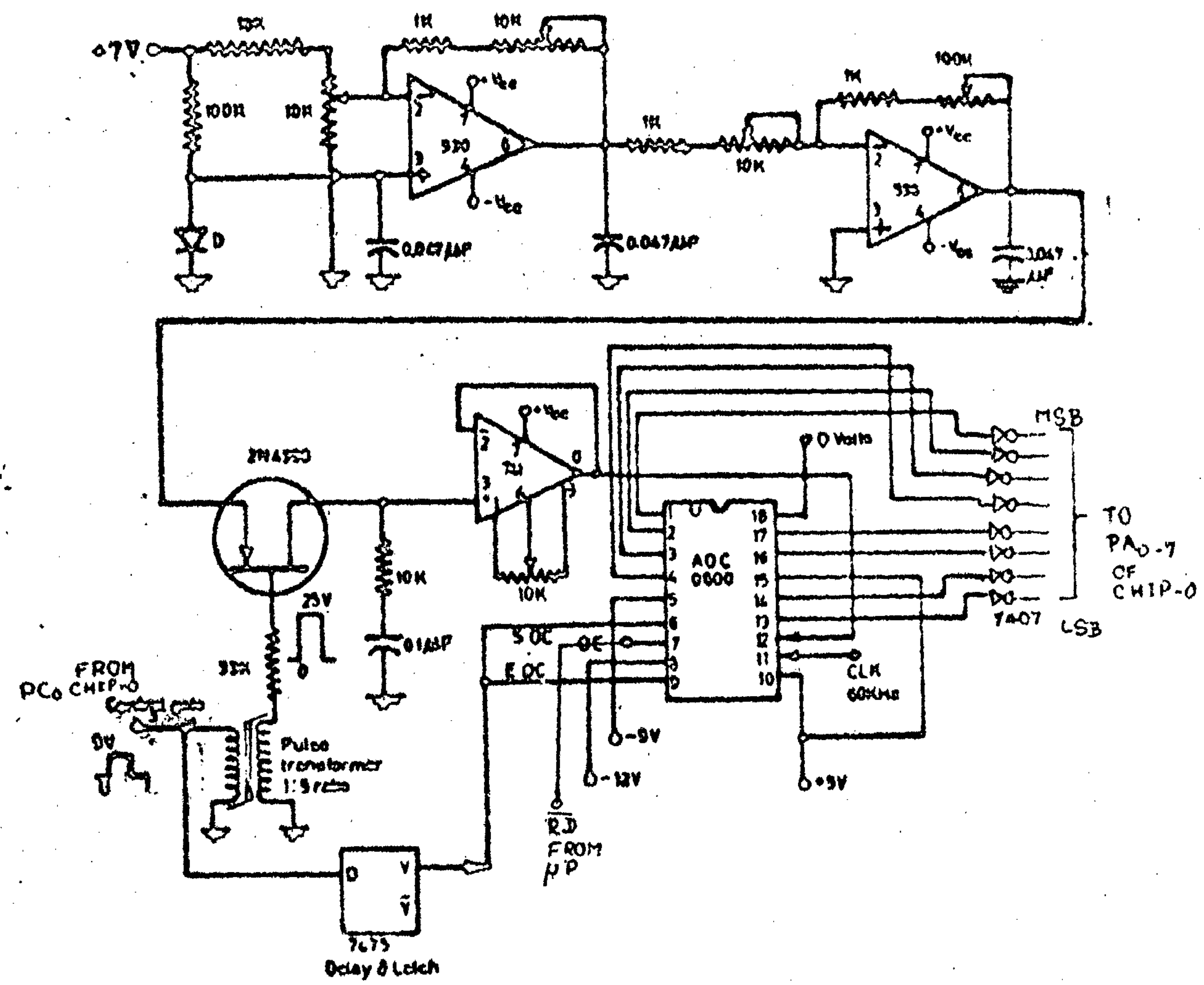


Fig. 16(a) - Circuit diagram for Dry Bulb Temperature Measurement.

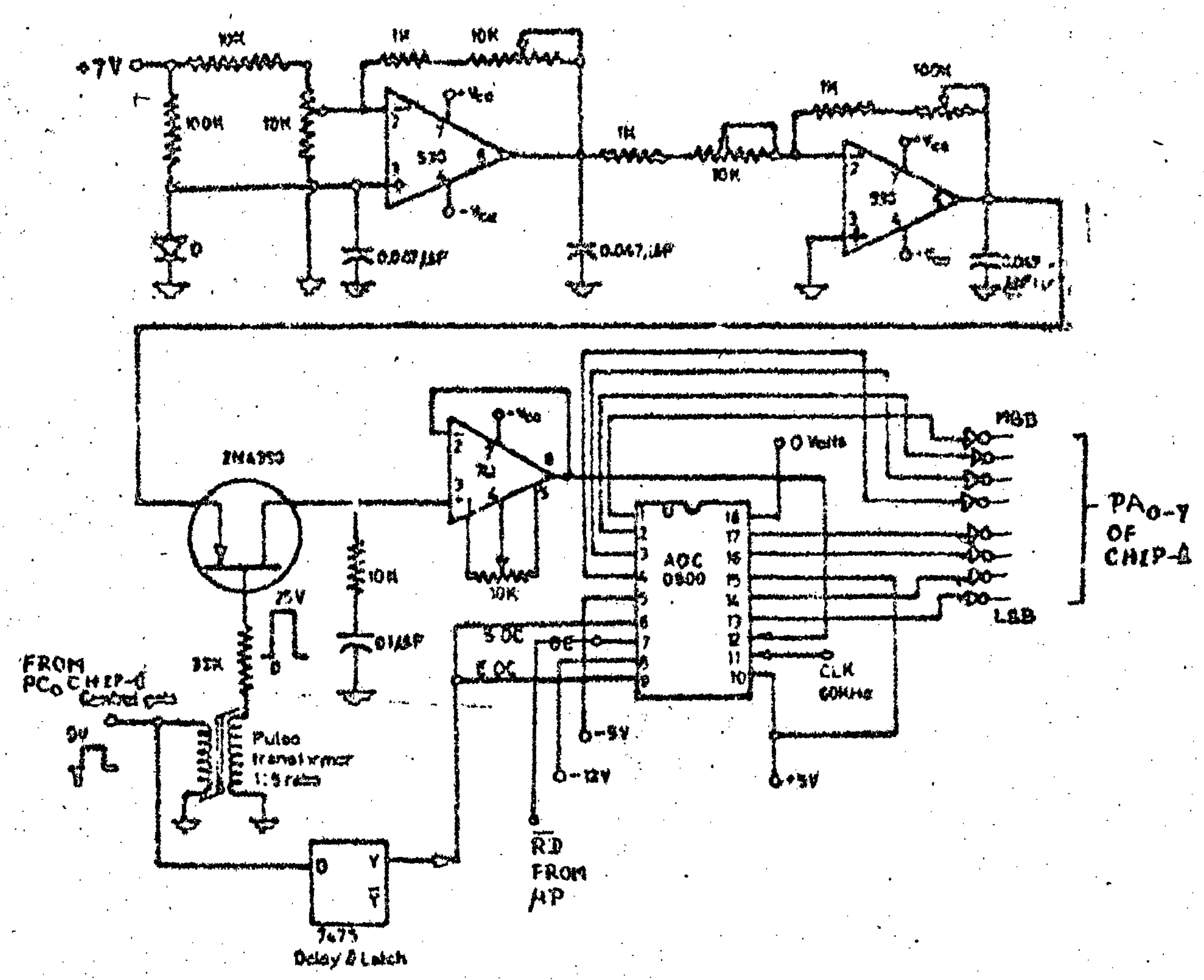


Fig. 16(b) - Circuit diagram forw wet bulb temperature measurement.

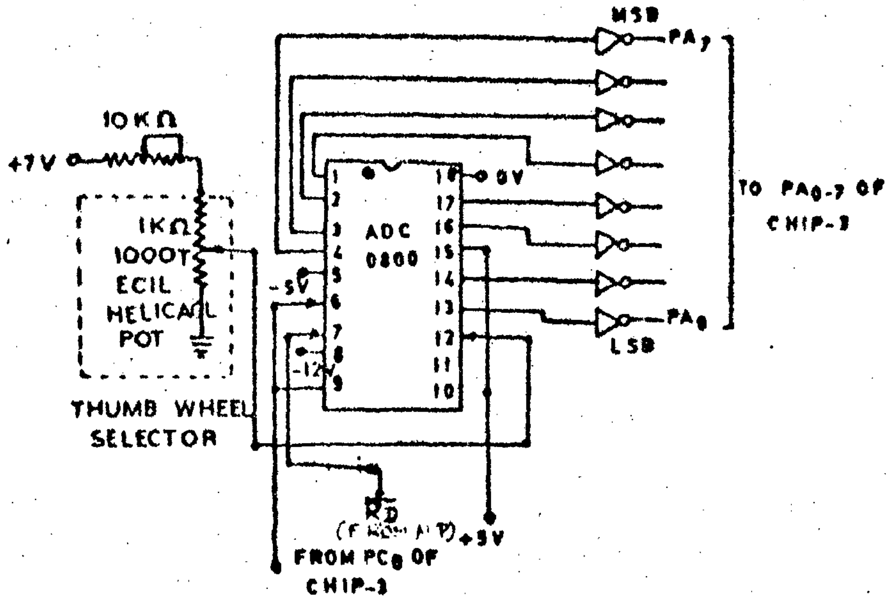


FIG.16(c) CIRCUIT DIAGRAM FOR SET VALUE AIR TEMPERATURE

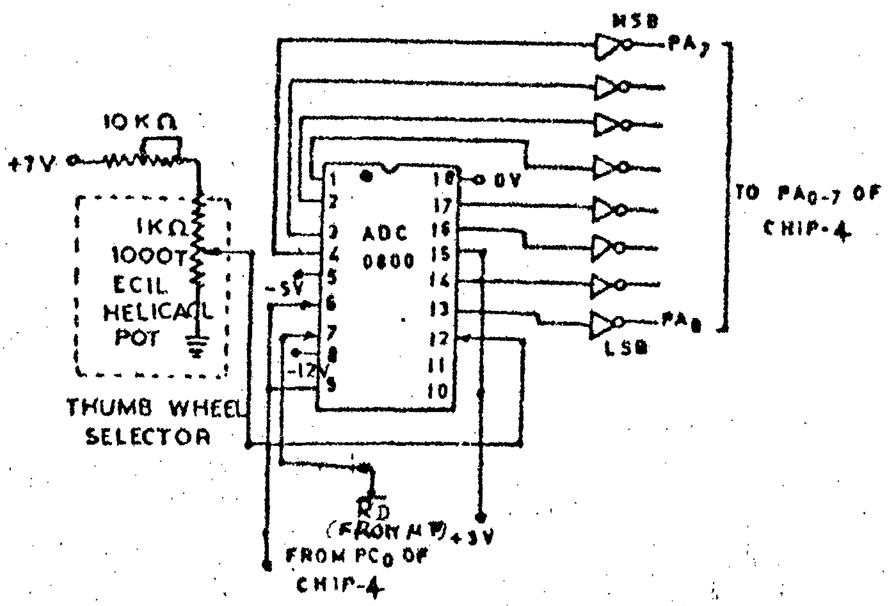


FIG.16 (d) CIRCUIT DIAGRAM FOR SET VALUE OF RELATIVE HUMIDITY.

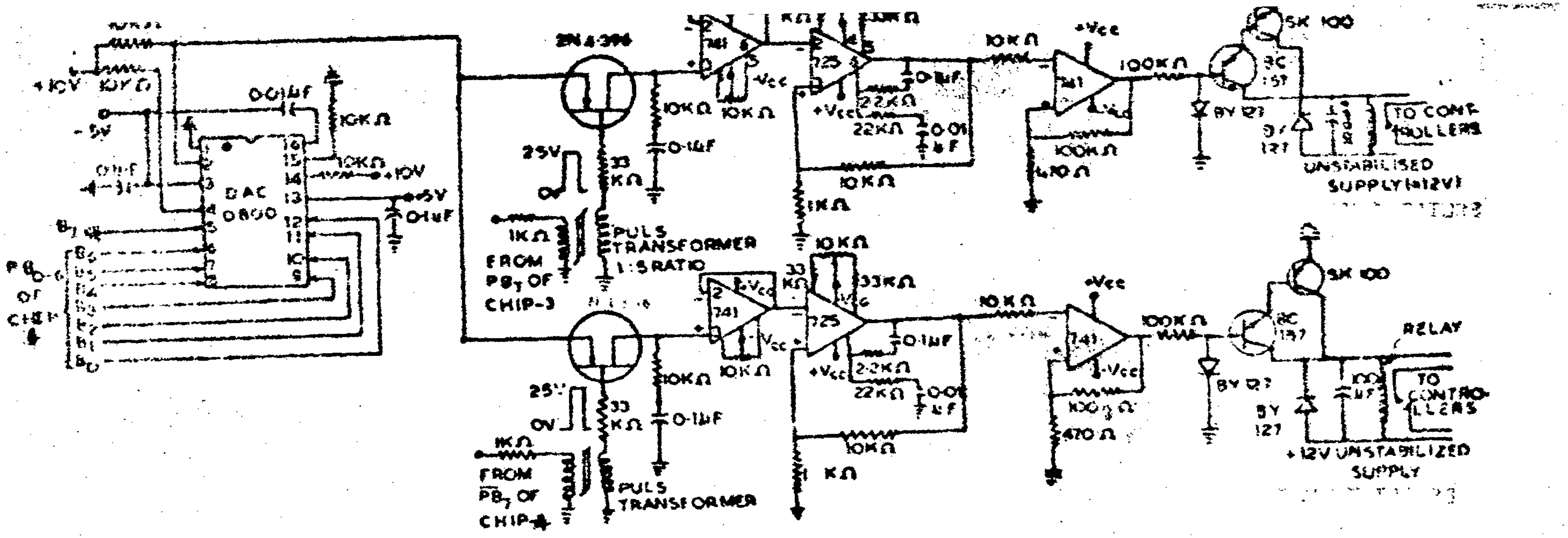


FIG. 15(e) CIRCUIT DIAGRAM FOR RELATIVE HUMIDITY CONTROL

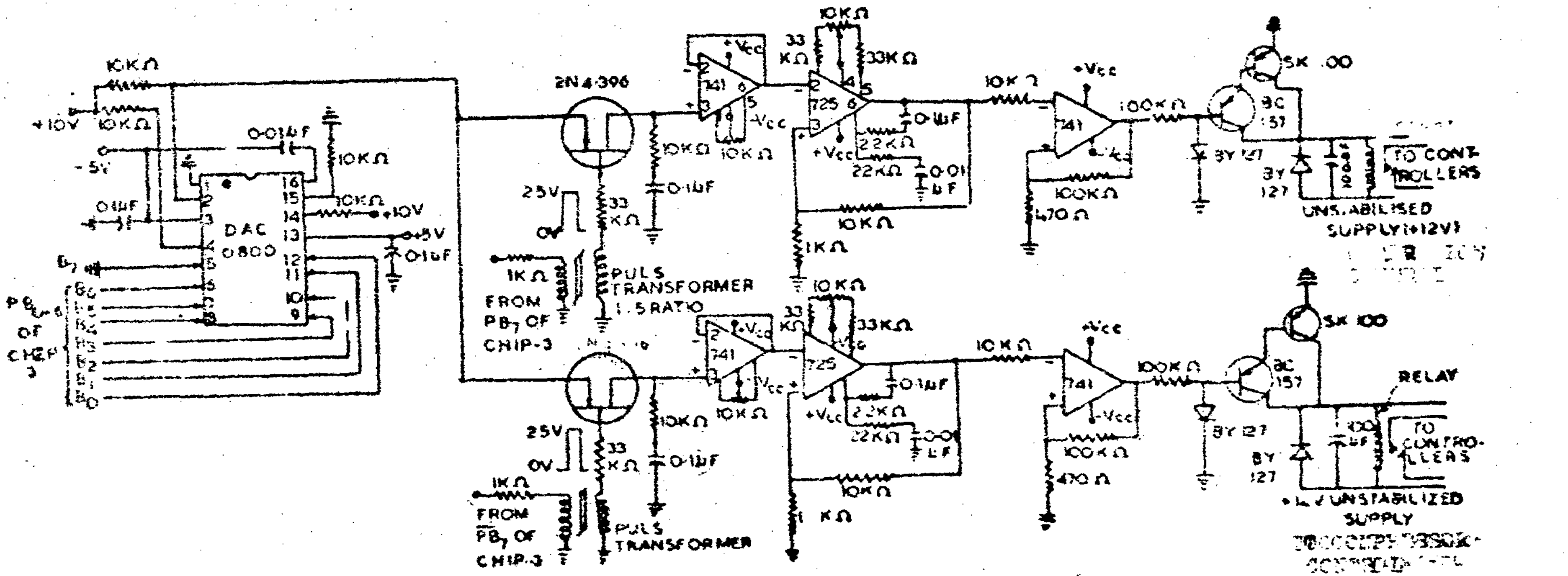


FIG. 15 (f) COMPLETE CIRCUIT DIAGRAM FOR TEMPERATURE CONTROLLER

The binary output (8-bits) of Dry Bulb Digital Thermometer is connected to bidirectional data bus of the microprocessor Intel 8085 via a programmable peripheral interfacer Intel 8155 chip-1 by selecting its port-A as input mode. If the microprocessor desires to input dry bulb temperature, it programs the PPI and issued a control gate pulse (PC_0 of chip-1) to the control gate of the dry bulb temperature transducer. When microprocessor READ signal is HIGH, the temperature data will be fed to the microprocessor via PPI (chip-0 of port-A). Since PPI is having tristate buffer/latches, this device is isolated from the system after processing the dry bulb temperature. On similar line wet bulb temperature is also fed via PPI (Intel 8155 RAM chip-2) of its port-A. To synchronise the input operation, the control gate pulses are advised to follow by delay latches via one shot, if necessary.

Set value selectors: For selecting set values of air temperature and relative humidity thumb wheel switches are used, and its circuit diagrams are shown in Fig.16(c) & Fig.16(d). These two circuits are identical in its construction. ECIL helical pot of 1k ohm linear resistance of 1000 turns with dial counter is provided as a thumb-wheel switch. A constant potential is applied at the terminal 'O', depending upon the accuracy of ADC. A trimpot 'P_A' is provided to make slight adjustments. Suppose set value is (~5); input voltage required for ADC is X mV/Binary digit (~20 mV/Bit) with an accuracy of 1/2 LSB then the input voltage of ADC is tX volts (~100 mV). The helical pot should give a potential (at its terminal 'Q') X volt/Binary digit

(20 mV/Binary digit). In order to achieve this the potential at terminal '0' should be 100X volts and fine adjustment can be made using trimpot P_A. The output of thumb wheel switch is given to input terminal ADC via S/H circuit as shown in Fig.18(d). The ADC outputs of Fig.16(d) and Fig.16(e) are connected to the PPIs (chip-4 of port A and chip-5 of port A respectively). Fig.16(d) is used imposing set value on air temperature of the refrigerant space. Fig. 18(e) is used for imposing the set value on relative humidity of the refrigerant space. If the microprocessor desires to input the set value of the relative humidity, it issue a control pulse (PC_0 of chip-5) to the control gate of the set value selector (Fig.18(e)). When the microprocessor READ signal is HIGH the set value of the relative humidity will be fed to the microprocessor via PPI (chip-5 of port-A). On the similar lines, the set value of air temperature is also fed via PPI (Intel 8155 RAM chip-4 of its port A).

A provision for processing air velocity is incorporated in the scheme (presented in Fig.18) but its value is taken from one of the memory location. This transducer can also be developed on the similar lines.

To output relative humidity value:

If the microprocessor desires to output the relative humidity value, it selects PPI (chip-2 of its port B in output mode) and outputs its value on its terminals of port-B of chip-2. Since PPI is having tristate buffers/latches this information will stand still till the port-B of chip-2 is again selected by the microprocessor. This port is connected to 8-bit to BCD convertor display circuit to display the relative humidity value. On the similar lines the dry bulb temperature data and wet bulb temperature data are fed to chip-0 of port B and chip-1 of port-B respectively. One of the display circuit is shown in Appendix.7. Five such circuits are required to display five variables.

Control Circuits:

Microprocessor computes the error signals of relative humidity and air temperature, and fed these signals on data output terminals of PPI chip-4 of port B, and chip-3 of Port B respectively. These outputs are fed to the display circuits and also control circuit to control the different parameters. Fig.16(e) shows the complete circuit diagram of the relative humidity control circuit. After computation of error signal, if the microprocessor desires to control the relative humidity, it outputs this signal on PPI chip-4 of port B. This error signal is in sign magnitude. Hence PA_7 of port-B of chip-4 will become HIGH for negative value of error signal and it will become LOW for positive value of error signal. ie, if set value is more than the process value the error signal will become negative, and its converse is true. If the error signal is negative, the humidifiers in the process should be operated. If the error signal is positive, the dehumidifiers should be operated.

Among the output 8-bits of port-B of chip-4 only seven LSB bits PB_6-PB_0 are fed to DAC as shown in Fig.16(f). PB_7 (first MSB bit) value is provided with two combinations by taking its inverse value also. PB_7 is directly connected to control gate of S/H circuit (1) to control humidity via error amplifiers and relays to drive humidifiers in the process. The inverted terminal is simultaneously applied to the control gate of S/H circuit (2) to control humidity via error amplifiers and relays to drive dehumidifiers in the process. Circuit design concepts are given in section-2 and wiring diagram details are presented in Appendix.3 Leaving first MSB bit, remaining six bit PB_6 - PB_0 are also given to 8-bit to BCD convertor display circuit keeping first MSB bit as LOW, to display the error signal of the relative humidity. Circuit used for temperature control is shown in Fig.16(g). It is similar to humidity control circuit except the final control elements to regulate the desired parameters will differ.

4.4 Software Design:

As it is evident from the flow charts presented earlier in chapter-3, and from hardware circuits, the complete software has also included the following subroutines in addition to chapter.3.

1. INIT - For intializing the program variables immediately after the system reset.

2. DILAY - To provide 15 sec. delay, whenever the microprocessor output the error signals of air temperature and relative humidity.

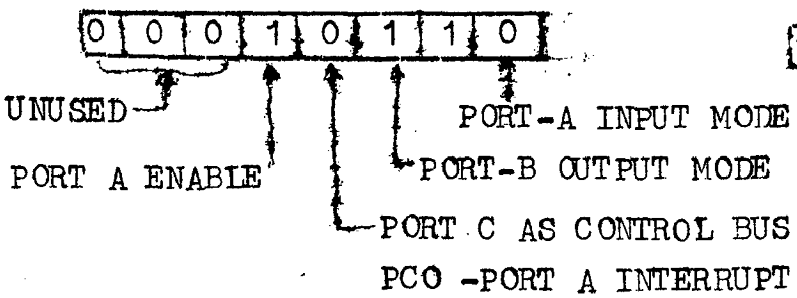
3. SAVE - To save the status of Intel 8085

4. RESTORE - To restore the status of Intel 8085.

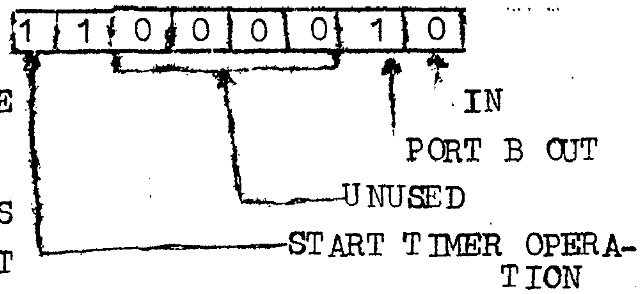
The flow chart to monitor this system is given in Figure.17. The assembly language and machine language is given in Appendix.12.

Initialization (INIT Subroutine):

Several variables and I/O ports are to be initialized before the main program infinite loop begins. All the ports may be initialized to be in modes specified in Table.2. The command word format for programming the various I/O ports and timer on 8155 was given in Appendix.11. The command words for chip 0,1,2,3 and 4 are assigned with symbols CWR0, CWR1, CWR2, CWR3, CWR4 and for timer of chip 0 assigned as CWR01. TIMERIL and TIMERIH are assigned for count length the timer to provide 15 sec. delay.



Command status word format for chip 0,1,2,3 and 4



Command status word for chip-0, to Start timer.

Command word	Content in Hex	Address of the Register in Hex	Address assignment
CWR0	16	0000	CSR0
CWR1	16	0800	CSR1
CWR2	16	1000	CSR2
CWR3	16	1800	CSR3
CWR4	16	2000	CSR4
CWR01	C2	0000	CSR0
TIMERIL	0C	0400	TIMER LB0
TIMERIH	0B	0500	TIMER HB0

Name assignment to ports	Address location	Specifications
PORT A0	0100	Port A of Chip 0
PORT B0	0200	Port B of Chip 0
PORT C0	0300	Port C of Chip 0
PORT A1	0900	Port A of Chip 1
PORT B2	0A00	Port B of Chip 1
PORT C1	0B00	Port C of Chip 1
PORT A2	1100	Port A of Chip 2
PORT B2	1200	Port B of Chip 2
PORT C2	1300	Port C of Chip 2
PORT A3	1900	Port A of Chip 3
PORT B3	1A00	Port B of Chip 3
PORT C3	1B00	Port C of Chip 3
PORT A4	2100	Port A of Chip 4
PORT B4	2200	Port B of Chip 4
PORT C4	2300	Port C of Chip 4

Subroutine to initialize I/O ports, Timer

```
* INIT:
     MVI     A, CWR0        ; GET CHIP-0 COMAND WORD
     OUT     CSR0
     MVI     A, CWR1        ; GET CHIP-1 COMMAND WORD
     OUT     CSR1
     MVI     A, CWR2        ; GET CHIP-2 COMMAND WORD
     OUT     CSR2
     MVI     A, CWR3        ; GET CHIP-3 COMMAND WORD
     OUT     CSR3
     MVI     A,CWR4         ; GET CHIP-4 COMMAND WORD
     OUT     CSR4
     MVI     A, TIMERIL     ; GET LOW BYTE
     OUT     TIMERLBO       ; SEND TO TIMER1
     MVI     A,TIMER1H      ; GET HIGH BYTE
     OUT     TIMER HBO      ; SEND TO TIMER1
     MVI     A,00           ; BLANK
     OUT     PORT B0          DRYTEMP DISPLAY
     MVI     A,00
     OUT     PORT B1        ; BLANK DISPLAY OF WETTEMP
     MVI     A,00           ; BLANK DISPLAY OF RH
     OUT     PORT B2
     MVI     A,00           ; BLANK DISPLAY OF TEMP ERROR (or)
     OUT     PORT B3          INITIALIZE CONTROLLERS
     MVI     A,00           ; BLANK DISPLAY OF HUMIDITY ERROR(or)
     OUT     PORT B4          INITIALIZE RH CONTROLLERS
     LXI     H,0002         ; INITIALIZE STACK POINTER
     SPHL                     TO 0200 (Hex)
     RET
```

Subroutine for 15 sec. delay:

The DELAY subroutine uses double loop which decrements H and L registers untill both will become zero. Before DELAY is called both H and L registers should be initialized to the proper values in order to get 15 sec. delay.

```
DELAY:

     X8 : DCR  L
          JNP  X80
          DCR  H
          JNP  X80
         RET
```

It may be easily provided that the delay 'D' caused by this subroutine is given by

$$D = 22 + (L'-1)* 14 + (H'-1)* (255*14)+25 \quad \text{clock cycles}$$

Where H' and L' denote the initial values of the H and L registers. Assuming 350 ns clock cycle, the value of H & L for a 15 sec. delay (approximately) H = OC, L = OB (other values are also possible).

Subroutines to SAVE and RESTORE the STATUS OF 8085:

```
SAVE       : PUSH  PSW
             PUSH  H
             PUSH  B
             PUSH  D
             RET

RESTORE    : POP  D
             POP  B
             POP  H
             POP  PSW
             RET
```

Computation of Error Signals:

Here computation of error signal program for relative humidity (it is a small portion in main program) is given. On similar lines computation of error signal for air temperature is achieved.

Before proceeding observe how to input or output the values from memory to I/O devices or from I/O devices to memory. Assume RH value is in Reg-B. It should output-ed to display.

```
OUT:  MVI  A,CWR4     ; Chip-4 is initialized with
      OUT  CSR4         command status word.
      MOV  A,B        ; Load ACC with RH value
      OUT  PORTB4     ; Load this value to output port A4.
```

On similar lines data can be input-ed to the memory of microprocessor from input devices.

```
IN:   MVI  A,CWRO
      OUT  CSRO       ; Chip-O is loaded with command
                        status word.
      IN   PORT AO    ; Then PC0 will start initialization
                        of ADC of analog signal.
```

Now analog process variable value is loaded in the Accumulator of the microprocessor.

Computation of Error Signal for Relative Humidity:

Assume relative humidity computed value is available in Reg-B.

```
      MVI  A, CWR4     ; Chip-4 is loaded with command
      OUT  CSR4          status word.
      IN   PORT A4     ; Set value of RH is input to ACC.
      SUB  B           ; Subtract process value from
                         set value.
      JP   X20
      CMA              ; If negative complement
      SBI  A,(01)H     ; Subtract '+' 1
      RAL              ; Get '-' sign.
      STC
      RAR
X20 : MOV  B,A           Now error signal is in sign
                         magnitude and stored in Reg.-B
      MVI  A,CWR4
      MOV  A,B
      OUT  PORTB4
```

Now port-B of chip-4 is loaded with error signal

```
CALL   SAVE
CALL   DELAY
```

Now provide 15 sec. delay to operate the controller in the process. Suppose error signal is negative humidifiers will be operated. If error signal is positive dehumidifiers will be operated.

On the similar lines error signal for temperature will be computed. But this is provided with ON and OFF controller.

Discussion:

When a team of designers is required to design a micro-processor based system, the hardware and software design may be done in parallel. The hardware design may first be tested on bread board. Only when this testing has been successful the hardware design may be implemented using printed circuit boards. The software after having been tested, may be stored in ROMs or EPROMs and integrated with hardware to produce the final system. One more testing phase is required after the hardware and software has been integrated to check for any error that may have crept in during the integration process. The decision by the hardware designers about the size of RAM and ROM is not easy to take before software design is complete. The software developed may be modified after the system has been used for some time. This may require more memory and expandability feature should also be incorporated during the initial design.

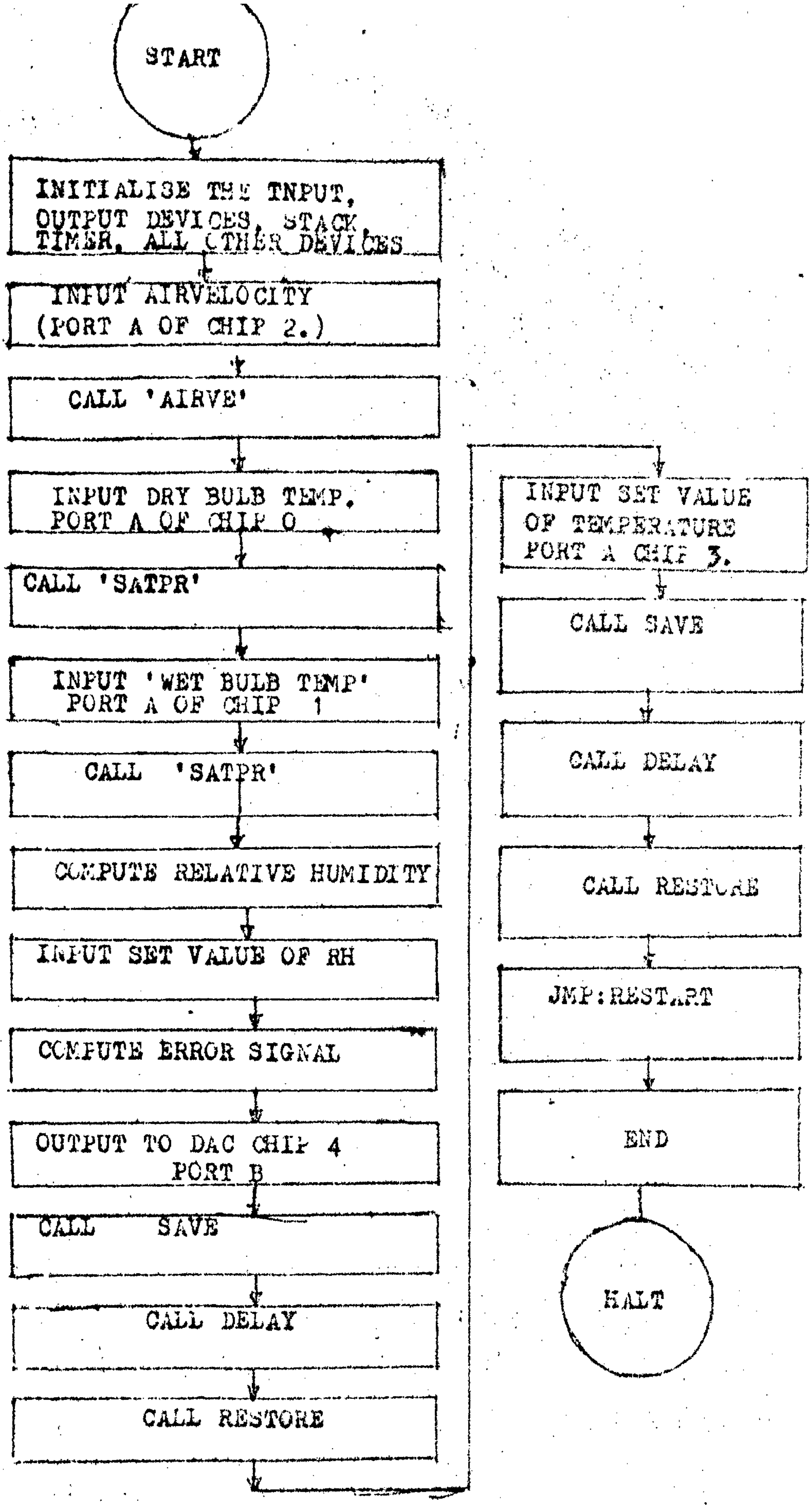


FIG. 17 - COMPLETE FLOW CHART FOR THE MONITOR SYSTEM.

CHAPTER-5

5. HIGH LIGHTS, CONCLUSIONS AND SUGGESTIONS FOR FURTHER STUDY IN MICROPROCESSOR BASED COLDSTORAGE PROCESS:

Measurement and control of relative humidity and temperature are very important in cold-storage process applications. If the humidity is not controlled properly in cold-storage process, the food stuffs such as meat, vegitable, etc may become unsalable, change colour, lose weight, etc. It is curious to note that this complaint is due to humidity, but not due to temperature. In order to achieve accurate measurement in humidity and its regulation, it is desirous to measure the temperature very accurately. In this temperature transducers have been developed to measure temperature with an accuracy of $\pm$ 0.1^{o}C with 8-bit resolution, at its cost. A provision is incorporated to change the accuracy in measurement of temperature of these transducers. For multi-cabin cold-storage systems, humidity measurement using LSI Technology becomes very complicate, increase cost and reduce reliability. In order to increase the performance, reduce cost to improve qualitycontrol and to increase the reliability automation is essential.

To provide automation in cold-storage process it has been selected to use Intel 8085 microprocessor. Further, software is preliminarily tested and achieved satisfactory results. The software [redacted] giving an accuracy $\pm$ 5% in measurement of the humidity and providing the wide flexibility in operating ranges to the user. Hence it is decided to develop hardware circuitary to measure and control temperature and humidity in cold-storage process. For hardware design at laboratory level it has been illustrated by taking single cabin cold-storage process. It can be easily extended for multicabin cold-storage process. Keeping in view of multichannel it is suggested to take individual channel for each variable. This provides a wide flexibility to the user to increase or reduce the number of channels. At the time of repair of one the cabin in the cold-storage plant, the other cabins can be kept in operation using this hardware. Hence it is suggested to select 8155 RAM as I/O device interfacers.

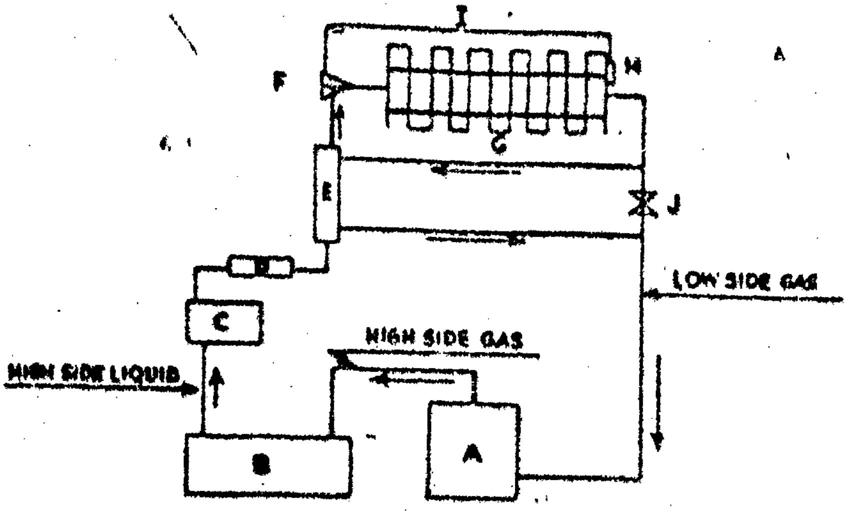
This report concentrates only on the theoritical aspect of humidity and temperature control. For further study, the hardware developed in this work can be practically tested and directly implemented as and when the components are available in the department. For further study it can be modified to multi-cabin cold-storage process.

The automation schemes developed here using microprocessor will improve the performance of operation and accuracy in measurement and control of process variable, reduce cost and increase the reliability.

APPENDIX : 1

REFRIGERATION PROCESS & COLD STORAGE

A typical block diagram of refrigeration system used in most of cold-storage processes is shown in Fig.A.1[1]. Generally compressors are available with coupling of an induction motor to drive it. Compressor used in this process is of two cylindrical vertical type. Vertical compressors are used in refrigeration because they do not have limit on number of cylinders. Compressor will have valve to arose and release the refrigerant alternatively. During the suction stroke the gas (Freon-12) to be compressed (LP Gas) enter the compressor space of the cylinder. Then the piston moves upward the valve closes automatically and compresses the gas. When it is reached to the designed pressure of the compressor, the gas will be released by opening the discharge valve (shown in Fig.A.1, HP Gas side). Normally Freon-12 gas is used as refrigerant in cold-storage systems. Freon-12 gas ($CCl_2 F_2$) does not react with copper pipe lines. In practice, copper is used for pipe line because of its conductivity. The gas released by the discharge valve of the compressor passes through the condenser under pressure. The condenser is a piece of equipment dedicated to the job of converting the gas into liquid. The water flows through the concentric coils which causes condensation of the refrigerant. The condensed refrigerant will reach the liquid receiver. In liquid receiver the refrigerant consists of both forms liquid and gas. From this the refrigerant gas will pass through dehydrator.



A. Compressor
B. Condenser
C. Receiver
D. Dehydrator
E. Heat exchanger
F. Expansion valve
G. Evaporator
H. Bulb for expansion valve
I. Capillary connecting bulb to expansion valve
J. Valve in heat exchanger by-pass circuit

FIG. A.1 SCHEMATIC DIAGRAM OF REFRIGERATION SYSTEM

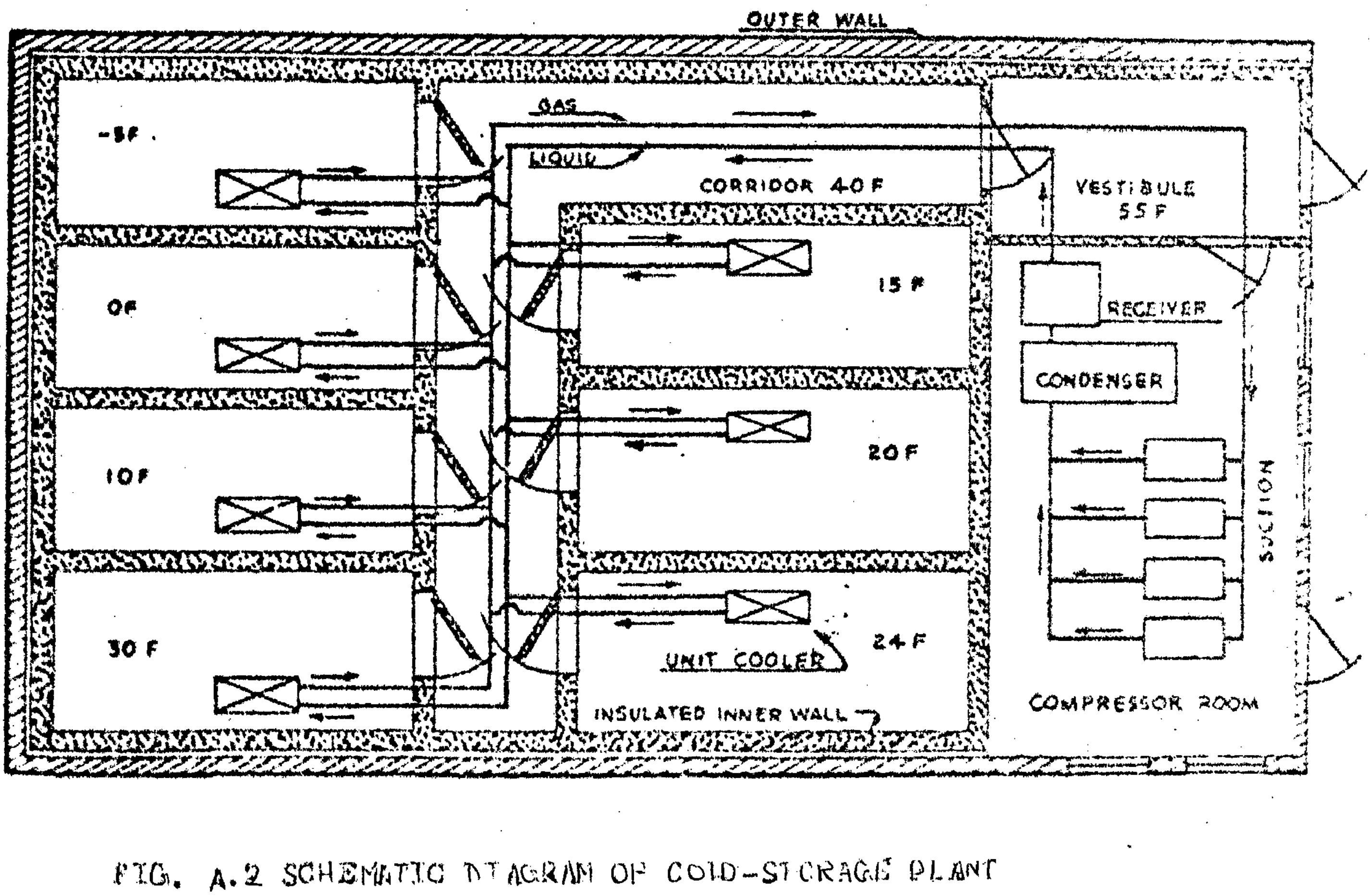


FIG. A.2 SCHEMATIC DIAGRAM OF COLD-STORAGE PLANT

Dehydrator is nothing but a metal cylinder packed with a substance called silica gel. This substance has an extra ordinary affinity for water or water vapour which it comes in contact. As the refrigerant flows over silica gel, the crystalline particles of the substance will be picked out the water retains it, there by permitting a water less refrigerant (both in liquid and gas form). Silica gel is also mixed with salt like white substance for giving indication when it requires to reactive. From dehydrator, the water less liquid gas will pass through the heat-exchanger. This is the second stage of eleminating water vapour from the refrigerant. Heat exchanger performs a doubly happy function. First it evaporates the suction gas, and keeping knocks out of the compressor; second, it removes heat from the liquid refrigerant going to the expansion valve, there by allowing this liquid to do a lot of job in cooling. From the heat-exchanger, the refrigerant is passed through the thermal expansion valve. It is a very important device. This valve is the controller of the refrigerant flow. If the refrigerated spaces are cold enough, the expansion valve remains closed; when more cooling is needed the expansion valve opens, so that more liquid refrigerant is admitted to the cooling coils. Thermostat is located to change the set point of the refrigerant spaces, and to regulate the temperature of the refrigerant spaces by operating the solenoid valve for refrigerant flow or operating the ON and OFF switch of the compressor. Thus refrigerant space is maintained at required temperatture.

Large cold-storage warehouses are of fire proof construction, usually of concrete. Normally two types of constructions of cold-storage warehouses may be observed. In one, the insulated walls of the storage spaces, together with the floors and ceilings, are free to expand or contract independently of the building walls. The alternative design is to build a building and tie the insulation and the floors firmly to the building structure, and let expansion and contraction finds its own compensation(1). Fig.A.2 shows the layout of cold-storage. In this each room tempera-ture is controlled separately by controlling the refrigerant flow in the evaporators and also by controlling air flow over the cooling coils.

Fan blowers are provided over the evaporaters to get conditioned air. This conditioned air is passed into the cold-storage cabin via ducts and recirculation of this conditioned air through cold-storage cabin is provided. So that the temperature in the cold-storage cabin is regulated at desired value by selecting one set value in the range of -25°C to 35°C.

Air Handling System:

The actual duct system assembly of the air handling system is shown in Fig.A.2.i. The duct work served to circulate the cold air at the desired low temperature into cold enclosure housing the product chamber shown in Fig.A.2.i.

The assembly is described as follows:

Low temperature air is supplied to the cold-encloser by means of the branch duct of size 20.3 cm x 20.3 cm. This branch duct obtained the low temperature air from the main duct of an existing air-conditioning plant, at a supply point, as shown in Fig.A.2.i. For this purpose, an opening of the same size of that branch was made in the main duct and an elbow was provided at the beginning of the branch duct. This elbow was fitted lightly in side the main duct, directly facing the cool air flowing in the main duct. This branch duct was connected to the inlet of the cold enclosure through a 10.16 cm(4") GI pipe (Galvonized Iron pipe) and a reducer as shown in Fig.A.2.i. The orifice meter was installed in this 10.16cm (4") pipe line. The outlet of the cold enclosure was connected to return duct, which returns the air to the main duct. An air blower (of total pressure 21.1 mm H_2O) was fixed at the end of the return duct.

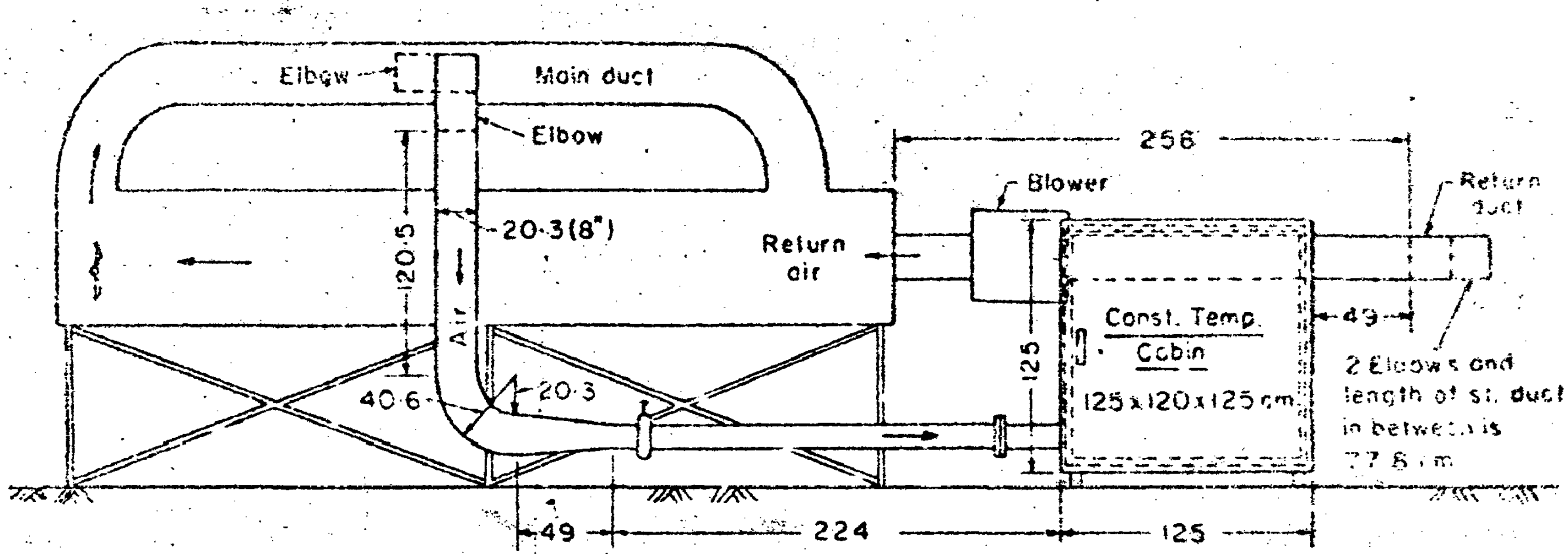
A gate valve was provided in the supply side (up stream side) of the branch duct system so that the air supply to the branch duct system can be completely cut off, where it was needed to circulate the air completely with in the main duct itself.

The entire branch duct system and the cold enclosure were covered with a layer of 48 mm thick thermocol. The sheets of the thermocol were cut to size to suit different surfaces and were fixed to the surface by means of the binding material (fevicol).

The cold enclosure (cold-storage cabin) served as a low and constant temperature bath for product chamber, in which fruits, vegitables, meats, etc. can be preserved. The cold enclosure tank (cold-storage cabin) was constructed of mild steel with out side dimensions 1.25 m x 1.0 m x 1.25m. A door of dimensions 1.25 x 1.25 m was provided to it. The door was vertically opened and it consists of M.S.Angles welded along the sides to the inside of the tank and sponge rubber straps were fixed to these M.S.Angles with a binding material as to ensure air tightness whenever the door was closed.

Taking all design considerations into account the specification of the refrigerant system selected for this process are as follows:

Primemover	:	Electric Motor (Induction tape) 230V, 1-Ø, 2HP
Compressor	:	Vertical reciprocating two cylinders $2\frac{1}{2}$" x 3" bore and stroke; rpm 455.
Refrigerant	:	Freon-12, Full charge- 152813
Evaporator	:	Cold diffuser type with defrosting arrangement
Refrigerant Control	:	Thermostat expansion valve.
Operating temperature	:	$-25^{o}C$ to $35^{o}C$.



Scale: 1:30

All dimensions in cm

FIG.2.1. AIR HANDLING SYSTEM

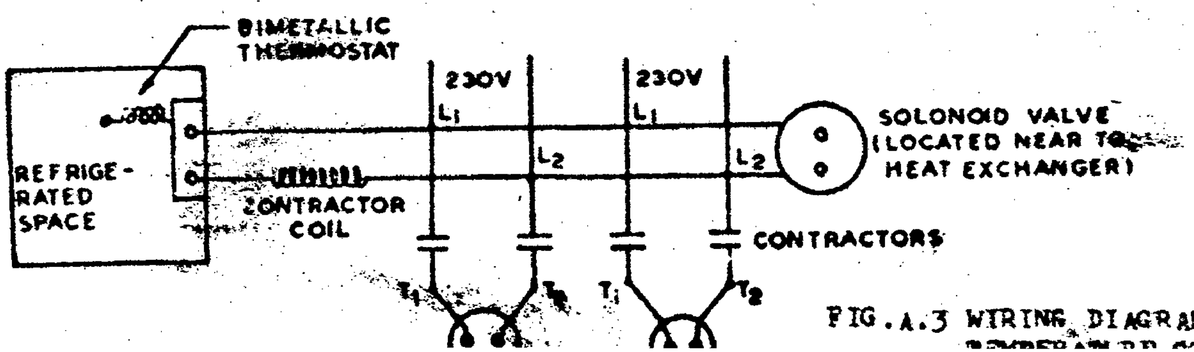


FIG.A.3 WIRING DIAGRAM FOR

APPENDIX : 2

TEMPERATURE REGULATION

Temperature regulation is achieved using thermostat control in this process. It is a single pole double through type bimetallic thermostat, and provided with a dial range from $-15^{o}C$ to $35^{o}C$. A thermostat is a device which responds to air temperature changes and causes a set of electrical contacts to open or to close. The wiring diagram used for temperature regulation in this cold-storage process is shown in Fig.A.3[(5)].

In this process three controllers are provided to regulate temperature. The solenoid valve used for regulation of refrigerant flow is an electromagnetic pilot operated type, and other controller specifications are given Appendix .1.

APPENDIX : 3

HUMIDITY REGULATION

Most of the humidity controllers are of two mode controllers; namely humidifiers and dehumidifiers.[5] A humidifier is a device, which causes to increase humidity by spraying excess moisture into air or by cooling the air. The simple type of humidifier used in this process is an air blower (universal type, operating voltage: 24V, 0.5 Amp. ¼ HP), provided with a water container at its out-let. When the humidifier is switched on, it suck the inside air of the refrigerant space and pass it over water container. From the water container the wet air will send into the process. So that the wet-ness of the air can be increased caused to increase in humidity[2]. The capacity of water container depends upon the size of blower. For this problem it is suggested to take 1000 ml capacity container with two ends opening. One end is connected to outlet of the blower and the other end is freely opened into the refrigerant space.

Dehumidifier[2] is a device used to remove the water vapour or moisture content of the refrigerant space. A simple dehumidifier .(this process)is an air blower (universal motor 24V, 0.5 Amp., ¼HP) provided with a chemical dehumidifier vessel[5]. A chemical dehumidifier contains silica gel material in a cylindrical vessel provided with two ends are opened. One opening end is connected to air blower and other opening end is freely opened into the refrigerant space. This vessel is packed with silica gel material and porous are maintained at random for

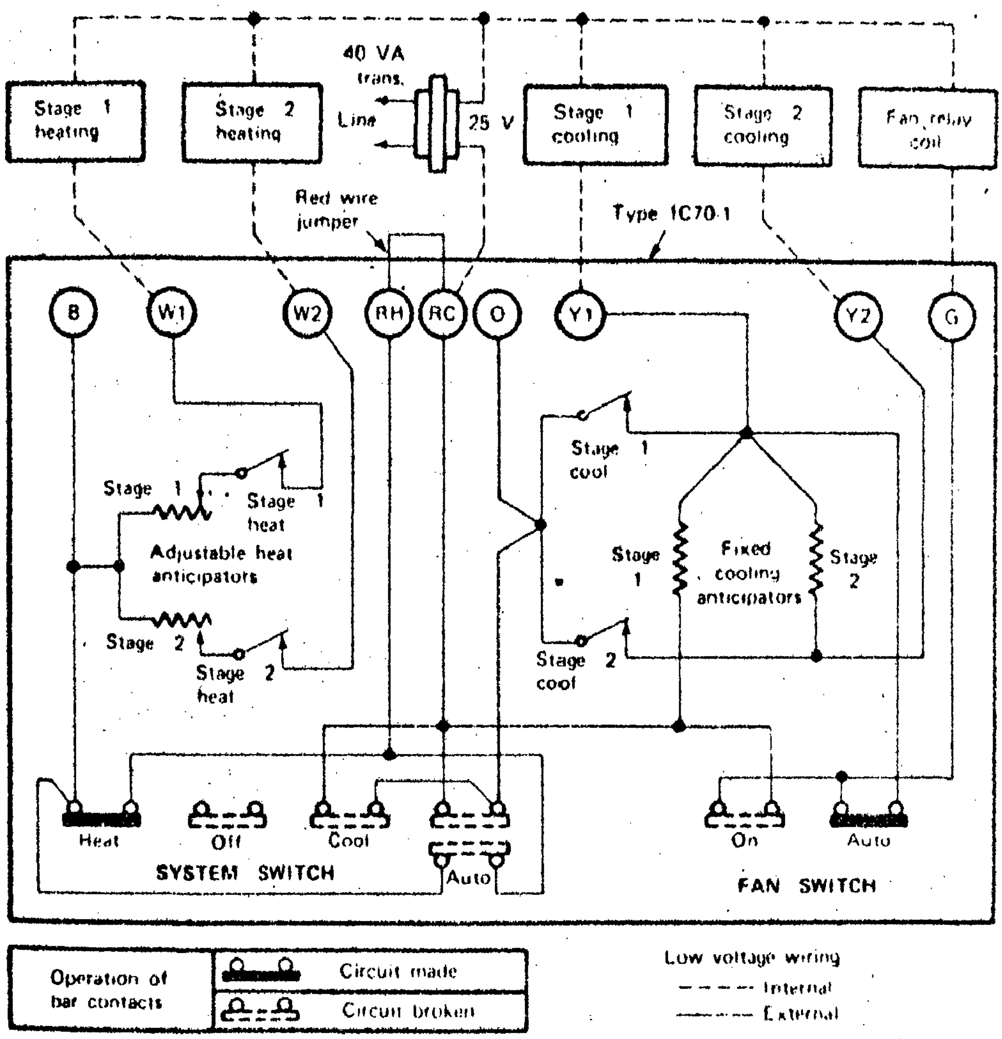


FIG. A.4 WIRING DIAGRAM OF HUMIDITY CONTROL passage of air. The capacity of the vessel suggested for this problem is 1000 ml. When the dehumifier is switched on, the blower will suck the inside air of the refrigerant space and pass it over the silica gel and then the water or moisture less air will send into the refrigerant space. Reactivation of the silica gel material is essential, in this process.

The wiring diagram for humidity control is shown in Fig.A.4[5]. From the diagram one can see that the system switch is on "heat" and the fan switch is on "auto". From one side of the transformer circuit is to the terminal of relay for cooling (RC), through the jumper wire relay for heating (RH), to the internal wiring to the bar contact on "heat" and the stage one and two heat anticipators. One can note that the terminal B can also connected to another circuit to energize continuously without having any additional hard-ware. Upon a call for heat, the stage one heating switch will close, giving us a circuit to W1, then the first stage of heating system and back to the other side of the transformer. If the humidity is continuous to rise, the stage two hea-ting will close, giving a circuit through W2, to the second stage of the heating system, and back to another side of the transformer.

When the selector switch is placed in "cool" position, it will break the "heat" bar contact and make the "cool" contact. It gives to the circuit from RC to the "cool" contact, and on to stage one and stage two contacts. When the stage one contact closes we have a circuit through Y1, a stage one cooling, and back to the other side of the transformer. If this is not sufficient cooling, stage two contact of this circuit is made through Y2, stage two cooling, and back to the other side of the transformer.

If the relative humidity is less than the set value, the humidity control circuit of Fig.12* will select the selector switch on "cool" position. If the relative humidity is more than the set value, the humidity control circuit will select the selector switch on "heat" position. In Fig.A.4, stage 1: heating, and stage heating devices are dehumidifiers; stage 2: cooling, and stage 2 cooling devices are humidifiers.

*See Section 2.3

APPENDIX : 4

MANUAL DETAILS OF ADC - 0800

The ADC 0800 is an 8-bit monolithic A/D convertor using P-channel ion-implanted MOS Technology[16]. It contains high input impedance comparator, 256 series resistors and analog switches, control logic and output latches. Conversion is performes using a successive approximation technique where the unknown voltage is compared to the resistor tie points using analog switches. When approximate tie point voltage matches the unknown voltage conversion is complete and digital outputs contains complementary binary word corresponding to the unknown voltage. It's features are (i) Low cost ii) $\pm$ 5V, 10V ranges, iii) No missing codes, iv) Ratiometric conversion, v) Tristate outputs, vi) Fast, vii) contains output latches, viii) TTL compatiable ix) 8-bit resolution, x) $\pm \frac{1}{2}$ LSB accuracy and good linearity, xi) high speed of conversion.

It is an 18-pin, monolithic p-channel, linear IC. Its pin configuration is shown in Fig.A.5[16] and its electrical characteristics are tabulated in Table : A.1.

TABLE A.1 *

Parameter	Conditions	Min	Type	Max.	Units
Non-Linearity	$T_A=25^oC$			±1	LSB
Differential non-linearity				$\pm\frac{1}{2}$	LSB
Zeroerror tempe-rature coefficient				0.01	$\%/^oC$
Zero error				±2	LSB
Full scale error				±2	LSB
Full scale error temperature coefficient				0.01	$\% / ^oC$
Input Leakage				1	uV
Logical "1" input voltage	All inputs	$V_{SS}-1.0$		V_{SS}	V
Logical "0" input voltage	All inputs	V_{GG}		$V_{SS}-4.2$	V
Logical "1" level output voltage	All outputs $I_{OH}=100$ uA	2.4			V
Logical "0" level output voltage	All outputs, $I_{OL}=16$ mA			0.4	V
Clock frequency	0^oC T_A $+70^oC$	50		800	KHz
	-55^oC T_A $+125^oC$	100		500	KHz
Start conversion pulse		1		$3\frac{1}{2}$	Clock periods
Power supply current	$T_A = 25^oC$			15	mA

* Manual details of ADC-0800

```
**********************
* C      TABULATION OF
* C      TWC=WET BULB T
* C      PA=PARTIAL PR
* C      TWF=WET BULB T
* C      TWK=WET BULB T
*        DATA PB,A,B,P/
*        DATA O,R,TW,TI
*        PRINT 10
*     10 FORMAT(2X,'AET
*      1  'HUMIDITY',2
*        V=1.5
*        AX=(65.+6.75/V
**********************

**********************
>>>>>>>>>>>*        DO 50 J=1,30
**********************

**********************
*        AJ=J
*        TDC=TD-AJ+1.
*        TDK=TDC+273.16
*        TDF=32.+TDC*1.
*        Y=(P+(A+(B*TDK
*        PS=225.6*735.5
**********************

**********************
>>>>>>>>>>>*        DO 50 I=1,30
**********************

**********************
```

```
C       TABULATION OF PSYCHROMETRIC CHARTS
C       TWC=WET BULB TEMP.,TDC=DRY BULB TEMP. IN DEG. CENTIGRADE
C       PH=PARTIAL PRESSURE ,PS=SAT.PRESSURE,PB=BAROMETRIC PRESSURE INCHES OF HG.
C       TWF=WET BULB TEMP.,TDF=DRY BULB TEMP. IN FHRENHEAT DEG.
C       TWK=WET BULB TEMP.,TDK=DRY BULB TEMP. IN DEG. KELVIN
        DATA PB,A,B,P/742.,.1152E-4,-.4787E-8,7.21379/
        DATA Q,R,TW,TD/483.16,647.31,15.,15./
        PRINT 8
  8     FORMAT(2X,'WET FHAR',2X,'WET CENT',2X,'DRY FHAR',2X,'DRY CENT',2X,
     1  'HUMIDITY',2X,'PARITAL', 2X,'SAT PRE')
        V=1.5
        AX=(65.+6.75/V)*1.E-5
        DO 10 J=1,30
        AJ=J
        TDC=TD-AJ+1.
        TDK=TDC+273.16
        TDF=32.+TDC*1.8
        Y=(P+(A+(B*TDK))*(TDK-Q)*(TDK-Q))*(R/TDK-1.)
        PS=225.6*735.59/EXP(Y)
        DO 10 I=1,30
        AI=I
        TWC=TW-AI+1.
        TWK=TWC+273.16
        TWF=32.+TWC*1.8
        IF(TWC.GT.TDC)GOTO 10
        X=(P+(A+(B*TWK))*(TWK-Q)*(TWK-Q))*(R/TWK-1.)
        PW=225.6*735.59/EXP(X)
        PH=PW-PB*AX*(TDC-TWC)
 11     RH=100.*PH/PS
        IF(RH.LT.0..OR.RH.GT.100.)GOTO10
 55     PRINT 70,TWF,TWC,TDF,TDC,RH,PH,PS
 70     FORMAT(/7(2X,F8.2)/)
 10     CONTINUE
        STOP
        END
```

PROGRAMS CALLED

LARS AND ARRAYS ("*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED)

```
C    1     *Q     2     *AJ     3     *B       4     *TDF    5
K    6     *AI    7     *TW     10    *PH      11    *Y      12
     13    *PS    14    *PB     15    *TDC     16    *P      17
     20    *A     21    .S0001  22    .S0000   23    *AX     24
     25    *TDK   26    *PW     27    *TD      30    *X      31
     32    *I     33    *TWF    34
```

PURARIES

```
                                    <ENTRY: MAIN>
                                          V
                                          V
                                          V
                                          V
     ************************************************************************
     * C         TABULATION OF PSYCHROMETRIC CHARTS                          *
     * C         TWC=WET BULB TEMP.,TDC=DRY BULB TEMP. IN DEG. CENTIGRADE    *
     * C         PH=PARTIAL PRESSURE ,PS=SAT.PRESSURE,PB=BAROMETRIC PRESSURE INCHES *
     * C         TWF=WET BULB TEMP.,TDF=DRY BULB TEMP. IN FHRENHEAT DEG.     *
     * C         TWK=WET BULB TEMP.,TDK=DRY BULB TEMP. IN DEG. KELVIN        *
     *           DATA PB,A,B,P/742,.1152E-4,-.4787E-8,7.21379/               *
     *           DATA Q,R,TW,TD/483.16,647.31,15.,15./                       *
     *           PRINT 10                                                    *
     *        10 FORMAT(2X,'WET FHAR',2X,'WET CENT',2X,'DRY FHAR',2X,'DRY CENT',2X *
     *          1 'HUMIDITY',2X,'PARITAL', 2X,'SAT PRE')                     *
     *           V=1.5                                                       *
     *           AX=(65.+6.75/V)*1.E-5                                       *
     ************************************************************************
                                          V
                                          V
                                          V
                                          V
     ************************************************************************
>>>>>>>>>>>>*           DO 50 J=1,30                                          *
     ************************************************************************
                                          V
                                          V
                                          V
                                          V
     ************************************************************************
     *           AJ=J                                                        *
     *           TDC=TD-AJ+1.                                                *
     *           TDK=TDC+273.16                                              *
     *           TDF=32.+TDC*1.8                                             *
     *           Y=(P+(A+(B*TDK))*(TDK-Q)*(TDK-Q))*(R/TDK-1.)                *
     *           PS=225.6*735.59/EXP(Y)                                      *
     ************************************************************************
                                          V
                                          V
                                          V
                                          V
     ************************************************************************
>>>>>>>>>>>>*           DO 50 I=1,30                                          *
     ************************************************************************
                                          V
                                          V
                                          V
                                          V
     ************************************************************************
     *           AI=I                                                        *
     *           TWC=TW-AI+1.                                                *
     *           TWK=TWC+273.16                                              *
     *           TWF=32.+TWC*1.8                                             *
     *           IF(TWC.GT.TDC)GOTO 50                                       *>>>>>>
     ************************************************************************
                                          V
                                          V
                                          V
                                          V
     ************************************************************************
     *           X=(P+(A+(B*TWK))*(TWK-Q)*(TWK-Q))*(R/TWK-1.)                *
     *           PW=225.6*735.59/EXP(X)                                      *
     *           PH=PW-PB*AX*(TDC-TWC)                                       *
     ************************************************************************
                                          V
                                          V
                                          V
                                          V
     ************************************************************************
     *        20 RH=100.*PH/PS                                               *
     *           IF(RH.LT.0..OR.RH.GT.100.)GOTO50                            *>>>>>>
     ************************************************************************
                                          V
                                          V
                                          V
                                          V
     ************************************************************************
     *        30    PRINT 40,TWF,TWC,TDF,TDC,RH,PH,PS                        *
     *        40 FORMAT(/7(2X,F8.2)/)                                        *
     ************************************************************************
                                          V
                                          V
                                          O<------------------------------------
                                          V
                                          V
     ************************************************************************
------------*        50 CONTINUE                                              *



     ************************************************************************
                                          V
                                          V
                                          V
                                          V
     ************************************************************************
     *           STOP                                                        *
     ************************************************************************


     ************************************************************************
```

```
C         TABULATION OF PSYCHROMETRIC CHARTS
C         TWC=WET BULB TEMP.,TDC=DRY BULB TEMP. IN DEG. CENTIGRADE
C         PH=PARTIAL PRESSURE ,PS=SAT.PRESSURE,PB=BAROMETRIC PRESSURE INCHES OF H
C         TWF=WET BULB TEMP.,TDF=DRY BULB TEMP. IN FHRENHEAT DEG.
C         TWK=WET BULB TEMP.,TDK=DRY BULB TEMP. IN DEG. KELVIN
          DATA PB,A,B,P/742,.1152E-4,-.4787E-8,7.213797/
          DATA Q,R,TW,TD/483.16,647.31,15.,15./
          PRINT 8
 8        FORMAT(2X,'WET FHAR',2X,'WET CENT',2X,'DRY FHAR',2X,'DRY CENT',2X,
     1    'HUMIDITY',2X,'PARITAL', 2X,'SAT PRE')
          V=1.5
          AX=(65.+6.75/V)*1.E-5
          DO 10 J=1,30
          AJ=J
          TDC=TD-AJ+1.
          TDK=TDC+273.16
          TDF=32.+TDC*1.8
          Y=(P+(A+(B*TDK))*(TDK-Q)*(TDK-Q))*(R/TDK-1.)
          PS=225.6*735.59/EXP(Y)
          DO 10 I=1,30
          AI=I
          TWC=TW-AI+1.
          TWK=TWC+273.16
          TWF=32.+TWC*1.8
          IF(TWC.GT.TDC)GOTO 10
          X=(P+(A+(B*TWK))*(TWK-Q)*(TWK-Q))*(R/TWK-1.)
          PW=225.6*735.59/EXP(X)
          PH=PW-PB*AX*(TDC-TWC)
 11       RH=100.*PH/PS
          IF(RH.LT.0..OR.RH.GT.100.)GOTO10
 55       PRINT 70,TWF,TWC,TDF,TDC,RH,PH,PS
 70       FORMAT(/7(2X,F8.2)/)
 10       CONTINUE
          STOP
          END
```

SUBPROGRAMS CALLED

EXP.

SCALARS AND ARRAYS ["*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED]

*TWC	1	*Q	2	*AJ	3	*B	4	*TDF	5
*TWK	6	*AI	7	*TW	10	*PH	11	*Y	12
*V	13	*PS	14	*PB	15	*TDC	16	*P	17
*J	20	*A	21	.S0001	22	.S0000	23	*AX	24
*RH	25	*TDK	26	*PW	27	*TD	30	*X	31
*R	32	*I	33	*TWF	34				

TEMPORARIES

```
LINE    LOC     LABEL     GENERATED CODE

        0                 JFCL     0,0
        1                 JSP      16,RESET.
        2                          0,0
210     3                 MOVEI    16,2M
        4                 PUSHJ    17,OUT.
        5                 PUSHJ    17,FIN.
270     6                 MOVSI    2,201600
        7                 MOVEM    2,V
280     10                MOVSI    2,203660
        11                FDVR     2,V
        12                FADRI    2,207404
        13                FMPR     2,[160517426542]
        14                MOVEM    2,AX
300     15                MOVEI    3,36
        16                MOVEI    2,1
        17                MOVEM    3,.S0000
        20      3M:
                          MOVEM    2,J
400     21      4M:
                          FLTR     2,2
        22                MOVEM    2,AJ
500     23                MOVSI    2,201400
        24                FADR     2,TD
        25                FSBR     2,AJ
        26                MOVEM    2,TDC
600     27                FADR     2,[211421121727]
        30                MOVEM    2,TDK
700     31                MOVE     3,TDC
        32                FMPR     3,[201714631463]
        33                FADRI    3,206400
        34                MOVEM    3,TDF
800     35                MOVE     3,TDK
        36                FADR     3,Q
        37                MOVE     5,R
        40                FDVR     5,TDK
        41                FADRI    5,576400
        42                FMPR     2,B
        43                FADR     2,A
        44                FMPR     2,3
        45                FMPR     2,3
        46                FADR     2,P
        47                FMPR     2,5
        50                MOVEM    2,Y
900     51                MOVEI    16,5M
        52                PUSHJ    17,EXP.
        53                MOVE     2,[225940750651]
        54                FDVR     2,0
        55                MOVEM    2,PS
1000    56                MOVE     2,[777742000001]
1100    57      6M:
                          MOVEI    3,0(2)
        60                FLTR     3,3
```

```
        61              MOVNM   3,AI
1200    62              MOVSI   3,201400
        63              FADR    3,TW
        64              FSBR    3,AJ
        65              MOVEM   3,TWC
1300    66              FADR    3,[211421121727]
        67              MOVEM   3,TWK
1400    70              MOVE    4,TWC
        71              FMPR    4,[201714631463]
        72              FADRI   4,206400
        73              MOVEM   4,TWF
1450    74              MOVE    4,TAC
        75              CAMLE   4,TDC
        76              JRST    0,10P
1500    77              MOVN    5,TWK
        100             FADR    5,G
        101             MOVE    7,R
        102             FDVR    7,TWK
        103             FADRI   7,576400
        104             FMPR    3,B
        105             FADR    3,A
        106             FMPR    3,5
        107             FMPR    3,5
        110             FADR    3,P
        111             FMPR    3,7
        112             MOVEM   3,X
1600    113             MOVEI   16,7M
        114             PUSHJ   17,EXP.
        115             MOVE    3,[222504075065]
        116             FDVR    3,0
        117             MOVEM   3,PW
1700    120             MOVN    5,TWC
        121             FADR    5,TDC
        122             MOVN    3,PH
        123             FMPR    3,AX
        124             FAPR    3,5
        125             FADR    3,PW
        126             MOVEM   3,PH
2200    127     11P:
                        FMPRI   3,207620
        130             FDVR    3,PS
        131             MOVEM   3,RH
2250    132             CAIL    3,0
        133             CAMLE   3,[207620000000]
        134             JRST    0,10P
2300    135     8M:
                55P:
                        MOVEI   16,9M
        136             PUSHJ   17,OUT.
        137             MOVEI   16,10M
        140             PUSHJ   17,IOLST.
2500    141     10P:
                        AOBJN   2,6M
        142             AOS     2,J
        143             AOSGE   0,.S0000
        144             JRST    0,4M
```

```
2[illegible]     145              MOVEI    16,1M
                 146              PUSHJ    17,STOP.
2705             147              MOVEI    16,1M
                 150              PUSHJ    17,EXIT.

 ARGUMENT BLOCKS:

        151                   0,,0
        152        1M:        0,,0
        153                   777777,,0
        154        7M:        200,,X
        155                   777777,,0
        156        5M:        200,,Y
        157                   777773,,0
        160        2M:        0,,777775
        161                   0,,0
        162                   0,,0
        163                   340,,8P
        164                   0,,24
        165                   777773,,0
        166        9M:        0,,777775
        167                   0,,0
        170                   0,,0
        171                   340,,70P
        172                   0,,3
        173                   0,,0
        174        10M:       1200,,TWF
        175                   1200,,TWC
        176                   1200,,TDF
        177                   1200,,TDC
        200                   1200,,RH
        201                   1200,,PH
        202                   1200,,PS
        203                   4000,,0

FORMAT STATEMENTS (IN LOW SEGMENT):

 220    35         8P:        (2X,'
        36                    WET F
        37                    HAR',
        40                    2X,'W
        41                    ET CE
        42                    NT',2
        43                    X,'DR
        44                    Y FHA
        45                    R',2X
        46                    ,'DRY
        47                     CENT
        50                    ',2X'
        51                    HUMID
        52                    ITY',
        53                    2X,'P
        54                    ARITA
        55                    L',2X
        56                    ,'SAT
```

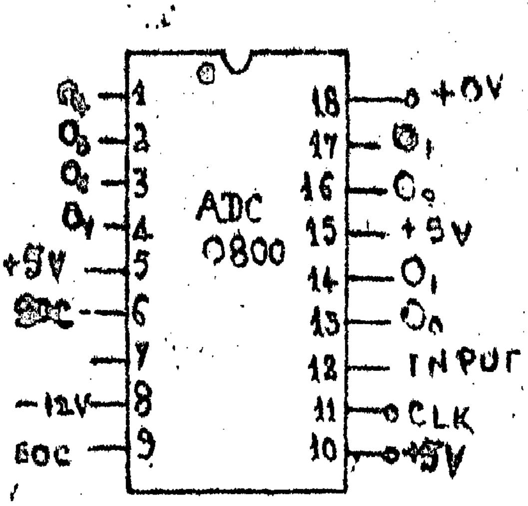


Fig. A.6 - PIN CONNECTIONS OF ADC-0800

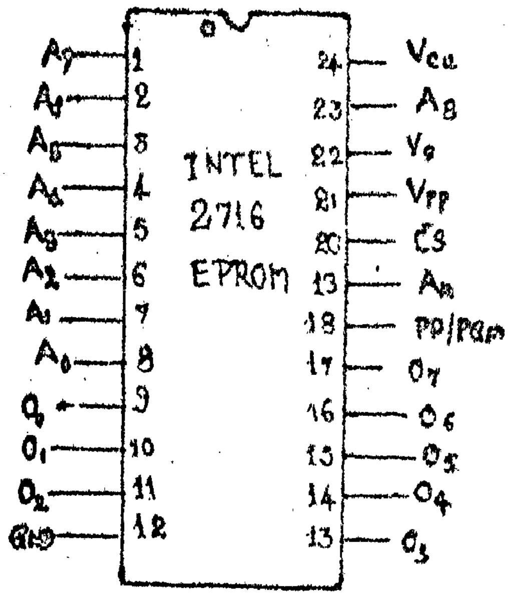


FIG. A.7 - PIN CONNECTIONS OF INTEL 2716

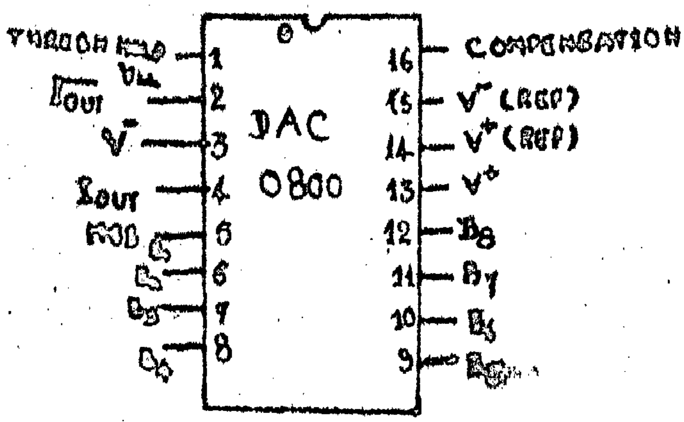


Fig. 9(a)

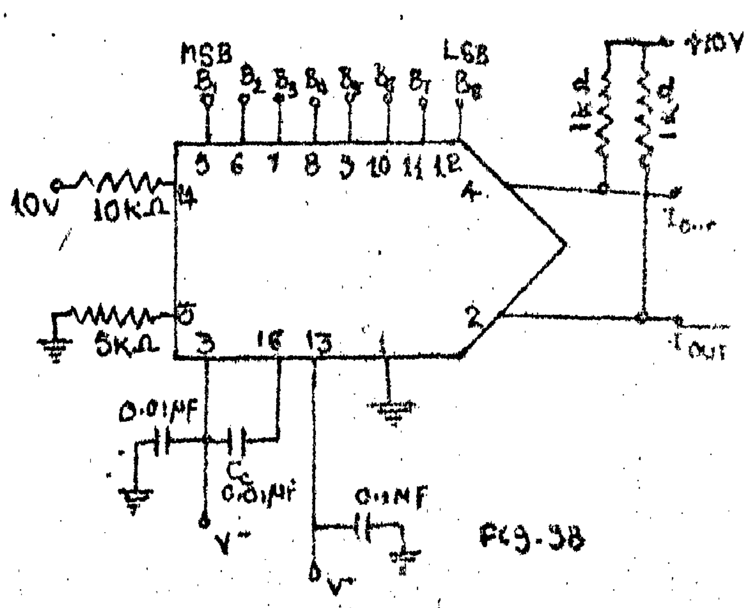


Fig. A.9 - PIN CONNECTIONS OF DAC-0800

APPENDIX : 6

MANUAL DETAILS OF EPROM INTEL 2716

Intel 2716 is a fully static 16,384 bit (2048 x 8) Erasable Programmable Read Only Memory, or EPROM[21]. This device is packed in a standard 24-pin DIP. This device requires a single power supply (V_{CC} = + 5V ± 5%) for normal read cycles; during programming the program power supply V_{PP} must be rised to + 25V, to program each location, a single TTL level pulse (PD/PGM) is required, one 50 msec. pulse for address programmes 8-bits in parallel. This address can be randomly programmed. The pin configuration of Intel 2716 DIP is shown in Fig: A.7. The functions of various control pins are shown in table A.3. From Table 3, during the read operation CS is used to select and deselect the 2716. The PD/PGM is maintained at V_{IL} while V_{PP}, the program power supply is maintained at +5V. Similarly other modes are achieved by selecting proper values from table A.3. It has an access time upto 350 msec., is ideal for high performance microprocessors such as Intel 8085, 8086. The Intel 2716, memory is completely static in nature. It has low power dissipation (525 mW); inputs and outputs are TTL compatible during Read and Program this memory chip.

TABLE A.3*

Pins/Mode	PD/PGM (18	CS 20	V_{PP} 21	V_{CC} 24	OUTPUTS 9-11, 13-17
Read	V_{IL}	V_{IL}	+5	+5	D_{OUT}
Deselect	Do not care	V_{IH}	+5	+5	HIGH Z
Programme	Pulse V_{IL} to V_{IH}	V_{IH}	+25	+5	D_{IN}
Programme verify	V_{IL}	V_{IL}	+25	+5	D_{OUT}
Program inhibit	V_{IL}	V_{IH}	+25	+5	HIGH Z

* Manual details of EPROM Intel 2716

APPENDIX:7

8-BIT TO BCD CONVERTOR,DISPLAY

8-bit to BCD convertor circuit dia-gram is shown in Fig. A.8. To convert 8-bit data into BCD form, three 74185A ICS are connected as shown in Fig.A.8[22] 74185A, 6-bit to BCD convertor is an open collector IC and therefore a pull up resistor of 3.3 K ohm is used with each output. The unused outputs of 74185 are kept high. The 74185A outputs are followed by a BCD to seven segment display. It requires three 7485 ~~driver decoders~~ delay latches, ~~five~~ three 7447 ~~buffer~~ driver/~~latches~~ decoders and three MAN-72 LEDS or FND-500. A resistance 100 ohms is connected at each input terminal of LEDS to limit the current.

DIAGRAM 1 - PIN NUMBERING

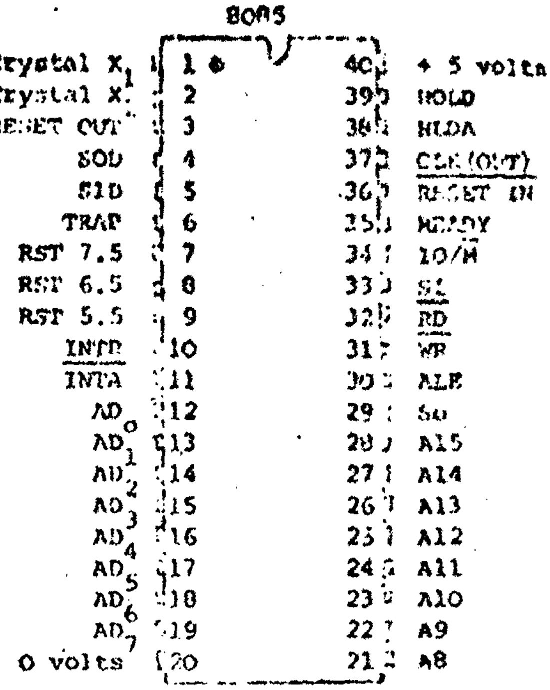


DIAGRAM 2 - SYSTEM SCHEMATIC

FIG.A.10 PIN CONFIGURATION OF 8085

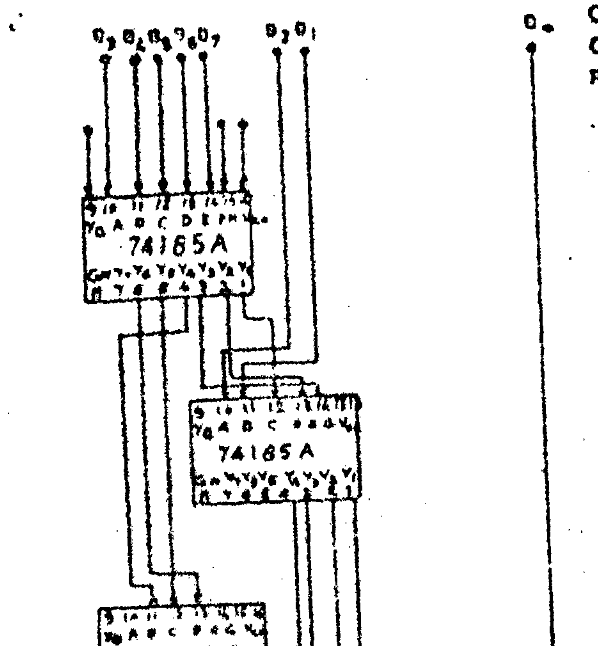
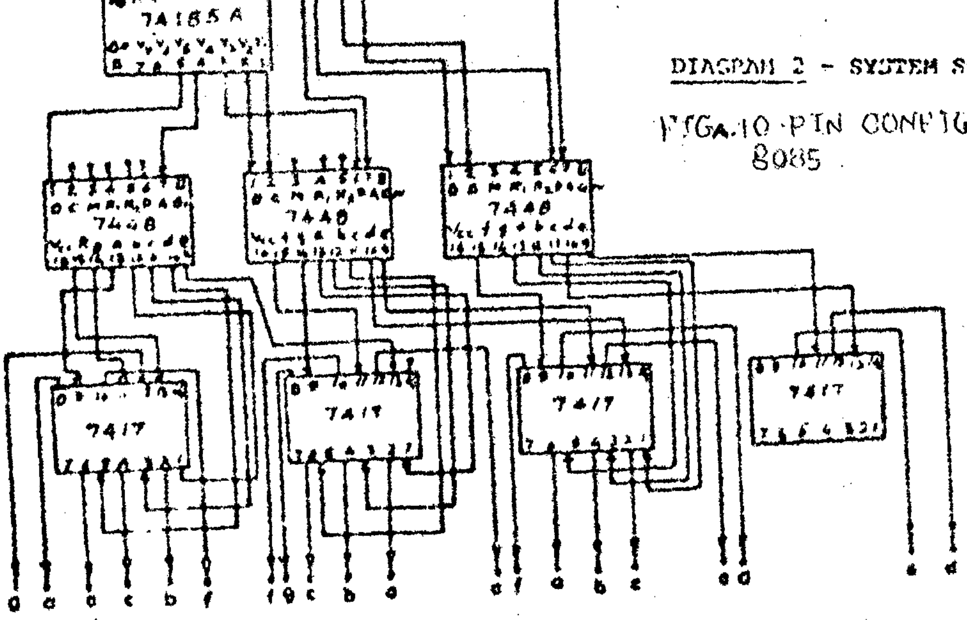



FIG.A.5 8-BIT BCD CONVERTOR, DISPLAY CIRCUIT

APPENDIX:8

MANUAL DETAILS OF DAC-0800

The DAC is a monolithic 8-bit high speed current output digital to analog convertor (DAC) featuring typical settling times of 100 n sec. It is having 16-pins and its configuration and external connections are shown in Fig.A.9[23]. The noise immune inputs of the DAC 0800 will accept TTL levels with the logic threshold pin, V_{LC}, pin 1 grounded.Simple adjustments of the V_{LC} potential allow direct interface to all logic families. The performance and characteristics of the device are essentially unchanged over the full scale ±4.5 volts to ± 18 volts power supply range; power dissipation is only 33 mW with ±5V supplies and is independent of the logic input states. It's features are (i) Full scale error ± 1LSB, (ii) Nonlinearity over temperature ± 0.1%, (iii) High output compliance -10V to + 18V, (iv) Interface directly with TTL, CMOS, PMOS and others, (v) Wide power supply range ± 4.5V to ± 18V, (vi) Low power consumption, and (vii) Low cost. Electrical characteristics:(V_S= ±15V, I_{REF} =2mA Table A.4 shows electrical characteristics of ADC-0800.

TABLE A.4 *

Parameter	Conditions	Min	Typical	Max	Units
Resolution		8	8	8	uV
Non-Linearity				±0.1	%
Settling time	To ±½LSB,all bits switched ON or OFF			100	n Sec.
t_{PLH}, t_{PHL} propagation delay each bit & all bits	T_A = 25°C **		35	60	n Sec.

* MANUAL DETAILS OF DAC-0800

** Further details see Manual of DAC 0800.

APPENDIX: 9

INTRODUCTION TO INTEL 8085

The Intel 8085 is an 8-bit, 40-pin dual in package microprocessor. The address and data are transfered between the microprocessor and environment on one 8-bit wide data bus/address bus and one 8-bit wide address bus. Fig. A.10 shows the pin configuration of Intel 8085 microprocessor.[25]

State transition sequence:

With in a machine cycle the microprocessor moves from one state to another state according to a fixed algorithm. The algorithm specifies what is known as state transition sequence of the uP. For 8085, the algorithm appears as a transition diagram in Fig.A.11[26]. Note that from this diagram, the microprocessor can movementarily stopped from executing machine cycle by HOLD signal, an interrupt can only be recognized at the end of machine cycle. This fact finds the utility when I/O devices are interfaced with uP or several 8085s are connected together.

Architecture of Intel 8085:

Inside the 8085 there are several registers which are used during execution of the program. Let us describe the size and use of each of the registers. Fig. A.12 may be referred to while reading about the registers.

There is one 8-bit register known as accumulator, abbreviated as ACC in Fig.A.12. It is used in various arithmetic and logical opera-tions. For example, during the addition of

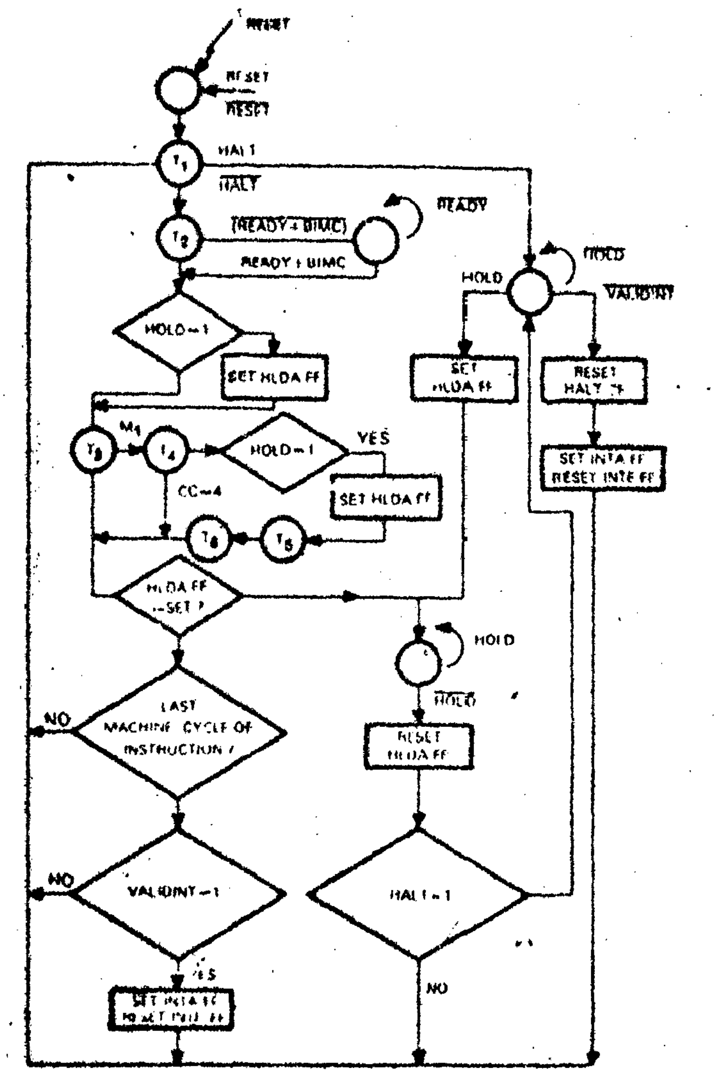


FIG. A.11 STATE TRANSITION DIAGRAM OF INTEL 8055 two eight bit integers, one of the operands must be in the accumulator. The other operand may be either in memory or in one of the registers.

There are six general purpose 8-bit registers that can be used by the programmer for a variety of purposes. The registers are labelled as B,C,D,E,H and L. They can be used individually or in pairs. The codes are mentioned in Table A.5. There is a 16-bit register which is used to keep track of the address of the instruction (in the memory) that has to be executed next. This register is called the program counter. The contents of the program counter are automatically updated by Intel 8085 during

TABLE A.5**

Register Pairs		General purpose registers	
Register pairs	Bit pattern desionating pair	Register	Code
B-C	00	A	111
D-E	01	B	000
H-L	10	C	001
SP*	11	D	010
		E	011
		H	100
		L	101

*This is a sixteen bit register and not a pair of two registers.

**See Manual of Intel 8085

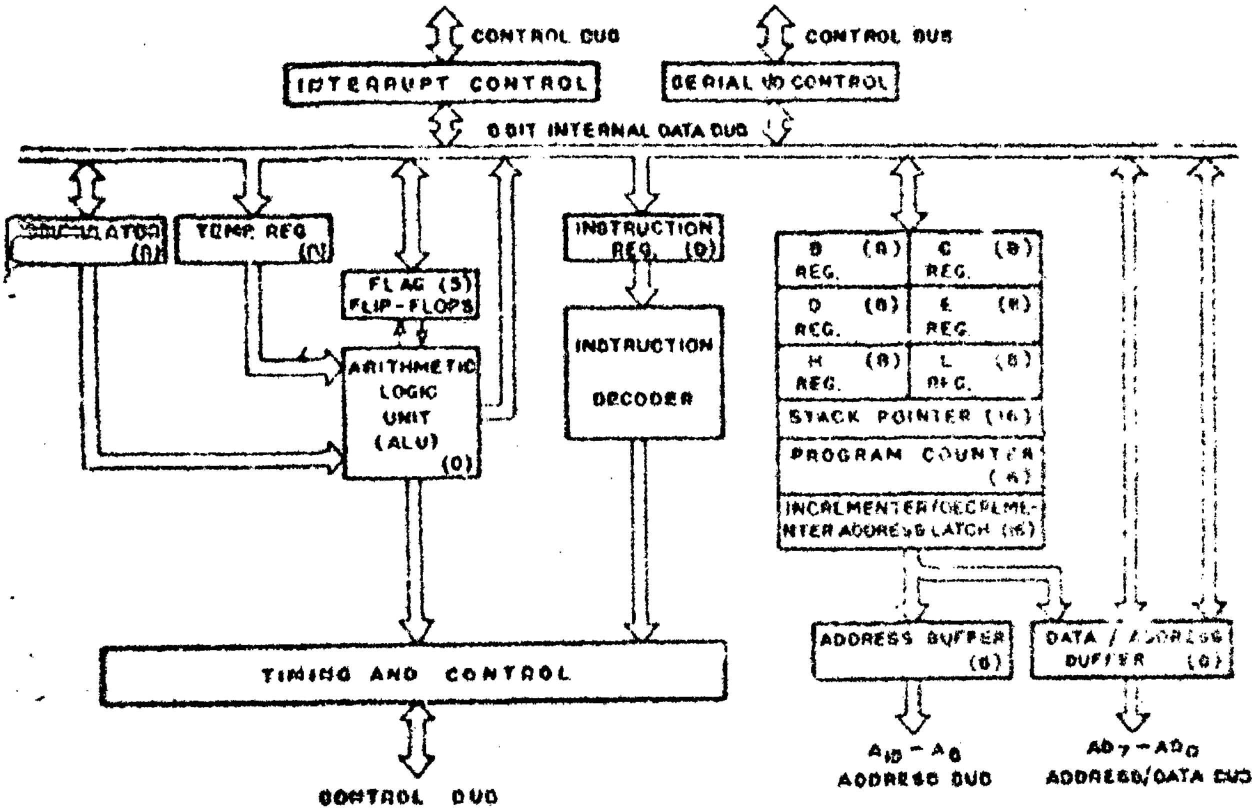


FIG. 4.1: ARCHITECTURE OF INTEL 8085

the execution of an instruction, so that at the end of execution of the instruction it points to the address of the next instruction in the memory. Recall that 16-bits of the address are sent out by 8085 on the address bus and on the data bus, in the same instance the PC contains this address before it is transmitted.

There is another 16-bit register known as stack pointer. It is used by the programmer to maintain a stack in memory.

A set of five flip-flops, are used to indicate certain conditions that arise during the arithmetic and logical operations. Each

S	Z	X	AC	X	P	X	CY
D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0

flag is one bit register. The eight bits of accumulator contents are formed as flags as shown above. The flags are named CY-Carry flag, S-Sign flag, Z-Z ero flag, AC-Auxilary carry flag , P-Parity flag[24].

Programming of 8085:

Programming refers to the process of developing a program. A program is a sequence of instructions that operate on certain data terms. A program is written in zeros and ones is known as a machine language. As it will be evident soon, writing a program in machine language is a cumbersome and error prone process. One may also write a program using mnemonics (operation codes) or symbollic for writing instructions and define the data using hexa decimal, octal or binary notation.

Before one begins to learn programming it is instructive to get an ov er view of the programming process. Fig.A.13 shows a flow-chart of depicting this process. After the problem has been stated one develops an algorithm for it. An algorithm is a precise statement of the procedure required for solving the problem. The algorithm may be expressed in variety of forms. It may be expressed using an english like language or assembly language or machine language. Then this program is fed to the memory.

Executing a Program:

The microprocessor sequentially reads the stored program from memory locations one after another and performs operations demanded by the instructions. Certain instructions like JUMP, CALL or RE TURN interrupt the normal sequential execution and forces the program to the some other programmed address location. The processor once again begins sequential memory reading from the new address location. Let us see how the microprocessor is able to interrupt an OP-code and performs the logical functions demanded by that instruction. The instruction decoder is basically a ROM within the processor. It is inaccessable to the user. The ROM contains 'microprogram' which tells the processor exactly what to do to execute in every machine cycle of an instruction. Its state transient diagram is shown in Fig. A.11. Let us consider the jump instruction. After executing the instruction previous to JMP instruction the microprocessor will automatically interrupt the content of the next memory location as an OP-code. It reads this OP-code for JMP and under stands that the next

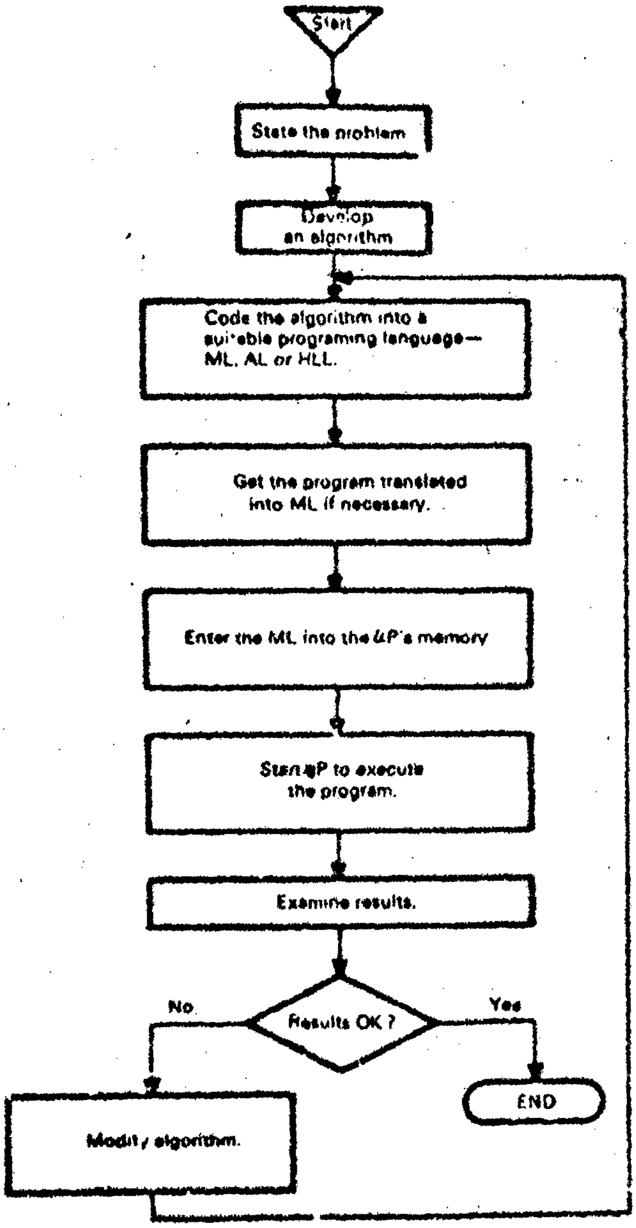


FIG.A13: PROGRAMMING PROCESS OF INTEL 8085 two memory locations contain the address of the memory location to where the program has to jump. This understanding power is present in the Instruction Decoder. In executing this instruction the processor changes the contents of the program counter to Jump address. Normal execution of the program continuous from the new address location. It is thus upto the programmer to rightly sequence his program and make sure that the processor does not interrupt a data as an OP-code and vice-versa. The instruction set of Intel 8085 is given in Table A.5.1*

*Manual of Intel 8085

EDUCOM 85 M

Assembly Language to Machine Language Hand Coding Sheet

DATA TRANSFER GROUP

Instruction	Mnemonic		X: A	B	C	D	E	H	L	SP	M	Bytes	Clocks (register/memory)	Flags affected
Move X to A	MOV A,X		7F	78	79	7A	7B	7C	7D		7E	1	4/7	None
Move X to B	MOV B,X		47	40	41	42	43	44	45		46	1	4/7	"
Move X to C	MOV C,X		4F	48	49	4A	4B	4C	4D		4E	1	4/7	"
Move X to D	MOV D,X		57	50	51	52	53	54	55		56	1	4/7	"
Move X to E	MOV E,X		5F	58	59	5A	5B	5C	5D		5E	1	4/7	"
Move X to H	MOV H,X		67	60	61	62	63	64	65		66	1	4/7	"
Move X to L	MOV L,X		6F	68	69	6A	6B	6C	6D		6E	1	4/7	"
Move X to Memory	MOV M,X		77	70	71	72	73	74	75			1	7	"
Move immediate to X	MVI X, data		3E	06	0E	16	1E	26	2E		36	2	7/10	"
Load rp immediate	LXI X, data			01		11		21		31		3	10	"
Load A direct	LDA	3A										3	13	"
Store A direct	STA	32										3	13	"
Load HL direct	LHLD	2A										3	16	"
Store HL direct	SHLD	22										3	16	"
Load A indirect	LDAX			0A		1A						1	7	"
Store A indirect	STAX			02		12						1	7	"
Exchange DE & HL	XCHG	EB										1	4	"

ARITHMETIC AND LOGIC GROUP

Instruction	Mnemonic		X: A	B	C	D	E	H	L	SP	M	Bytes	Clocks (register/memory)	Flags affected
Add X to A	ADD X		87	80	81	82	83	84	85		86	1	4/7	All
Add immediate to A	ADI data	C6										2	7	"
Add X to A with carry	ADC X		8F	88	89	8A	8B	8C	8D		8E	1	4/7	"
Add immediate to A with carry	ACI data	CE										2	7	"
Subtract X from A	SUB X		97	90	91	92	93	94	95		96	1	4/7	"
Subtract immediate from A	SUI data	D6										2	7	"
Subtract X from A with borrow	SBB X		9F	98	99	9A	9B	9C	9D		9E	1	4/7	"
Subtract immediate from A with borrow	SBI data	DE										2	7	"
Increment X	INR X		3C	04	0C	14	1C	24	2C		34	1	4/10	All except CY
Decrement X	DCR X		3D	05	0D	15	1D	25	2D		35	1	4/10	All except CY
Increment rp X	INX X			03		13		23		33		1	6	None
Decrement rp X	DCX X			0B		1B		2B		3B		1	6	None
Double add rp X to HL	DAD X			09		19		29		39		1	10	only CY
Decimal Adjust A	DAA	27										1	4	All
And X with A	ANA X		A7	A0	A1	A2	A3	A4	A5		A6	1	4/7	All, CY cleared, AC set
And immediate with A	ANI data	E6										2	7	All, CY cleared, AC set
Exclusive or X with A	XRA X		AF	A8	A9	AA	AB	AC	AD		AE	1	4/7	All, CY, AC cleared
Exclusive or immediate with A	XRI data	EE										2	7	"
Or X with A	ORA X		B7	B0	B1	B2	B3	B4	B5		B6	1	4/7	"
Or immediate with A	ORI data	F6										2	4	"
Compare X with A	CMP X		BF	B8	B9	BA	BB	BC	BD		BE	1	4/7	All CY set if A<X
Compare immediate with A	CPI data	FE										2	7	"
Rotate A left	RLC	07										1	4	Only CY
Rotate A right	RRC	0F										1	4	"
Rotate A left through CY	RAL	17										1	4	"
Rotate A right through CY	RAR	1F										1	4	"
Complement A	CMA	2F										1	4	None
Complement carry	CMC	3F										1	4	Only CY
Set carry	STC	37										1	4	"

CONTROL TRANSFER AND MISCELLANEOUS INSTRUCTIONS

Instruction	Mnemonic		X: NZ	Z	NC	C	PO	PE	P	M	Bytes	Clocks (False/True)	Flags affected
Jump	JMP	C3									3	10	None
Jump conditional	JX		C2	CA	D2	DA	E2	EA	F2	FA	3	7/10	"
Call	CALL	CD									3	18	"
Call conditional	CX		C4	CC	D4	DC	E4	EC	F4	FC	3	9/18	"
Return	RET	C9									1	10	"
Return conditional	RX		C0	C8	D0	D8	E0	E8	F0	F8	1	6/12	"
HL to PC	PCHL	E9									1	6	"

Instruction	Mnemonic	X: 0	1	2	3	4	5	6	7	Bytes	Clocks	Flags affected
Restart	RST X	C7	CF	D7	DF	E7	EF	F7	FF	1	12	"

Instruction	Mnemonic		X: B	D	H	PSW	Bytes	Clocks	Flags affected
Push rp on stack	PUSH X		C5	D5	E5	F5	1	12	"
Pop rp from stack	POP X		C1	D1	E1	F1	1	10	"
Exchange top of stack & HL	XTHL	E3					1	16	"
HL to SP	SPHL	F9					1	6	"
Input	IN	DB					2	10	"
Output	OUT	D3					2	10	"
Enable interrupt	EI	FB					1	4	"
Disable interrupt	DI	F3					1	4	"
Halt	HLT	76					1	5	"
No operation	NOP	00					1	4	"
Read Interrupt Mask	RIM	20	SID I7.5 I6.5 I5.5 IE M7.5 M6.5 M5.5				1	4	"
Set Interrupt Mask	SIM	30	SOD SDE X R7.5 MSE M7.5 M6.5 M5.5				1	4	"

APPENDIX:10

[illegible] PROGRAM [illegible] CONVERSION
[illegible] IN [illegible]

[illegible] BIT

[illegible] INTEGER NUMBER

[illegible] IN MANTISSA

[illegible] IN MANTISSA

[illegible] ********************************
[illegible] ********************************

[illegible] POINT MULTIPLICATION
[illegible] X IN SIGN
[illegible] X IN SIGN MAGNITUDE
[illegible] Y IN SIGN MAGNITUDE
[illegible] Y IN SIGN MAGNITUDE

/R [illegible]

[illegible] R ATION OF MANTISSA STORED
[illegible] REG CONTAINS [illegible]
[illegible] OF X AND Y RESPECTIVELY

/S [illegible] N [illegible] HIGER ORDER
[illegible] COMPONENT OF THE
[illegible] SIGN [illegible]

[illegible] COMPLEMENT
[illegible] VE NUMBER

[illegible] NUMBER

/POSITIVE SIGN TO EXPONENT SUM

, SUM OF EXPONENTS IN SIGN MAGNITUDE

/IF MSB OF PRODUCT IS ZERO
ADD +1 TO EXPONENT

X22

X17 R

/REG 8 C MANTISSA PRODUCT OF X AND Y WITH OUT
SIGN BIT
/REG 0 C EXPONENT OF PRODUCT IN SIGN MAGNITUDE

/BRING SIGN TO MANTISSA PRODUCT

A, E

```
         MOV   L,A    /        /IF VALUE OF  Y  X JUMP TO X21
         JMP   X21
X12:     LDA   CF              /IF EXP  OF X IS '-' & Y IS '+'
         RAL
         JC    X14
         MOV   A,D
         ADD   E               / VALUE OF Y  X   ,HENCE JUMP TO X21
         MOV   L,A
         JMP   X21
X14:     MOV   A,D
         CMP   E               /IF BOTH ARE EXPS '-'VE
         JNC   X17
         JC    X16
X13:     MOV   D,A
         ADD   E
         MOV   L,A
X20:     LDA   CD
         MOV   D,A
         MOV   A,L             /IF EXP OF Y IS SMALLER THAN X
         JZ    X22              SHIFT MANTISSA OF Y RIGHT SIDE TILL
         DCR   L                EXP'S DIFFERENCE IS ZERO
         MOV   A,C
         STC
         CMC
         RAR
         MOV   C,A
         JMP   X20
X21:     LDA   CF              /IF EXP OF X IS SMALLER THAN EXP OF Y
         MOV   D,A
         MOV   A,L
         JZ    X22
         DCR   L
         MOV   A,B
         STC
         CMC
         RAR
         MOV   B,A
         JMP   X21
X22:     LDA   CC
         RAL
         JC    X23
         LDA   CE
         RAL
         JC    X24
X28:     MOV   A,B
         ADD   C
         RAL
         JNC   X25
         RAR
         STC
         CMC
         RAR
         MOV   B,A
         MOV   A,D
```

A.10.6

/CHECK SIGN BITS OF X ONLY
MANTISSAS AND [illegible] PROPER
SIGN TO RESULT

X3 [illegible]

B,A

[illegible] ISSA OF RESULT [illegible] MAGNITUDE
[illegible] OF RESULT [illegible] MAGNITUDE
****
[illegible]

MANTISSA ... [illegible] AS ZEROS

B,A

3 ⟹ JMPX62

```
        [illegible]
        [illegible] X[illegible]
        [illegible]
        [illegible] X[illegible]
        [illegible]A C2
        [illegible]
        JA[illegible] X13
        JMP X15
X[illegible]:  MOV A,B
        RAL
        S[illegible]
        RAR
        MOV B,A
/REG -B CONTAINS MANTISSA OF RESULT WITH PROPER SIGN BIT
        IN SIGN MAGNITUDE
/SUBTRACTION OF EXPONENT STARTS
X15:    L[illegible] C1
        [illegible]
        J[illegible] X16
        [illegible]
        A[illegible]
        [illegible]
        A[illegible] A,[illegible]
        M[illegible] [illegible]
        J[illegible] X[illegible]
X[illegible]:  [illegible]
        MOV [illegible]
X[illegible]:  [illegible]
        [illegible]
        J[illegible] X[illegible]
        [illegible]
```

```
[illegible]
[illegible]
[illegible]
[illegible] EXIT [illegible]
        MOV C,B
        [illegible] A,D
        RAL
        STC
        CMC
        [illegible]
        MOV B,A
        MVI A,[illegible]
        SUB E
        JZ X12
        MOV E,A
X10:    MOV A,B
        STC
        CMC
        RAR
        MOV B,A
        DCR E
        JNZ X10
X12:    MOV A,C
        RAL
        JNC X11
        MOV A,B
        RAL
        STC
        RAR
        MOV B,A
X11:    RET
;[illegible] B CONTAINS FP EQ. INTEGER NUMBER
;[illegible]
;[illegible]
;[illegible]
;[illegible] LANGUAGE FOR [illegible] COEFFICIENT
;[illegible]
;[illegible]
;[illegible] AIR COEFFICIENT BEGINS
        [illegible] 0807
        [illegible] 0A11
        [illegible] 0B08
        [illegible] 0B13
        [illegible]
        [illegible] 0810
        [illegible]
        [illegible]
        [illegible]
```

A.10.10

```
        [illegible]
        [illegible]          ==> MVI A,61
                                 STA 0B03
        [illegible]
        [illegible]
[illegible]  [illegible] SCA
        MOV A,E
        STA 0B03             ==> MOV A,D
        MVI A,[illegible]         STA 0B04
        STA 0B05
        MVI A,8E
        STA 0B06
[illegible] FMUL
        MOV A,B
        STA 0B01
[illegible] MANTISSA IS IN REG-B
         EXPONENT IS IN REG-E
        MOV A,D
        STA 0B02
        RET
;AIR [illegible] [illegible]ITY COEFFICIENT IS STORED IN REG-B/D
        AND ALSO IN <0B01>/<0B02> LOCATIONS
[illegible]*****************[illegible]
[illegible]*****************[illegible]

[illegible] SUBROUTINE "POWEX"
[illegible] LANGUAGE FOR COMPUTATION OF
        [illegible](TD*B))*(TD-Q)*([illegible])*(R/TD - 1.)
[illegible] EXECUTE THIS PROGRAM [illegible] ARE
        <0B50>:MANTISSA OF TEMPERATURE IN DEGREE KELVIN
;       <0B51>:EXPONENT OF TEMPERATURE IN DEGREE KELVIN
        [illegible] 0B50
        STA 0B03
        [illegible] 0B51
        STA 0B04
        MVI A,B4
        STA 0B05
        MVI A,9A
        [illegible] 0B06
[illegible] [illegible]
        MOV A,B
        STA 0B09
        [illegible] [illegible]
        [illegible] 0B0A
        [illegible] A,0D
        STA 0B0B
        [illegible] A,8E
        [illegible] 0B0C
[illegible] [illegible]
        [illegible] A,B
        [illegible] 0B03
        MOV A,D
        [illegible] 0B04
        [illegible] 0B50
        [illegible] 0B09
        [illegible] 0B01
        [illegible] 0B0A
        [illegible]
        [illegible]
        [illegible]
        [illegible] [illegible]0C
[illegible] [illegible]
        [illegible]
        [illegible]
        [illegible]
```

4.10.11

```
#CA[illegible]                /COMPUTATION OF (A+(B*TD))*(TD-Q)[illegible]
        [illegible]
        STA 0B03
        MOV A,D
        STA 0B04
        [illegible]
        MOV A,B
        STA 0B09
        MOV A,D
        STA 0B0A
        MVI A,73
        STA 0B0B
        MVI A,03
        STA 0B0C
#CALL   FPSU[illegible]
        MOV A,B
        STA 0B03
        MOV A,D
        STA 0B04          /COMPUTATION OF
        LDA 0B50
        STA 0B12
        LDA 0B51
        STA 0B13  ==>  MVI A,62
                       STA 0B10
        MVI A,0A
        STA 0B11
#CALL   [illegible]DIV              (F+(A+(B*TD))*(TD-Q)*(TD-Q)
        MOV A,B
        STA 0B09
        MOV A,D
        STA 0B0A
        MVI A,00
        STA 0B0B
        MVI A,01
        STA 0B0C
#CALL   FPSUM      /COMPUTATION OF F+(A+(B*TD)O*(TD-Q)*(TD-Q)6
                                   *(R/TD -1)
        MOV A,B
        STA 0B05
        MOV A,D
        STA 0B06
#CALL   FPMUL
        RET
/RESULT IN REG B:MANTISSA OF POWER OF EXPONENT
FOR GIVEN TEMP,  ,REG-D EXPONENTOF RESULT
*******************************************************************
```

A.10.12

```
[illegible] EXP IN [illegible]
[illegible] EXPONENT IN [illegible]
[illegible] 0870,0872 [illegible] 0871,0873 [illegible]
[illegible]
[illegible] ALSO STORED [illegible]
[illegible] NUMBER OF [illegible]
      0870
      [illegible]
      0E7
      [illegible]
      [illegible]
      1310
      0173
      [illegible]
[illegible]                    /CALCULATION OF [illegible]
      [illegible]
      0809
      [illegible]
      0604
      [illegible]
      1508
      0873
      [illegible]
[illegible]                 /COMPUTATION OF SUM OF [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]        /COMPUTATION OF N. STARTS
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
[illegible]              [illegible] N VALUE INCREMENTAL
[illegible]
```

A10.13

```
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]    /X**N COMPUTED
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
MOV [illegible]
[illegible] 0675
MOV [illegible]
RET
[illegible] MANTISSA OF EXPONENT VALUE OF X
[illegible] OF RESULT FOR VALUE OF [illegible]
[illegible] ***********************[illegible]
[illegible] ***********************[illegible]
[illegible]
[illegible] OF SAT.
[illegible] LOCATIONS WITH [illegible]
[illegible]
[illegible]
```

9

```
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
```

```
        STA 0B05
        MVI A,55
        STA 0B05
        MVI A,0A
        STA 0B06
  $CALL FPMUL
        MOV A,B
        STA 0B10
        MOV A,D
        STA 0B11
  $CALL FPDIV
        RET
/B & C CONTAINS MANTISSA OF SAT.PRE.
/D & E CONTAINS EXPONENT OF SAT.PRE.
**************************************************************************************

**************************************************************************************

*******MAIN PROGRAM**********
/EVALUATION OF RELATIVE HUMIDITY MAIN PROGRAM
/INPUT AIR VELOCITY
/0B52 CONTAINS AIR VELOCITY
        LDA 0B52
        STA0B00
  $CALL
        FPCON
        MOV A,C
        STA 0B07
        MOV A,E
        STA 0B08
  $CALL AIRVE
/0B01,0B02 CONTAINS AIR VELOCITY COE.
        /INPUT DRY BULB TEMP.
              0B53 CONTAINS DRY TEMP.
        LDA 0B53
        STA 0B00
  $CALL FPCON
        MOV A,C
        STA 0B54
        STA 0B09
        MOV A,E
        STA 0B0A
        STA 0B55
  $CALL SATPR
        MOV A,B
        STA 0B56
        MOV A,D
        STA 0B57
/0B56,0B57 CONTAINS SAT.PRE.
```

```
STA OB09
MOV A,E
STA OB5A
STA OB0A
CALL SAT.PRE.0D70
MOV A,B
/OB5C:OB5D CONTAINS SET
PRESSURE AT WET TEMP.
STA OB5C
MOV A,D
STA OB5D
/EVALUATION OF PARTIAL
PRESSURE STARTS
LDA OB54
STA OB0B
LDA OB55
STA OB0C
LDA OB59
ADI A,B0
/TO CONVERT '-'VE
STA OB09
LDA OB5A
STA OB0A
CALL ADDITION
/COMPUTATION TD-TW
MOV A,B
STA OB03
MOV A,D
STA OB04
LDA OB01
STA OB05
LDA OB02
STA OB06
CALL MULT
/COMPUTATION OF AX *(TD-TW)
MOV A,B
STA OB03
MOV A,D
STA OB04
MVI A,5D
STA OB05
MVI A,0A
STA OB06
CALL MULT
MOV A,B
ADI A,80
STA OB09
MOV A,D
STA OB0A
LDA OB5C
STA OB0B
LDA OB5D
STA OB0C
CALL ADDITION
MOV A,B
STA OB10
MOV A,B
STA OB10
MOV A,D
STA OB11
LDA OB56
STA OB12
LDA OB57
STA OB13
CALL FP DIVISION
/COMPUTATION OF PH/PS=RX
MOV A,B
STA OB03
MOV A,D
STA OB04
MVI A,64
STA OB05
MVI A,07
STA OB06
CALL MULT
MOV A,B
/REG.B CONTAINS MANTISSA OF RH
STA OB5E
MOV A,D
/REG-D CONTAINS EXP OF RH
STA OB5F
CALL FP TO INTEGER CON
MOV A,B
STA OB60
HLT
/REG-B & OB60 CONTAINS RH VALUE IN
HEXA DECIMAL
*************************************
```

```
..JBRO[illegible]   .CON" ORG-CONT ORG-CONT ORG-CONT ********************
*<0800 [illegible]     0847 0F   0880 72   088C 02 *SUBROUTINE [illegible]
 LOCA[illegible]                4F         B3        C1 *[illegible]09>MANTISSAOFY
*R[illegible] [illegible]SUL*MANTI         7C         08        08 *<080A>EXEPONENTA
 SSA[illegible] RESULT          D2         DE   0880 1F *<080B>MANTISSAOFX
 EXPON[illegible]********        4E          01         78 *<080C>EXEPONENTOFY
 ORG-CONT********          08         2F         17  ORG-CONT ORG-CONT
 0800 3A *SUBROUTI          80         17         37 0900 3A   092C DA
       0C [illegible] FPMUL" 084E 1F          37         3F         09         47
       03 *<0803>LO         67         1F         1F         08         09
       57 CAININCON         7A   0833 57         C3         17         3A
       1E TAINSMANT         1F         7B         C6         D2         0C
       08 SSAOFMUL         57         17       08         08        0B
       7A TIPLIER          1D         1A   08B9 1F         09         17
       D2 *<0804>CO         C2         9C         3A         3F         D4
       0B NTAINEXP         46         08         05   0908 1F         5C
       08 ONENTOFMU         08         1F         0B         47         09
       3F LTIPLIER          5C         7A         17         3A         7A
 080B F2 *<0805>CO         3A         17         D2         0B         BB
       11 NTAINSMAN         04         02         B0         0B         D4
       08 TISSAOFMU         0B         95         08         17         41
       17 LTIPLICAN         17         08   08C1 1F         D2         09
       3F D                 D2         1F   [illegible] 78 [illegible] [illegible] [illegible] 7A
       1F *<0806>CO         67         C6         17         09         93
 0811 17 NTAINSAEXP         08         01         37         3F         3F
       DA ONENTOFMU         3F         C3         1F   0912 1F         C3
       19 LTIPLICAN         1F         97   08C6 47         4F         3F
       08 I                 DE         05         37         3A         09
       1D *ORG-CONT         01   0895 1F         3F         0A   0941 7B
       C3   0836 37         2F         3D [illegible] C9   0B               92
       11         3F         C3   0897 57                    17         6F
       09         3A         69         78 *RESULTIN          D2         C6
 0819 1F         03         08         C3  REG-B,D           1C         70
     4F         0B   0867 1F         A0 *REG-B-CO         09         09
       7A         1A   0868 47         08  NTAIN MA 0918 3F         3A
       17         47         3A   089C 1F  NTISSA    091C 1F         0C
       1D         37         06         37 *REG-CCON         37         03
       2A         3F         0B         3F  TAINSEXP         3A         17
       08         3A         17         1F  ONENT             0C         DA
     79         05         D2   08A0 47 *********          0B         54
       B7         0B         78         3A                    17         09
       1F         17         08         03                    D2         7A
       C3         4F         3F         0B                    26         83
       2A         37         1F         17                    09         6F
        08         3F         DE         D2                    3F         C3
 082[illegible] [illegible]   1E         01         B9               926 1F         7C
                  08         2F         08                    5F         09
                  16         C3         1F                    3A   0954 7A
                  00         79         3A                    0A         BB
 082A 41         26         08         05                    0B         D2
 082B 4F         3D   0878 1F         0B              092B 17         3D
 082C C9 [illegible] 79 [illegible] [illegible] 08[illegible]C [illegible] 17              0958 09
```

0973 0A40

0941

0954 0A53

0A5A

DA
41
09

0A64

0A6A

0986

17.10.78

```
  [illegible] 1F 0C00 CD 0C29 3A 0C5D 3E 0C92 32
0A76 57[illegible]            00         16         4D         0B
     [illegible]              09         03         32         0B
     7C 0A1C 3A               78         32         12         7A
     0A        07             32         03         0B         32
0A7[illegible] 1[illegible]   0B         03         0B         3E         0B
     57        32             0B         32         0D         0C
0A[illegible] 3A    1[illegible]  7A     05         32         CD
     13        0[illegible]   32         0B         13         00
     0B        3A             04         3A         0B         09
     17        0B             0B         17         CD         C3
     D2        1F             3E         0B         00         00
     8C        32             0A         32         0A         0F
     0A        13             32         04         78*FETCH ADD
     3F        3A             0[illegible]  0B      32<ESS<0F00>
     1F        3[illegible]   0B         32         09 0F00 78
     2F        0[illegible]   3E         06         0B         32
     C6        32             8D         0B         7A         09
     01        1C             32         CD         32         0B
     5F        0B             06         30         0A         7A
     C3        3E             0B         80         0B         32
     8E        03             CD         78         CD         06
     0A        3[illegible]   30         32         30         0B
0A8C 1F        11             08         05         80         CD
     5F        0B             78         0B         78         30
0A8E 7A        CD             32         7A         32         80
     93        00             01         32         05         78
     3C        0A             0B         06         0B         32
     F2        78             7A         0B         32         05
     9A        B2             32         3A         10         0B
     0A        09             02         0F         0B         32
     2F        0B             0B         0B         7A         10
     C6        7A             C9         3D         32         0B
     01        32 *********   32         06         7A
     17        0A **********  0F         0B         32
     37        0BSUBROUTIN    0B         32         06
     1F        3E-E*EXPVA*    C2         11         0B
0A9A 57        61<0B16>MAN    3C         0B         32
0A9B C9        32TISSA OFX    0C         3E         11
***********    0B<0B17>EXP    3A         4D         0B
***********    0BUNENT OFX    05         32         3E
 <0AD0><0AFD    3EREG-B,REG    0B        12         59
 >#<0C00><0    07D CONTAIN    32         0B         32
 C20>AREUSED   32MANTISSA,    10         3E         12
*SUBROUTINE    0CEXPONENT     0B         10         0B
 "AIRVE"       0B0F RESULT    3A         32         3E
 <0B07>AIR     C3 OR3-CONT    06         13         13
 VELOCITY      00 0C15 3E     0B         0B         32
 [illegible]SSA  0[illegible]  06   32   [illegible]  13
 <0B08>AIR#FETCHADD   32      11         00         0B
 [illegible]   0[illegible]   0B         0A
 [illegible]   06                        78
```

```
ORG-CON CRG-CONTORG-CONTORG-CONTORG-CONTORG-CO
0F87 10 0F87 78 0F87 32 0F8B 32 0CA3 32 0CD5 3A
        00         32         0B         0B         03         50
        01         0B         0B         0B         0B         08
        78         0B         7A         7A         3A         32
        32         7A         32         32         51         09
        0B         32         0C         0B         0B         0B
        0B         0C         0B         CD         32         3A
        7A         0B         CD         00         04         51
        32         3A         00         09         03         0B
        0C         00         09         78         3E         32
        0B         09         78         32         B4         04
        CD         78         32         03         32         0B
        00         32         09         0B         05         3E
        09         09         0B         7A         0B         F9
        78         0B         7A         32         3E         32
        32         7A         32         04         9A         0B
        09         32         0A         0B         32         0B
        0B         0A         0B         3E         06         3E
        7A         0B         CD         60         0B         09
        32         CD         30         32         CD         32
        0A         30         08         05         30         0C
        0B         80         78         0B         08         0B
        CD         78         32         3E         78         CD
        30         32         05         01         32         00
        80         05         0B         32         09         09
        78         0B         32         06         0B         78
        32         32         10         0B         7A         32
        05         10         0B         CD         32         05
        0B         0B         7A         30         0A         0B
        32         7A         32         08         0B         7A
        10         32         06         C9         3E         32
        0B         06         0B ********         0C         06
        7A         0B         32 ********         32         0B
        32         32         11 *SUBROUTIN          0B       CE
        06         11         0BE"FUEXP"            0B         30
        0B         0B         3E0B50>TE-            3E         80
        32         3.         72.MANTI              8C         78
        11         4C         32SA IN KEL           32         32
        0B         32         120B51>TE-            0C         03
        3E         12         0BF.EXPON-            0B         0B
        6D         0B         3ENT IN KEL           CD         7A
        32         3E         1DEG-B,D              00         32
        12         1A         32ESULT               09         04
        0B         32         13 ORG-CON            78         0B
        3E         13         0B 0CA0 3A            32         CD
        16         0B         CD         50         03         30
        32         3A         00         03         0B         08
        ..         00         0A                    7A         78
        0E         0A         78                    32         3A
        CE         78                               04         09
        00                                          0B         0B
        0A                                                     7A
```

```
*MAIN PROGRAM EVALUATION OF RELATIVE HUMIDITY CRO CONT
/INPUT RAW DATA-CONTORO-CONTORO-CONTORO-CONTORO 0247 32
 VELOCITY) 0CC4 7B 0212 32 0246 32 0E77 CD        5_
 CONVERT TO       3A       0D       06       00       0_
 NORMALIZED       0A       0B       0B       09       7A
 FORM 0852        0B       3A       CD       78       32
 RELATIVE          3A       54       30       32       0_
 DATA INT-        55       0B       08       10       0B
 GER FORM         0B       32       78       0B       CD
 /OBTAIN DRY      CD       09       32       7A       3A
 BULB TEMP.       70       0B       03       32       08
 IN INTEGER       0D       3A       0B       11       78
 /OBTAIN WET      78       55       7A       0B       32
 BULB TEMP.       32       0B       32       3A       60
 IN INTEGER       56       32       04       56       08
   ORD CON        0B       0A       0B       03       76
   0DC0 3A        7A       0B       32       32 **********
        52        32       3A       3E       12 **********
        0D        57       59       32       08 REG-B/<0860>
        32        0B       0B       03       3A CONTAINS
        C0        3A       3E       0B       57 RELATIVE HU-
        0B        58       80       3E       0B MIDITY VALUE
        CD        0B       32       0A       32 IN INTEGER
        00        32       0B       32       13 **********
        08        06       0B       06       0B
        79        0B       3A       CB       CD
        32        CD       5A       CD       00
        07        00       0B       30       0A
        0B        08       32       08       78
        7B        79       0C       78       32
        3A        32       0B       3E       03
        08        59       CD       08       0B
        0B        0B       00       32       74
        CD        32       09       0B       32
        00        09       78       03       04
        0A        0B       32       7A       0B
        3A        7B       03       32       3E
        53        32       0B       0C       64
        0B        5A       7A       08       32
        32        0B       32       3A       05
        00        82       04       5C       0B
        09        0A       0B       08       3E
        CD        0B       3A       32       07
        00        CD       01       09       32
        08        70       0B       0B       06
        79        03       32       3A       0B
        32        78       05       5D       CD
        04        32       0B       08       30
        0F        CD       3A       32       08
        32        0B       02       0A       7B
        0_        7A       08       0B
        __
```

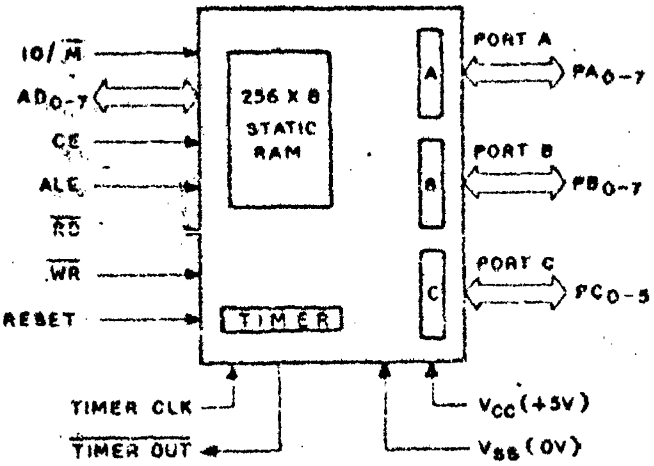
```
ORG CO    ORG-CON ORG-CON ORG-CON ORG-CONT
0D00 32 005C 32 0072 32 00A4 3E 0898 78
     0A       09       0B       5B       37
     0B       0B       0B       32       3F
     3E       7A       3E       05       1F
     78       32       09       0B       47
     32       0A       32       3E       1D
     0B       0B       0C       0A       C2
     CB       3E       0B       32       D8
     3E       C0       CD       06       08
     03       32       00       0B    8E1 79
     32       0B       09       CD       17
     0C       03       78       30       D2
     09       3E       32       80       FB
     CD       01       05       78       08
     00       32       0B       32       78
     09       0C       7A       109      17
     78       05       32       0B       37
     32       C9       51       7A       1F
     03       C0       0B       32       47
     0B       09       CD       11       C9
     7A       78       A0       0B ********
     32       32       0C       CD ********
     04       05       78       00
     0B       0B       32       0A
     3A       7A       36       C9
     50       32       0B ************
     03       06       7A *************
     32       0B       32 *SUBROUTI-
     12       CD       17  NE"INCON"
     09       30       03 *REG-B CO-
     3A       08       CD  NTAINS
     0B       78       35  MANTISSA
     3E       17       0C *REG-E CO-
     32       37       78  NTAINS
     13       3F       32  EXPONENT
     0B       1F       12 *RESULT<B>
     3E       47       0B   ORG-CONT
     62       C9       7A   08CA 48
     32********        32       78
      0********        13       17
     0BSUBROUTI-       0B       37
     3ENE"SATPR"       3E       3F
     0A<0B09>MAN-       91      1F
     32TISSA TEMP       32 08D0 47
     ..  0B04>EXP-      03      3F
     0?ONENT TEMP       03      07
     C9IN CENTIG-       3E      92
     ?GRADE               3?    92
     DEGRADE            C?      CA
     C9   ORG-CON      32       E1
     ?2   0070 3E      04       08
                44     0B       5F
```

APPENDIX:11

INTEL 8155 I/O PORTS & PROGRAMMING

The Intel 8155 static MOS RAM has 256x8 words of memory or 256 BYTES of memory. It has two programmable 8-bit I/O ports, Port A and Port B. Each port can be programmed, i.e., each port can be used as input or output by programming the command/status register is also in RAM chip. There is a 6-pin port C which can be used as an input or output port or it provides the control signals for port A and port B. Port C is also programmed through command /status word or CSR-Register. In addition to these, it will have IO/M, CE, ALE, RD, WR, RESET, TIMER CLK, TIMER OUT, V_{CC}, V_{SS} control lines. It has 40-pins dual in package and its block diagram and pin connections are shown in Fig.A.14[25-26].

The memory or I/O section is addressed using the 8-bit AD BUS whether the address on AD BUS is for memory or I/O port depends on IO/M line. The I/O selection is selected if its IO/M is HIGH, and the memory is selected if it is LOW. The same AD BUS is used for data transfer to and from the microprocessor. To READ the memory or I/O port, RD is kept LOW and IO/M is used as described earlier. Similarly to WRITE into the memory or I/O port WR is kept low as IO/M is used as described earlier. RESET to initialize the system may provided the microprocessor on RESET IN line. Input high on this line resets the chip and intialize I/O ports in the input mode. CE input is used for enabling the chip. The 8155 also have 14-bits programmable binary counter/ timer to provide either square wave or terminal count for use



~~Fig. 4.14 The 8156 RAM Block diagram~~

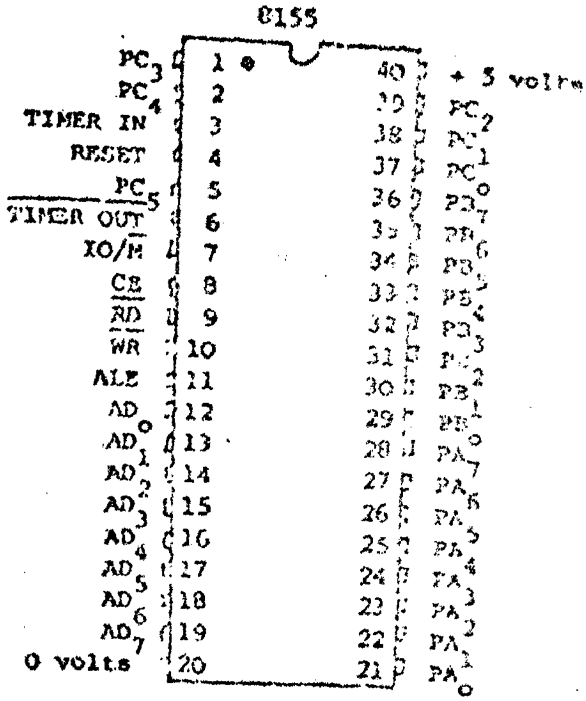


FIG. 4.14 THE 8155 RAM BLOCK DIAGRAM AND PIN CONNECTION

in timing of any desired operation.

The 8155 has been designed to be interfaced to 8085 without any wait state. It has an internal address latch. Other memories do not have such latches may require an external latch if they are to receive the address from AD BUS of the Intel 8085.

8155 I/O Ports & Programming:

The I/O ports of 8155 are referred to as PA, PB and PC. At the time of initialization, the three ports may be programmed suitablly using the 8-bits of the command status register (CSR). The LSB 6-bit of this register can set or reset these three ports. Table A.6 shows the bit assignment of the CSR.

TABLE A.6

Bit Assignment of CSR

Bit No.	Value	Function
0	0	Port A to be used as input
	1	Port A to be used as output
1	0	Port B is used as an input
	1	Port B is used as an output
2,3	00	Port C can be used as output
	10	PC_3-PC_5 of port C to be used as an output, PC_0 will be used for A interrupt, PC_1 indicate whether A buffer is full or not., PC_2 indicates strobe signed for port A
	01	PC_0-PC_1 same as for the bit value 10, PC_3-PC_5 same as PC_0-PC_2 but for port B.
4	0	Disable port A interrupt
	1	Enable port A interrupt
5	0	Disable port B interrupt
	1	Enable port B interrupt

Port C can be used as I/O port or control port for ports A and B. When it is used as control port for both A and B, the six lines are divided into two groups three of each. The three lines in each group are used to indicate:

1. an interrupt signal
2. whether a port buffer is full or not.
3. a strobe signal for strobbing in or out the data ports A and B.

The interrupt signal may be used to interrupt the microprocessor. If a port is being used in strobe input mode, the interrupt line will go HIGH when the input buffer is full. The processor may use this interrupt to read the data from the port into a register or RAM location. If the port is used in output mode, the interrupt line goes HIGH after the output device read the data from the port. This interrupt may be used by the microprocessor to transfer the next byte of the data to the port. These interrupts are generated only if the corresponding enable bits in the CSR is one.

When the microprocessor receives an interrupt signal it can determine which device has interrupted, using polling. The status of the ports can be read by microprocessor by issuing an IN command with a suitable address. In response the 8155 sends an 8-bit status word on the data bus to the microprocessor. The format of this word is shown in Table A.7.

The address assigned to the different ports in the 8155 and to the CSR are given in Table A.8. Note only the least significant bit may be used for chip select if more than one 8155 is connected to the system.

TABLE A.7

Status Word Format of 8155

Bit No.	Status
0	Interrupt request for port A
1	Port A buffer full/empty
2	Port A interrupt enable
3	Interrupt request for port B
4	Port B buffer full/empty
5	Port B interrupt enable

TABLE A.8

Address assigned to different ports of 8155

Address	Assigned to different ports
x x x x x 0 0 0	Command/status register
x x x x x 0 0 1	Port A (I/O)
x x x x x 0 1 0	Port B (I/O)
x x x x x 0 1 1	Port C (I/O or control port)
x x x x x 1 0 0	Lower order byte of the timer
x x x x x 1 0 1	Higher order byte of the timer

Timer Operation:

As said earlier, the Intel 8155 has also a timer of 14-bit down counter which counts the input pulses. Normally CLK of the microprocessor Intel 8085 is connected to TIMER IN input of 8155. This implies that the counter will be decremented by 1 each clock cycle. The timer may be operated in four possible modes. The desired mode is specified by programming the timer. 8155 timer operating modes are given in table A.9.

TABLE A.9

8155 Timer Operating Modes

Mode bits M_2	M_1	Function
0	0	Low during the second half of the count.
0	1	Square wave output with period equal to count length automatic reload of the counter when terminal count is reached.
1	0	Single pulse of one clock cycle duration when terminal count is reached.
1	1	Same as 10 with automatic reloading of the counter when TC is reached.

The counter may be stopped or started by using 6 & 7-bits of command-status register. Table A.10 gives the combination of these bits and corresponding functions. Immediately after the system reset the counter stops counting.

M_1	M_2	T_{13}	T_{12}	T_{11}	T_{10}	T_9	T_8	T_7	T_6	T_5	T_4	T_3	T_2	T_1	T_0
		MSB of count length						LSB of count length							

Timer mode bits.

TABLE A.10

Timer mode operations using CSR for 8155

CSR7	CSR6	Function
0	0	Do not affect timer operation.
0	1	If timer is running, stop counting, else no operation.
1	0	Stop after terminal count, No operation if the timer is not running.
1	1	Load the mode and count length and immediately start after loading. If the timer is running enter the new mode and load the new count length immediately after present count length is reached.

APPENDIX-12

MAIN PROGRAM

```
RESTART: CALL INIT
         MVI A,CWR2
         OUT CSR2
         IN  PORTA2
         STA OB62
         STA OB61
/OB62 LOCATION CONTAINS AIR
VELOCITY IN INTEGER FORM
         CALL FP CON
         MOV A,C
         STA OB07
         MOV A,E
         STA OB08
         CALL AIRVE
         MVI A, CWRO
         OUT CSRO
         IN  PORTAO
         STA OB53
         STA OB61
/OB53 LOCATION CONTAINS DRY
BULB TEMP IN INTEGER FORM
         CALL FPCON
         MOV A,C
         STA OB54
         STA OB05
         MOV A,E
         STA OBOA
         STA OB55
         CALL SATPRE
         MOV A,B
         STA OB56
         MOV A,D
         STA OB57
/OB56;OB57 LOCATIONS CONTAINS
SATURATED PRESSURE OF WATER
VAPOUR AT DRY BULB TEMP...
         MVI A,CWR1
         OUT CSR1
         IN PORTA1
         STA OB58
/OB58 LOCATION CONTAINS WET
BULB TEMPERATURE IN INTEGER
FORM
         STA OB61
         CALL FPCON
         MOV A,C
         STA OB59
         STA OB09
         MOV A,E
         STA OB5A
         STA OBOA
         CALL SATPRE
```

```
         MOV A,B
         LDA OB5C
         MOV A,D
         STA OB5D
/EVALUATION OF PARTIAL PRESSURE
BEGINS
         LDA OB54
         STA OB09
         LDA OB55
         STA OBOA
         LDA OB59
         ADI A, 08
         STA OBOB
         LDA OB5A
         STA OBOC
         CALL FP SUM
         MOV A,B
         STA OB03
         MOV A,D
         STA OB04
         LDA OB01
         STA OB05
         STA OB06
         CALL FP MUL
         MOV A,B
         STA OBOB
         MOV A,D
         STA OB04
         MVI A,5D
         STA OB05
         MVI A,0A
         STA OB06
         CALL FP MUL
         MOV A,B
         ADI A,08
         STA OBOB
         MOV A,D
         STA OBOC
         LDA OB5C
         STA OB09
         LDA OB5D
         STA OBOA
         CALL FP SUM
         MOV A,B
         STA OB10
         MOV A,D
         STA OB11
         LDA OB56
         STA OB12
         LDA OB57
         STA OB13
         CALL FP DIV
```

```
        MOV A,B
        STA 0B03
        MOV A,D
        STA 0B04
        MVI A,64
        STA 0B05
        MVI A,07
        STA 0B06
        CALL FP MUL
        MOV A,B
        STA 0B5E
        MOV A,D
        STA 0B5F
        CALL INCON
        MOV A,B
        STA 0B60
/0B60 CONTAINS RH VALUE IN
INTEGER FORM & AISO REG-B
        MVI A,CWR4
        OUT CSR4
        IN PORTA4
/INPUT SET VALUE OF RH
        SUB B
        JP X120
        CMA
/ERROR SIGNAL COMPUTATION
        SBI A,01
        RAL
        STC
        RAR
X120:   MOV 3,A
        MVI A,CWR4
        OUT CSR4
        MOV A,B
        OUT PORTB4
/ERROR SIGNAL APPLIED TO DAC
CONTROL CIRCUIT OF RH
        CALL DELAY
        LDA 0B61
        MOV A,B
        MVI A,CWR3
        OUT CSR3
        IN PORTA3
/INPUT SET VALUE OF THE DRY
AIR TEMPERATURE
        SUB B
        JP X121
        CMA
        SBI A,01
        RAL
        STC
        RAR
X121:   MOV B,A
        MVI A,CWRe
        OUT CSR3
        MOV A,B
/OUTPUT ERROR SIGNAL TO PORT B3
OF TEMP & CONTROL CIRCUIT
        OUT PORTD3
**************************************
```

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