DEVELOPMENT OF A PSYCHROMETER FOR INDUSTRIAL USE

A DISSERTATION

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(Measurement and Instrumentation)

by

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CERTIFICATE

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ABSTRACT

This dissertation deals with the design and development of an electronic psychrometer for the measurement of humidity. Thermistors have been used as basic temperature sensing elements. One thermistor has been used as dry bulb thermometer and the other thermister as wet bulb thermometer. The changes in the thermistors resistance values have been processed using astable multivibrator circuits. The output of the system has been given to a digital display unit.

Existing material on relative humidity measurement has been reviewed in earlier part of the dissertation.

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CHAPTER - I

INTRODUCTION

1.1 General

Psychrometer is a device for the measurement of humidity i.e. measurement of water vapour present in the air or gases. Usually the mass of water vapour present in air or gas is expressed in terms of relative humidity (RH). Relative humidity is defined as the ratio of the partial pressure of water vapour present in the gas to the partial pressure of water vapour in saturated gas. In other words it is the ratio of the amount of water vapour present in the air to the maximum amount of water vapour that air could hold at the same temperature.

Some terms are widely used in the literature of humidity measurement and in order to familize with them, these are listed in Appendix I.

1.2 Necessity of Humidity Measurement in Industries

In many industries, manufacture of certain types of components and products is possible only by maintaining pre-determined value of humidity in surroundings. In such applications it is necessary to closely monitor the value of humidity. Some of such applications in which humidity measurement is necessary are given below.

1.2.1 Humidity influence on textile products

The measurement and control of moisture and humidity is very important in the textile industries. The cotton fibers have their good strength and stiffness at a relative humidity of 65 percent. This specified value of RH can be maintain by humidification or dehumidification of the surroundings (19).

The similar process is used in jute fibers and wool fibers. In the case of jute and wool fibers, the RH value will be maintain at 50 percent and 90 percent respectively.

1.2.2 Humidity influence on wood and timber

There is a close relation between the atmospheric humidity and the weight of moisture, present in timber and its products. As humidity increases moisture content increases and vice-versa. The amount of moisture changes the several properties of wood and timber. Among these dimensional stability is most important. Wood shrinks as it dries. So far maintaining the specific value of dimension it is necessary to change the amount of moisture. Hence humidity measurement is essential.

For the seasoning, preservative treatments, polishing etc. also needs some specific value of moisture. In general a 30 percent relative humidity needs for wet timber in the process of drying at room temperature.

1.2.3 Humidity influence on pulp and paper product

The problems of measurement and control of moisture and humidity in pulp and paper mills are very similar to those in textiles. The physical properties of paper such as strength, weight, electrical resistance and dielectric properties are affected by its moisture content and atmospheric humidity.

A change in the moisture content causes a change in the dimensions of the sheet. Therefore for a desired dimensions of the sheet, moisture and relative humidity is maintained constant. Some specified value of water vapour is also essential for the pulp and paper products. Such as an overwet paper may crush in the calender rolls and the desired may never be obtained. Hence dehumidification is essential at given value of RH.

1.2.4 Humidity influence on foods and allied agricultural products

The moisture plays an important role in the storage and processings of different types of foods and agricultural products (23). The biological and chemical effects produced in grains and seeds during the process of storage at different values of moisture and RH, under practical storage conditions, the moisture content is usually the principal governing factors keeping in view the quality of food grains and other agricultural products. For any given level of moisture content in the grains, there is a corresponding level of atmospheric humidity(18). The value of moisture can be changed by the humidification or dehumidification at given value of RH. If it is not maintained at a specified value deterioration, heating, insect damage etc. may be take place. The protein, fat and carbohydrate of the food products can be maintained only at specified value of moisture of relative humidity. Humidity and moisture plays very important role in the sugar and sugar products as well as fruits and dairy products.

1.2.5 Humidity influence on drugs and pharmacetical materials

The fundamental influences which are responsible for the deterioration of drugs are humidity, light, temperature and the oxygen of air. The more visible agents of deterioration arise secondarily as a result of growths, which can occur only under certain conditions of humidity and temperature. There are in the atmosphere innumerable spores and germs which settle on all exposed surfaces in the form of dust. If the humidity and temperature are suitable will quickly germinate and develop into organisms, such as bacteria, molds, mites and insets. All of which will attack drugs when conditions are favourable (20). As protoplasm cannot exist without sufficient moisture, it is a suitable degree of humidity which most largely affects the development of these living organisms. Hence humidity measurement is necessary.

1.2.6 Humidity measurement in air conditioning

Air conditioning is the simultaneous mechanical control of temperature, humidity, air purity and air motion. It is clear that humidity plays an important role in the air conditioning. The control of temperature can mean either cooling or heating. The control of humidity can mean either humidifying or dehumidifying. An air conditioning system can maintain any atmospheric condition regardless of variations of the outdoor atmosphere. Hence humidity measurement is essential. The comfortable value of RH is 50 percent in the temperature range from 22.2°C to 26.7°C (2).

CHAPTER - II

METHODS OF HUMIDITY MEASUREMENT IN INDUSTRIES

There are basically two methods for measurement of relative humidity in industries :

(i) Hygrometric method

(ii) Psychrometric method.

2.1 Hygrometric Methods

The hygrometric methods are based on the absorption of water vapour by hygroscopic materials. These materials are human hair, animal skins etc. The dimensions of the hygroscopic material changes with the change in relative humidity of the surrounding atmosphere. Following hygrometers belongs in this categories :

(i) Mechanical or hair hygrometer.

(ii) Salt conductivity hygrometer

(iii) Electrolytic hygrometer

(iv) Infrared absorption hygrometer

(v) A long path infrared hygrometer.

2.1.1 Mechanical or hair hygrometer

The expansion and contraction of human hair has been used to measure relative humidity for nearly two centuries. The amount of water vapour taken up by the hair from the surrounding atmosphere is an indication of RH. The length of hair increases with increase in water content in its surrounding

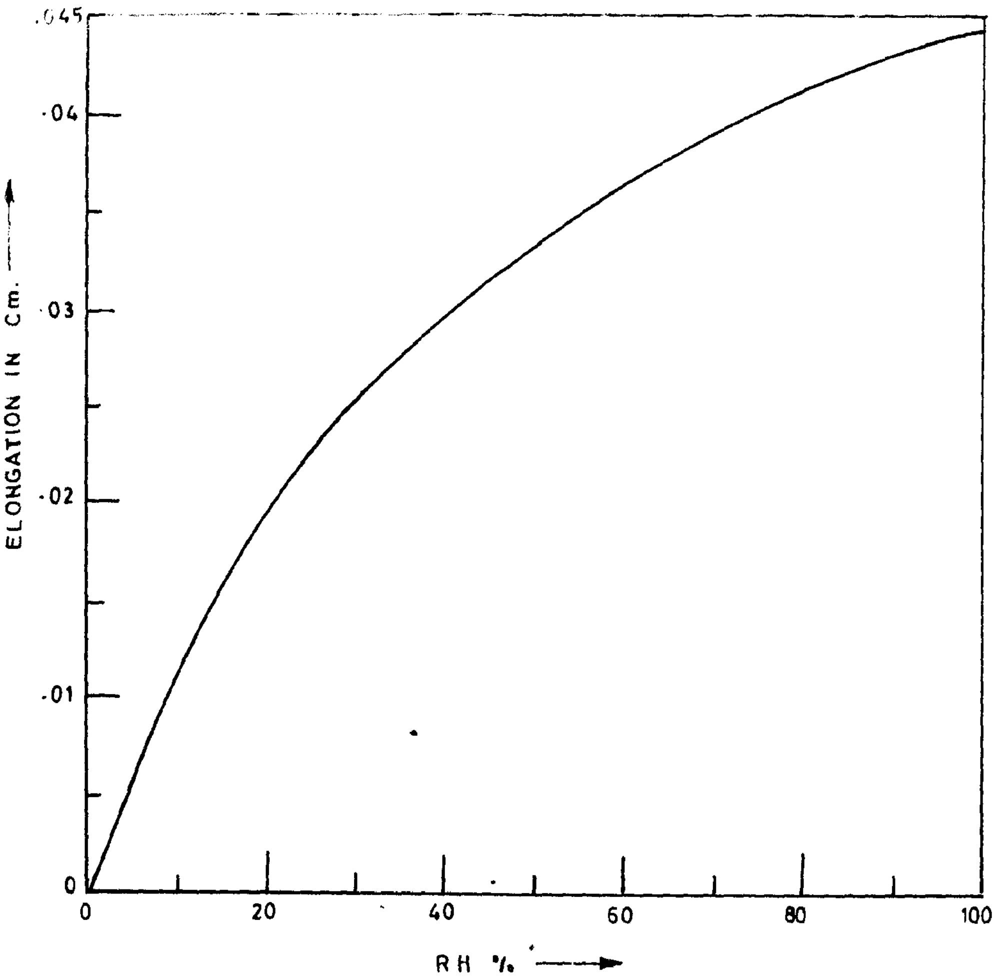

FIG 2.1.1(a) A CURVE BETWEEN RH AND ALONGATION OF HAIR

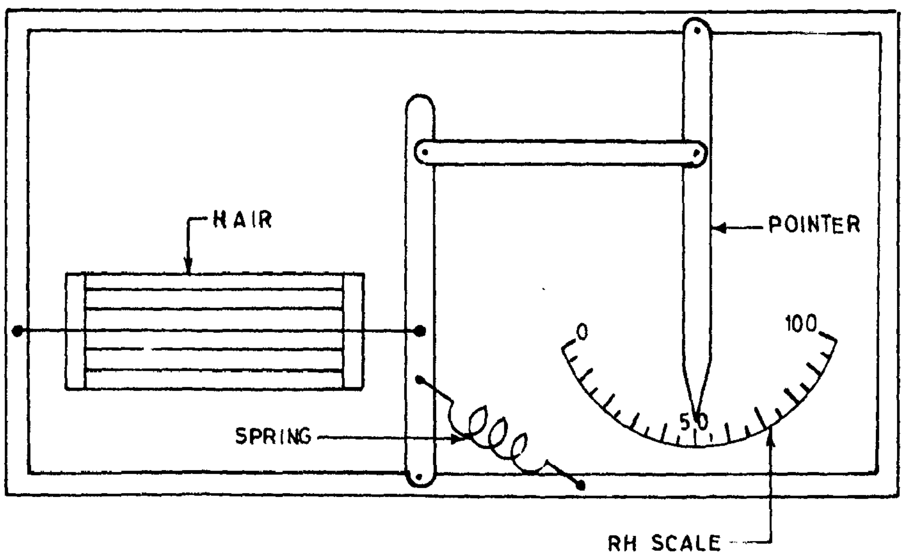

FIG. 2.1.1(b) HAIR HYGROMETER

Fig.(2.1.1a) shows a typical curve of hair elongation as a function of relative humidity.

For the measurement of RH, human hair is mounted on a suitable structure as shown in Fig.(2.1.1b). The instrument has spring, pointer and a RH scale. A number of hairs are used as one hair is not enough strong. The human hairs used as sensor should be free from fats and oils.

The rolling of hair is essential for the faster response. In the treatment of rolling, the hair is passed between two rollers which change the circular cross-section of hair to an elliptical cross section. Rolled hair response much faster than normal hair. The response time is reduced by a factor of 5 to 10 depending on the rolling pressure used. The cost of hair is less. The overall device is usually simple and inexpensive. The main disadvantage of the device is its non-linear response. The instrument generally covers a range of RH from 15 to 85 percent. It has poor stability at high temperature and sluggish response at very low temperatures.

2.1.2 Salt conductivity hygrometer

A definite relationship exist between the concentration of the salt solution and the relative humidity of atmosphere. If the value of RH is changed, then concentration of salt solution, exposed in the atmosphere, is also changed. If atmospheric humidity increases, then concentration of salt in salt solution decreases and vice-versa. Due to change in the concentration, the electric conductivity of the solution is also changed. This effects has been put to practical use in a humidity measuring device. It consists of a thin Aluminium tube of length of about 4.5 cm and diameter of about 1.2 cm. The outer surface of the tube is painted with a layer of insulating water resistance varnish. A bifilar winding of palladium wire is placed on the varnished surface. Over the bifilar winding a moisture sensitive film of polyvinyl acetate, containing the appropriate quantity of salt solution is placed as shown in Fig.(2.1.2). The variation in resistance of the bifilar winding, according to atmospheric humidity, is measured with a suitable resistance measuring device. This value of resistance gives the value of RH. It has non-linear variation of resistance. Which may be considered as a great disadvantage of this method.

2.1.3 Electrolytic hygrometer

The phosphorous pent oxide has a property to absorb the water. This property is utilized for the measurement of RH value in air or in any other gases.

When humid air or gas is passed through phosphorous pentoxide, it absorbs a good amount of water. This absorbed water is electrolytically decomposed. There is a flow of current in the circuit due to electrolysis of water. This value at current is taken as a direct measure of amount of water in the air or gas. It is calibrated in terms of RH

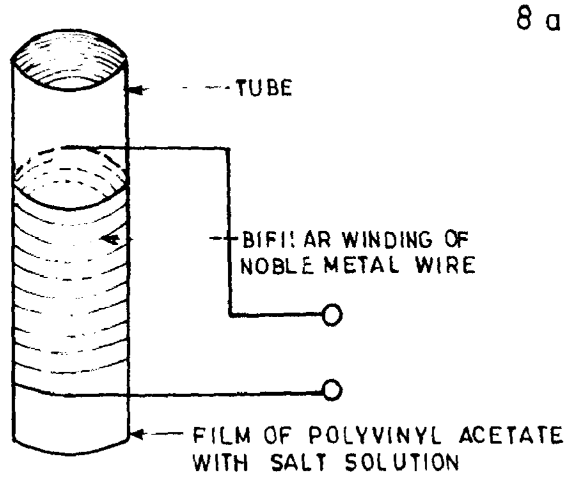

FIG 2.1.2 SALT CONDUCTIVITY HYGROMETER

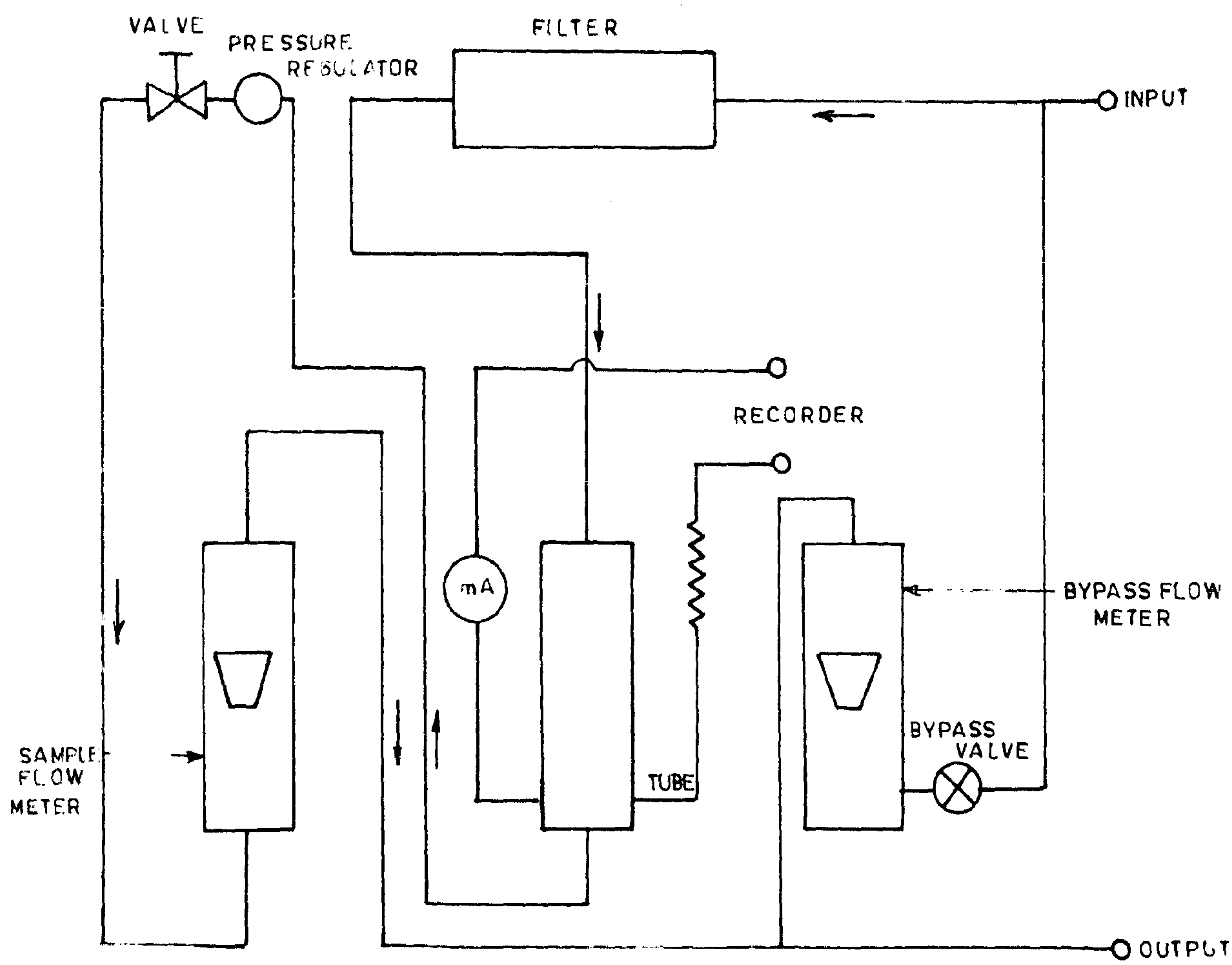

FIG. 2.1.3 ELECTROLYTIC HYGROMETER

values. A small diameter plastic tube is the heart of the electrolytic hygrometer. The tube has a bifilar winding of noble metal wire in contact with its inner surface which coated with phosphorous pent oxide.

A fixed rate viz 100 cc/min of air or gas can be maintained using a pressure regulator, valve and a rotameter as shown in Fig. (2.1.3). The electrolytic current is indicated by a milliammeter which is connected with bifilar winding. The current can also be measured and recorded by a recorder. The value of current in the circuit gives the RH value in the air or gas passing through the tube. This instrument is widely used in natural gas industry.

2.1.4 Infrared absorption hygrometer

The infrared absorption hygrometer is an optical instrument which is designed to measure the absolute humidity of the atmosphere by measuring the absorption of radiant energy over a given optical path in the spectral region of an infrared water vapour absorption band. The relation of absorption to the absorbing water vapour mass is expressed by the relation,

$$A = (P/P_o)^{1/2} (T_o T)^{1/4} K(W)^{1/2} \qquad ...(2.1.4)$$

where, A = fractional absorption

T_o = Saturated temperature

P_o = Saturated pressure

T = normal temperature

p = normal pressure

K = constant depending on the spectral region of absorption

W = absorbing water mass.

The relation (2.1.4) shows that the absorption increases linearly with the square root of the water mass. Therefore, the relation holds good only for a limited range of absorptions. For strong absorptions, the increase in absorption is less than the square root of the water mass. It is fact that the exact form of the water mass absorption function is not known and probably cannot be expressed by a single relation.

The rate of change of absorption increases with a decrease of water vapour concentration in the optical path (24). This behaviour results in an increase of sensitivity in the infrared absorption hygrometer with a decrease in water vapour absorption. For the infrared absorption hygrometer, 1.27 μ water vapour absorption band is used. Its selection criteria can be expressed with the help of spectrogram shown in Fig.(2.1.4a). It is clear from the spectrogram that the band intensity or coefficient of absorption varies from band to band. For long optical path and high humidities, a shallow band, such as the one at 0.93 μ should be used, while for a short optical path and low humidities, a deep band such as the one at 2.7 μ would be more desirable. A band which will saturate 100 pe cent absorption for water vapour of interest is not satisf tory. For best results the maximum absorption should be to 40 percent or less. This requirement hold good for an optical path of a meter or less with 1.37 μ band.

The infrared absorption hygrometer desired to take advantage of the inherent qualities of the absorption spectra method, has a number of features not common to other instruments for measuring humidity. The features are :

(i) High sensitivity at low water vapour concentrations
(ii) Fast speed of response for all water vapour concentrations.

A schematic arrangement of the 1.37 μ absorption band hygrometer as shown in Fig.(2.1.4b). Basically it consists an optical train and the electrical and electronic assemblies. The major components of the optical train are a lamp, oscillating filter, modulator, mirror, lens, monitor photocell and detector photocell. The major electrical and electronic components and assemblies are a servomotor, servoamplifier, lamp power supply, and phase shift network.

When air passes through a narrow slit the water vapour is observed by energy of light beam near 1.37 μ spectral region. The lelectronic circuit configurations are designed to always give a null signal at detector-photocell. This null signal is obtained by automatically adjusting the lamp temperature and hence the energy distribution of the beam to compensate for water vapour absorption losses in the absorption spectra of the beam. Other monitor photocell output is

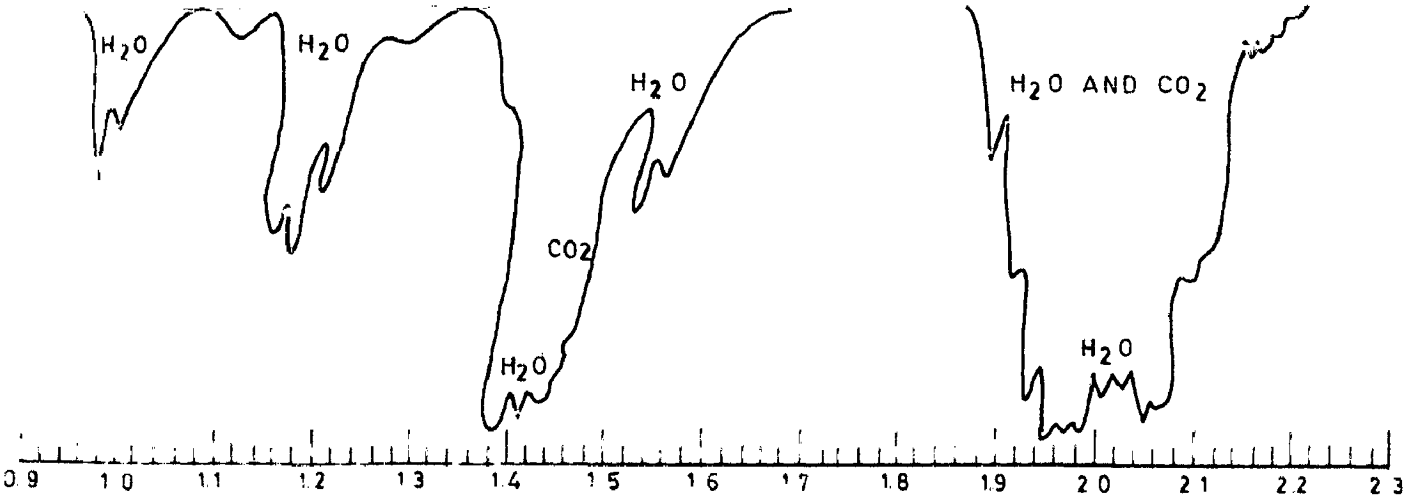

FIG 2.1 4(a) NEAR-INFRARED SPECTRUM IN THE NEOUGHBOURHOOD OF THE 1.37 μ WATER VAPOR OBSARPTION BAND

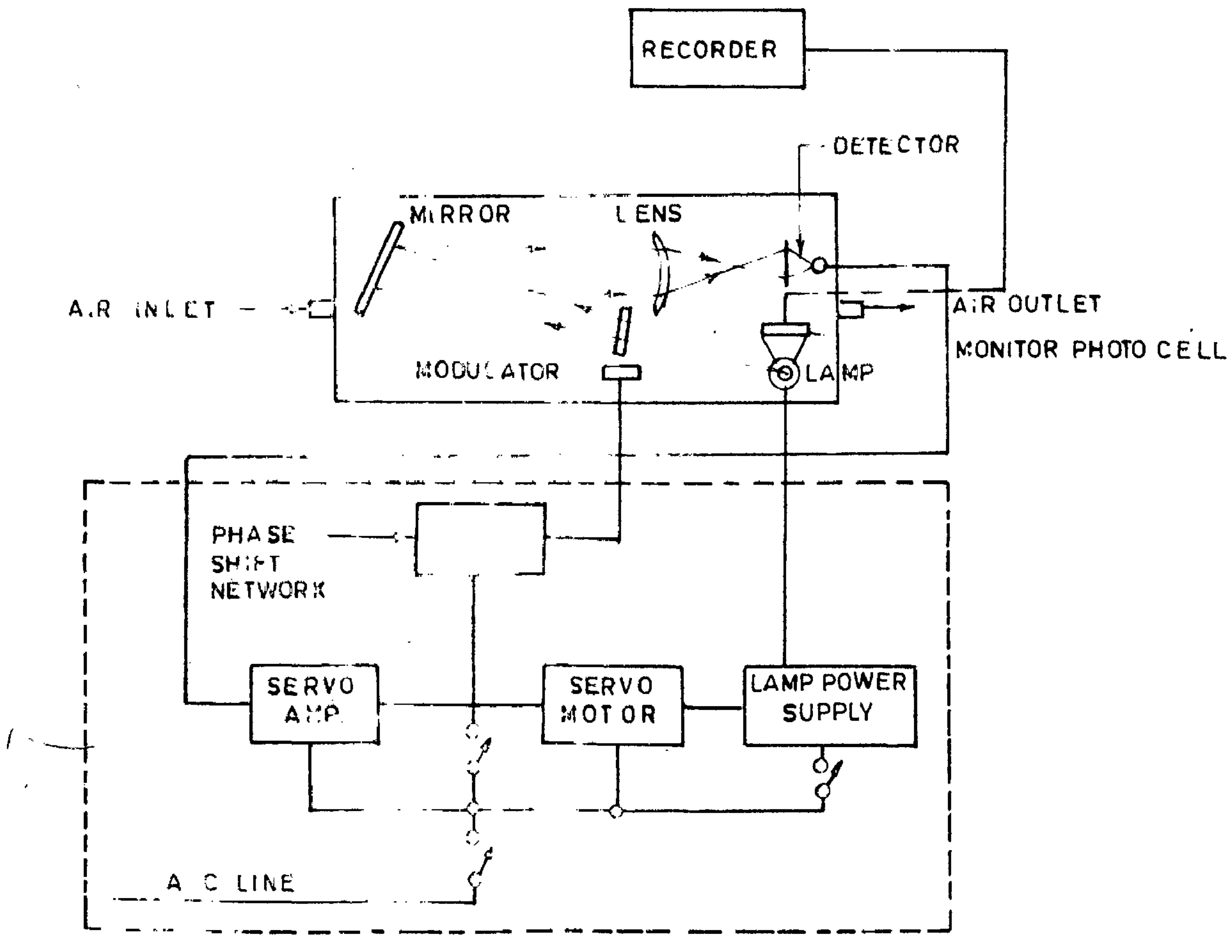

FIG 2.1 4(b) 1-METER FOLDED PATH INFRARED ABSORPTION HYGROMETER

an index of lamp temperature and an indication of the water vapour in the beam. This output of monitor photocell is recorded by a recorder and gives humidity of the air. The instrument is still classes as a special purpose device and is not yet suitable for general field applications.

2.1.5 A long-path infrared hygrometer

This hygrometer measures the total atmospheric water vapour content in a collimated beam of light. A beam of energy propagated over a measured path, is collected at a receiver through a single aperture. Temperature compensated lead sulphide cell detectors are used to sense the intensity of the collected energy in two bands of the infrared spectrum, one centered at a wave-length of 1.9 μ, the other at 2.2 μ. The former band is subjected to attenuation by water vapour while the latter is not. The ratio of received band energies is thus sensitive to the total amount of water vapour in the light path (24). The choice of wave-length of 2.2 and 1.9μ, for reference and sensing band respectively, is made because (i) both wavelengths lie within the range of peak sensitive of uncooled, lead sulphide cell detectors, (ii) back ground radiation at such short wave-lengths is practically nonexistent and (iii) ordinary glass transmits nearly 100 percent of incident energy at these wavelengths.

In a long path infrared hygrometer the collimated beam is collected at the receiver through a single 6.5 cm diameter aperture. A 180-degree prism beam splitter located behind the entrance aperture and collimating tube directs approximately half the incident energy through 2.2 μ reference filter and half through 1.9 μ sensing filter. Both arms of the split beam are then focused into carefully matched lead sulphide cell infrared detectors. The comparison of the two detector output signals would provide a measure of the water vapour content of the atmosphere within the beam of collected energy. The ratio between the two signals provides the much more reliable comparison because errors that could arise due to a decrease in the general level of sensed energy caused by the presence of fog in the light beam would thereby be eliminated. For the determination of ratio between two signal the high d.c. biase voltage applied to the cells. The light beam is chopped mechanically at the receiver aperture by a simple paddle type chopper.

A.C.carrier signals are fed through capacitor coupled a.c. logarithmic converters as shown in Fig.(2.1.5). The converters rectify the a.c. signals and give d.c. output proportional to the logarithm of the rms value of the input signals. These outputs are fed into a d.c.differential amplifier to obtain the difference between the two logarithmic signals. The output from the differential amplifier, which is proportional, now, to the logarithm of the two ratio of the band energies sensed. Then the output is fed to strip chart recorder which gives the total amount of the water vapour present. This hygrometer measures the total amount of water vapour in path

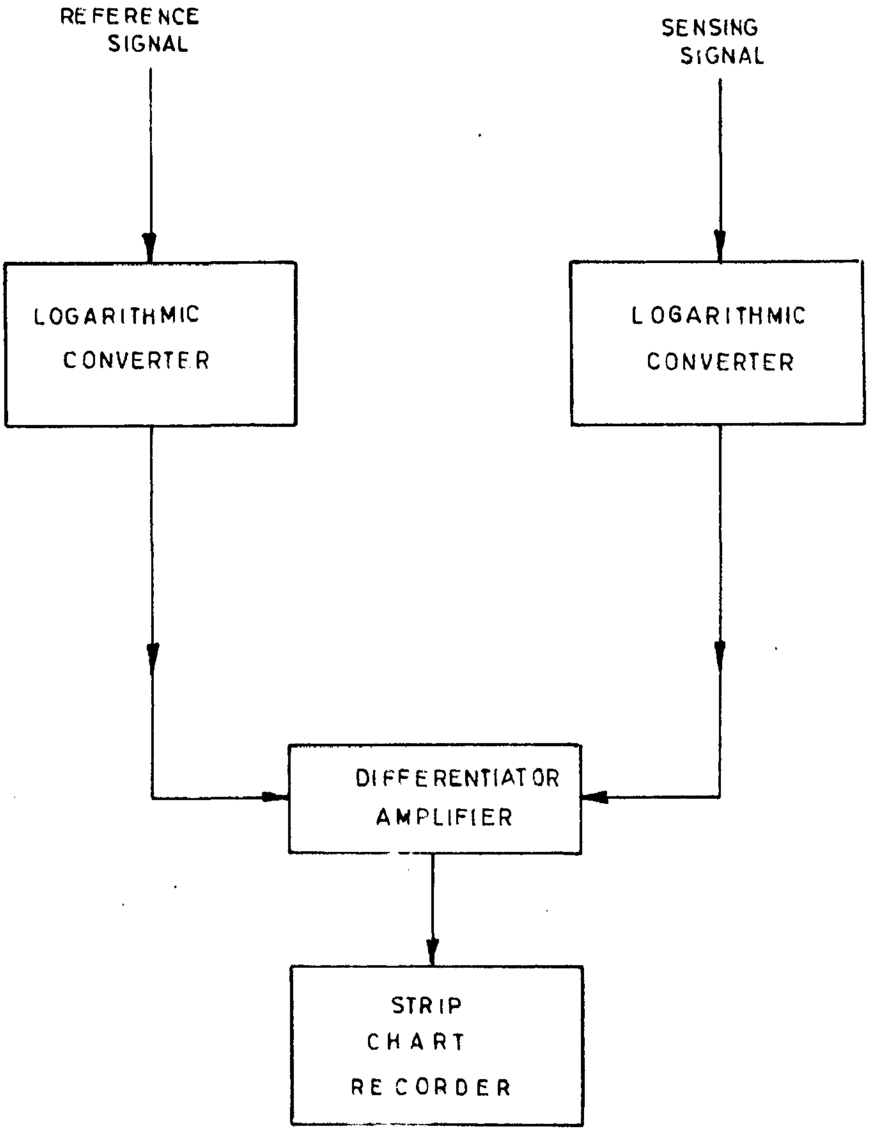

FIG. 2.1.5 BLOCK DIAGRAM FOR MEASUREMENT OF TOTAL WATER VAPOR

through the atmosphere between source and receiver.

2.2 Psychrometric Methods

The evaporation of the water vapour is utilized in the psychrometric methods for measurement of RH value. Psychrometer uses the readings of two thermometers for measurement of relative humidity. One of the thermometers has its bulb directly exposed to the measurand medium and the other has its bulb covered by a wick maintained continuously wet. The first thermometer measures actual temperature of measurand while the second one gives the thermodynamic equilibrium temperature reached between the cooling, effected by the evaporation of water and heating by convection till the surrounding air becomes saturated. Readings of these two thermometers are related to relative humidity by psychrometric charts.

2.2.1 Theory of psychrometer

Psychrometry was well established on the emperical basis before any satisfactory theory was developed. James Clark Maxwell in 1877 developed the theory based on a relation between cooling and heating.

According to that the readings of wet and dry bulb thermometers can be related to relative humidity by means of a psychrometric chart (4). Readings of two thermometers are related by the expression,

$$e = e_1 - AP\,(t-t_1)$$

where, e = Partial pressure of water vapour in H_g, corresponding to wet and dry bulb thermometers t_1 and t^oF, respectively.

e_1 = Saturated pressure of water vapour, in H_g at the wet bulb temperature $t_1{}^oF$.

P = Total atmospheric pressure in Hg.

$A = 0.000367 \left[1 + 0.00064 (t_1 - 32)\right]$

The partial pressure of water vapour as calculated above is converted into relative humidity by the following relation

$$RH\ \% = \frac{e}{e_s} \times 100$$

where e_s = Saturated pressure of water vapour at dry bulb temperature,

RH = Relative humidity

There are different schemes available to sense wet bulb and dry bulb temperatures. Based on the sensing methods, the psychrometers are classified as follows :

(i) Siling psychrometer

(ii) Assmann psychrometer

(iii) Thermocouple psychrometer

(iv) Elevated temperature psychrometer

2.2.2 Siling psychrometer

The simplest form of the wet and dry bulb temperature is the siling psychrometer. This consists of two mercury in - glass thermometers mounted on a suitable frame. The frame can be arranged with a whirling mounted handle at one end so that it can be swing rapidly to give proper air velocity. One of the bulbs (the wet bulb) is covered with a knitted cotton wick. It is shown in Fig.(2.2.2).

The wick of wet bulb thermometer is wetted with clean water. The frame is whirled for 15 to 20 sec. in a regular circular path. Readings of two thermometers are taken quickly. The wet bulb reading made first, because as soon as whirling stops its temperature starts rising very fast. The whirling procedure is repeated until two successive readings of the wet bulb are same. The dry bulb must be kept free of moisture throughout the procedure. If whirling time is too long then the wick will dry and the wet bulb temperature will rise again. It is essential that the wet bulb and wick be kept clean, otherwise, it will not absorb water properly. The water must be clean. Matching of wet and dry thermometers is important.

The sling psychrometer is simple and inexpensive but capable of good accuracy when carefully used. The chief advantage is portability. The principal disadvantage is that it gives serious error for careless procedure. Breakage of thermometers is frequent when used by semi-skilled person.

2.2.3 Assmann psychrometer

The Assmann psychrometer is a modification of the siling psychrometer. It is a forced ventilated instrument. It consists

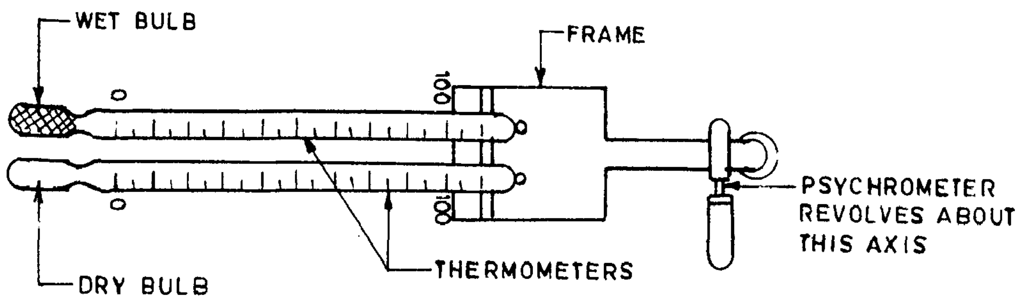

FIG. 2.2.2 SILING PSYCHROMETER

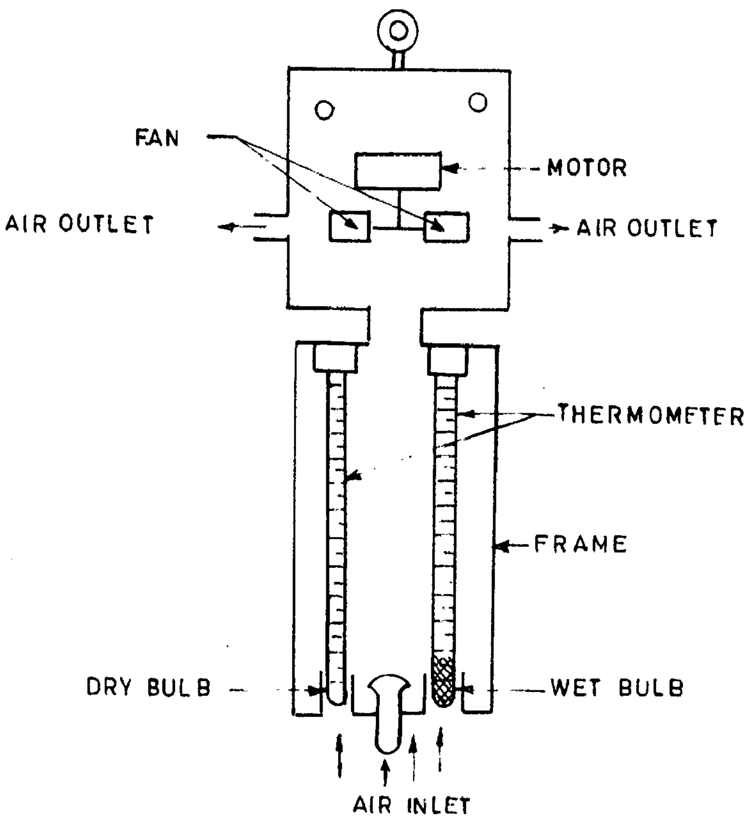

FIG. 2.2.3 ASSMANN PSYCHROMETER

two mercury thermometer viz wet bulb and dry bulb thermometer, as shown in the Fig.(2.2.3). The circulating air is produced by a motor fan set (11). In this case a high speed air passes in the medium surrounding wet and dry bulbs for a time period of 15 to 20 sec. The temperatures readings of wet and dry bulb changes due to the circulation of the air. The readings are taken and the procedure is repeated until two successive readings of wet bulb thermometer are same. Finally with the help of wet and dry bulb temperature readings and psychrometric chart, relative humidity is calculated.

Since proper air flow is provided by the fan hence there are less chances of error in this method than with siling psychrometer.

2.2.4 Thermocouple psychrometer

The principle of thermocouple psychrometer is based on Seeback and Peltier thermal electromotive force (EMF) effects.

According to Seeback, in a circuit consisting of two dissimilar metals formed into two junctions, a current flow is induced by a temperature difference between two junctions viz hot and cold junctions. Current flows in such a direction as to equalize the temperature of junctions. The hot junction tends to cool and liberate heat energy to its environment and the the cold junction tends to warm and absorb heat energy from it environment.

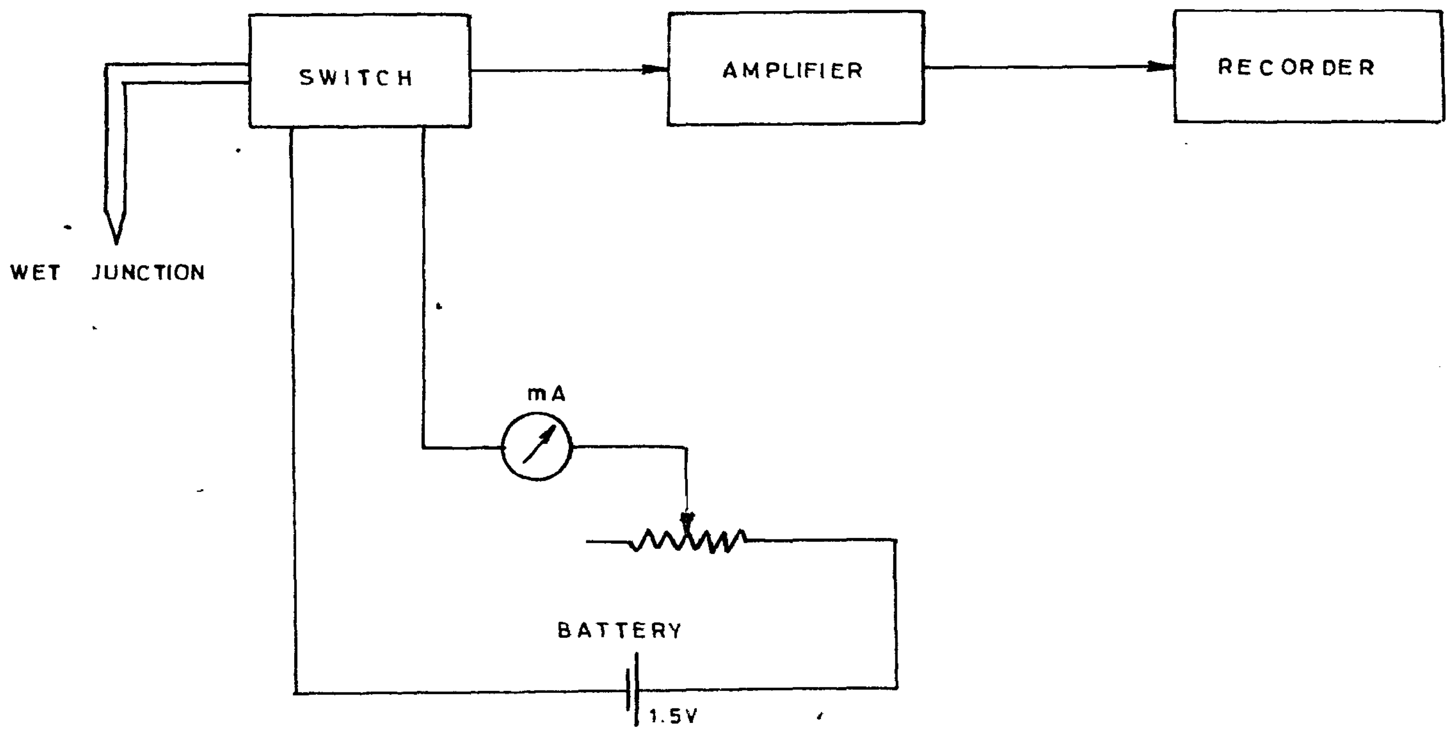

FIG. 2.2.4 BLOCK DIAGRAM OF CIRCUIT USED WITH THE PELTIER JUNCTION

According to Peltier effect, current flow is induced by a battery in a circuit having two dissimilar metals formed into two junctions, one cools and other one heat up.

The Peltier effect is used in the thermocouple psychrometer to cool one junction (known as wet junction) below dew-point temperature for the purpose of condensing water. This condensation of water has been done with a battery connected in circuit. Due to Seebeck effect, on EMF generates when condensation takes place. The reading of EMF can be taken just after terminating current flow in the circuit. Because after termination, the condensate starts evaporating. The value of thermal EMF gives the value RH. The thermal EMF is amplified through the DC amplifier and recorded by the chart recorder as shown in Fig. (2.2.4). Generally cooling currents 5, 10, 15 and 20 mA flow for a duration of 15, 30, 60 and 120 seconds at an environment temperatures of 10, 24.8 and 50°C. Copper and constantan wires are used for making the thermocouples.

2.2.5 Elevated temperature psychrometer

At low temperatures, relative humidity changes are large in proportion to the difference between the wet and dry bulb readings. When the wet bulb readings are near 0°C, it is difficult to determine the exact state of equilibrium. Therefore for determination of relative humidity of air at temperature of 0 to -40°C, an elevated temperature psychrometer is used.

The elevated temperature psychrometer is a conventional method for measurement of relative humidity below freezing temperature after determination of dew-point (23). The dew-point is determined with help of elevated wet and dry bulb thermometer readings. Relative humidity is calculated from the ratio of water vapour pressure corresponding to the dew-point temperature to the water vapour pressure corresponding to saturated air at the ambient dry bulb temperature. The theory and procedure for determination of dew-point from wet and dry bulb readings at higher temperature values are discussed below (22).

A schematic diagram illustrating an arrangement of different components to provide for an elevated temperature of wet- and dry bulbs is shown in Fig.(2.2.5). It consists a fan for sucking the atmospheric air, a electrical heater for increasing the air temperature and three thermometers. One thermometer is used to measures the temperatures of entering air to device. This is the ambient temperature of dry bulb. Other two thermometers read the temperature of wet and dry bulbs. Initially air circulation fan is started. The entering air is heated with electrical heater and then passed into an insulating mixing chamber which consists of wet and dry bulbs. The baffles are used for mixing up of heated air. The air is heated without any change of moisture content. The water reservoir is enclosed for this purposes. With the

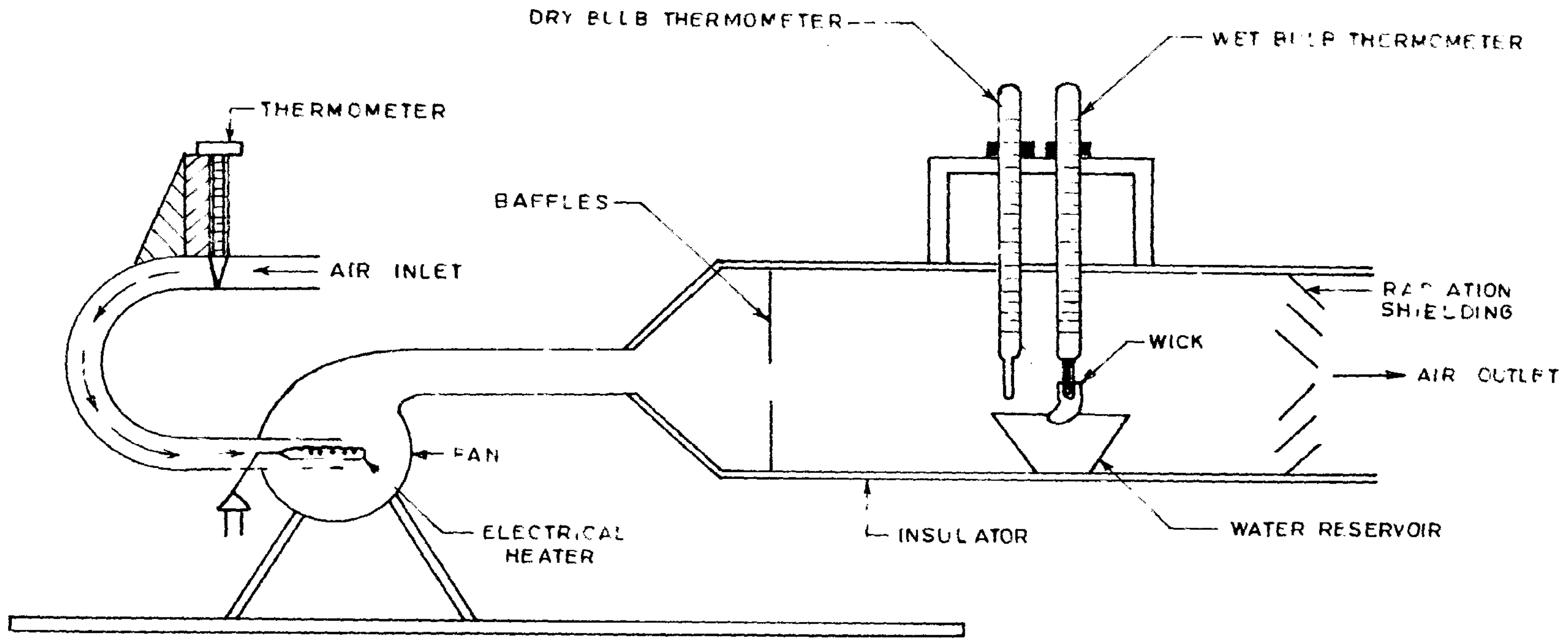

FIG. 2.2.5 ELEVATED TEMPERATURE PSYCHROMETER

help of wet and dry bulb thermometer readings and psychrometric chart, dew-point is calculated. Water vapour pressures are calculated corresponding to this dew-point and ambient temperature. Relative humidity is foundent after calculation of two water vapour pressures.

CHAPTER - III

ELECTRONIC PSYCHROMETER

3.1 Introduction

The electronic psychrometer is a device which indirectly measures the relative humidity in digital form. It is based on the measurement of the temperature ratio between wet bulb and dry bulb temperature readings. Two thermistors are used instead of thermometers for the measurement of wet and dry bulb temperature.

3.1.1 Principle of measurement of relative humidity

The temperature ratio of the wet and dry bulbs is calculated in the form of frequency ratio (18). The frequency ratio is in digital form. With the help of this digital reading and calibration curve shown in Fig.(3.1.1a), RH is obtained. The curve is drawn between relative humidity and temperature ratio of wet bulb to dry bulb. A Table (3.1.1) is obtained with the help of psychrometric charts as given in Fig.(3.1.1b). This table gives the calibrated curve. It has been noted from psychrometric chart that relative humidity is linearly related to ratio of wet bulb thermometer reading to dry bulb thermometer reading.

For the calculation of wet and dry bulb temperature ratio in the form of frequency ratio, an electronic circuit is used. Two identical astable multivibrator circuits are used for linear temperature to frequency conversion : one with two

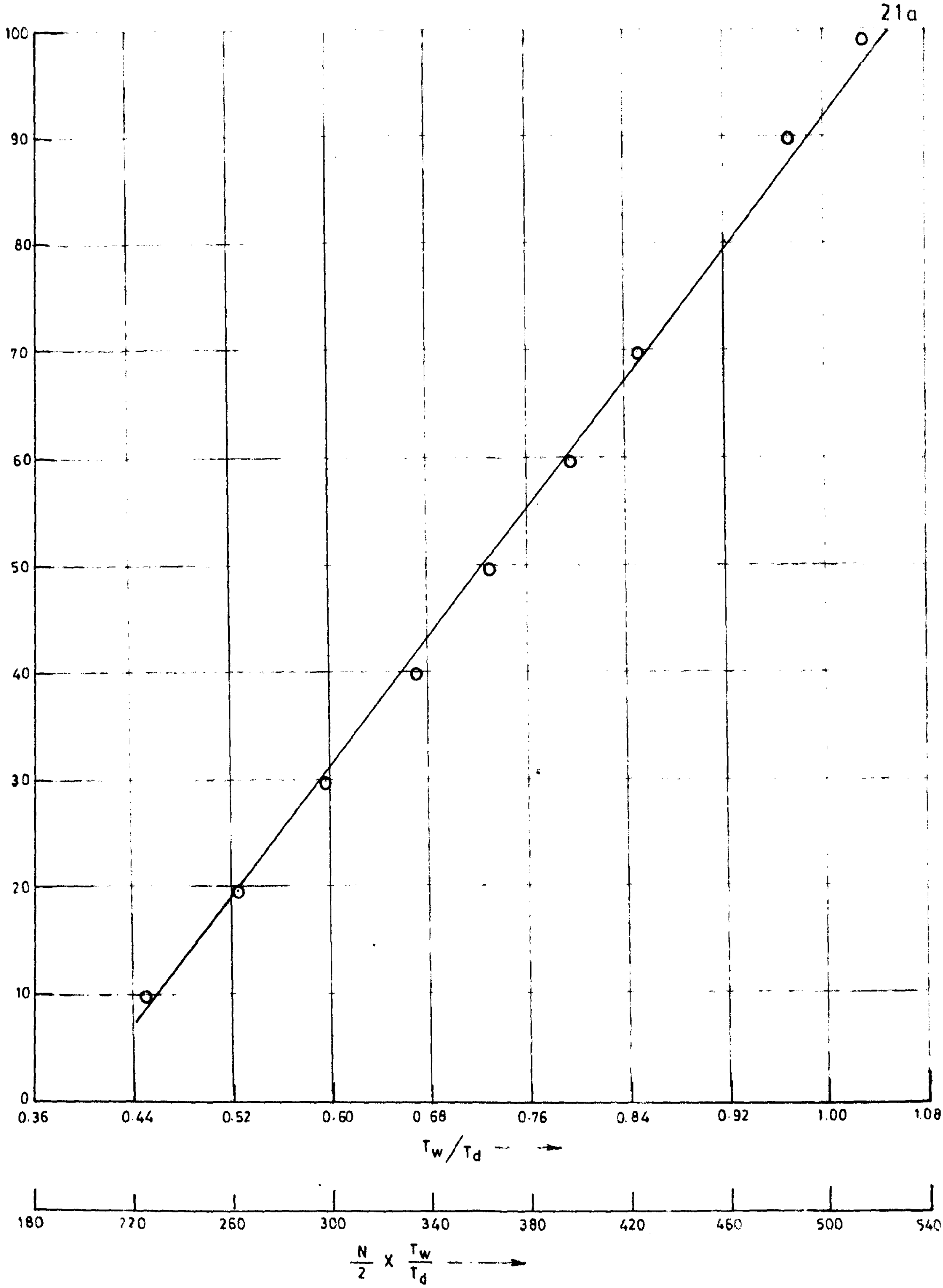
21a
100
90
80
70
60
50
40
30
20
10
0
0.36
0.44
0.52
0.60
0.68
0.76
0.84
0.92
1.00
1.08
T_w / T_d
180
220
260
300
340
380
420
460
500
540
$\frac{N}{2} \times \frac{T_w}{T_d}$

FIG. 3.1.1 (a)

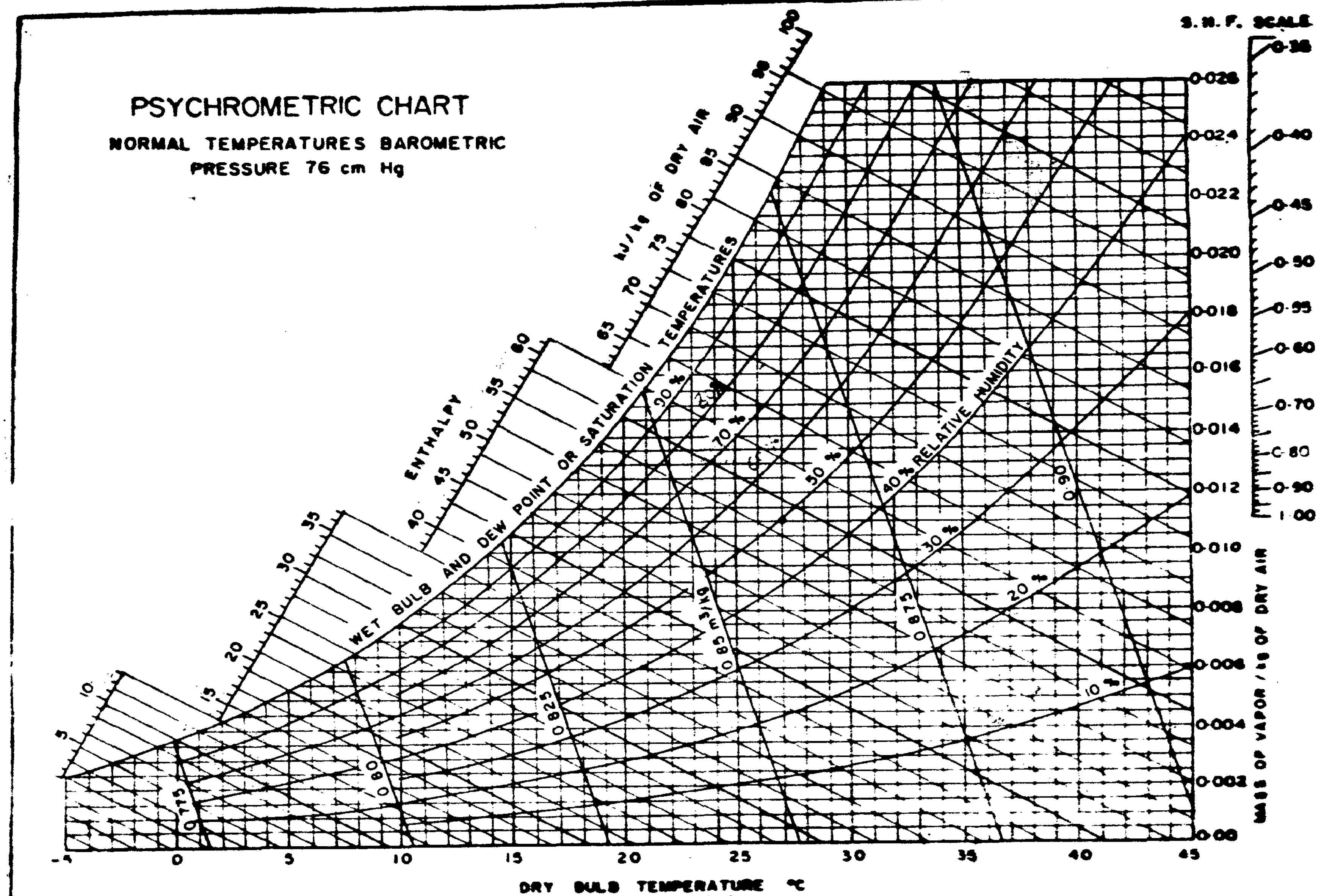
PSYCHROMETRIC CHART
NORMAL TEMPERATURES BAROMETRIC
PRESSURE 76 cm Hg
ENTHALPY
kJ/kg OF DRY AIR
WET BULB AND DEW POINT OR SATURATION TEMPERATURES
RELATIVE HUMIDITY
90 %
70 %
50 %
40 %
30 %
20 %
10 %
0.775
0.80
0.825
0.85 m³/kg
0.875
0.90
S.H.F. SCALE
MASS OF VAPOR / kg OF DRY AIR
DRY BULB TEMPERATURE °C

FIG. 3.1.1 (b)

thermistor in astable multivibrator circuit for wet bulb thermometer. Both circuits are identical which means that thermistors have same resistance values. Hence both astable multivibrator generate same frequency when corresponding thermistors are subjected to same temperature. These frequencies vary linearly with temperature. An integrated circuit gives the frequency ratio corresponding to wet and dry bulb temperature ratio. This ratio can be read with digital counter circuit and display. An electric fan is used to circulate the air around the thermistors with an air speed of more than 2.5 m/s.

Table (3.1.1)

Sl. No.	Relative Humidity	Dry bulb temperature °C (T_d)	Wet bulb temperature °C (T_w)	$\frac{T_w}{T_d}$
1	10	30	13.5	0.450
2	20	30	15.8	0.526
3	30	30	17.9	0.596
4	40	30	20.0	0.666
5	50	30	21.9	0.730
6	60	30	23.8	0.793
7	70	30	25.5	0.850
8	80	30	27.2	0.906
9	90	30	28.8	0.960
10	100	30	30.0	1.000

The observations can be taken more accurately with electronic psychrometer due to digital display. Thermistor is very sensitive to temperature. It can be used to measure RH upto 100 percent.

3.2 Basic Block Diagram of Electronic Psychrometer

The complete block diagram of an electronic psychrometer is shown in Fig.(3.2). It consists of wet and dry bulb sensors and linearizing circuits, frequency divider, differentiators and clippers, timer circuit, frequency ratiometer circuit, inverter and counter. The details of the block diagram are given below.

3.2.1 Sensor

In the electronic psychrometer, thermistor is used as temperature sensing element. Thermistor is a thermally sensitive variable resistor. The electrical resistance of thermistor is function of its temperature, which depends upon ambient temperature, atmospheric temperature and internal power dissipation (12).

Thermistors are essentially semi-conductor device. They have both types of temperature coefficient i.e. negative temperature coefficient (N.T.C.) as well as positive temperature coefficient (P.T.C.). Their temperature coefficient is not constant but is an inverse function of temperature.

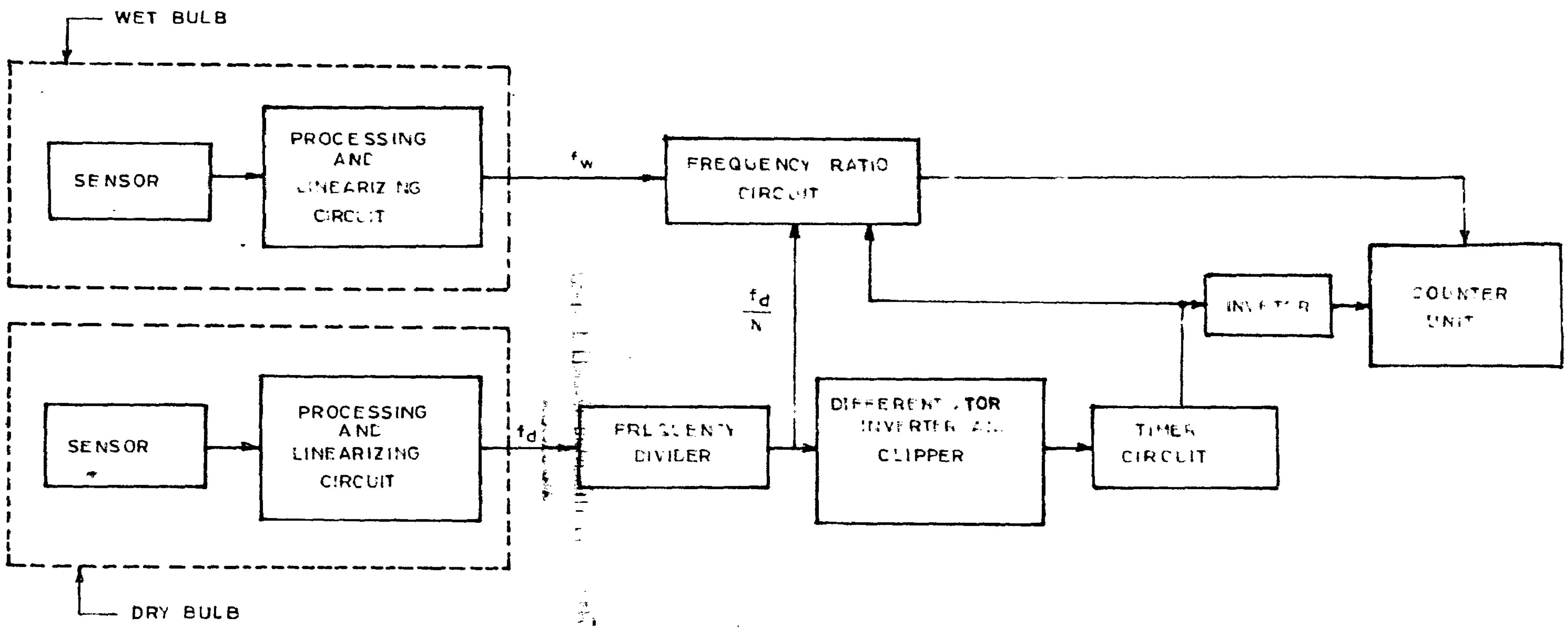

FIG. 3. 2 BLOCK DIAGRAM OF ELECTRONIC PSYCHROMETER

P.T.C. thermistors are made from two kinds of material : compound having the barium titanate ($BaTiO_3$) structure (posistors) and diamond lattice type semiconductor such as silicon (silistors). These types of thermistors have their temperature resistance characteristic as shown in Fig. (3.2.1a). Posistors and silistors have their temperature 60 percent per°K and 0.8 percent per°K. They are not used for measurement purposes.

N.T.C. thermistors are made of metal oxides and their mixtures viz. oxides of cobalt, copper, nickel, maganese, iron, tin, magnesium, titanium, uranium and zinc. The resistance range at temperatures varies from a few ohms to few mega ohms and the room temperature coefficient of resistance usually lies between - 4 percent and -5 percent per°K. These thermistors are approximately 10 times sensitive than of common metal like platinum or copper. Due to this characteristic, these are extensively used for the measurement purposes over the temperature range from -100 to + 300°C. These have their temperature resistance characteristic in the exponential form as shown in Fig. (3.2.1b). The variation of resistance is given by the equation :

$$R_T = R_{T_o} \, e^{B\left(\frac{1}{T} - \frac{1}{T_o}\right)}$$

where R_T = resistance of thermistor at temp. T°K.

R_{T_o} = resistance of thermistor at temperature T_o°K

B = Thermistor material constant lies between 3400/°K to 3900/°K.

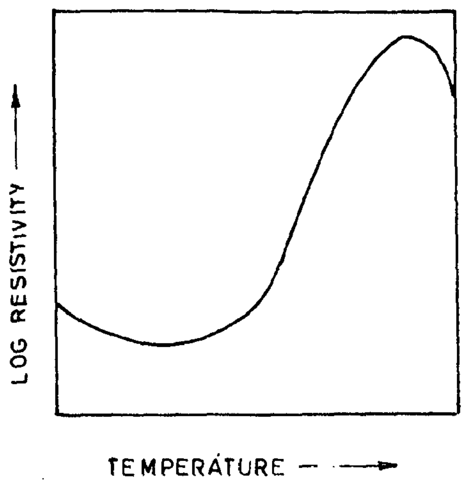

FIG.3.2.1(a) PTC THERMISTOR CHARACTERISTIC

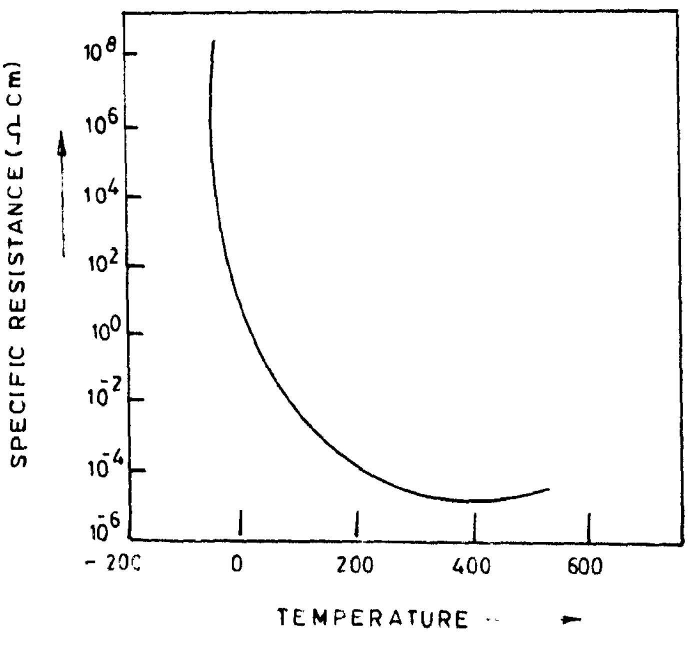

FIG. 3.2.1(b) NTC THERMISTOR CHARACTERISTIC

3.2.2 Processing and linearizing circuit

At previous discussed that NTC type thermistors are used for temperature sensing element in an electronic psychrometer. Thermistor has exponential characteristic between temperature and resistance. Therefore, it is necessary to linearise the response of thermistors. The variation of resistance can be linearized by several methods (6). A simple astable multivibrator circuit with OPAMP is also used for this purpose. Here astable multivibrator linearizing circuit is used to linear temperature to frequency conversion. Basically astable multivibrator is a square wave generator. As shown in Fig.(3.2.2a) circuits around the OPAMP A_1 perform the function of an astable multivibrator, where as the OPAMP A_2 isolates the multivibrator section from the frequency counter circuit. The OPAMP A_2 contains a diode in feedback loop to provide square wave pulses for TTL logic systems.

Astable multivibrator circuit consists of thermistor R_T in the output side with resistor r and R_C in series. The output voltage v_o is grounded by two zener diodes connected back to back and is limited to either $\pm V_z$ (± 5 V). A fraction of the output voltage βU_o available across the thermistor-resistor combination is fed back to the noninverting input terminal. β is feedback ratio and is equal to $(R_C + R_T)/(r + R_C + R_T)$. The generation of square wave voltage can be under stand as follows :

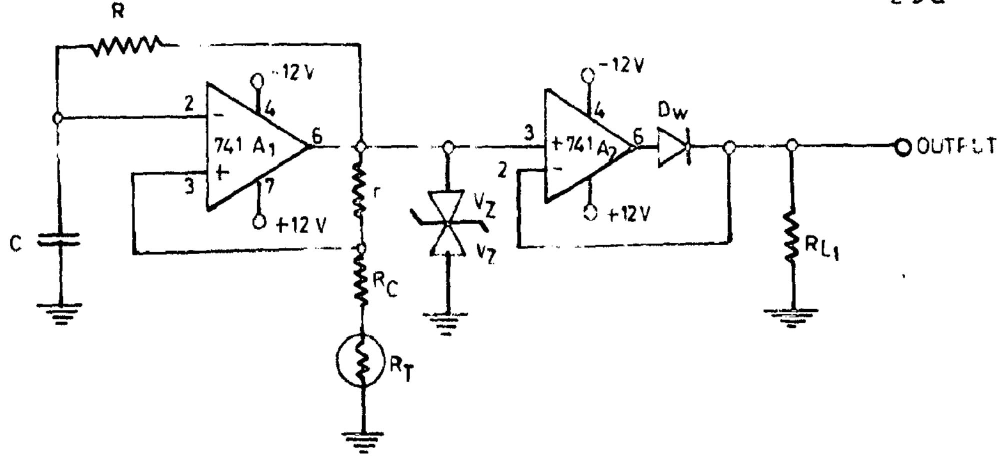

FIG 3.2 2(a) ASTABLE MULTIVIBRATOR CIRCUIT FOR LINEAR RELATIONSHIP BETWEEN TEMPERATURE AND FREQUENCY

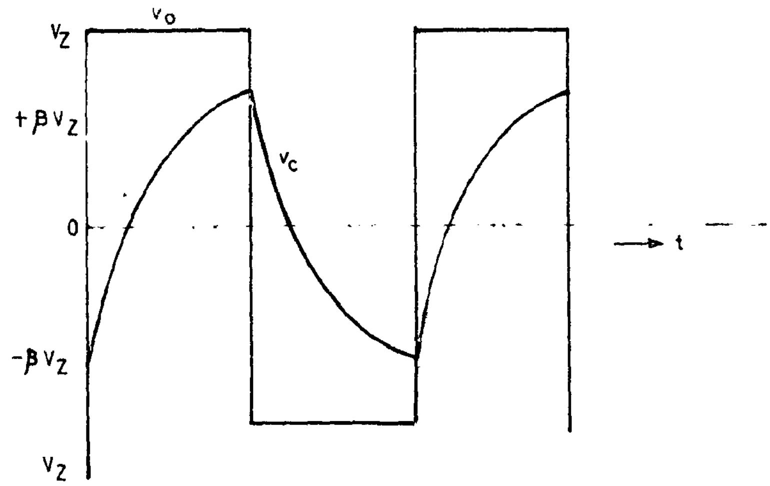

FIG. 3.2.2 (b) OUTPUT AND CAPACITOR VOLTAGE WAVE FORM

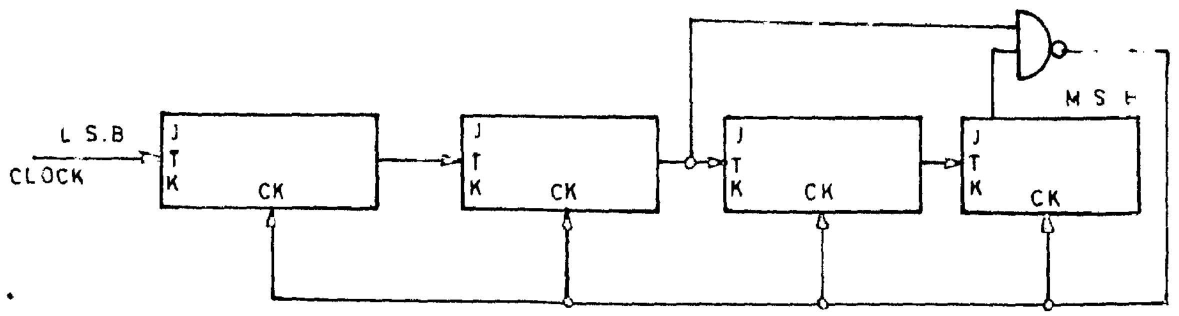

FIG.3 2 3 BLOCK DIAGRAM OF DECADE COUNTER PRINCIPLE

The differential input voltage v_i is given by

$v_i = v_c - \beta \, v_o$

where v_c = capacitor charging voltage.

When value v_i is negative the capacitor c charges exponentially towards lower zener diode voltage v_z through the integrating R_C combination (18). The output voltage remains constant at v_z until v_c equals $+\beta \, v_z$ at which time the output reverses to $-V_z$. Now v_c charges exponentially towards upper zener diode until v_c equals $-\beta \, v_z$. The output voltage v_o and capacitor voltage waveforms are shown in Fig. (3.2.2b).

IC741 OPAMP has been used here. It has very high input resistance (idealy $R_i = \infty$), very lowoutput resistance (idealy $R_o = 0$), high voltage gain (ideally $A_v = -\infty$) and high band width (ideally $= \infty$). It is a 8 pin IC. Its connection are given below.

Pin No. (1) - offset null

Pin No. (2) - inverting terminal (-ve)

Pin No. (3) - Non- inverting input (+ve)

Pin No. (4) - negative supply voltage (-12 V)

Pin No. (5) - offset null

Pin No. (6) - output

Pin No. (7) - positive supply voltage

Pin No. (8) - Not connected.

According to thermistor characteristor (7)

$$R_T = R_{T_o}\, e^{B\left(\frac{1}{T} - \frac{1}{T_o}\right)} \qquad \ldots (1)$$

The frequency of square wave is given by the expression :

$$f = \frac{1}{2RC\,\ln \frac{1+\beta}{1-\beta}} \qquad \ldots (2)$$

where
$$\beta = \frac{R_c + R_T}{r + R_c + R_T} \qquad \ldots (3)$$

From the equation (2) and (3)

$$f = \frac{1}{2RC\,\ln \left[1 + \frac{R_c + R_T}{r + R_c + R_T}\right]}$$

$$= \frac{1}{2RC\,\ln\left(\frac{r + R_c + R_T + R_c + R_T}{r + R_c + R_T - R_c - R_T}\right)}$$

$$= \frac{1}{2RC\,\ln\left(\frac{r + 2R_c + 2R_T}{r}\right)}$$

$$= \frac{1}{2RC\,\ln\left(1 + \frac{2R_c}{r} + \frac{2R_T}{r}\right)}$$

$$= \frac{1}{2RC\,\ln\left(\frac{2R_T}{r}\left(1 + \frac{R_c}{R_T} + \frac{r}{2R_T}\right)\right)}$$

$$= \frac{1}{2RC\ \ell n \left[\frac{2}{r} R_{T_0}\, e^{B\left(\frac{1}{T} - \frac{1}{T_0}\right)} \left(1 + \frac{R_c}{R_T} + \frac{r}{2R_T}\right)\right]}$$

from the equation (1)

$$= \frac{1}{2RC \left[\ell n\ e^{B\left(\frac{1}{T} - \frac{1}{T_0}\right)} + \ell n\ \frac{2R_{T_0}}{r}\left(1 + \frac{R_c}{R_T} + \frac{r}{2\,R_T}\right)\right]}$$

$$= \frac{1}{2RC \left[B\left(\frac{1}{T} - \frac{1}{T_0}\right) + \ell n\ \frac{2R_{T_0}}{r}\left(1 + \frac{R_c}{R_T} + \frac{r}{2\,R_T}\right)\right]}$$

$$= \frac{1}{2RC\left[\frac{B}{T} - \left\{ \frac{B}{T_0} - \ell n\ \frac{2R_{T_0}}{r}\left(1 + \frac{R_c}{R_T} + \frac{r}{2R_T}\right)\right\}\right]} \qquad \ldots(4)$$

$$\text{if } A = \frac{B}{T_0} - \ell n\ \frac{2R_{T_0}}{r}\left(1 + \frac{R_c}{R_T} + \frac{r}{2\,R_T}\right) \qquad \ldots(5)$$

$$\text{then} \quad f = \frac{1}{2RC\left(\frac{B}{T} - A\right)}$$

$$= \frac{1}{2RCB\left(\frac{1}{T} - \frac{A}{B}\right)}$$

$$= \frac{T}{2RCB\left(1 - \frac{A}{B}T\right)}$$

$$= \frac{1}{2\,RCB} \cdot \frac{T}{\left(1 - \frac{A}{B}T\right)} \qquad \ldots(6)$$

The equation (6) shows a linear relationship between the frequency and the temperature, provided AT/B remains constant.

This can be achieved in practice if the circuit components are selected in such a way that A varies linearly as the reciprocal of the temperature i.e.

$$A = \frac{A_o T_o}{T} \qquad \ldots(7)$$

where A_o is the value of A at $T = T_o$.

From the equation (5) it is clear that A is dependent upon the temperature mainly because of the presence of R_C. Since r is negligible compared to R_C. As the temperature increases, R_T decreases and this causes A to decrease (1). For $A_o T_o = AT$, practically it is possible to select an optimum value of R_C/R_T. For this a relation can be obtained from equation (5) and (7) as

$$\frac{\left(\frac{R_C}{R_{To}}\right)_{opt}}{1+\left(\frac{R_C}{R_{T_o}}\right)_{opt}} + \frac{T_o}{B}\, \ln \left[1+\left(\frac{R_C}{R_{T_o}}\right)_{opt}\right] = \left[1 - \frac{T_o}{B}\, \ln \frac{2R_{To}}{r}\right] \qquad \ldots(8)$$

Thus a value of $\left(\frac{R_C}{R_{T_o}}\right)_{opt}$ satisfying equation (8) keeps AT/B constant over a wide range of temperature and hence we get a linear response.

Two astable multivibrator circuits as described earlier are used for measurement of wet bulb and dry bulb temperatures. Initially both multivibrators generators equal frequencies if both wet as well as dry bulb thermistors are exposed to same atmospheric conditions. They generate different frequencies. When wet bulb thermistor is immerged in the water with wick and dry bulb thermistor is exposed in the atmosphere. Symbolically these are written as f_w and f_d for wet and dry bulb thermistors respectively.

3.2.3 Frequency divider

For the ratio of frequency f_w to the f_d it is necessary to divide f_d by an integer N(1000). An IC 7490 is used for division by 10. This division by 10 can be easily under stood the block diagram as shown in Fig.(3.2.3). For division by 1000, three 7490s are cascaded. The IC 7490 has 14 pin and there connections are given below

Pin 1 - input (B)	Pin - 8 - Q_C
Pin 2 - $R_0(1)$	Pin - 9 - Q_B
Pin 3 - $R_0(2)$	Pin -10 - Q_{ND}
PIN 4 - NC	Pin -11 - Q_D
Pin 5 - $+V_{cc}$	Pin -12 - Q_A
Pin 6 - $R_g(1)$	Pin -13 - NC
Pin 7 - $R_g(2)$	Pin -14 - input (A)

3.2.4 Frequency ratio circuit

The frequency ratio has been obtained by using an AND gate. If pulses of two frequencies are in high level i.e. at logic 1, than AND gate will be ON, otherwise, it will be in OFF.

Mathematically if there are two frequencies f_w and f_d and f_d is divided by N (an integer) in order to get a waveform of frequency f_d/N. Pulses of f_w and f_d/N are passed through AND gate when both types of pulses are in high level. The number of positive pulses n of frequency f_w is calculated as below (10).

The time period of the frequency f_d/N i.e.

$$T_d = \frac{1}{f_d/N}$$

$$= \frac{N}{f_d}$$

The no.of positive pulses of frequency f_w during up counting cycle i.e. in the time period $T_d/2$,

$$n = f_w \times \frac{T_d}{2}$$

$$= f_w \times \frac{N}{2f_d}$$

$$= \frac{N}{2} \cdot \frac{f_w}{f_d}$$

$$\therefore \quad \frac{f_w}{f_d} = \frac{2}{N} \cdot n \qquad \ldots(1)$$

According to equation (1) if we count the pulses n and then it is multiplied by 2/N, the actual ratio of two frequencies is obtained. For AND gate an IC 7408 is used. It has four gates as shown in Fig.(3.2.4a). Only two gates are used here one for frequency ratio and other for counter. The waveform

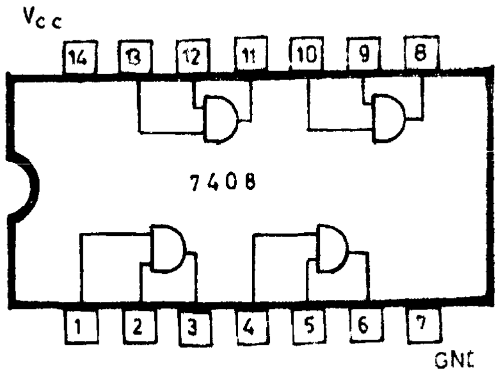

FIG. 3.2.4 (a) BLOCK DIAGRAM OF IC 7408

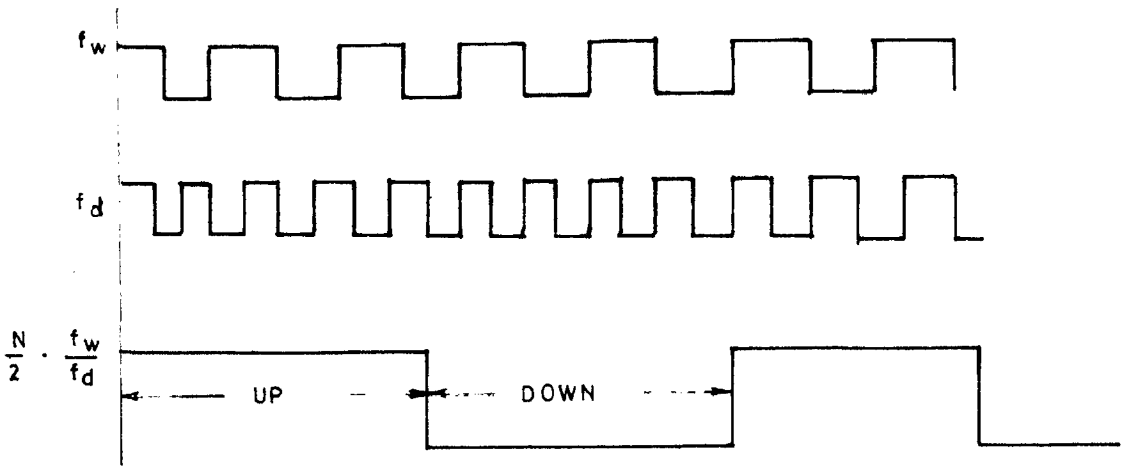

FIG. 3.2.4 (b) FREQUENCY RATIO WAVE FORM

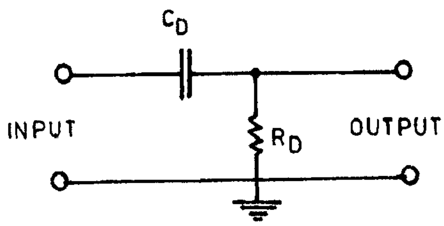

FIG. 3.2.5 (a) DIFFERENTIATOR CIRCUIT

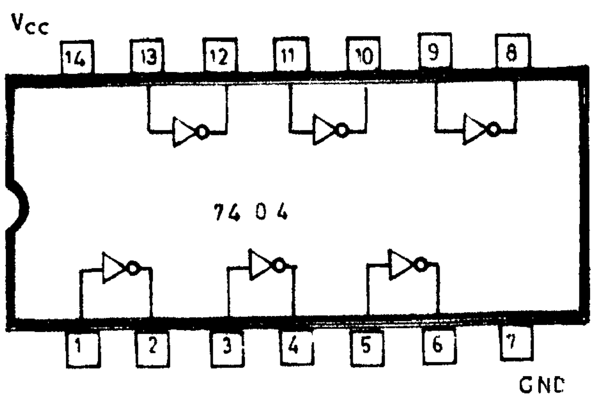

FIG. 3.2.5 (b) BLOCK DIAGRAM OF IC 7404

of frequencies ratio is shown in Fig.(3.2.4b). Truth table of AND gate is given in Table (3.2.4).

Table (3.2.4)

A	B	4
0	0	0
1	0	0
0	1	0
1	1	1

3.2.5 Differentiator - inverter - clipper circuit

A monostable timer circuit require short duration negative pulse for its triggering. Since f_d/N frequency has its pulses of long duration and hence unable to trigger the timer monostable circuit. For making a short duration pulses i.e. spikes a differentiator circuit can be used as shown in Fig.(3.2.5a). It is a combination of capacitor C_D and resistor R_D. For the design of differentiating circuit the time constant will be less than one tenth of the pulse width.

An invertor i.e. NOT gate and clipper is used for the synchronise of timer monostable multivibrator circuit with AND gate. NOT gate invert the output pulses of differentiator circuit. An IC 7404 used for this purposes. It has inverter gatesas shown in Fig.(3.2.5b). The clipper circuit is a combination of diode and resistance. It clippes the positive spikes and gives only negative spikes for triggering the timer monostable multivibrator circuit. The clipper circuit is given in Fig. (3.2.5c). The value of resistance R_p will be geometric mean of the forward and reverse resistances of the diode D_p. The output waveforms of differentiator, invertor and clipper are shown in Fig.(3.2.5d).

3.2.6 Mono-Stable multivibrator using timer (555)

For counter circuit it is necessary to have set and reset pulses. A monostable multivibrator circuit is used for this purposes. It is an one shot timer. The output of monostable multivibrator gives a designed pulse width whatever the width of input pulse (9). These pulses are shown in Fig.(3.2.6) Monostable multivibrator circuit contains a combination of capacitor C_m and resistor R_m for giving the desired width of output pulses. When negative pulse is applied to input, the voltage across the capacitor rises exponentially with time constant R_m C_m. When the voltage across the capacitor equals $\frac{2}{3}$ V_{cc}, the capacitor discharges rapidly and drives the output to its low state. The circuit triggers on a negative going input signal when the level reaches $\frac{1}{3}$ V_{cc}. The time that the output is in high state is given by $t = 1.1\ R_m\ C_m$. The timer used is 555 IC. It consist eight pin. Its connection are given below.

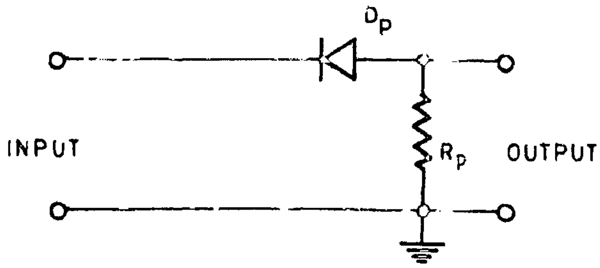

FIG. 3.2.5(c) CLIPPER CIRCUIT

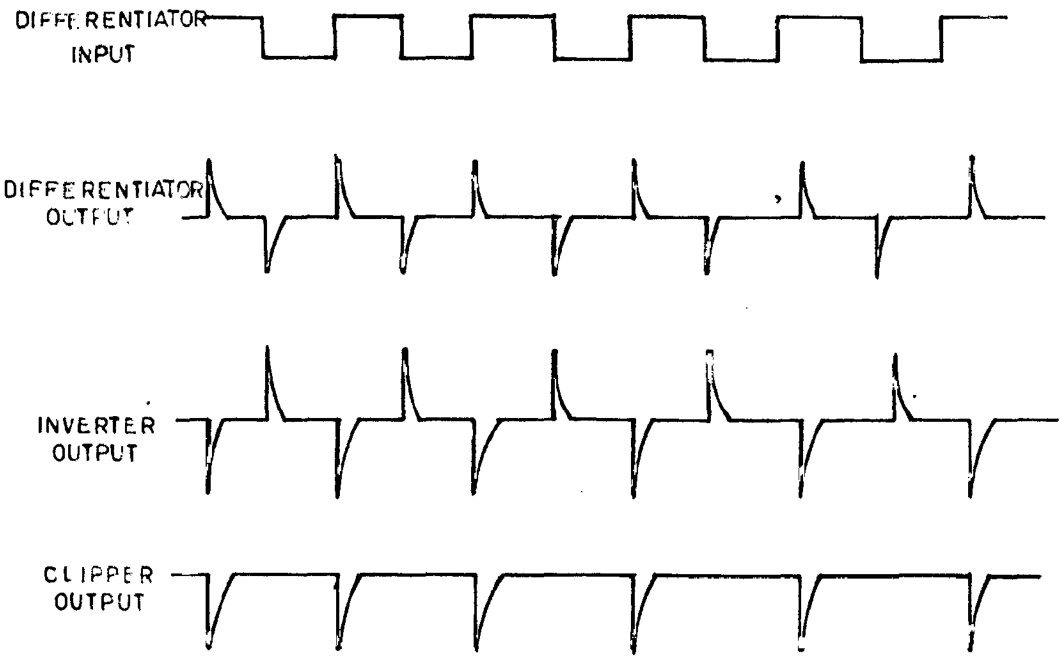

FIG. 3.2.5 (d) CLIPPER OUTPUT WAVE FORM

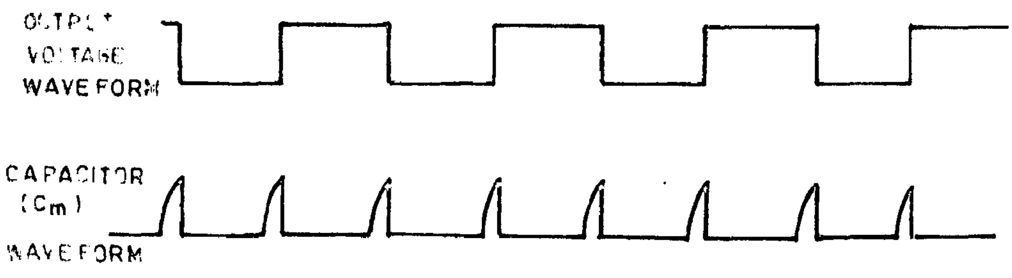

FIG. 3.2.6 MONOSTABLE OUTPUT WAVE FORM

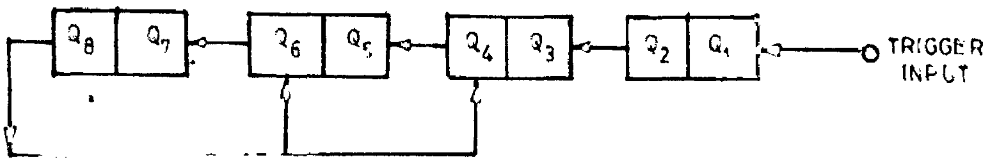

FIG. 3.2.8 1(a) BLOCK DIAGRAM OF FOUR FLIP-FLOP AS DECADE COUNTER

pin 1 - Ground

pin 2 - Trigger

pin 3 - Output

pin 4 - Reset

pin 5 - Control voltage

pin 6 - Threshold

pin 7 - Discharge

pin 8 - Supply (V_{cc})

3.2.7 Inverter circuit

It is a NOT gate which gives an output to counter and latch circuit in antiphase to that of counting input pulses. The truth table of NOT gate is as below.

A	Y
0	1
1	0

3.2.8 Counter unit

The counter unit consists decade counter, latch circuit, decode driver and seven segment display. The details of these circuits are given below.

3.2.8.1 Decade counter assembly

Decade counter is a circuit which produces one single output pulse for every ten input pulses. The scale of -16 counter has a cascade of four flip flops (2). A scale of ten or decade counter can be achieved to eliminate the first six states of a scale -16 counter. Its block diagram is shown in

Fig. (3.2.8.1a). The initial condition of decade counter will be 0110 (decimal 6). In this condition, transistor Q_4 and Q_6 must be in the OFF state. For decade counter truth table is given in Table (3.2.8.1) and wave forms are shown in Fig. (3.2.8.1b).

Table (3.2.8.1)

Q_8 D	Q_6 C	Q_4 B	Q_2 A	Decimal count	
0	1	1	0	0	
0	1	1	1	1	
1	0	0	0	2	
1	0	0	1	3	
1	0	1	0	4	
1	0	1	1	5	
1	1	0	0	6	
1	1	0	1	7	
1	1	1	0	8	
1	1	1	1	9	
Reset: 0	0	0	0	10	Reset
0	1	1	0	0	

Decadecounter IC 7490 has been used. Three cascaded IC 7490 can count upon 999. They count unit, tens and hundreds respectively in BCD form. Initially all 7490 are reset to

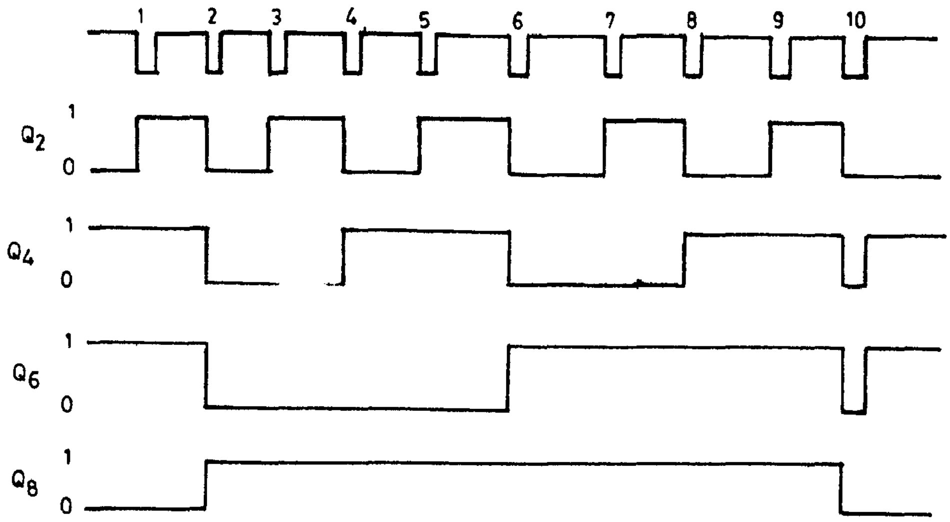

FIG 3.2.8.1(b) COLLECTOR WAVE FORMS OF FOUR FLIP-FLOP

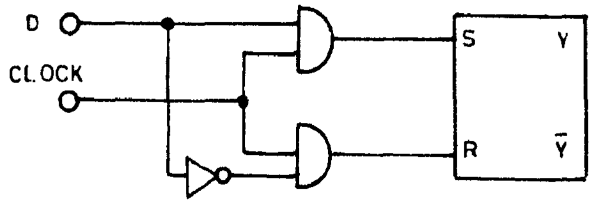

FIG. 3.2 8 2(a) D - FLIP FLOP

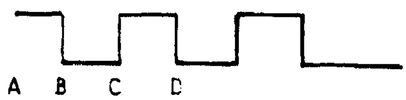

FIG.3.2.8.2 (b) TRIGGER CLOCK PULSES

DCBA = 0110

This is done by applying a reset pulse simultaneously to all 7490S. The clock pulse drive first 7490. After nine clock pulses, the unit counter has an output condition of

DCBA = 1111

All other counter still have

DCBA = 0110

On the tenth clock pulse, the D output of the unit counter goes from a 1 to a 0 and triggers the tens counter. Because of this the, output condition of all three 7490S is

0110 0111 0110 equivalent to decimal 10.

As each additional clock pulse arives, the unit counter advances one count. Every time the unit counter resets to 0110, it triggers the tens counter, which advances one count. After 99 clock pulses, the BCD output of the three 7490S is

0110 1111 1111 equivalent to decimal 99.

On the 100th clock pulse, the tens counter resets to 0110 and triggers the hundred counter. Therefore, after 100 clock pulses, the BCD output of the 7490S is

0111 0110 0110 equivalent to decimal 100

3.2.8.2 Latch circuit

A latch isolates the display devices from the counting circuits while counting is in progress. At the end of the counting time, a signal to the latch causes the display to change to the decimal equivalent of final condition of the counting circuits. If the input frequency is constant then the displayed count remains constant. The counting circuits continue to count the input frequency and the latches are repeatedly triggered to check the displays against each final stage of the counting circuits.

The working principle of the latch is based on D flip-flop as shown in Fig.(3.2.8.2a). This kind of flip-flop prevents the value of D from reaching the y output until a clock pulse occurs. When the clock pulse is low, both AND gates are disabled, therefore, D can change values without affecting the value of y. On the other hand, when the clock is high both AND gates are enabled (15). In this case, y is forced to equal the value of D. When the clock again goes low, y stores the last value of D.

The IC 7475 contains four D-type latches. It is sometimes called a 'quad bistable latch'. Due to four D-flip-flop it is a temporary storage of four-bit data. Briefly for the display of decimal 999, the working function of the system is described with the help of Fig.(3.2.8.2b). Between time A and B, the 7490S are counting in the BCD form. The BCD outputs are the data input to the 7475S. Because of the inverter, however, the 7475S are disabled while counting is taking place. The BCD output of 7490 is

1111   1111   1111

At point B the 7475s are enabled, therefore, the BCD output of 7490S transfer through the 7475s to the 7447s. The IC 7447 is a BCD decoder/driver suitable for seven segment indicators. At the point B the number 99 is displayed. At point C the 7490S are reset to zero and new count begins. At the same time the 7475s are disabled and retains the BCD output of 1111 1111 1111.

This BCD number is temporarily stored while the 7490S are going through a new count. Thus readout continues displaying decimal 999 while new count is in progress. At point D, the displayed gives new count. The 7475 avoids a blinking read while 7490 counts.

3.2.8.3 Binary to decimal and decimal to seven segment display conversion

The output of a decade counter can be given in binary form if collector voltages are read as 1 when high and 0 when low. For display purposes, it is necessary to convert this binary number to decimal with seven segment display. For the conversion from binary to decimal IC 7447 is used while MAN 72 is used for seven segment display. These conversions can be understood with the Fig.(3.2.8.3a).

It consists two diode matrix, one for binary to decimal conversion and other one for decimal to seven segment conversion (2). There are ten transistors (Q_{10} - Q_{19}). The transistor emitters are commoned and connected to ground via diode D_{41}.

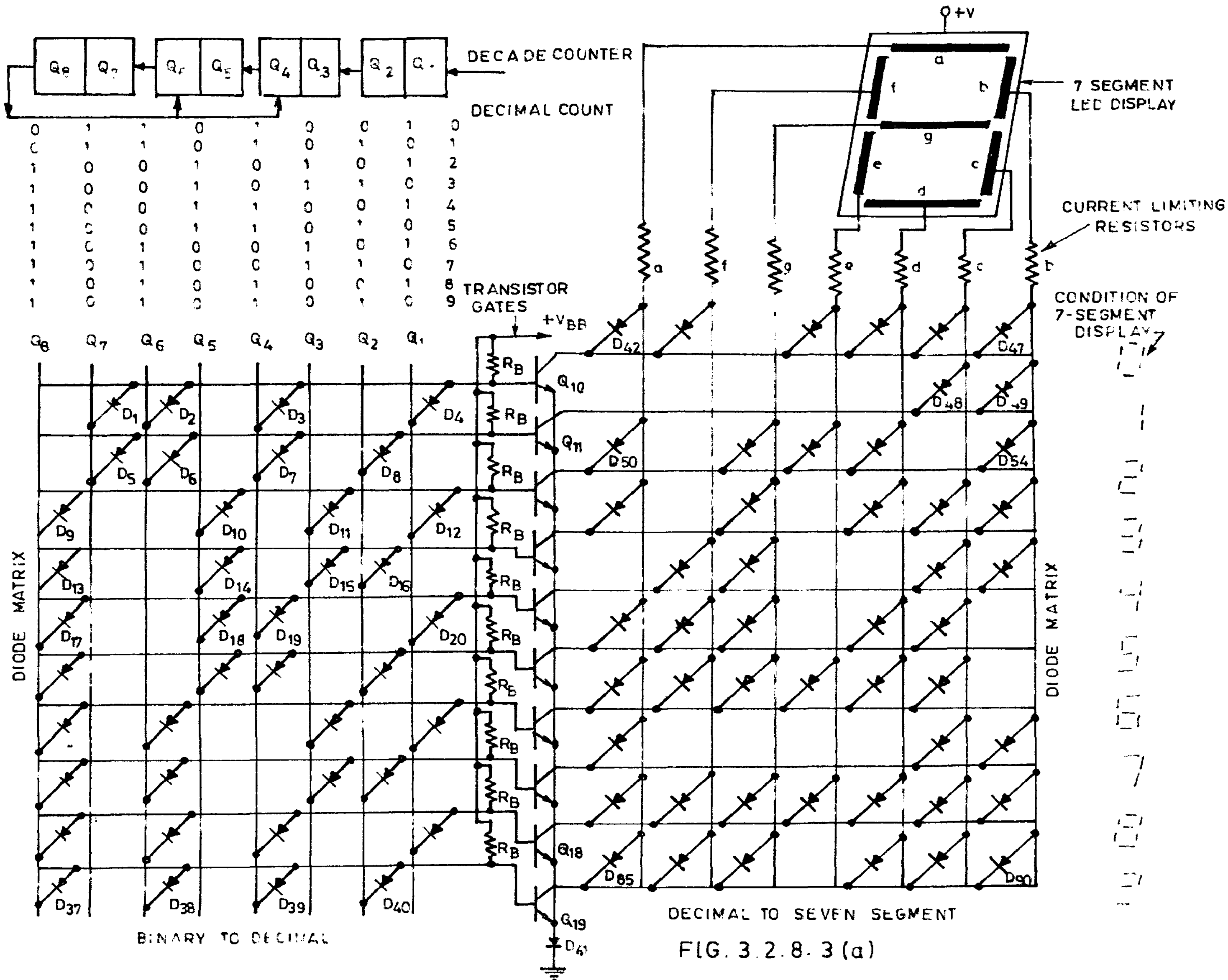
DECADE COUNTER
DECIMAL COUNT
7 SEGMENT LED DISPLAY
+V
CURRENT LIMITING RESISTORS
CONDITION OF 7-SEGMENT DISPLAY
TRANSISTOR GATES
+VBB
DIODE MATRIX
BINARY TO DECIMAL
DECIMAL TO SEVEN SEGMENT

FIG. 3.2.8.3 (a)

The presence of D_{41} ensures that the base voltage of each transistor has to be approximately 2 V_{BB} above ground level for it switch ON. Each gate transistor has four diodes connected to its base. When the cathode of one or more of these diodes is at 0 (i.e. near ground level), the transistor base is held below the switching voltage. In this condition the transistor cannot switch ON. When the cathodes of all four diodes connected to the base of any gate transistor are at 1, the diodes are reverse-biased, and the transistor is biased ON via base resistance R_B. At a time only one transistor will be ON i.e. when Q_{10} is ON, all other gates transistors (Q_{11} - Q_{19}) must be biased OFF.

For the seven-segment display, the anodes of the LEDs are commoned and have a positive supply voltage (+ 5V). The cathodes from each segment (lettered a tog) have separate terminals.

The collectors of each transistor (Q_{10} to Q_{19}) have seven diodes. The cathode of the diodes are connected to the transistor collector so that they are forward biased when transistor is ON.

Now consider the collector voltage levels and decimal count for the decade counter. For a decimal count of 0, reading all transistor collector levels, Q_8 to Q_1 are read as 01 10 10 01. At this condition diodes D_1, D_2, D_3 and D_4 which are connected to the base of Q_{10} are reverse-biased. Base current flows from V_{BB} via R_B into the base of Q_{10}. Therefore Q_{10} will be ON and collector of this will be at 0 level. For this diodes D_{42} to D_{47} will be forward-biased, therefore LED segments a, b, c, d, e and f will be energized. With this seven segment display, indication is of the form 0 . Similarly, other decimal (1 to 9) can be obtained. These conversions can be logically represented as shown in Fig.(3.2.8.3b). The pin connections of 7475 and 7447 are below.

IC 7475

Pin 1 - $1\bar{Q}$
Pin 2 - $1Q_D$
Pin 3 - $2Q_D$
Pin 4 - Enable 3-4
Pin 5 - V_{cc}
Pin 6 - 3D
Pin 7 - 4D
Pin 8 - $4\bar{D}$
Pin 9 - 4Q
Pin 10- 3Q
Pin 11- $3\bar{Q}$
Pin 12- GND
Pin 13- Enable 1-2
Pin 14- $2\bar{Q}$
Pin 15- 2Q
Pin 16- 1Q

IC 7447

Pin 1 - B input
Pin 2 - C input
Pin 3, Pin 4, Pin 5 - V_{cc}
Pin 6 - D input
Pin 7 - A input
Pin 8 - GND
Pin 9 - e
Pin 10- d
Pin 11- c
Pin 12- b
Pin 13- a
Pin 14- g
Pin 15- f
Pin 16- V_{cc}

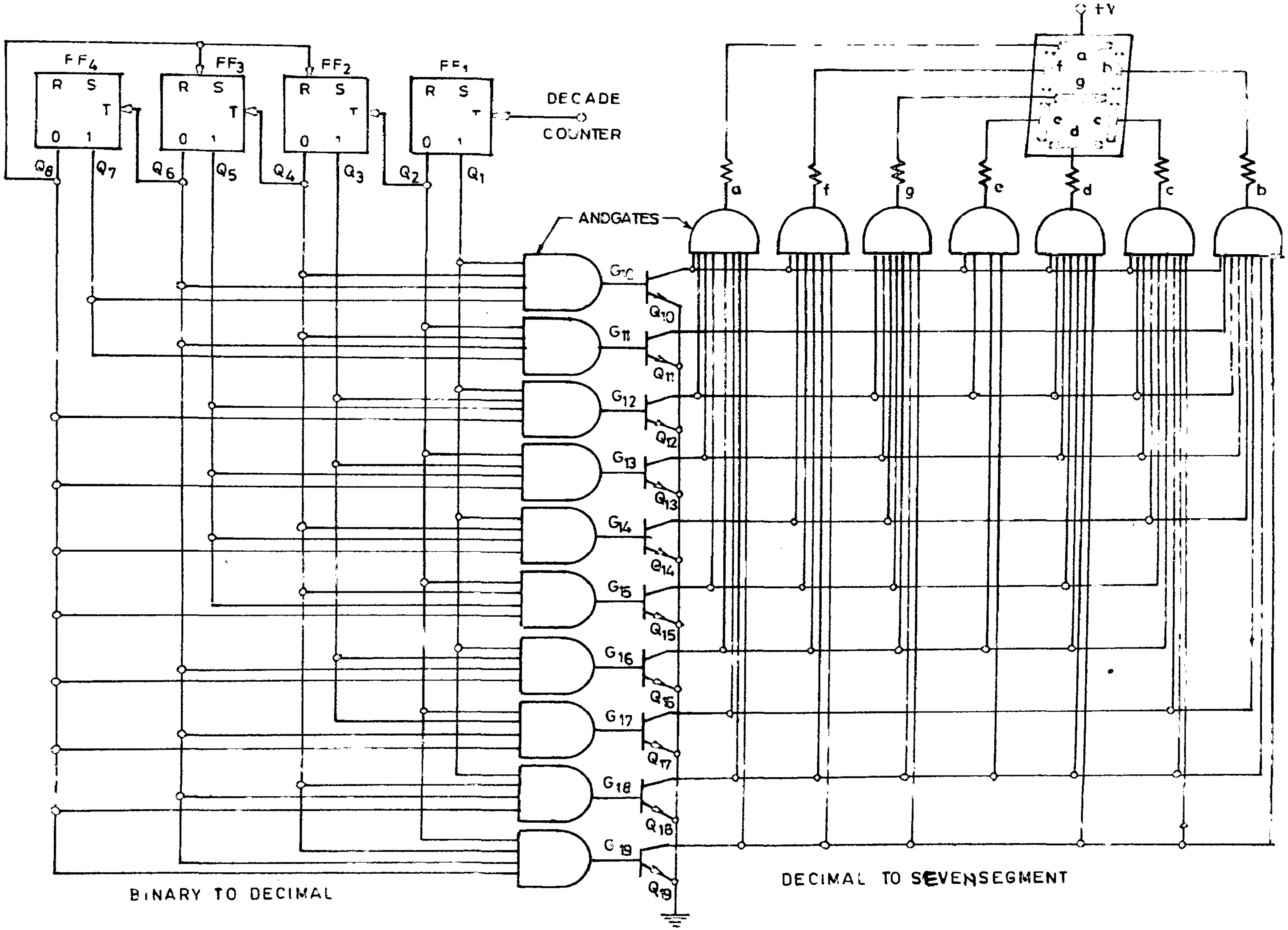

FIG. 3.2.8 3(b) LOGIC DIAGRAM FOR BINARY TO DECIMAL AND DECIMAL TO SEVEN SEGMENT CONVERSION

3.3 Complete Circuit Diagram

As shown in Fig. (3.3a), it is a comple circuit diagram of electronic psychrometer.

For the measuring the frequency ratio $\frac{N}{2}\frac{f_w}{f_d}$ it is required to count it by counting circuit. As shown in Fig.(3.3a) The output of AND gate 1 i.e. pulses of frequency $f_w(\frac{N}{2}\ \frac{f_w}{f_d})$ passes through AND gate 2. The square wave pulse $\frac{N}{2}\ \frac{f_w}{f_d}$ passes to the counting circuit only when output of timer will be at high level i.e. (i) will be at logic 1. Since for the timer monostable multivibrator time period T = 2 second. Therefore, timer output is alternately at level 1 for one second and at level 0 for one second. Consequently the AND gate 2 is alternately ON for one second and OFF for one second. During the time that the AND gate 2 is ON, the pulses of $\frac{N}{2}\ \frac{f_w}{f_d}$ triggers the counting circuits. The exact number of input pulses are counted during that time and it will be $\frac{N}{2}\ \frac{f_w}{f_d}$.

The output (ii) is in antiphase to (i). This pulse is employed for reseting the counter circuits and for opening and closing the latches.

At the beginning of the counting time output (ii) is a negative going pulse. This triggers the reset circuitry in each decade counter. Since output (ii) is at logic 0 during the counting time, its application to the latching circuits ensures that each latch is OFF. That is during counting time,

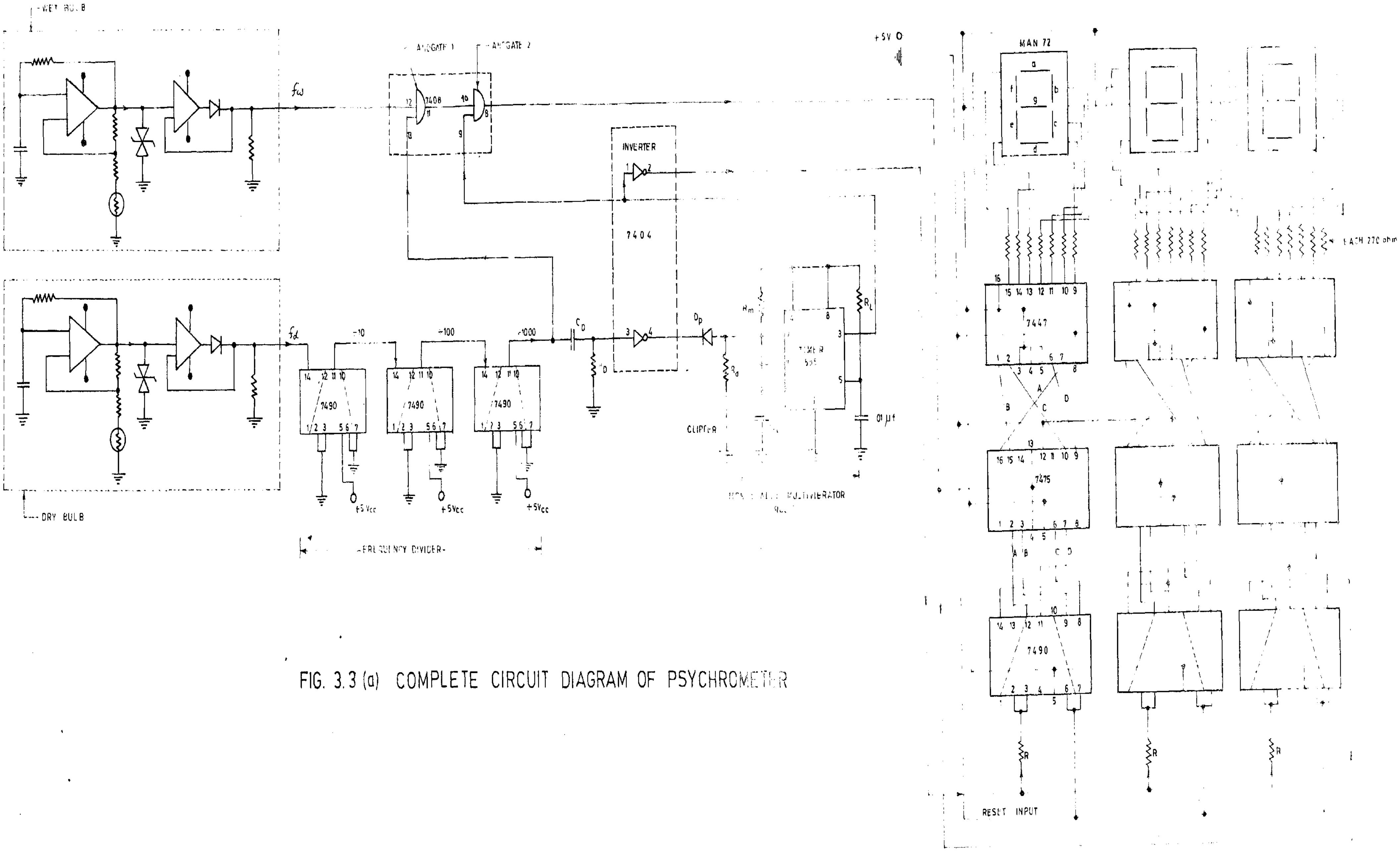

FIG. 3.3 (a) COMPLETE CIRCUIT DIAGRAM OF PSYCHROMETER

nothing passes through latch circuit. At the end of the counting time, the pulse fed to the latch inputs goes to logic 1. This triggers each latch ON so that the condition of the displays are corrected. During the latch ON Time, the AND gate 2 is OFF and no counting occurs. Therefore, once corrected, the display remains constant. The display remains constant also during the counting time, since the latch circuits are OFF. These are shown in Fig.(3.3b).

3.4 Design of Circuits

3.4.1 Astable multivibrator circuit design

Thermistor resistance R_{T_O} = 33 K ohms

Thermistor material constant B = 3500/°K ohms

Since maximum atmospheric temperature will be upto 50°C. Hence we design the circuit upto a temperature of 50°C.

Resistance of thermistor at 50°C.

$$R_{T_{50}} = 33\ e^{3500\left(\frac{1}{323} - \frac{1}{273}\right)}$$

$$= 13.29 \text{ K ohms}$$

According to relation

$$\frac{\left(\frac{R_c}{R_{T_O}}\right)_{opt}}{\left(1 + \frac{R_c}{R_{T_O}}\right)_{opt}} + \frac{T_O}{B}\ \ell n\left(1 + \left(\frac{R_c}{R_{T_O}}\right)_{opt}\right) = 1 - \frac{T_O}{B}\ \ell n\left(\frac{2 R_{T_O}}{r}\right)$$

R_c = 21 K ohms

r = 50 ohms

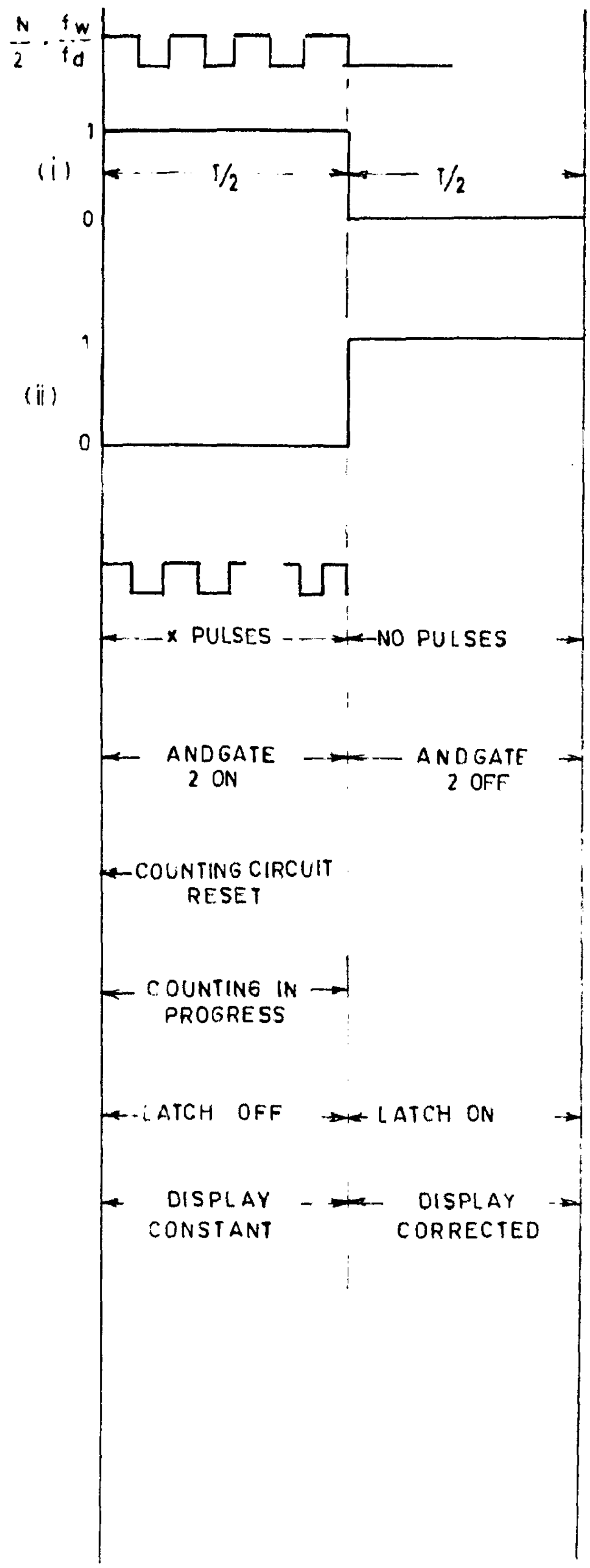

FIG 3.3(b) WAVE FORMS FOR COUNTER AND LATCH CIRCUIT

According to relation

$$A = \frac{B}{T_o} - \ln \frac{2R_{T_o}}{r} \left(1 + \frac{R_c}{R_T} + \frac{r}{2 R_T}\right)$$

Value of A at 50°C i.e.

$$A_{50} = 4.686$$

Since astable multivibrator circuit can generate only upto 10 KHz. Hence for a frequency 8 KHz the value of

$$R = 2.2 \text{ K ohms}$$

$$C = 0.004 \ \mu f$$

Value of resistance $R_d = R_w = R_f R_r$

Where R_f = forward resistance of diode

R_r = reverse resistance of diode

i.e. $R_d = R_w = 50 \times 10^{-3} \times 100$

$$= 2.2 \text{ K ohms}$$

3.4.2 Design of differentiator

Pulse width of differentiator's input frequence :

$$P_w = \frac{1000}{2 \times 8000} = 0.0625 \text{ sec.} \quad \because N = 1000$$

Therefore time constant

$$C_D R_D < \frac{.0625}{10}$$

for this

Hence R_D = 10 K ohms and $D_d = D_w^{\cdot} = D_p$

C_D = .01 μf

3.4.3 Design of monostable multivibrator circuit

Therefore

$R_m C_m$ = 2 sec.

$\therefore$ R_m = 200 K ohms

C_m = 10 μf

Load resistance R_L = 10 K ohms

3.5 Fabrication of Circuits

The circuit has been fabricated on printed circuit board. The prepared printed circuit board is as shown in Fig.(3.5). The line diagram for P.C.B. was finalized and drawn on graph paper.

3.6 Testing Result of The Circuit

Finally circuit is tested at different points. The variation of thermistor resistance and frequency with resistance is given in Table (3.6).

Table (3.6)

Sl. No.	Temperature ^{o}K	Thermistor resistance K	Frequency Hz
1	298	33.00	4558
2	303	27.08	4646
3	308	22.41	4731
4	313	18.68	4820
5	318	15.72	4902
6	323	13.10	4995

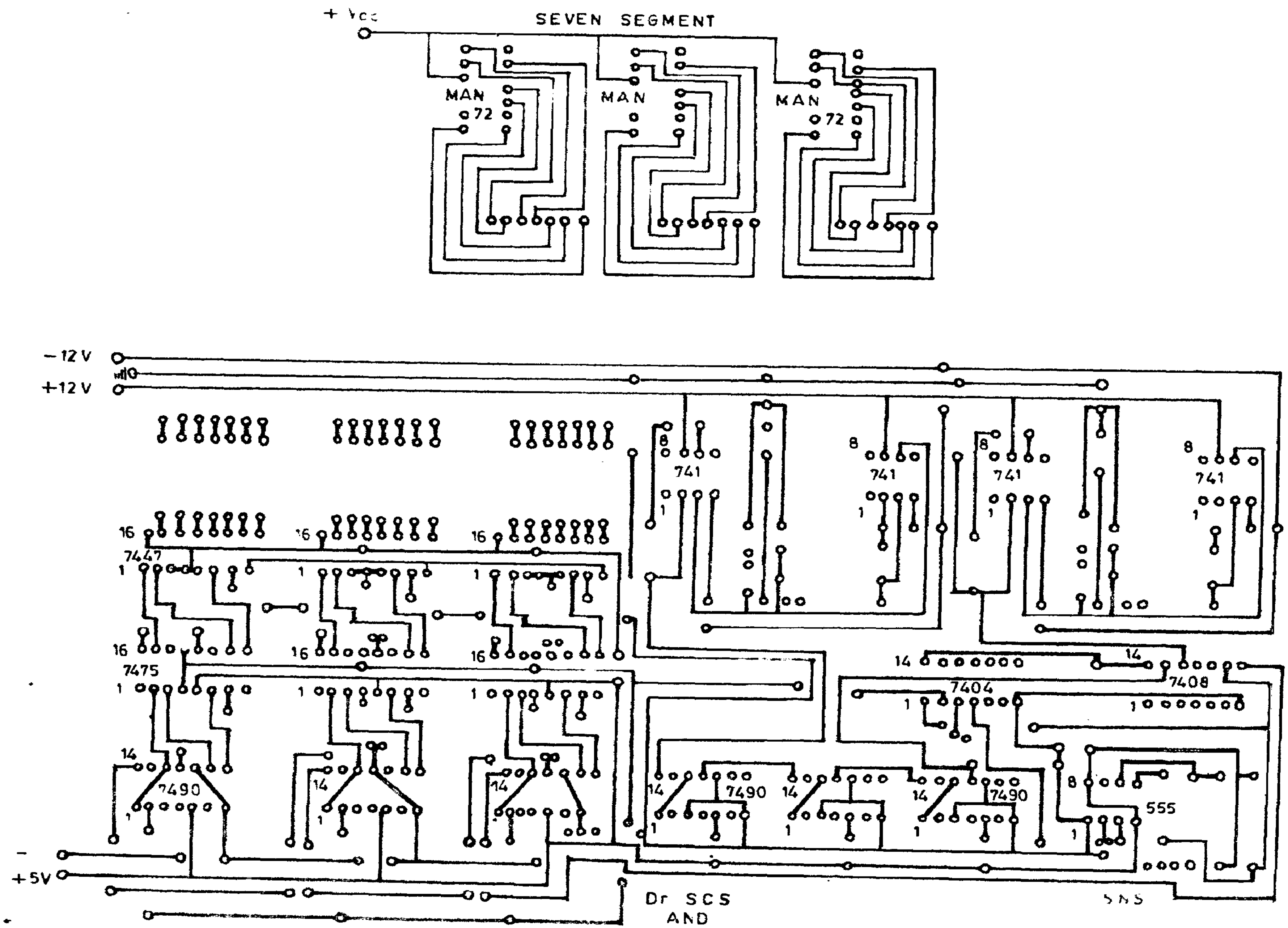

FIG. 3 5 P.C.B DIAGRAM

CHAPTER - IV

CONCLUSIONS

The measurement of relative humidity in many industries : like textiles, paper and pulp mills etc. is an important parameter. There are two types of devices used for the measurement of RH value of humidity. These are based on hygrometric and psychrometric principles.

Hygrometric devices are hair hygrometer, salt conductivity hygrometer, electrolytic hygrometer etc. These are used in industries for measurement of RH value but gives poor performance due to non-linearity behaviour and sluggish response.

Sling psychrometer, Assmann psychrometer etc. are psychrometer devices. In the case of psychrometer the accurate reading of wet bulb is a necessary factor. It is difficult to read exact value of wet bulb temperature due to its fast rise and fall. Therefore, measurement with these devices is susceptible to errors.

It is, therefore, necessary to have a humidity meter which has, as far as possible, linear and smooth response. In this dissertation the aim was to design and develop an electronic psychrometer to give linear electrical output corresponding to RH value directly.

After a review of other methods available for RH measurement, the electronic psychrometer has been designed for this measurement with a digital readout.

It is based on the principle of finding out the frequencies corresponding to wet and dry bulb temperatures and relate a ratio of these frequencies by a calibrated curve between RH and frequency ratio. It has seen that the frequency ratio varies linearly with wet and dry bulb temperature ratio. The calibration curve has been plotted with the help of psychrometric chart and is a linear characteristics between the ratio of wet bulb to the dry bulb temperatures and RH values. If the abscissa reacting of the curve is multiplied by a proportionality constant ($\frac{N}{2} = \frac{1000}{2}$) then it gives direct value of RH in terms of frequency ratio.

Thus in actual development two thermistors are used as wet and dry bulb temperature sensors in the proposed electronic psychrometer. These are very sensitive to temperature. Therefore this psychrometer gives a fast response than other methods.

Astable multivibrator is the heart of this device which gives linear relationship between temperature and frequency. Two such multivibrators are used. They are fed by wet and dry bulb temperature sensors give two frequencies. AND gates are used for getting the ratio of these frequencies. The counter and display unit is suggested to give a digital readout.

Such electronic psychrometer can be used to measure RH value in industries like textiles, pulp and paper mills. It gives directly a digital output as against any conventional type RH measuring device. This output in digital form can be fed to computers for further processing.

It can also be used in an automatic control system for measuring and recording RH by remote control. Further, such a psychrometer is free from human judgement errors.

REFERENCES

1. Anwar A. Khan and Gupta R. Sen.," A linear temperature to frequency convertor using a thermistor, IEEE Transaction on Instrumentation and measurement, Vol.IM30, No.4, Dec.1981, pp.296-298.

2. Bell, David A., " Solid state pulse circuits", Reston Publishing Company, Inc., Reston, Virginia, A Prentice Hall Company, 1976. pp.339-347.

3. Blythe Broughton M.," Analysis and design of almost temperature transducer", IEEE Transaction on Instrumentation and measurement, Vol.IM 23, No.1, March 1974, pp-1.

4. Considine D.M., Process Instruments and Control Hand Book, McGraw Hill Book Company, 1974. pp.10.3-10.11.

5. Coulson J.M. and Richardson J.F., Chemical Engineering., Vol.One, Fluid flow, heat transfer and mass transfer, Perigamon Press, Oxford, pp.361-367, 1978.

6. Dragan K. Stankovic, linearized thermistor multivibrator bridges for temperature measurement, IEEE Transaction on Instrumentation and measurement, March 1977, Vol.IM 26, No.1, pp.41-45.

7. Edward A.," Thermistor bead matching for temperature RF Power thermistor mounts", IEEE Transaction on Instrumentation and measurement, Sept.1967, Vol.IM 16, pp.192.

8. Fisher P.D. Lillevik S.L. & Jones A.L., " μp simplifying humidity", IEEE Transaction on Instrumentation and measurements, Vol.IM 32, No.1, March 1981, pp.57-63.

9. Gothmann H. William, Digital electronics, An introduction to theory and practice, 1977. pp.290.

10. Gupta S.C. and Dewal M.L., " A novel technique for the measurement of average rotor temperature of brushless synchronous machines", IEEE Transaction on power apparatus and system, Vol. PAS 98, No.4, July/Aug.1979.pp.1238-1241.

11. Hickman, M.J. measurement of humidity- Her Majesty Stationary Office, London, 1970, pp. 11.

12. Hyde F.J., Thermistor, London iliffe books, 1971, pp.1-30

13. Jain C. Cyan, Practical Semiconductor Manual, Vol.2,1976 pp.110

14. Langley B.C., Refrigeration and air conditioning, Reston Virginia, A Prentice Hall Company, 1978, pp. 535-545.

15. Malvino Albert Paul and Leach P. Donald, Digital principles and applications, Second editions, California Los Altos Hills, July 1979, pp. 177-185.

16. Millman Jacob and Halkias C. Christos, Integrated electronics, Analog and digital circuits and systems, 1972, pp. 579-580.

17. Misevich, K.W., " Capacitive humidity transducer", IEEE Transaction on Industrial electrocs and control instrumentation, Vol. IECI 16, No.1, July 1969, pp.6-12.

18. Nantou Yasuo, " Digital ventilated psychrometer", IEEE Transaction on Instrumentation and measurement, Vol.IM28, No.1 March 1979, pp. 42-45.

19. Pandey A., " Hand book of moisture determination and Control", Vol.3, New York Marcel Dekker, 1975, pp. 585-689.

20. Pandey A." Hand book of moisture determination and control", Vol.4, New York, Marcel Dekker, 1975,pp.1089.

21. Penman H.L.," Humidity", Reinhold Publishing Co. New York, May 1955. pp.62.

22. Stankovic and Elazor J.," Thermistor multivibrator as the temperature to frequency convertor measurement, IEEE Transaction on Instrumentation and measurement, Vol.IM 26, No.1, March 1977, pp.41-45.

23. Wexler Arnold, Humidity and moisture measurement and control in science and industry, Vol.1, Reinhold Publishing Corporation, New York, 1965, pp.95-114.

24. Wexler Arnold, Humidity and moisture measurement and control in science and industry Vol.1, Reinhold publishing Corporation, New York, 1965, pp.491.

25. Texas Instruments, The TTL Data Book for Design Engineers, Second Edition, 1981.

APPENDIX-I

(i) Moisture:- The amount of water vapour present in the air.

(ii) Dew-point:- is the temperature at which a mixture of air and water vapour is saturated.

(iii) Humidity(H):- mass of water vapour associated with unit mass of dry gas.

(iv) Humidity of Saturated gas (H_o):- Humidity of the gas when it is saturated with vapour at a given temperature

$$\% \text{ humidity} = \frac{H}{H_o} \times 100$$

(v) Absolute humidity :- It is the weight of the vapour (W_u) in unit weight of the dry gas (W_g) i.e. $H = \frac{W_u}{W_g}$.

(vi) Humid heat :- Heat required to raise unit mass of dry gas and its associated water vapour through unit temperature difference at constant pressure.

(vii) Humid Volume :- Volume occupied by a unit mass of dry gas and its associated vapour (5).

(viii) Saturated volume:- It is the humid volume of saturated gas.

(ix) Humidification:- The process of adding moisture to the air is called humidification.

(x) Dehumidification:- The process of removing moisture from the air is called dehumidification.

(xi) Saturated Air :- It is air which contains all the water vapour that it is capable of holding at that particular temperature and pressure. When the air is saturated the dry bulb, wet bulb and dew-point temperature are the same.

(xii) Psychrometrics :- The science which deals with the relationships that exist within a mixture of air and water vapour is known as psychrometrics (14).

(xiii) Psychrometric chart:- It is a diagram which represents the various relationships that exists between the heat and moisture content of air and water vapour.