DESIGN AND CONSTRUCTION OF DIGITALTEMPERATURE MEASURING INSTRUMENT USING THERMISTOR

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A PROJECT REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG.) DEGREE IN THE DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING, SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY

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NIGER STATE

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CERTIFICATION

This is to certify that this work titled, *Design and construction of Digital Temperature measuring instrument* using *Thermistor* was carried out by me Ajagunna B. James under the supervision of Engr. M.D Abdullahi, for the award of Bachelor of Engineering (B.Eng) Degree in Electrical and Computer Engineering of Federal University of Technology, Minna.

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DECLARATION

I hereby declare that this project work was wholly and solely conducted by me under the supervision of Engr. M.D Abdullahi, department of Electrical and computer Engineering , Federal University of Technology , Minna.

Ajagunna B. James

6/12/2017

Student's Signature

DEDICATION

This project work is absolutely dedicated to the Almighty God, my most beloved parents – Mr. and Mrs. E.O Ajagunna, my younger brother Master Ajagunna Oluwasesan and my heartthrob Apata Lydia A.

ACKNOWLEDGEMENT

First and foremost, I hereby acknowledge the extravagant grace and divine assistance of the Almighty God in making this project a reality and a success.

My profound gratitude goes to my able supervisor – Engineer M.D Abdullahi and all my lecturers within and out side the Department.

Profoundly acknowledged are also the financial, spiritual and moral aids of my beloved parents – Mr. and Mrs. E O Ajagunna, Maternal Grandfather Mr. E. A. Adebiyi.

I wish to acknowledge my spiritual mentors in Living Faith Church (Winners Chapel) Minna; the pastoral team and my unit (C. C .U) members for the spiritual and moral assistance.

The acknowledgement will be incomplete if I fail to acknowledge the financial and moral support of my aunts and uncles Rev and Mrs. A.O Awebohoye, Mr and Mrs. S.N. Eyiaro, Mr. Ayodele Olufayo, Mr. Sule A.I and Master Ajagunna Dele D.I will like to acknowledge all my siblings for their financial and words of encouragement every now and then. They are: Mrs. R.A Adewumi, Mrs. O.D Oshodi, Mrs. G.F Abiola, Master Ajagunna Sesan, Dupe, Christy, Joke and the others.

I am indebted to my heartthrob, Apata Lydia Sylvia, for the moral and enthusiastic support she always gives me. I pray that Almighty God will reward you immensely.

Finally, I want to acknowledge the various supports I enjoyed from my friends on campus (Federal University of Technology, Minna), most especially my partner in this project work, Folaranmi Matthew A , and my colleagues; Atipo Kolawole, Balogun Ayodeji, Mosunmola Sidiku and the rest of them. God bless you all.

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ABSTRACT

Measurement of physical quantities is one of the most vital activities in harmonizing man, machine and human environment to the real world of elemental changes.

In view of the above, the focus of this project work ' *Design and Construction of Digital Temperature Measuring Instrument* ' that can measure temperature between 0°C to100°C, has been deemed appropriate.

The instrument mentioned above consists of three fundamental units: - power supply unit, which supplies direct voltages to the system; processing unit Thermistor, which senses the temperature, converts it into electrical voltage and then amplifies the voltage; and display unit, which gives out the actual value of the temperature measured in digital mode.

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CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 INTRODUCTION.

Measurement of physical quantities is one the most important ways in relating man, machine and human environment to the real time of elemental changes.

In industries, especially electric power stations and manufacturing companies, so many equipment and machines are designed to operate within a particular range of temperature for effectiveness and efficiency. Temperature measuring device, e g. Thermometers are usually attached to equipment to measure temperature of things like cooling airs, cooling oil and cooling water instantaneously as the machine in the operation.

Although, temperature which is of primary interest in this project work, is analogue (continuous) in nature, digital instrumentation often provides the most convenient and accurate means of processing and display .

Ambient temperature is the principal concern of measurement and changes in the magnitude of this fundamental quantity may be monitored in an optimized manner for any situation such as the case with incubators, silo grain e.t.c.

Development in electronics engineering and invention of integrated circuit has resulted in less tedious, less time consuming and most convenient way of designing instrument (digital in this case), suitable enough for the purpose intended in this project .

Analogue instruments or devices are gradually dwindling in the global village, while digital instruments are ever skyrocketing in number. Their versatility in applications is a consequence of their great accuracy and improved sensitivity.

This project is designed to measure temperature from 0°C to 100°C using a digital instrument.

The major advantage of digital instrument is that it eliminates error due to parallax and reduces human error associated with interpolating the position of a pointer on an analogue scale.

1.2 PROJECT OBJECTIVE AND MOTIVATION

The main objective of this project is to design and construct a digital temperature measuring instrument that measure temperature from 0°C to 100°C and display the temperature digitally. This easily gives the user the ability to interprete the exact, value of the temperature.

Another objective of this project is to eliminate error due to parallax, scale calibration, bent pointers, and variation of the pointer associated with analogue meters.

Finally the aim is to construct a digital temperature measuring instrument, suitable for use in measuring temperature of non-conductive fluid such as air and also an environment but it excludes solid objects.

1.3 PROJECT LAYOUT

The layout of this project is divided into three chapters for easy comprehension.

Chapter one encompasses the general introduction of the topic and also gives an insight into the state-of –art of the knowledge about the project work

Chapter two basically deals with system design and analysis. In this chapter, the system is further divided into three basic units with their principles of operation explained briefly. The system comprises of power unit, processing unit and display unit.

Chapter three is concerned with the construction and testing of the system. The procedure involved in the building of the three functional basic units of the system together with the results obtained on testing are presented in this chapter.

Chapter four includes conclusion on the project and recommendation for future improvement of the project

Following chapter four is the presentation of the references.

CHAPTER TWO

2.0 LITERATURE REVIEW

There are various temperature monitoring devices existing today using different transducers and method of displaying. Some systems are designed based on the principle of thermo-couple, a device that uses the voltage developed by the junction of two dissimilar metals to measure temperature difference. One junction the sensing junction is placed at the point of interest, while the other, called the reference junction is maintained at a reference temperature. The voltage developed across the junction is proportional to the difference between the two temperatures.

Another transducer that can be use is an IC (LM35), this generate an output voltage proportional to the temperature. The LM35 is a convenient 3-terminal temperature sensor that behaves like a zener diode with a voltage of +10mV/k for example, at 25.c(288.2 k) it acts like a2.982-volt zener.

The LM35 also provides a voltage output with +10m V/C slope, powered by +5volts to +30volts applied to a third terminal; it has an internal offset such that the output is 0 Volts at 0 degree celsius . To operate near or below 0 degree celsius a pull down resistor must be used.

The sensor used for this project work is a Thermistor. A negative temperature coefficient (NTC) thermistor is used here as a temperature sensor. This sensor is a temperature dependent resistor whose resistance decrease with increase in temperature.

The figure below (fig. 2.1) shows the variation of the resistor with temperature of NTC thermistor. It also shows the variation of resistance with

temperature of positive temperature coefficient (PTC) thermistor whose resistance rises on heating

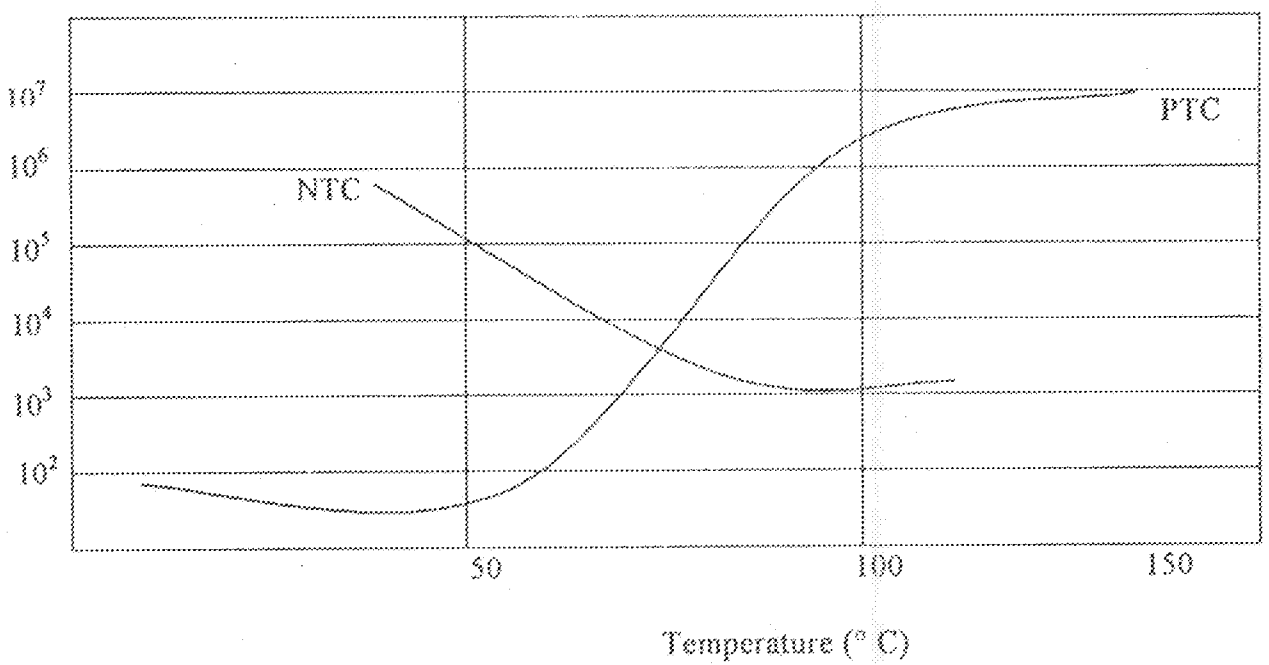


Fig 2.1 Resistance Temperature characteristics of NTC and PTC

The problem about the IC sensor is the scarcity. Most of them are not available in the market and the ones that are available in the market have limited supply.

The method of temperature display also varies. Some used direct temperature readout on a scale calibrated in degree celsius. Others converts the output voltage from the temperature measuring circuit, which is analogue, to digital signal. This is then display on an electronic LED display.

CHAPTER THREE

THEORY AND DESIGN

3.0 INTRODUCTION

It is very important and essential in electrical, electronics and computer engineering to always depict systems with the aid of block diagrams. So, the block diagram of the system; digital temperature measuring instrument is hereby presented in figure 3.0 below.

Each block represent a basic unit briefly presented below. Power supply unit: this supply power or energy to the system and its significant can be appreciated from the fact that, without it the system will not be able perform any work.

Processing unit: this is the unit that is concern with the sensing of the physical quantity (temperature) to be measured, convert it into an electrical signal and then amplifies the latter.

Display unit: this unit constitute electronic component for converting the analog signal output of the previous unit into its digital equivalent and for presenting the latter in a form comprehensible to human being.

3.1 POWER SUPPLY UNIT

Most of the electronic devices and circuit require a dc source for their operation. Thus the electronic circuit being designed requires dc voltages +5 V, +9 V, -5V, and –9 V with their common ground, the power supply unit converts the domestically supplied 220 V – 240 V ac voltages into the required dc voltages, which are expected to be constant even though the variations occur in the ac supply voltage.

A typical dc power supply consist of four stages they include:

Transformation stage;

Rectification stage

Filtering stage

Regulation stage.

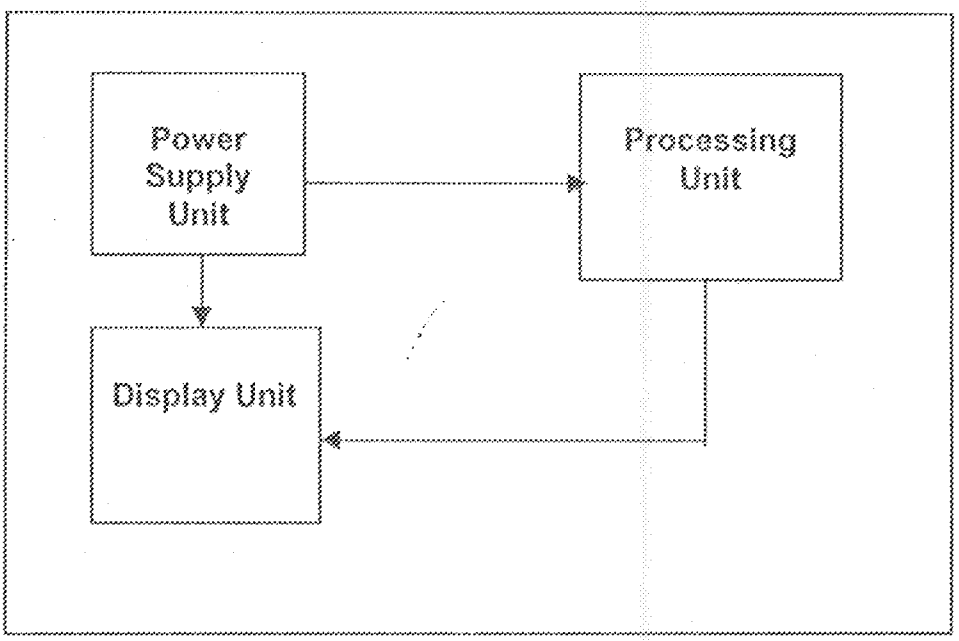


Fig. 3.1: block diagram of the Digital Temperature Measuring Instrument

A typical dc power supply block diagram showing the various stages involved and their output waveforms are shown below in figure 3.2

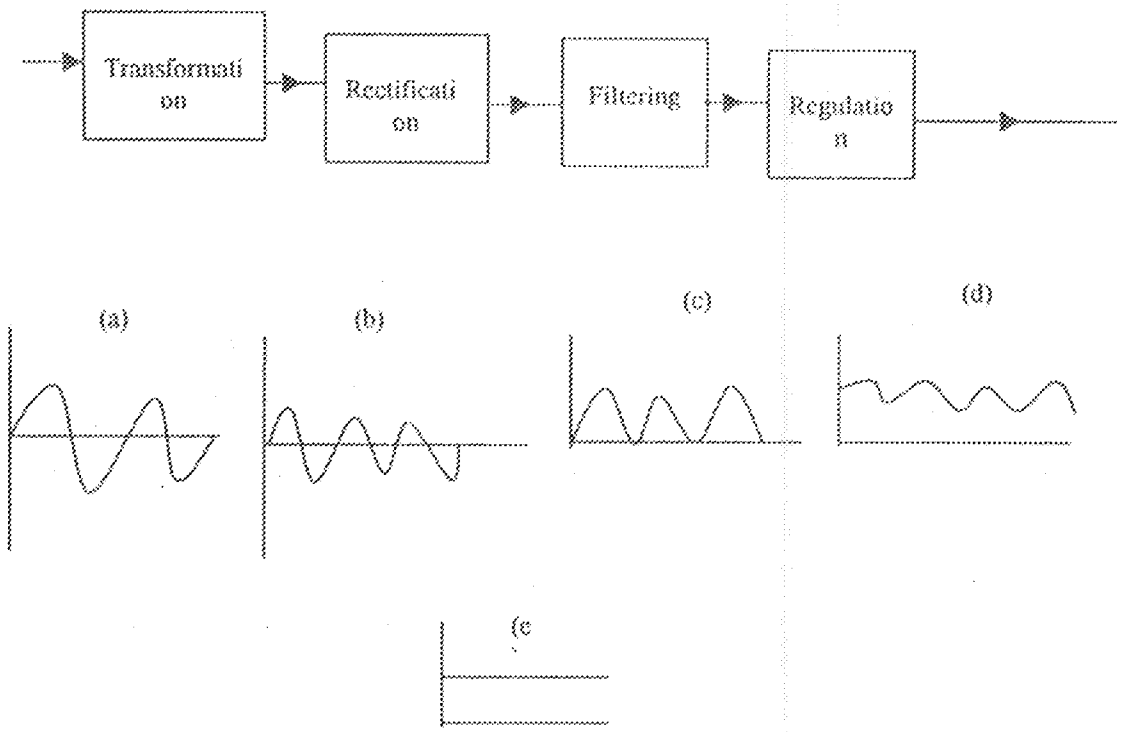


Fig.3.2 Block diagram of a full wave rectification

(a) ac supply voltage

(b) ac stepped-down voltage waveform

© rectifier (dc) voltage waveform

(d) filtered voltage waveform

(e) regulated output dc voltage waveform

3.1.1 TRANFORMATION STAGE

This stage involves transforming the ac supply from the usual 240 v into a lower level of 12- 0-12 V. Therefore, a step-down transformer with centre tapping is needed and of course used.

The output current of the transformer used from the manufacturer is 500mA.The circuit diagram of the transformer is shown below in figure 3.3

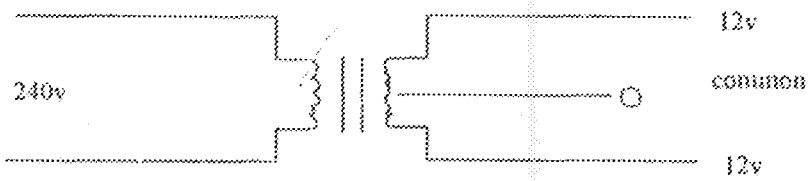


Fig.3.3 Circuit diagram of a step - down centre- tapped transformer

3.1.2 Rectification Stage

The purpose of this stage is to rectify the stepped-down 12 V-0-12V ac voltage by converting it into a dc voltage of approximately the same value. An IC(B1280: B500C1000/700),which integrates a full wave bridge rectifier diodes and has four legs as shown below in figure 3.4 is used for the purpose of rectification. The internal circuit diagram of the bridge rectifier is depicted below in figure 3.5

The principle that backs rectification is that only two diodes, which are forward biased, conduct for both positive and negative half cycles of the ac voltage. The peak to peak value of the output dc voltage from the rectifier is given as $V_{sm}=2V_m/\Pi$, where V_m is the peak value of the ac voltage and is related to the root mean square value of the ac voltage by; $V_{rms} = V_m/\sqrt{2}$; where V_{sm} is the maximum value of transformer secondary.

Therefore, $V_{sm} = 24\sqrt{2}\ V_{rms}$; where V_{rms} =24 V

$V_{sm} = 2\sqrt{2} \times 24/\Pi = 21.6$ V

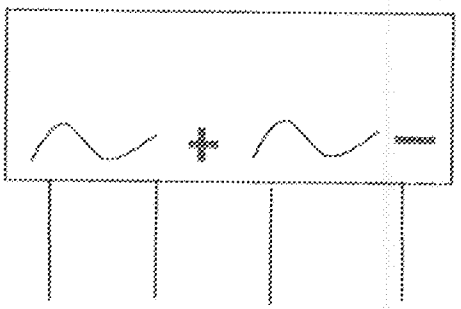


Figure 3.4 circuit symbol of an integrated full wave bridge rectifier

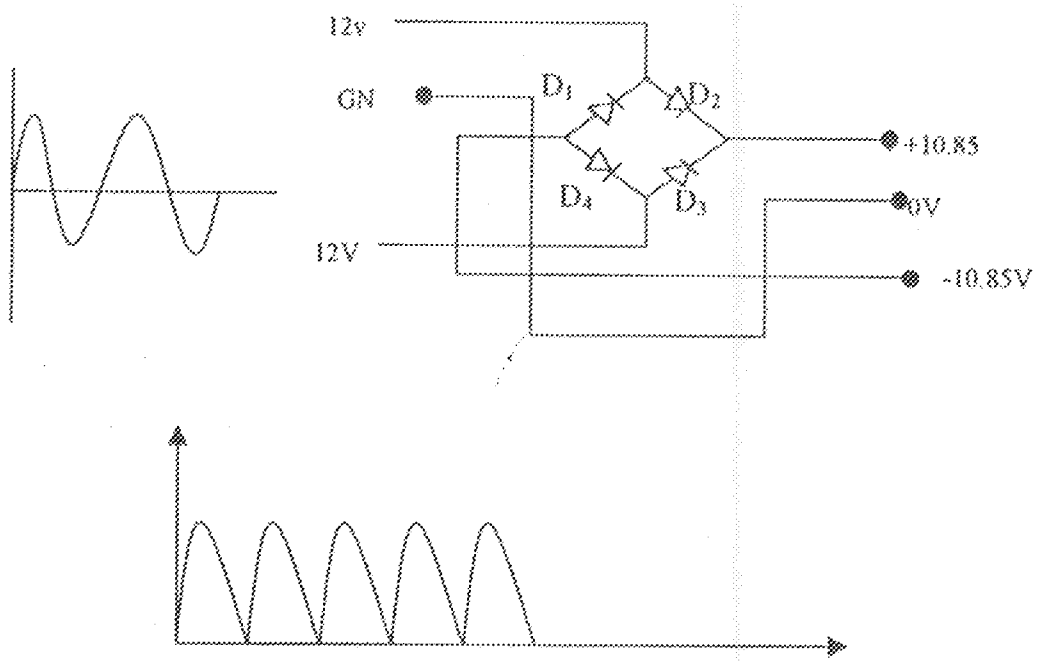


Fig. 3.5 circuit diagram of a full wave bridge rectifier

The full wave bridge rectifier is adopted because:

- It has lower ripple factor compare to half wave rectifier;
- It makes use of smaller transformer;
- Its peak inverse voltage (PIV) rating of each diode is also less.

The output of the rectification is pulsating, therefore smoothening is needed, this gives rise to the next stage – filtering.

3.1.3 Filtering Stage

The importance of filtering stage is to eliminate the ripple or at least reduce it to such value that its influence becomes insignificant in the circuit.

Different type of filters exists but the choice for this project work is a shunt capacitor filter shown in figure 3.6.

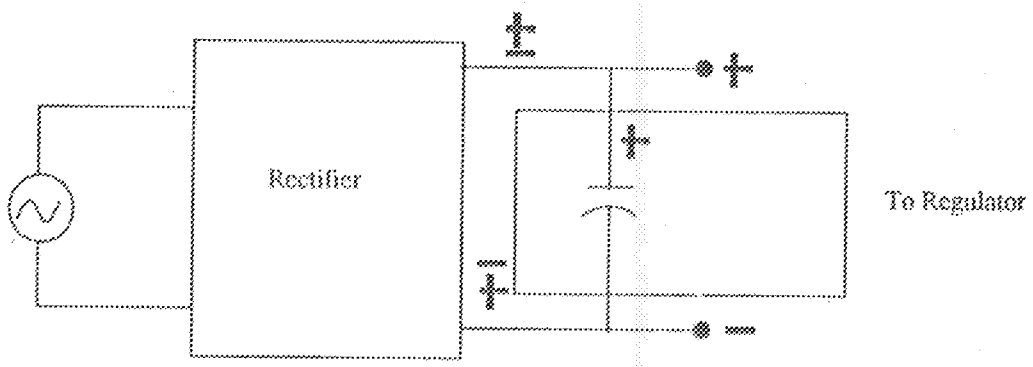


Fig. 3.6 circuit showing a shunt capacitor

Filtering Design

When positive half cycle of the ac input is applied, D1 (figure 3.5) is forward biased. This allows C1 to quickly charge up to peak value of ac input time voltage (point b in fig 3.7b) because charging time constant is almost zero. It is so because there is no resistance in the charging path except diode forward resistance, which is negligible. Hence capacitor follows the charging voltage as shown.

After being fully charged, the capacitor holds the charge till input supply to the rectifier falls below the peak value. At this point the capacitor start to discharge in the load to point c in figure 3.7b and its voltage decreases somewhat. The discharging time constant which is equal to R1C1, is usually very high than the charging time. Hence C1 does not

discharge appreciably before the next possible half cycle exceed the capacitor voltage at point c, C1 is again charged quickly to peal value of input voltage at point d. when input voltage falls below the peak, C1 is forced to discharged through the load during the interval 'de'.

The same operation takes place at the negative voltage of terminal E with capacitor C2. In this way the load sees a nearly constant dc voltage across it at all time. The filtering of full wave rectification increases the dc load voltage slightly towards the peak voltage and ripple voltage has also reduced by half

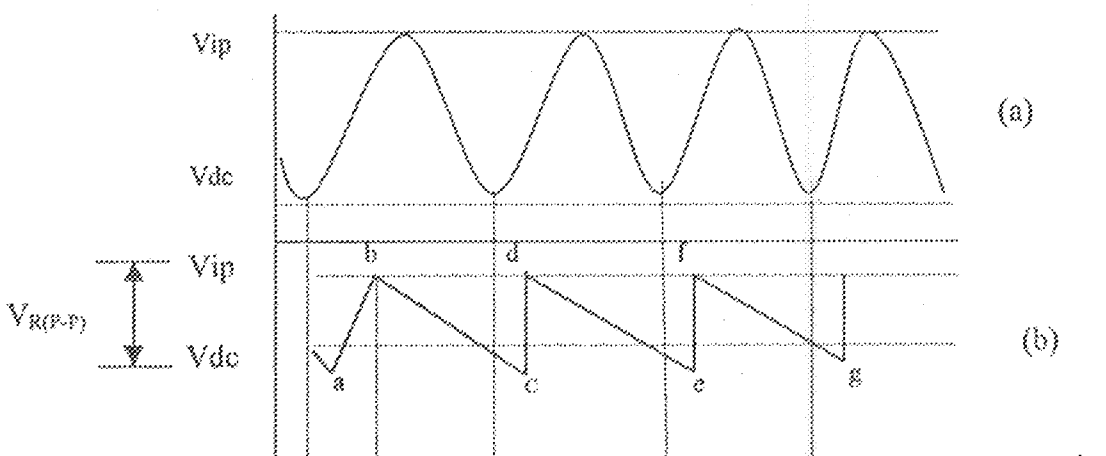


Fig. 3.7 graphical representation of the output voltage.

Vr(p-p) is the amount by which the capacitor voltage drops during discharging period, T. where T is the discharging time.

The charge □Q lost in this interval T is

□Q = Idc . T; where Idc is the current flowing through the load.

So ; Vr(p-p) = □Q /C = Idc . T/C = Idc/F.C = Vdc/C.FRL

Where F is the frequency of the ripple component.

The root mean square value of the triangular ripple is

$Vr(rms) = Vdc/2\sqrt{3}\ F.C.R_L$;

$Idc = 2\ Im/\Pi$

The ripple factor r is defined as ;

$$r = Vr(rms)/Vdc = Idc/4\sqrt{3}\ F.C.Vpp$$

for the design in progress, a ripple factor r = 1.5% is desired for optimum performance.

Im =500mA

F =50Hz

Vpp =24 V

Therefore; $C = 2\ xIm/4\sqrt{3}\ f.r.Vpp$.

$= 2 \times 500 \times 10^{-3}/4\sqrt{3} \times \pi \times 50 \times 0.015 \times 24$

$= 2500\ \mu F$

hence a capacitor value of 2500 μF is used.

As a result of the above design; figure 3.7 below shows the circuit diagram of the filter for both +10.8 V and –10.8 V.

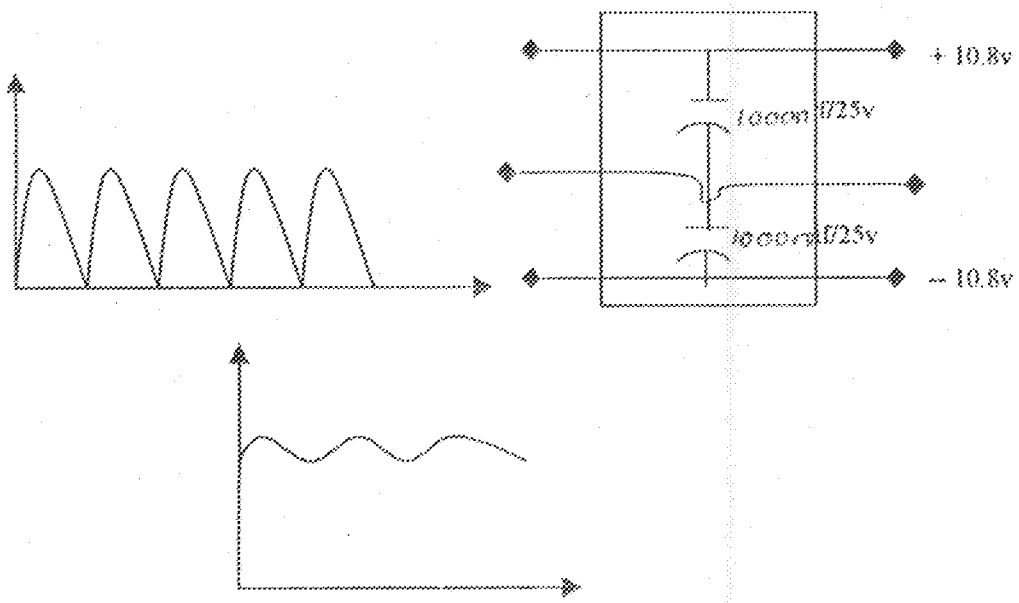


Fig 3.8 Filter circuit

The shunt capacitor filter was chosen because it provides a very good smoothening of the ac ripples from the rectifier's output. An electrolytic capacitor was used for the shunting.

3.1.4 REGULATION STAGE

Its main function is to keep the terminal voltage of dc supply constant even when;

(I) Ac input voltage to the transformer varies or

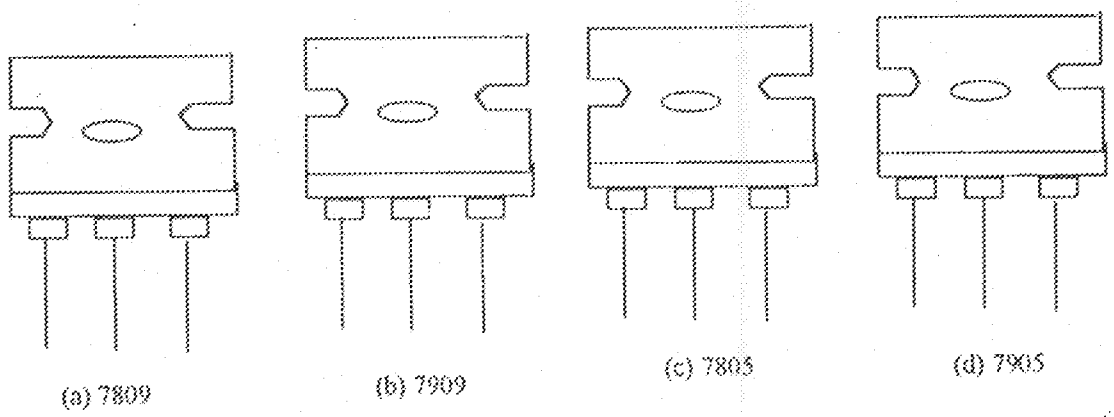
(II) The load varies.

Power supply circuit suffers from the drawback that their dc output voltage changes with changes in load or input voltage. Such dc power supply is unregulated. Regulated power supply is obtained by using a voltage-regulated circuit. The regulator is an electronic control circuit, which is capable of providing a nearly constant dc output voltage even

when there are variations in load or input voltage. There are various types of regulator circuit such as zener diode regulator, transistors series voltage regulator, switching regulators and so on.

The type of regulator used in this dc supply is the integrated circuit (IC) voltage regulators, 7809, 7909,7805, and 7905 for +9 V, -9 V, +5 V, AND –5 V respectively. The IC regulator has much improved performance as compared to those made from discrete components. This has unique built-in features such as current limiting self-protection against over temperature and feedback current limiting.

The circuit diagrams and circuit symbols of the regulators are shown with pin description in figure 3.9 (a and b) below. The input voltage range for the four regulators are [+7 V to + 35 V], [+7 V to +35 V], [-10.5 V to –35 V], and [-10 V to –35 V].



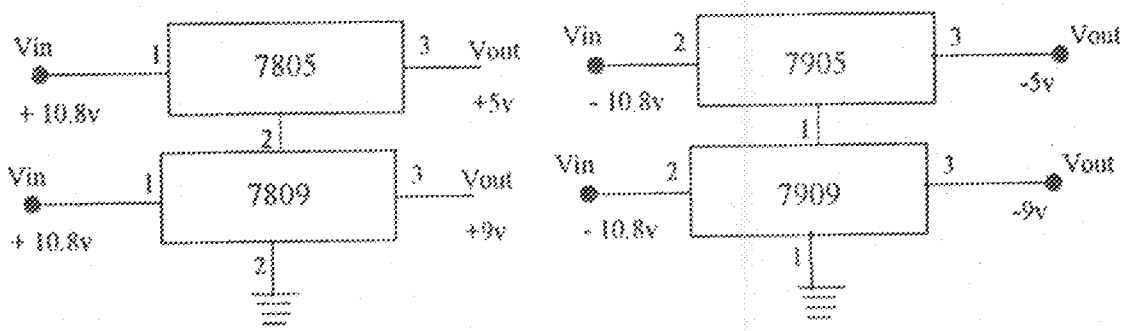


Fig 3.9 circuit symbol and diagram of 7805,7809,7905, and 7909 IC

3.1.5 Power Indication

Four light emitting diodes (LEDs) each of maximum current rating of 20mA and forward voltage drop of 2v are used for power indication. For these LEDs to function properly in this power supply unit for power indication, a series resistor, whose value is calculated as shown below is connected with each of them as depicted in figure 3.10 the resistor is there to limit the current that flows through of the LEDs.

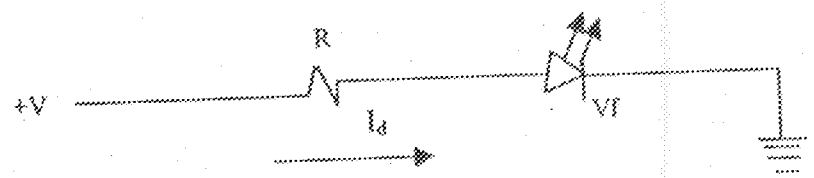


Fig 3.10 LED indicator circuit for power indication

Calculation of value of R

Applying kirchoffs' voltage law (KVL) to the circuit diagram of figure 3.10, "the algebraic sum of emf in a close loop is equal to the algebraic sum of voltage drops in that loop" i.e $Vcc = IdR + Vf$

Hence $R = (Vcc - Vf)/Id$

For +9 V and –9 V;

$R = (9-2)/0.02 = 350\ \Omega$

Then for +5 |V and –5 V;

$R = (5-2)/0.02 = 150\ \Omega$

The whole circuit diagram of the power supply unit (PSU) is shown below in figure 3.11

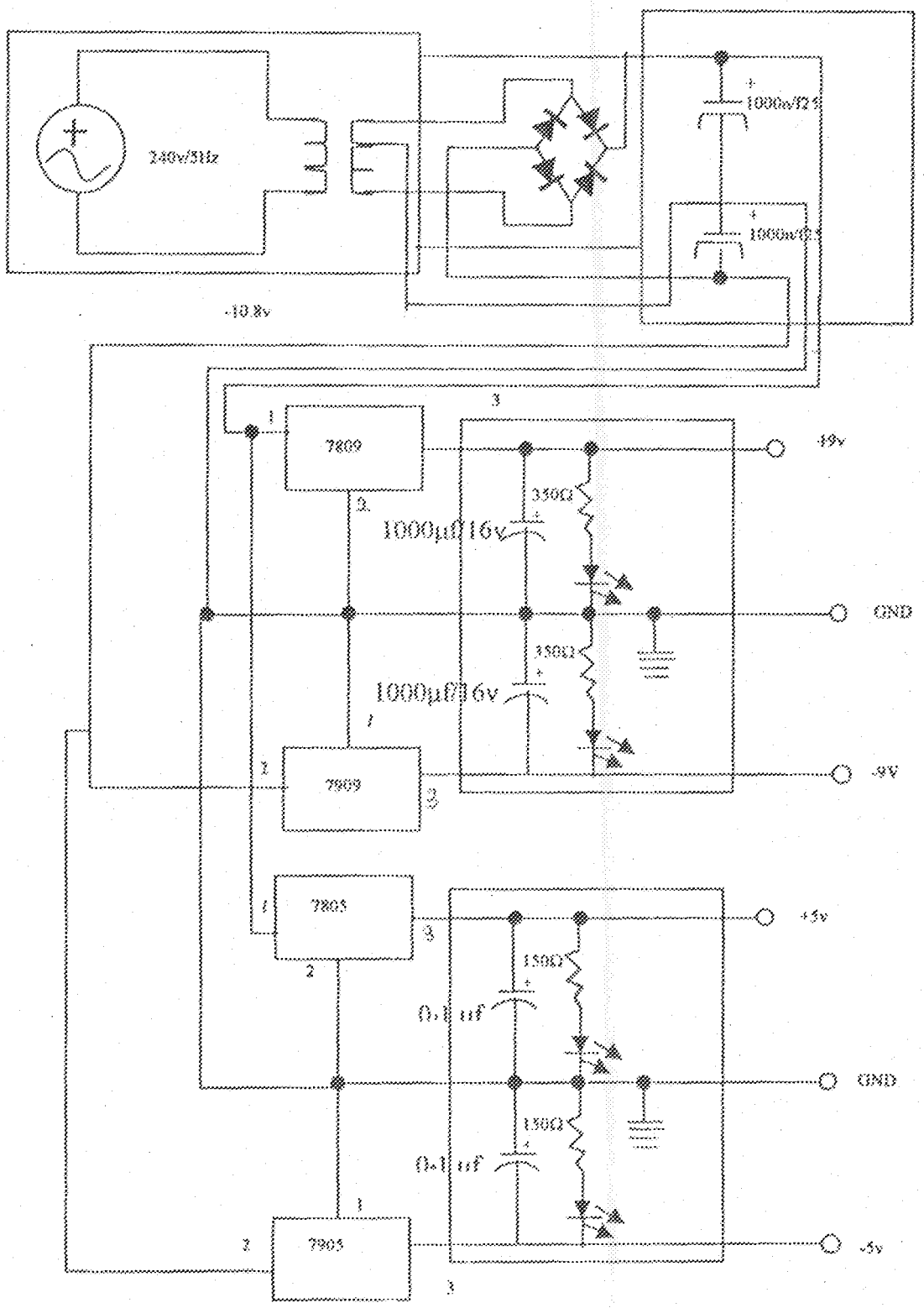


Fig. 3.11 circuit diagram of the power supply unit

3.2 PROCESSING UNIT

This unit is concerned with the sensing of the temperature (of the object) to be measured, transducing it into an electrical signal and the amplification of the latter to matched the requirement of the display unit. So it consists of transducer and an amplifier circuit.

3.2.1 TRANSDUCER

There are various monitoring devices existing today using different transducers and method of displaying. Some system are designed based on the principle of therm-couple, a device that uses the voltage developed by the junction of two dissimilar metals to measure temperature difference, Thermistor, although both positive and negative temperature coefficient thermistors are available, the latter is used almost exclusively in temperature measuring applications. For this project design, Thermistor is used as temperature sensor.

Figure 3.12 show below is the processing unit circuit used in this project. It has a thermistor TH1 that is used as the temperature sensor. The circuit also contains op- amps μA741 IC labeled 1 and 2. IC_1 is connected in the circuit as unity gain buffer and IC_2 is connected in the circuit as inverting amplifier.

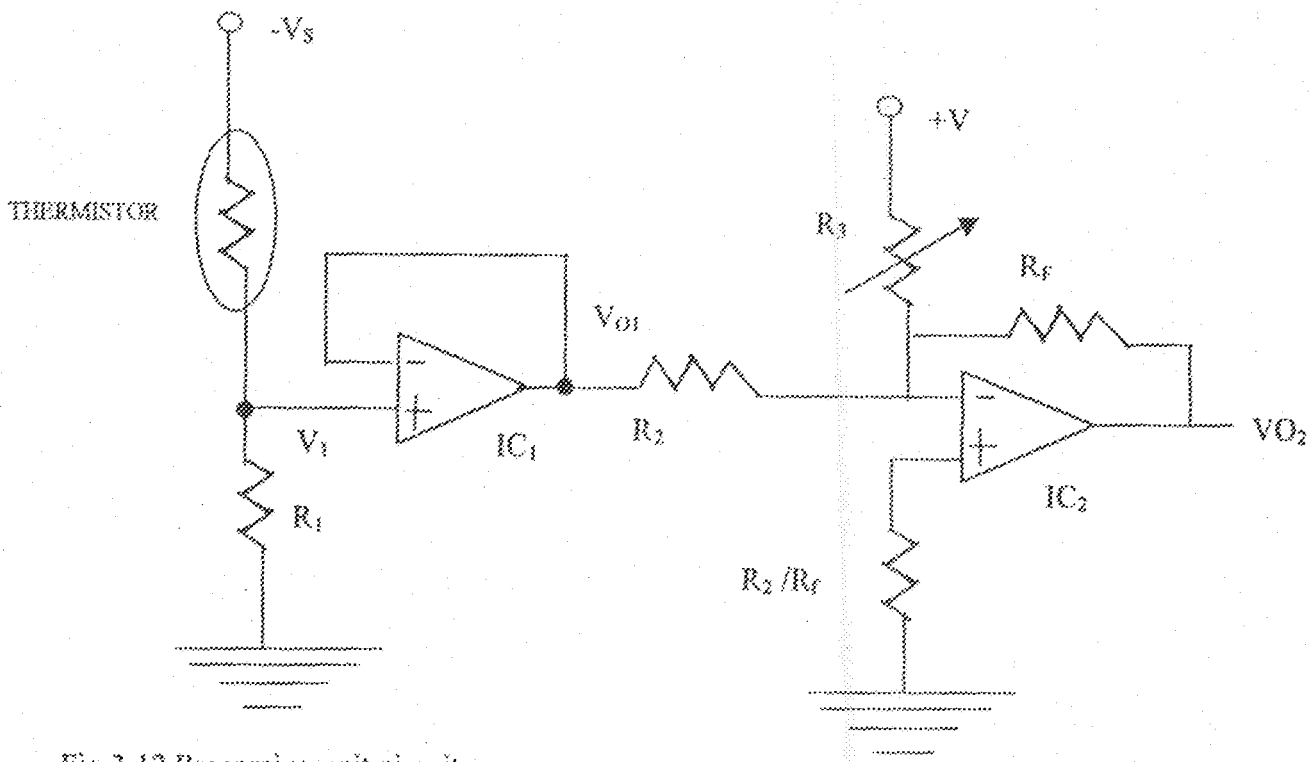


Fig 3.12 Processing unit circuit.

3.2.2 THEORY OF THERMISTOR

A thermistor is basically made of oxides of nickel and maganese and is a device that undergoes a very large change of resistance with temperature. Most of the types have a negative temperature coefficient (NTC). That is, their resistance falls with increase in temperature of their surrounding, but some are positive coefficient (PTC) varieties whose resistance increases with increase in temperature

The general form of the thermistor resistance characteristic is shown below

$$R_{TH} = R_o e^{\beta (1/T_t - 1/T_o)}$$

Where: R_{TH} = Thermistor resistance

R_o = Thermistor resistance at base temperature T

β = Thermistor constant [^oK] which is a characteristics of the particular material

The table below shows the resistance of the thermistor at various temperatures and the Voltage drop across R = 100Ω when a – 5V is applied to the voltage divide network of Figures.3.12

Table 3.1 Resistance of the Thermistor and voltage Drop Across R_1 At various temperatures.

TEMP. [C]	$R_T(\Omega)$	V_{R1} (V)
0	1500	-0.313
10	1360	-0.342
20	1240	-0.373
30	1000	-0.415
40	843	-0.534
50	576	-0.740
60	502	-0.830
70	400	-1.000
80	346	-1.120
90	285	-1.300
100	233	-1.500

3.2.3 THEORY OF OPERATION AL AMPLIFIER [OP-AMPS]

The Op-Amp comes in various kinds from different manufacturers. The one used for this design is Analogue 741 op-Amp and its circuit diagram is shown in fig. 3.12 below followed by manufacturer specification for it.

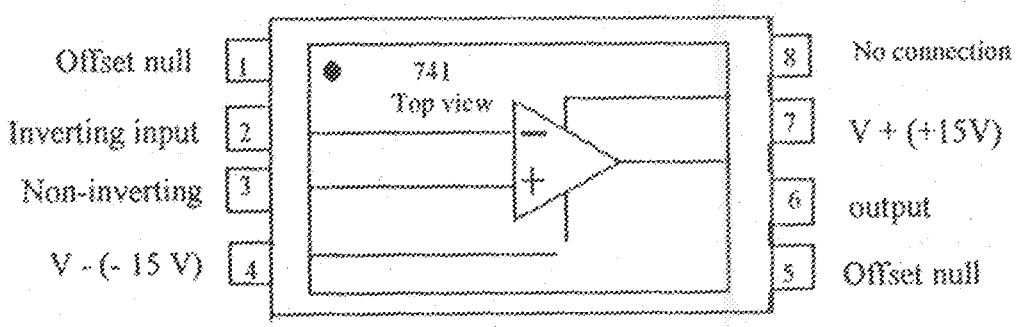


Fig. 3.13 Circuit diagram and symbol of 741 Op-Amp

Parameters	Value	Units
Saturation voltage, Vsat	15	V
Saturation current, Isat	2	mA
Slow rate, SR	0.5	Vlus
Bias current, Jb	80	nA
Offset current, Jos	20	nA
Input offset voltage, Vos	1	mV
Input resistance, Ri	2	M
Output resistance, Ro	75	Ω
Differential gain, A	200	V/mv
Common mode Rejection Ratio, CMRR	31.6	V/mv
Gain bandwidth Product, B	1	MHz

Inventing Amplifier: This is a single op-amp whose basis form is shown below:

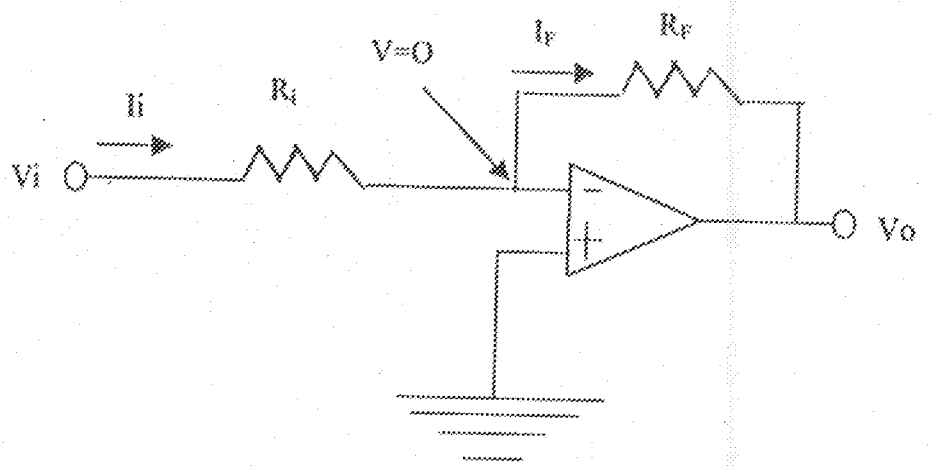


Figure 3.14 Inverting Amplifier

In actual practical, a resistance is often connected between the non-inverting input and ground to minimize certain effects due biased currents.

Assuming stable linear operation, if forced to be zero, or V = V Sina V =0 [none-inverting terminal is grounded], the inverting terminal is also forced to be at ground potential, that is V = 0 [virtual ground]. This means the input voltage Vi appears across Ri

Therefore Ii = V_i/R_i

Next this assumption of zero amplifier input current is used. Since no current can flow into or out of the amplifier, the current must flow through Rf

Therefore

Since the inverting input of the op-amp is at virtual ground, the output voltage is the voltage across Rf, but with the reference positions terminal on the left hand side of Rf.

This leads to

Vo = -Rf Vi/Ri

If A = Vo /Vi = - Rf /Ri

The input impedance Rin of the circuit is

Rin =Vi /Ii = Ri

VOLTAGE FOLLOWERS [UNITY GAIN BUFFER]

The basic form of this is shown below:

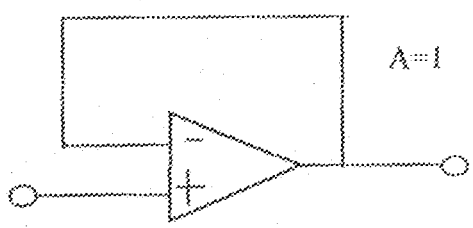


Fig. 3.15 Unity Gain Amplifier

The closed loop gin may be determined using equation

A = Vo/Vi = 1+ Rf/Ri =Ri+Rf/Ri, by considering the limiting case when Rf = 0 and Ri =□

Therefore A = Ri+ Rf / Ri

The voltage gain is thus unity, and the output voltage "follows" the input voltage.

3.2.4 PROCESSING UNIT DESIGN

Figure 3.17 is the temperature measuring current
V_S = 5v

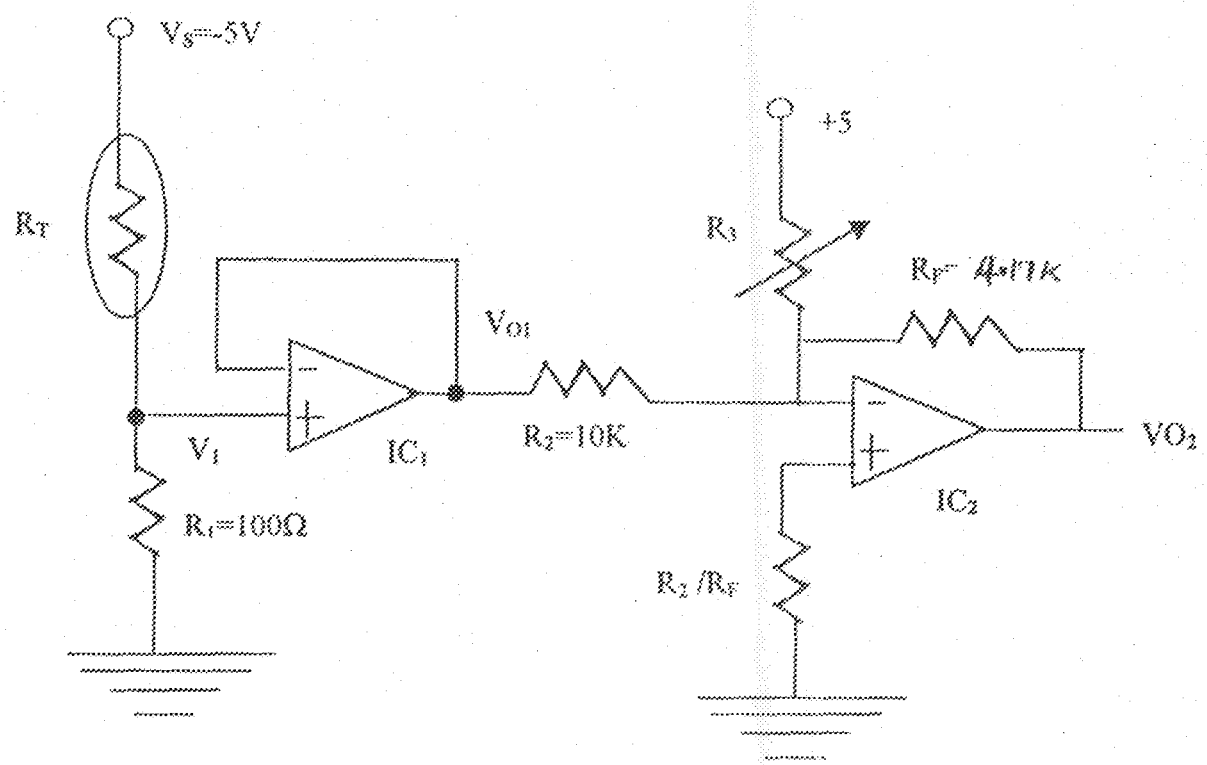


Fig. 3.16 Temperature measuring circuit

The intent of this project is to generate analogue voltage representing temperature from O^O C to 100^O C. This is, at O^O C the output voltage V is OV and at 100^O C, the output voltage is 0.5v.

The thermistor TH1 and 100 Ω (Ri) form a voltage divider network. The voltage drop across Ri is given by: $Vi = Ri/(Ri + Rt) \times Vs$

This is output of the voltage divider network, which ranges from:

$Vi = 100/(100 + 1500) \times -5 = -0.313V$ at 0^{O} C to

$Vi = 100/(100+233) \times -5 = -1.502V$ at 100^{O} C

IC1 is a unity gain buffer that prevents the later parts of the circuit from loading the voltage divider.

Thus Vo1 =V1

The range –0.313V to –1.502V is to be converted to a ov to 0.5v range. To do this Voi is shifted and scaled. Voi is shifted by + 0.313 V so that a O V signal is obtained at 0□ C instead of a –0.313V signal and its –1.500V range i.e. 1[-1.500]-[-0.313]1 = 1.2 is scaled to a 0.5V range.

In figure 3.17 IC2 [an op-amp] and resistors R2 , R3 and Rf from an inverting summing amplifier which perform the operation. A value of 10K□ is assumed for R2. At 0□ C, Vo =-0.313 V.

The current I, through R2 = 10K□ and into the summing junction is

Vo/R2 = - 0.313 / 10

I1 = - 0.031m A

One side of V is connected to +5v. To compute R3, a positive current equal to I, in magnitude has to flow through it to balance the current I, and causes the current through Rf, to be zero, and thus the output voltage Vo2 is also zero since the inverting input voltage is also zero.

I..e Vo1/R1 =+5/ R3

-0.31m A= 5/R3

R3 =5/-0.031m A

= 161.3KΩ

Now to make the output Vo2 of the IC2 0.5V when Vo1 = -1.500 V which corresponds to (-1.500V)-(-0.313) = -1.2 V after shifting the desire gain will have to be computed.

The gain of an inverting amplifier is given by:

A = -Rf /R1

The negative sign shows that the output voltage from inverting amplifier is inverted.

Therefore, Vo =-Rf /Ri x Vin

Where Vo =Vo2 ; Vin = Vo1

This implies -Vo2 /VO1 =-Rf /R1 ;Vo2 = 0.5 V; Vo1 = - 1 . 2

⇒ 0.5 /- 1. 2 = -Rf/ 10 KΩ

Rf = 42KΩ

Therefore the gain A =42KΩ/ 10KΩ

= 0.42

The output voltage Vo2 with a range of O V to 0.5 V corresponds to a temperature range of 0□ C to 100□ C and is analogue signal.

The results obtain on simulating the amplifier circuit on the Electronic work Bench are presented below on table 3.1 for ideal op-Amp, while those obtained on testing the circuit with 741 on bread board are presented in table 3.2

Table 3.1 Results obtained for an ideal op-Amp on simulating the amplifier circuit on the computer.

T (^{0}C)	V_i (v)	A_{f1}	V_{o1} (v)	V_{o12}	A_{f2}	V_{o2}
0	310	1	310	0	0.42	0
30	415	1	415	0.13	0.42	42.1
50	740	1	740	0.43	0.42	176.6
70	1000	1	1000	0.60	0.42	285.8
90	1300	1	1300	0.99	0.42	410.8

Table 3.2 Results obtained for 741 op-Amp on testing the amplifier circuit on bread board.

T (^{0}C)	V_i (v)	A_{f1}	V_{o1} (v)	V_{o12}	A_{f2}	V_{o2}
0	310	1	308	0	0.45	0
30	415	1	416	105	0.45	47.5
50	740	1	740	428	0.45	189.3
70	1000	1	1000	686	0.45	307
90	1300	1	1298	980	0.42	440

In addition, Appendix C includes the photographic illustration of project prototype.

The circuit diagram of the processing unit is thus shown below in fig. 3.16. The output of this unit is analogue in nature and needs to be converted into digital form and a readable value-the necessity of the next unit.

3.3 DISPLAY UNIT

This unit is the most interesting part of the project because it allow the readability as well as offering improved accuracy of the measured temperature values. It is composed of analogue to digital conversion stage and digital stage.

3.3.1 ANALOGUE TO DIGITAL CONVERSION STAGE

This stage utilizes a 3½ digit analogue to digital converter IC, intersil 7107CPL, for converting the output analogue voltage of the processing unit into its digital equivalent.

The 7107CPL is chosen because it does the conversion directly from analogue into 7-sedgement equivalent without requiring an interface such as a BCD17-sedgement decoder.

In addition, it also exploits the advantages of dual-slope integration techniques in its operation.

Moreover, it includes an automatic zeroing cycle in its operation and finally, it requires minimum number of external components for normal operation.

The IC generates a periodic pulse (clock signal), whose frequency is determined by the values of the resistors and capacitor connected between pins 39 and 38 respectively, and is given as:

R = 100k and C = 100nf;

$$f = \frac{0.45}{RC} = \frac{0.45}{100 \times 10^{3} \times 100 \times 10^{-12}} Hz$$

f = 45 KHz

The period of the pulse, $T = \frac{1}{f} = 1/45K\ Hz = 0.011ms$

The output of the IC is either a pulse ('1' or HIGH for 3v to 5v) or a no-pulse ('0' or LOW for 1v to 2,9v). It actually counts from 000 to 999 making a total of 1000 counts.

However, for this design the desirable range is from 000 to 100 for 0 ^{0}C to 100^{0}C, which is equivalent to OV to 0.5v output voltage range of the processing unit.

No. of counts = 1000 (V_i / V_{ref}); where

V_{ref} = reference voltage of the ADC;

V_i = the analogue input to the ADC from the processing unit.

At T = 100^{0}C; i.e. No. of counts = 100, V_i = 0.5v; then V_{ref} = 1000 (0.5v / 100) = 5v. Therefore the reference voltage is equal to 5v.

At this point, it is worth mentioning some of the advantages of the dual-slope integrated techniques:

- It provides immunity to temperature caused variation in R and C
- Conversion accuracy is independent of both the capacitor value and the clock frequency, because they affect both the up-slope and the down-slope in the same ratio.

The circuit symbol of the 7107CPI IC is shown in fig. 3.17 while the photograph of the unit is shown in Appendix D

3.3.2 DIGITAL READOUT STAGE

Two dual 7-segment display numeric indicators (IDDG 59 50H ICs) connected in series are used for making reading of digital output of the ADC visible. These ICs are green LED 7-sedgement display.

The ICL 7107CPL generates a seven bit code (a,b,c,d,e,f,g) to control the display. It output a logic '0' (false) to turn ON any of the seven segment (a-g), and output a logic '1' (true) to turn it OFF. The anode of all the three digits are connected to +5v. Each of the seven segment inputs from the ADC forms the cathode for that segment. The circuit diagram of the display unit is shown below in fig. 3.17 and the circuit symbol for LED 7 – segment display is shown below in fig. 3.18

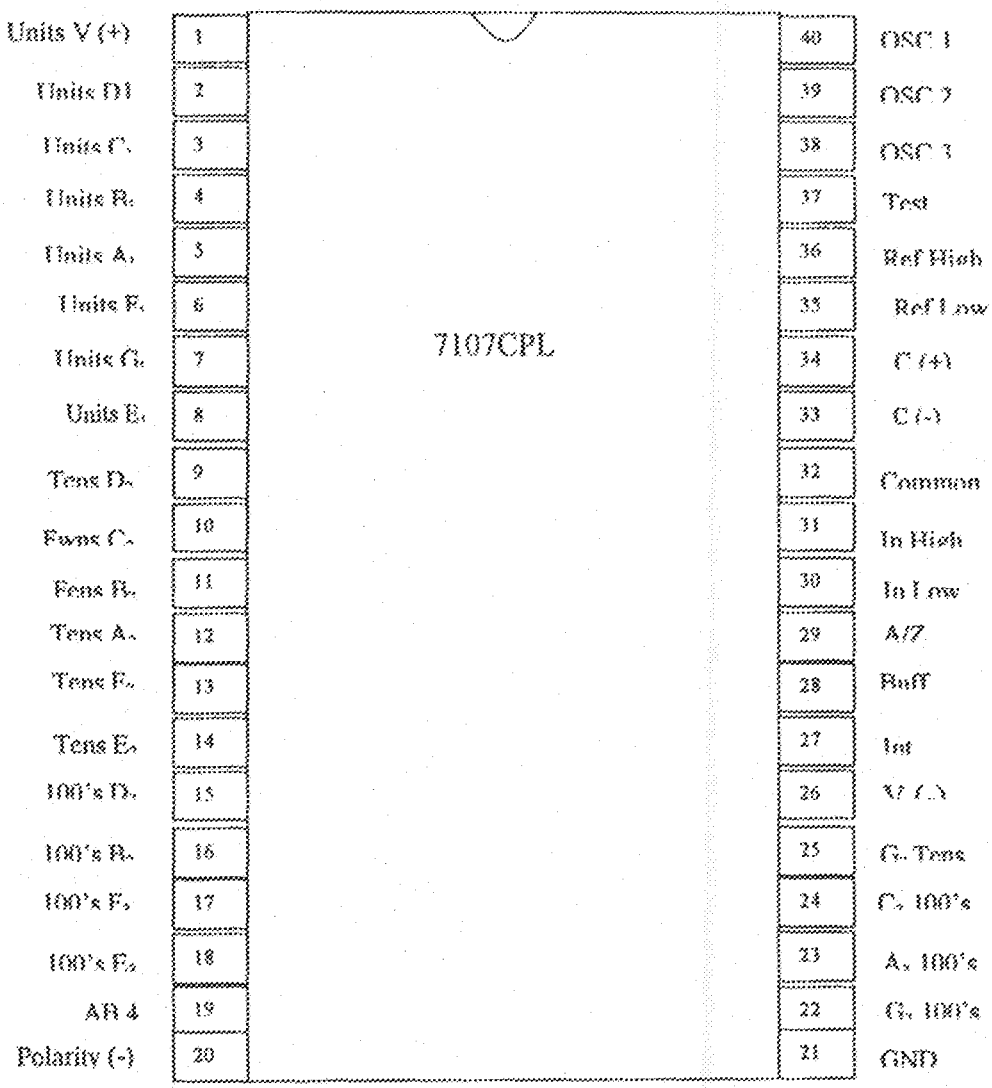


Fig. 3.17 Circuit symbol (with pins descriptive for ICL 7107CPL 3½ digit ADC of 7-segment.

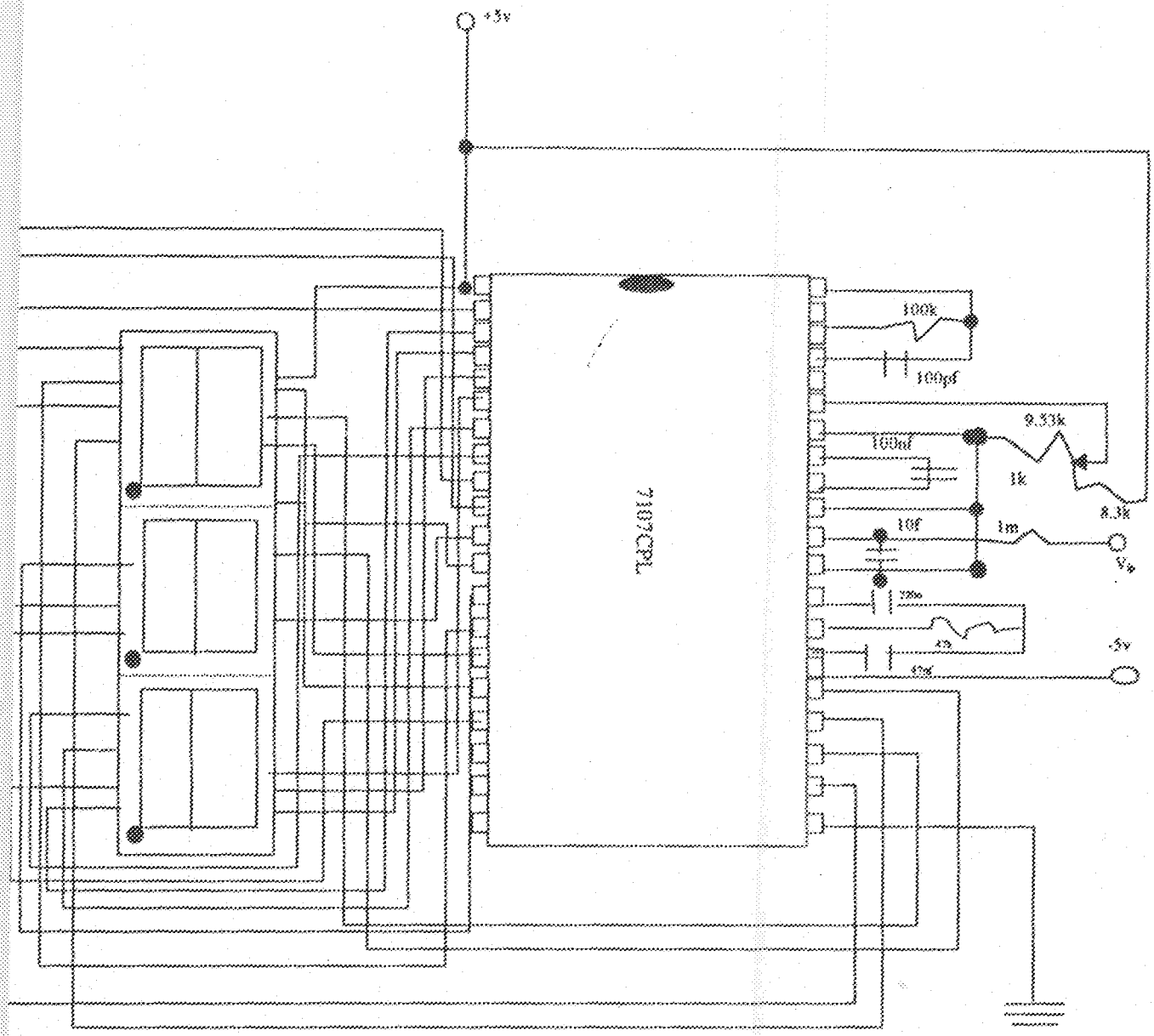


Fig. 3.18 Circuit diagram of the display unit

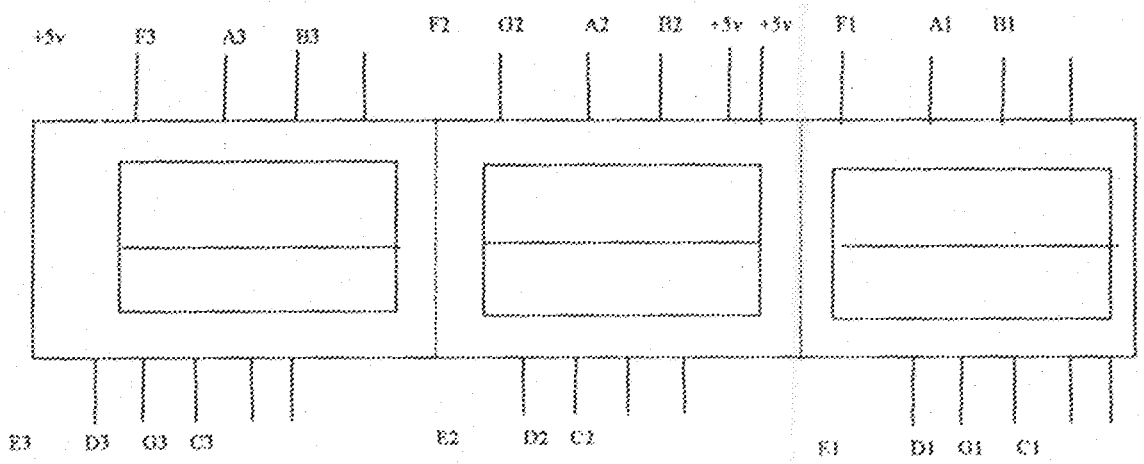


Fig. 3.19 Circuit symbol of IDDG5950H with pins identifications

The circuit diagram of the whole system is presented in appendix C

CHAPTER 4

4.0 CONSTRUCTION, TESTING AND RESULT.

This chapter concerns with the construction and testing of the digital temperature measuring instrument using specified components as outlined and designed in the previous chapter. This was done to make the construction easy and to test each section constructed for proper functioning. All the sections were first constructed on the breadboard for testing before the whole system was also constructed on the veroboard.

4.1 CONSTRUCTION

The design was first simulated on a microcomputer using an electronic based software – Electronic work bench (EWB), VERSION 5.0, before proceeding to the real construction.

The construction of the design was splinted into stages as depicted in the system block diagram as; power supply unit, processing unit and the display unit

4.1.1 POWER SUPPLY UNIT

The power supply unit was constructed with use of the following components:- Step-down transformer, Rectifier IC, Voltage regulators, filtering capacitors, light indicators (LED) and current limiting resistors. There components were transferred to the project board (bread board) as it was in the veroboard.

The step-down transformer, primary side was connected to the main supply and the voltage across each of the output terminal with respect to ground was

measured, with the use of digital voltmeter. The output voltages were taken and compared with standard values.

With the obtained values compared, and with satisfaction, the component of the power circuit was transferred and soldered on the veroboard.

4.1.2 PROCESSING UNIT

This unit comprises of the temperature sensor and amplification at the temperature sensor used is a thermistor sensor as mentioned earlier.

The two terminals of the sensor inserted in different socket of the bread board into the op-Amp were also inserted place on the bread board with the input and feed back resistor in place. In accordance to the manufacturer data sheet for the electronic component being used, all relevant connection to the power supply and interconnection between sensor and the op-Amp were carried out in accordance to the design in the previous chapter.

After testing the outputs of the op-amp with varying temperature conditions, the elements were then transferred and soldered into the veroboard to allowed the op-amps. This is to prevents the op-amps from damaging due to excess heat while soldering.

4..1.3 DISPLAY UNIT

The analog to Digital converter integrated circuit (ICL7107CPL), the light emitting diode (7-segment display LED) and the supporting components were properly inserting and arranged according to the design onto the veroboard. The required operation voltages were supplied to the unit from the PSU and was tested.

Having pleased with the performance of the circuit, each of the components were transformed and soldered correctly on the veroboard (except for the ICL 7107CPL IC). Even the 40 – pin IC socket was soldered in place in which the ICL7107CPL ADC was inserted.

4.1.4 PRECAUTIONS.

Several precautions were taken in ensuring efficient and successful construction of this work. Below are the precautions;

* All components values were carefully chosen to avoid malfunctioning of the project work
* Components were properly soldered to the veroboard to avoid breakage of their legs, and short circuiting.
* All ICs socket were first soldered into veroboard before the ICs were inserted. This is to avoid damages while soldering due to heat from the soldering bit.
* Components with polarity, such as electrolytic capacitors were soldering into circuit with correct polarities to ensure best performance.

4.2 TESTING

Each of the constructing units of the instrument being constructed was simulated one after the other using electronics based software (EWB and Tina pro) on a microcomputer. This was followed by another series of test when arranged on a breadboard and after being soldered to the veroboard used in the construction.

The output voltages of various units were measured employing a digital mulitmeter connected in parallel across the output terminals.

To test for the performance of the device, a soldering iron was plugged into an ac mains outlet and was brought close enough to the temperature sensor. As the heat emitted by the soldering iron varies, the output of the sensor also varies and the equivalent temperature in degree centigrade displayed.

The readings indicated by the designed instrument is compared with readings (values) obtained using a standard thermometer in table 4.0 below.

STANDARD THERMOMETER	CONSTRUCTED INSTRUMENT
T□C	$T^{0}C$
0	0
30	29.6
50	50.3
70	69.8
90	88.6

Table 4.0 comparison of results obtained using a standard thermometer and the device constructed.

4.2.1 RESULTS

Table 4.0 above shows the results obtained compared with that of a standard thermometer

4.2.2 DISCUSSION OF RESULTS

The deviation of the readings obtaining by the instrument from those of standard thermometer are very small as presented in the table. This shows how accurate, digital system could be in measuring or process desired information This discrepancies are due to the assumption that the thermistor sensor resistance varies with temperature in a linear form, this actually not accurately linear.

Another reason might be in the area of choice of resistor. The values of some resistors used in this project. Are actually not exactly equal to the values obtained during the design. Some of the values of resistors obtained during design are not standard values, so standard values close to calculated ones were chosen. The use of higher resolution ADC and IC sensors could improve on the accuracy of the design.

CHAPTER FIVE

CONCLUSION AND RECOMMEDATION

5.1 CONCLUSION

The design and construction of a digital temperature measuring instrument has been presented in the previous chapters. Although the device is designed to measure temperature from $0^0C - 100^0C$

The device consists of three basic units:

- The power supply unit, which provides the necessary dc voltages to the circuit by transforming, rectifying, filtering and regulating the domestically supplied ac voltage
- The processing unit, which is concerned with sensing the physical quantity – temperature, converting it into electrical signal, which is then amplified and processed to meet the requirement of the next – unit – display unit.
- The display unit, which converts the analogue voltage from the previous units into a digital equivalent (7 segment), which is then converted into digits (digital readout)

5.2 RECOMMENDATIONS

The project was designed and constructed using a thermistor as temperature sensor.

There are other temperature sensing device that can be used as input transducer. Such device include thermocouple PN junction diodes, Integrated circuit LM35 and so on

Area of application, it can be used in measuring the temperature of silo grain, it can be used in industries and many other places.

The device can also be modify to provide for displaying the temperature in Fahrenheit and not only in centigrade.

REFERENCES

1. Holt, C.A (1978): *Electronic circuits Digital and analogue*, John Wiley and Sons Inc. New York.
2. MC Graw Hill (1982): *Electronics Engineering Handbook*, 2nd edition , The Kingsport press, USA.
3. NTE (1992);*Electronics incorporation*.
4. Paul, H and Winfield, H.(1995): *The Art of Electronics*, 2nd edition, Cambridge University Press, UK.
5. Richard, C. D and James, A.S. (1986): *Introduction to Electrical Circuit*,
6. Internet: www.national.com
7. Theraja, B.L. and Theraja, A.K. (1999): *Electrical Technology*, 2nd edition, Rajendra Ravindra Printer(pvt) Ltd, New Delhi.
8. Stanley, W.D (1989): *Operational Amplifiers with Linear Integrated Circuits*, 2nd edition, Merrill Publishing Company, London.
9. Jones, L. (1993): *Basic Electronics for Tomorrow's World, Cambridge* University Press, Great Britain.

Photographic Illustration of the System