Sudan University of Science and Technology

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Wearable Body Temperature Device For Home Monitoring

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بسم الله الرحمن الرحيم

الآيـــــــــــة

قال الله تعالى:

{لا يُكَلِّفُ اللَّهُ نَفْساً إِلَّا وُسْعَهَا لَهَا مَا كَسَبَتْ وَعَلَيْهَا مَا اكْتَسَبَتْ رَبَّنَا لا تُؤَاخِذْنَا إِنْ نَسِينَا أَوْ أَخْطَأْنَا رَبَّنَا وَلا تَحْمِلْ عَلَيْنَا إِصْراً كَمَا حَمَلْتَهُ عَلَى الَّذِينَ مِنْ قَبْلِنَا رَبَّنَا وَلا تُحَمِّلْنَا مَا لا طَاقَةَ لَنَا بِهِ وَاعْفُ عَنَّا وَاغْفِرْ لَنَا وَارْحَمْنَا أَنْتَ مَوْلانَا فَانْصُرْنَا عَلَى الْقَوْمِ الْكَافِرِينَ}

البقرة {286}

Dedication

We praise and thank Allah for what we have achieved.

This project is dedicated to our families, who supported us throughout this journey,

Our friends who gave us strength to complete it and

Our teachers who guided us through it.

Acknowledgement

We would like to express our deepest appreciation to all those who provided us with the possibility to complete this project.

Many thanks go to our project supervisor Dr. Mai Abdelrhman who invested her full effort in guiding the team to achieve our goal.

A special gratitude is given to the Sudan Atomic Energy Commission for their helpful efforts.

Finally we would like to thank our volunteers for helping us achieve our final result.

Abstract

Patient health monitoring is a common thing done by doctors to monitor their patients' health condition. The most crucial reading monitored by doctors is the patient's body temperature. Unfortunately, current systems used didn't provide continuous monitoring. Also, it causes disturbance for patient and health care provider.

This project represents a "wearable flexible body temperature monitoring device" that aims for continuous home monitoring. The project is based on a microcontroller and a temperature sensor that converts the body's temperature to a proportional analog voltage. The output from the sensor is connected to one of the ADC channel inputs of the microcontroller to derive the equivalent temperature value in digital format. The computed temperature is displayed in a character LCD in degree centigrade. All components were connected on fabric using conductive thread.

It is not so costly, industrially that can be spread out vastly. The device is made of flexible fabric materials. And that was our object to construct such a flexible device which can be used easily, comfortably and continuously.

المستخلص

مراقبة صحة المرضى هو امر شائع يقوم به الاطباء لمراقبه الوضع الصحي لمرضاهم.اهم القياسات المراقبة من قبل الاطباء هو قياس درجة حرارة جسم المريض.للاسف، الاجهزة المستخدمة حاليا لم توفر المراقبة المستمرة. ايضا، فانها تسبب الانزعاج لكل من المريض و مقدم الخدمة الصحية.

هذا المشروع يقدم جهازا مرنا قابلا للارتداء لمراقبة درجة الحرارة بهدف المراقبة المستمرة في المنزل. يرتكز هذا المشروع على وجود متحكم و حساس حراري الذي يقوم بتحويل درجة حرارة الجسم الى جهد متناسب معها. خرج الحساس الحراري يتصل بأحد قنوات الدخل للمتحكم التي تقوم بتحويل القيم من تماثليه الى رقمية للتحصل على القيمة المكافئة لدرجة الحرارة في صورة رقمية وهذه القيم المحسوبة بالدرجات المئوية تعرض على الشاشة . كل مكونات الدائرة تم تثبيتها على قماش و ربط بينها عن طريق خيط موصل للكهرباء.

هذا الجهاز قليل التكلفة و يمكن انتشاره صناعيا الى حد كبير.صنع من مواد مرنه و كان الهدف من تصنيع جهاز مماثل ان يكون استعماله سهلا ,مريحا ومستمرا.

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Abbreviations

Abbreviation	Description
LCD	Liquid crystal display
LED	Light emitting diode
ECG	Electrocardiogram
NTC	Negative temperature coefficient
PC	Personal computer
RGB	Red green blue
ADC	Analogue to digital converter
GSM	Global system mobile
FUO	Fever of undetermined origin
NICE	National institute of clinical excellence
SIGN	Scottish intercollegiate guidelines network
DSP	Digital signal processor
MC	Microcontroller
RISC	Reduce instruction set computing
RAM	Random access memory
SPI	Serial peripheral interface
USB	Universal serial bus
USART	Universal synchronous/ asynchronous receiver/ transmitter
A/D	Analogue to digital
PWM	Pulse width modulation

LIN	Local interconnect network
CAN	Controller area network
DIL	Dual in line
CMOS	Complementary metal-oxide semiconductor
EEPROM	Electrically erasable programmable read only memory
I2C	Inter-integrated circuit
EUSART	Enhanced Universal synchronous/ asynchronous receiver/transmitter
CCP	Capture/compare/pwm
MIPS	Microcontroller without interlocked pipeline stages
MH	Mega hertz
AC	Alternating current
DC	Discrete current

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Temperature is a measure of the degree of heat intensity. The temperature of a body is an expression of its molecular Excitation. The human body’s core temperature varies from day to day, and from time to time, but these fluctuations are small, usually no more than 1.0ºC.

Humans are homoeothermic and body temperature is regulated at about 37ºC ±1ºC. Temperature is read to establish a baseline of normal body Temperature for the location and measuring conditions. The Main reason for examining body temperature is to hunt for any signs of systemic infection or inflammation in the presence of a fever or high significantly above the individual's normal Temperature [1].

The commonly used methods and sites of measurement do not lend well for continuous measurement at home, uncomfortable and disturbing. However, continuous monitoring using non-invasive, small, low cost sensors could have many applications like detection of fever in low birth weight neonates in rural settings [2].

Wearable body sensor network or system is one of the medical devices that can provide a convenient, secure and long term monitoring. The term "wearable" means the devices can either be dressed up or appeared as a form of garment. In a nutshell, the development of wearable systems speed up as it can provide advantages over the traditional medical devices.

Wearable devices provide a room for:

- Monitoring patients over extensive periods of time.
- Asses the daily body condition of the subject at home or outdoor.
- Gather physiological data by using an ambulatory system [3].

Recently, the new concept of a textile technology has made its entry into the textile world. This concept aimed at enhancing the quality of life for human beings by providing them with wearable comfortable devices [4].

1.2 Problem Background

This project overcomes the disadvantages of the traditional methods of body temperature measuring such as:

- Monitoring of the patient is not continuous.
- Disturbance of the patient.
- Disturbance of the healthcare provider.
- Detecting of the abnormal conditions isn't instantly.

1.3 Problem statement

Consistent with all facts mentioned above, this project aimed to investigate the possibilities of designing, prototyping, and testing a flexible temperature Sensor that is made of flexible materials.

1.4 Objective of the Project

The main objective of the current project is to design, prototype, and test a Wearable Flexible Temperature Monitoring Device.

1.5 Specific Objectives

The specific objective of this project is to build a device that is:

- Continuous patient monitoring
- Home monitoring for chronic and elderly patient
- Portable and small in size
- Low cost
- High accuracy
- Easy to use
- Comfortable

1.6 Scope of the Study

In this research, an effort has been made to study the possibilities of designing and fabricating a Wearable Flexible Temperature Monitoring device, where the scopes of this research are detailed as follows:

i. Study and understand the usage of temperature sensor and the possibilities of replacing rigid sensor by a wearable flexible temperature sensor.
ii. Conduct simulation and experiments techniques to investigate, examine and categorize each component required and necessary for designing the wearable flexible system.
iii. Evaluate and compare measured results and consequences of the wearable flexible temperature sensor system with simulated results.
iv. Finalize the designs, compile reports, and produce regional/international conferences and journal papers.

1.7 Research Methodology

The Methodology of this project is based on microcontroller to organize the operation of the system by connecting temperature Sensor as input with the LCD and indicators as output.

1.8 Thesis organization

The thesis consists of seven chapters. The current chapter discusses the problem definition, justification for carrying out the research, and objectives. The chapter is introduced with the vision of the emerging technology between textile concept and electronic circuit’s designs.

Chapter 2 reviews some of the previous researches on temperature sensing device. The chapter also discusses the issues of using temperature sensor, microcontrollers and textile circuit’s designs proposed previously.

Perceptions, principles, requirements and different sites of temperature measuring are introduced in Chapter 3. Comparisons between different measuring devices are also discussed.

Chapter 4 presents the system components required for the design with brief fundamental concepts of the mentioned components.

In Chapter 5, the design procedures began with programming the microcontroller using the suitable software packages, simulating the circuit and connection of hardware components

Chapter 6 discusses and presents results obtained by the design. The performances of fabricated temperature measuring device are investigated and compared in terms of rigid board and fabric materials.

The conclusions are stated in Chapter 7 together with the findings summary of the research and suggestions for other areas of additional research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Several prototypes of wearable functional device have been proposed in the last few years. Most of them take the approach of attaching conventional off-the-shelf electrical/electronic devices and components to clothes, such as microcontrollers, LEDs, optical fibers, piezoelectric transducers, etc.

This approach has been led by the well-established high performances of readily available conventional electronics. Furthermore, the consolidated textile technology for the integration of woven metallic yams into clothes has encouraged their use as a suitable means of connection, data communication, and power transfer for chip packages sewn into textiles.

In the following session, there are some reprehensive projects proposed by several research groups, representing the most relevant contributions to the e-textile field, taking into account the degree of device integration, the resulting wearability, and demonstrated performances.

2.2 Wearable devices

Shirley Coyle *et al* presented wearable textile-based Sensors that can provide real-time information regarding sweat activity. A pH sensitive dye incorporated into a fabric fluidic system was used to determine sweat pH.

To detect the onset of sweat activity a sweat rate sensor was incorporated into a textile substrate. The sensors were integrated into a waistband and controlled by a central unit with wireless connectivity. They stated that the use of such sensors for sweat analysis may provide valuable physiological information for applications in sports performance and also in healthcare[5].

Prashanth Shyamkumar *et al* represented a Wearable Wireless Cardiovascular Monitoring Using Textile-Based Nanosensor and Nanomaterial Systems .The textile platform for that application was an inner vest that can incorporate nano-biosensors, It could also incorporate an infrared emitter-detection system for plethysmography and temperature sensors.

The system was an implementation of a multichannel wearable wireless textile-based nano-biosensor that monitors ECG and blood pressure [6].

M. A. R. Osman *et al* represented an Embroidered fully textile wearable Antenna For Medical Monitoring Applications. The fabrication was conducted using copper self adhesive sheet conducting material and the conducting thread for each antenna prototype. Each of the conducting material has been applied to the radiating element (front side) as well as the ground metal (back side). At the same time, three stacked layers of flannel fabric have been used as the substrate material in both antenna prototypes.

The paper stated that the usage of the conducting thread material and the fabricated antenna has satisfied the requirements of providing the wearer with compact size, flexible materials and ease of washing [7].

2.3 Wearable temperature devices

In 2013 Artem Dementyev *et al* presented a long-term temperature monitoring system that uses miniature wearable sensor nodes that connected via Bluetooth to a cellular phone in a star topology. The system provided immediate remote feedback through a phone’s internet connectivity and eliminated the need for a dedicated base station.

The system was fully autonomous, the connections were reliable, no data were lost also, data collection did not interfere with the phone's other functions, such as calling and Internet browsing. The disadvantage of the device was its bulkiness, which made it uncomfortable to be worn for a long period of time [8].

Wei Chen *et al* proposed and demonstrated a design of non-invasive neonatal temperature monitoring with wearable sensors in 2010. Conductive textile wires were used to make the sensor integration compatible for a wearable non-invasive monitoring platform, such as a neonatal smart jacket. A prototype belt was built of soft bamboo fabrics with NTC sensor integrated to demonstrate the temperature monitoring.

The prototype belt achieved accurate temperature monitoring and the monitoring errors were within 0.1 degrees Celsius. The drawback of the device was that the belt was connected to a digital oscilloscope for data acquisition and a PC was used for processing the data and displaying the measured temperature, which made the device importable [9].

In 2006 Leah Buechley presented a temperature-sensing hat that was constructed with the microcontroller, temperature sensor and RGB LED along with the on/off switch and battery. All of the electronic components except the RGB LED were mounted inside the hat so that they were hidden from view. The temperature sensor was attached so that it poked through the knitting on the top of the hat to get a good reading. The RGB LED was stitched to the crown of the hat and then covered with a fluffy pompom that diffused its light. As the temperature increased, the pompom got redder; as the temperature decreased it got bluer. At room temperature the pompom glowed a yellowish green.

The cap was surprisingly comfortable. While not clearly visible in full sunlight, the LED was seen outside on cloudy days or after dusk and in any indoor setting [10].

2.4 ATmega8 microcontroller

MAMUN *et al* designed a low cost and portable microcontroller based heart-rate counting system for monitoring heart condition that can be implemented with off-the-shelf components. An Atmel microcontroller (ATmega8) was used to collect and process data. The ATmega8 was small in size and its power consumption was low. Thus it was ideal to be used as an embedded system.

The pulse signal of heart extract from finger was fed to the port PD-4 of ATmega8. The counter of microcontroller was used to measure the pulse rate per minute. Microcontroller also initiated the corresponding command for LCD display [11].

Vaskar Roy *et al* implemented a Digital Thermometer using ATmega8 Microcontroller to measure the surrounding's temperature. A sensor LM35 was connected to a microcontroller (ATmega8). ATmega8 achieved through puts that were approaching 1MIPS per MHz, which allowed the system designed to optimize power consumption versus the processing speed. When sensor can sense the temperature, it sended an information signal to the microcontroller. Microcontroller took the signal as an input. A program was written to display the information on convenient format. The output data was displayed through LCD display [12].

2.5 LM35 sensor

A. Goswami *et al* designed an embedded system for the control of Temperature &Light intensity with continuous monitoring in a single system using sensors (LM35).

In the system, temperature measurement and light intensity from the ADC channels was taken. The performances of the channels were distinguished on the basis of its accuracy. The accuracy indicated how closely the sensor measured the actual or real world parameter value. The more accurate a sensor is, the better it would perform. To achieve that, calibration was done with a standard digital thermometer and since LM35 is a linear device so calibration process yielded good result [13].

B.Jyosthna *et al* designed a device to be wearied by the patient and parameters such as ECG, Temperature using temperature sensor (lm35) and Heart Beat continuously being transmitted and monitored through wireless technology GSM. At the receiver side (doctor side) the data was wirelessly received using GSM.

The paper stated that the LM35 did not require any external calibration or trimming to provide typical accuracies [14].

A.Chandana *et al* presented a project that was attempted to provide a cheap method to detect and transmit ECG signals. The project used

Bluetooth/GSM technology to transfer the measured value to a mobile device which uses the internet platform for transmission to medical facility in the proximity of the location where primary health centre is located.

The main task lifted was to monitor the health status of the patient, primarily the heart rate and the temperature. These parameters which were to be monitored were observed initially as analog inputs which were primarily fed to the sensors namely heartbeat sensor and temperature sensor-LM35 which were given digitally converted by using an A/D convertor ADC0808 [15].

CHAPTER THREE

METHODOLOGY

3.1 Introduction:

The goals of this research are mainly achieved by dividing the process of investigations into three stages. The first stage concerns with choosing the components and the Design of the circuit. The second stage clarifies the process of connecting and programming the hardware component of the device as well as testing the device after each stage of connection. At the end comes the third stage that explains the process of sewing the components as well as testing the overall performance of the device.

3.2 Stage one

Stage one concerns choosing suitable components and designing the circuit using software.

3.2.1 Literature review

Choosing suitable components requires reviewing the current knowledge and substantive findings, as well as theoretical and methodological contributions to the wearable devices field.

3.2.2 Component choosing

To study and investigate the different choices of components and choosing suitable ones in terms of performance, size, cost and ease of use

3.2.3 Software design

The circuit simulation was conducted using proteus, chosen components were dragged and connected, which was an easy way to test it and investigate if it's possible to be conduct as hardware

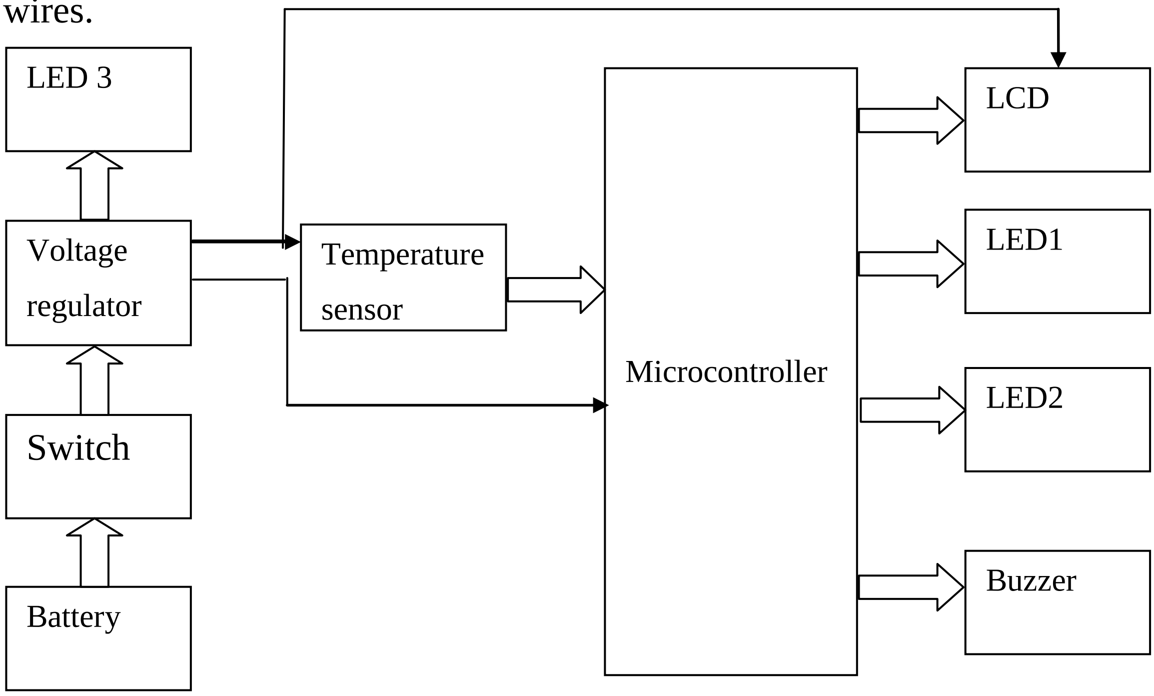
These steps were repeated tell the desired results were obtained and the methodology reached its second stage

3.3 Stage two

Stage two concerns connecting and testing components on circuit board.

3.3.1 Components connecting

Component were placed and connected on rigid test board using typical wires.



3.3.2 Programming

Bascom for AVR code were used to program the microcontroller. The code included instruction for the configuration of the microcontroller ports as well as the hardware connected to it. Also, it included the equation to calculate the value of the temperature sensed by the sensor together with the equation to calculate the average of these values every 15 minutes and then displaying them on the LCD.

Depending upon the average temperature values different ports are activated to enable different sound and visual indicators to work correspondent to them.

3.3.3 Testing

This stage ends with examining the performance of the hardware component after connection, by taking different measurements of temperature and ensuring that it is displayed and the different indicators are working within the specified ranges.

Steps of the stage were repeated till the desired results were fully achieved and the methodology reached its third stage.

3.4 Stage three

Stage three concerns connecting and testing components on fabric.

3.4.1 Components sewing

Circuit components were sewn on fabric using tracks of conductive thread instead of wires.

3.4.2 Testing and comparing

After sewing, the overall performance of the device was examined, different measurements of temperature were taken and the results were compared with those of stage two to ensure reliability.

Steps of the stage were repeated till the desired results were fully achieved and the project was finally finalized

3.5 Summary

All methodological steps of this project are summarized in the following figure.

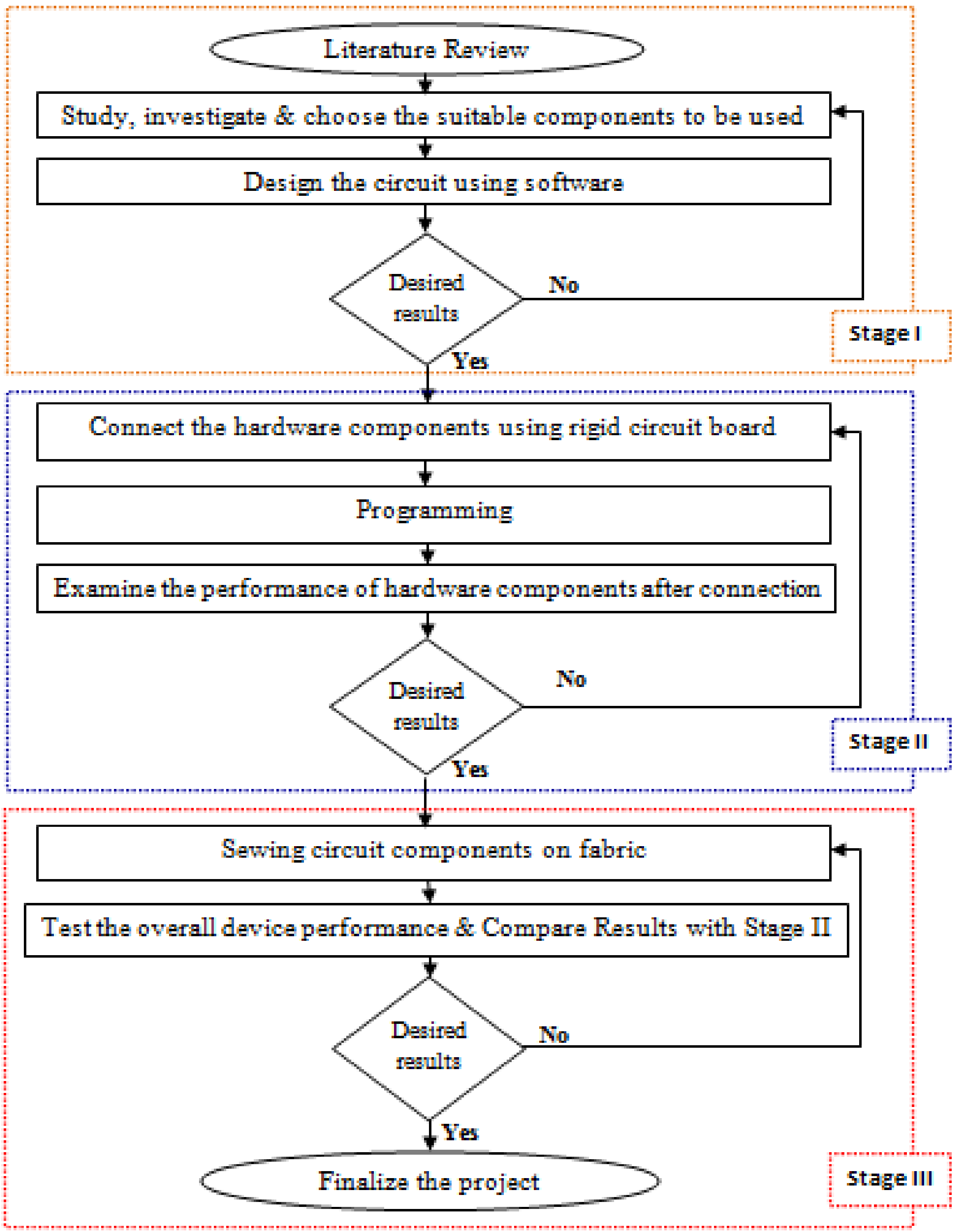


Figure (3.1) project methodology

CHAPTER FOUR

GENERAL CONCEPTS

4.1 Introduction

Body temperature is one of the four main vital signs that must be monitored to ensure safe and effective care. Temperature measurement is recommended by the National Institute of Clinical Excellence a part of the initial assessment in acute illness in adults (NICE, 2007). and by the Scottish Intercollegiate Guidelines Network guidelines for post-operative management in adults (SIGN, 2004). Despite applying in all healthcare environments, wide variations exist on the methods and techniques used to measure body temperature [16].

4.2 Body Temperature

Body temperature is the measure of the body's ability to generate and get rid of heat. The body is very good at keeping its temperature within narrow range, safe range in spite of large variations in temperatures outside the body.

When you are too hot, the blood vessels in your skin expand (dilate) to carry the excess heat to your skin's surface. You may begin to sweat, and as the sweat evaporates, it helps cool your body. When you are cold, your blood vessels narrow (contract) so that the blood flow to your skin is reduced to conserve body heat. You may start shivering, which is an involuntary rapid contraction of the muscles. This extra muscle activity helps generate more heat. Under normal conditions, this keeps your body temperature within a narrow, safe range [17].

4.3 Measuring Human Temperature

Different parts of the body have different temperatures and can be taken in any of the following ways:-

- Orally: temperature can be taken by mouth using either the classic glass thermometer, or the more modern digital thermometer that uses an electronic probe to measure body temperature.

- Rectally: temperatures can be taken rectally (using a glass or digital thermometer) tend to be 0.5 to 0.7 degrees F higher than when taken by mouth.

- Auxiliary: temperatures can be taken under the arm using a glass or digital thermometer. Temperatures taken by the route tend to be 0.3 to 0.4 degrees F lower than those temperatures taken by mouth.

- By ear: a special thermometer can quickly measure the temperature of the ear drum, which reflects the body core temperature (the temperature of internal organs).

- By skin: a special thermometer can quickly measure the temperature of the skin on the forehead [18].

When comparing these types of measurements, one can conclude rectal or vaginal measurements, or measurements taken directly inside the body cavity, are typically slightly higher than oral measurements. While oral measurements are somewhat higher than skin temperature measurements.

The commonly accepted average core body temperature (taken internally) is 37.0 °C (98.6 °F). the typical oral (under the tongue) measurement is slightly cooler, at 36.8 °C ± 0.4 °C (98.2° ± 0.7 °F), and temperatures taken in other places (such as under the arm or in the ear) produce different typical numbers. Although some people think of these averages as representing the normal or ideal temperature, a wide range of temperatures has been found in healthy people.

The body temperature of a healthy person varies during the day by about 0.5 °C (0.9 °F) with lower temperatures in the morning and higher temperatures in the late afternoon and evening, as the body’s needs and activities change. Other circumstances also affect the body’s temperature. The core body temperature of an individual tends to have the lowest value in the second half of the sleep cycle, the lowest point, called the nadir, is one of the primary markers for circadian rhythms. The body temperature also changes when a person is hungry, sleepy, or cold [19].

4.4 Commonly Accepted Body Temperature

The findings of Sund-Levander, *et al* are summarized in Table (4.1) [20].

Table (4.1): Normal Human Temperature At Different Body Sites

Body part	Temperature(°C)
Oral	33.2–38.2
Rectal	34.4–37.8
Typanic (ear canal)	35.4–37.8
Axillary (armpit)	35.5–37.0

4.5 Human temperature variation effects

The human body's core temperature varies from day to day, and from time to time, but these fluctuations are small, usually no more than 1.0ºC.

4.5.1 Hot variations

Fevers are not to be confused with heat stroke. In fever the person can feel cold at high body temperatures. One theory is that the body is fooled into thinking it is cold by the infecting microbe. The more recent alternative hypothesis is that fever is a constructive response to infection, and that the chills are an evolutionary mechanism whose function is to motivate individuals to seek warmth, to help facilitate the increase in body temperature.

- 44 °C (111 °F) or more – almost certainly death will occur, however, patients have known to survive up to 46.5 °C (115.7 °F).

- 43 °C (109 °F) – normally death, or there may be serious brain damage, continuous convulsion and shock. Cardio-respiratory collapse will likely occur.

- 42 °C (108 °F) – subject may turn pale or remain flushed and red. They may become comatose, be in sever delirium, vomiting and convulsions can occur. Blood pressure may be high or low and heart rate will be very fast.

- 41 °C (106 °F) – (medical emergency) – fainting, vomiting, severe headache, dizziness, confusion, hallucination, delirium and drowsiness can occur. There may also be palpitations and breathlessness.

- 40 °C (104 °F) – fainting, dehydration, weakness, vomiting, headache and dizziness may occur as well as profuse sweating. Starts to be life-threatening.

- 39 °C (102 °F) – severe sweating, flushed and red. Fast heart rate and breathlessness. There may exhaustion accompanying this. Children and people with epilepsy may be very likely to get convulsions at this point.

- 38 °C (100 °F) – (this is classed as hyperthermia if not caused by a fever) feeling hot, sweating, feeling thirsty, feeling slightly uncomfortable, slightly hungry. If this is caused by fever, there also may be chills [19].

4.5.2 Normal variation

The normal range of human body temperature varies due to an individual's metabolism rate; the higher (faster) it is the higher the normal body temperature or the slower the metabolic rate the lower the normal body temperature. Other factors that might affect the body temperature of an individual may be the time of day or the part of the body in which the temperature is measured at. [21]. 37 °C (98.6 °F) – normal internal body temperature (which varies about 36.12 – 37.6 °C (97.02 – 99.68 °F)) [19].

4.5.3 Cold Variation

Body temperature can fall due to numerous reasons; abnormally low body temperature can also be a potential symptom of diseases and disorders. Shivering is one of the most obvious and easily recognizable symptoms. Shivering is accompanied with chattering of teeth and goose bumps [20].

- 36 °C (97 °F) – feeling cold, mild to moderate shivering (body temperature may drop this low during sleep). May be normal body temperature.
- 35 °C (95 °F) – (Hypothermia is less than 35 °C (95 °F) – intense shivering, numbness and bluish/grayness of the skin. There is possibility of heart irritability.
- 34 °C (93 °F) – severe shivering, loss of movement of fingers, blueness and confusion. Some behavioral changes may take place.
- 33 °C (91 °F) – moderate to severe confusion, sleepiness, depressed reflexes, progressive loss of shivering, slow heart beat. Shivering may stop. Subject may be not responding to certain stimuli.
- 32 °C (90 °F) – (medical emergency) hallucinations, delirium, complete confusion, extreme sleepiness that is progressively becoming comatose. Shivering is absent (subject may even they are hot). Reflex may be absent or very slight.
- 31 °C (88 °F) – comatose, very rarely conscious. No or slight reflex. Very shallow breathing and slow heart rate. Possibility of serious heart rhythm problems.

- 28 °C (82 °F) – sever heart rhythm disturbances are likely and breathing may stop at any time. Patient may appear to be dead.
- 24-26 °C (75-79 °F) or less – Death usually occurs due to irregular heart beat or respiratory arrest; however, some patients have been known to survive with body temperatures as low as [14.2 °C (57.5 °F)] [19].

4.6 The Need to Measure Body Temperature

There are many reasons, requirements and need to measure body temperature:

- Detect fever.
- Detect abnormally low body temperature (hypothermia) in people who have been exposed to cold.
- Detect abnormally high body temperature (hyperthermia) in people who have been exposed to heat.
- Help monitor the effectiveness of a fever-reducing medicine.
- Help plan for pregnancy by determining if a woman is ovulating [22].

4.7 Fever

Fever is the temporary increase in the body's temperature in response to a disease or illness. Fever is an important part of the body's defense against infection. Most bacteria and viruses that cause infections in people thrive best at 98.6°F. Many infants and children develop high fevers with mild viral illnesses. Although a fever signals that a battle might be going on in the body, the fever is fighting for, not against the person

Brain damage from a fever generally will not occur unless the fever is over 107.6°F (42°C). Untreated fevers caused by infection will seldom go over 105°F unless the child is overdressed or trapped in a hot place. Febrile seizures do occur in some children. Most febrile seizures are over quickly and do not mean your child has epilepsy. These seizures also do not cause any permanent harm. Unexplained fevers that continue for days or weeks are called fevers of undetermined origin (FUO) [23].

4.8 Causes of fever

Almost any infection can cause a fever, including:

- Bone infections (osteomyelitis), appendicitis, skin infections or cellulitis, and meningitis.
- Respiratory infections such as colds or flu -like illnesses, sore throats, ear infections, sinus infections, mononucleosis, bronchitis, pneumonia, and tuberculosis.
- Urinary tract infections.
- Viral gastroenteritis and bacterial gastroenteritis.

Children may have a low-grade fever for 1 or 2 days after some immunizations. Teething may cause a slight increase in a child's temperature, but not higher than 100°F.Autoimmune or inflammatory disorders may also cause fevers. Some examples are:

- Arthritis or connective tissue illnesses such as rheumatoid arthritis and systemic lupus erythematosus.
- Ulcerative colitis and Crohn disease.
- Vasculitis or periarteritis nodosa.

The first symptom of a cancer may be a fever. This is especially true of Hodgkin disease, non-Hodgkin lymphoma, and leukemia. Other possible causes of fever include:

- Blood clots or thrombophlebitis.
- Medications, such as some antibiotics, antihistamines, and seizure medicines

4.9 Types of thermometers used to measure body temperature

Several different types of thermometers are available:

4.9.1 Electronic Thermometers

They are plastic and shaped like a pencil, with a display window at one end and the temperature probe at the other end. They work by measuring how well electricity travels through a wire. Electronic thermometers are used in the mouth, rectum, or armpit. They are easy to use and easy to read. If you buy an electronic thermometer, check the package for information about its accuracy.

4.9.2 Ear Thermometers

They are plastic and come in different shapes. They use infrared energy to measure body temperature. The small cone-shaped end of the thermometer is placed in the ear, and body temperature is shown on a digital display. The results appear within seconds. Some models also show the corresponding oral and rectal readings.

4.9.3 Temporal Artery Thermometers

These types are electronic devices that measure body temperature on the skin over an artery in the forehead (superficial temporal artery). The device has a small "cup" that is moved across the skin over the artery. Infrared energy is used to determine the temperature. When used correctly, temporal artery thermometers are accurate for measuring body temperature.

4.9.4 Disposable Thermometers

They are thin flat pieces of plastic with colored dots and temperature markings on one end. The color of the dots shows the temperature. Disposable thermometers can be used in the mouth or rectum. A patch form can be used on a baby's skin to measure temperature continuously for 48 hours. These thermometers are safe, but they are not as accurate as electronic or ear thermometers. They do not contain glass, latex, or mercury. You can reuse the thermometer during an illness and then throw it away.

4.9.5 Forehead thermometers

These use skin temperature to determine body temperature. They are thin pieces of plastic with numbers on them. You press the strip against a person's forehead, and the temperature makes some numbers change colors or light up. These thermometers are not very accurate.

4.9.6 Pacifier Thermometers

They are shaped like a baby's pacifier but have a display that shows the temperature. You place the pacifier in your child's mouth to measure temperature. These thermometers may take longer to get a reading and are not as accurate as other types.

4.9.7 Glass Thermometers

These types containing mercury are no longer recommended. If you have a glass thermometer, contact your local health department for instructions on how to dispose of it safely. If you break a glass thermometer, call your local poison control center immediately [22].

4.10 Summery

Our design is a wearable flexible body temperature measuring device made of textile material used for continuous monitoring of the body temperature. The temperature is sensed under the arm and is displayed on an LCD screen. LED indicators are also used, green light indicates for normal temp, red light for slight increase in temp, red light with alarm for high increase in temp and no light when temp is under the normal.

CHAPTER FIVE

SYSTEM COMPONANT

5.1 Introduction:

This chapter includes the discussion about the system components as well as the features of each component and the reasons for choosing the components that were used to implement the system.

5.2 System components:

1- One Atmega8 Microcontroller.
2- One Speaker.
3- One Regulator (LM).
4- ON-OFF Switch.
5- Three LEDs.
6- One Buttery (9v).
7- Conductive Thread.
8- One lm35 temperature sensor

5.3 Signal Processing Unit

The signal that comes from the sensor needs to be processed so we can get the desired result. This can be happed by using DSP unit or a microprocessor or a microcontroller. A microcontroller will be used in this project, due to the fact that it is easy programmable, cheap, fast and available.

However, several types of MC are provided in the market.

5.3.1 The PIC microchip microcontrollers

PIC is a family of modified Harvard architecture microcontrollers made by Microchip Technology, derived from the PIC1650 originally developed by General Instrument's Microelectronics Division.

PICs are popular with both industrial developers and hobbyists alike due to their low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools, and serial programming (and re-programming with flash memory) capability[24].

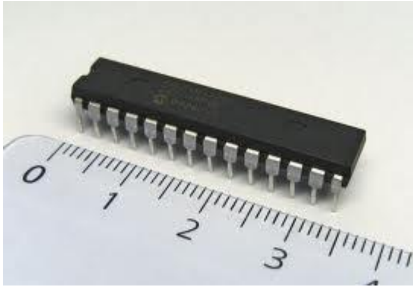


Figure (5.1): PIC microchip microcontrollers

Table (5.1): indicating Advantages and Disadvantages of PIC Family Controllers

Advantages	Disadvantages
Small instruction set to learn	One accumulator
RISC architecture	Register-bank switching is required to access the entire RAM of many devices
Built in oscillator with selectable speeds	Operations and registers are not orthogonal; some instructions can address RAM and/or immediate constants, while others can only use the accumulator.
Easy entry level, in circuit programming plus in circuit debugging PICKit units available for less than $50	
Inexpensive microcontrollers	
Wide range of interfaces including I²C, SPI, USB, USART, A/D, programmable comparators, PWM, LIN, CAN, PSP, and Ethernet	
Availability of processors in DIL package make them easy to handle for hobby use.	

Table (5.2): PIC family microcontrollers

PIC10FXXX	**is called Low-Range.** The PIC10FXXX devices from Microchip Technology are low-cost, high-performance, 8-bit, fully static, Flash-based CMOS microcontrollers. They employ a RISC architecture with only 33 single-word/ single-cycle instructions. The 12-bit wide instructions are highly symmetrical. The easy-to-use and easy to remember instruction set reduces development time significantly. The PIC10FXXX devices contain an 8-bit ALU and working register.
PIC12FXXX PIC12HVXXX	**Is called Mid-Range.** The PIC12FXXX most popular among these starter their way in this field. Mid-Range devices feature 14-bit program word architecture and are available in 8 to 64-pin packages that offer an operating voltage range of 1.8-5.5V, small package footprints, interrupt handling, an 8-level hardware stack, multiple A/D channels and EEPROM data memory. Mid-range devices offer a wide range of package options and a wide range of peripheral integration. These devices feature various serial analog and digital peripherals, such as: SPI, I2C™, USART, LCD and A/D converters.
PIC16FXXX PIC16HVXXX	With six variants ranging from 3.5K-14 Kbytes of Flash memory, up to 256 bytes of RAM and a mix of peripherals including EUSART, CCP and onboard analog comparators. These devices are well suited for designers with applications that need more code space or I/O than 14-pin variants supply, and are looking to increase system performance and code efficiency by employing hardware motor control and communications capability.

<table>
<tr><td>PIC18FXXX</td><td rowspan="3">The PIC18 family utilizes a 16-bit program word architecture and incorporates an advanced RISC architecture with 32 level-deep stack, 8x8 hardware multiplier, and multiple internal and external interrupts. With the highest performance in Microchip’s 8-bit portfolio, the PIC18 family provides up to 16 MIPS and linear memory. PIC18 is the most popular architecture for new 8-bit designs where customers want to program in C language.</td></tr>
<tr><td>PIC18FXXJXX</td></tr>
<tr><td>PIC18FXXKXX</td></tr>
</table>

5.3.2 Atmel AVR microcontroller

With ease-of-use, low power consumption, and high level of integration in mind, Atmel® AVR® 8- and 32-bit microcontrollers complement Atmel's ARM® microcontrollers and microprocessors to deliver a unique combination of performance, power efficiency and design flexibility. Optimized to speed time-to-market, they are based on the industry's most code-efficient architecture for C and assembly programming. No other microcontrollers deliver more computing performance with better power efficiency. Industry-leading development tools and design support let you get to market faster. Once there, the large AVR family lets you reuse your knowledge when improving your products and expanding to new markets—easily and cost-effectively [25].

Figure (5.2): Atmel AVR microcontroller

5.3.3 The Atmel ATmega family

The ATmega164P/324P/644P is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega164P/324P/644P achieves throughputs approaching 1 MIPS per MHz allowing the system designed to optimize power consumption versus processing speed [26].

Table (5.3): Atmel ATmega family

Device	Flash	EEPROM	RAM	Speed (MHz)	Power Supply	Operational Range
ATmega164P	16 Kbyte	512 Bytes	1 Kbyte	10	1.8V - 5.5V	Industrial (-40^{o}C to 85^{o}C)
				20	2.7V - 5.5V	
				10	1.8V - 5.5V	Extended (-40^{o}C to 105^{o}C)
				20	2.7V - 5.5V	
ATmega324P	32 Kbyte	1 Kbyte	2 Kbyte	10	1.8V - 5.5V	Industrial (-40^{o}C to 85^{o}C)
				20	2.7V - 5.5V	
				10	1.8V - 5.5V	Extended (-40^{o}C to 105^{o}C)
				20	2.7V - 5.5V	
				10	1.8V -	Industrial

ATmega644P	64 Kbyte	2 Kbyte	4 Kbyte		5.5V	(-40^{o}C to 85^{o}C)
				20	2.7V - 5.5V	
				10	1.8V - 5.5V	Extended (-40^{o}C to 105^{o}C)
				20	2.7V - 5.5V	

5.4 Voltage regulator

A voltage regulator is designed to automatically maintain a constant voltage level. A voltage regulator may be a simple "feed-forward" design or may include negative feedback control loops. It may use an electromechanical mechanism, or electronic components. Depending on the design, it may be used to regulate one or more AC or DC voltages.

A simple voltage regulator can be made from a resistor in series with a diode (or series of diodes) see figure (5.3). Due to the logarithmic shape of diode V-I curves, the voltage across the diode changes only slightly due to changes in current drawn or changes in the input. When precise voltage control and efficiency are not important, this design may work fine.

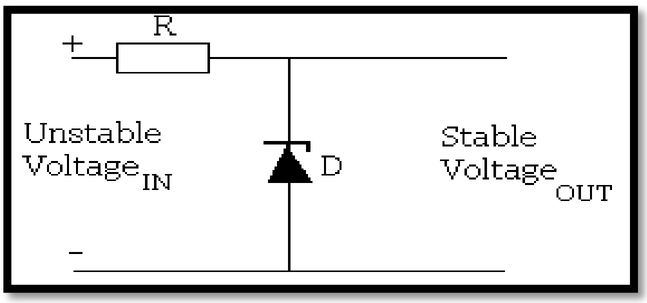


Figure (5.3): Voltage regulator

The 78xx (sometimes L78xx, LM78xx, MC78xx...) is a family of self-contained fixed linear voltage regulator integrated circuits. The 78xx family is commonly used in electronic circuits requiring a regulated power supply due to their ease-of-use and low cost [27].

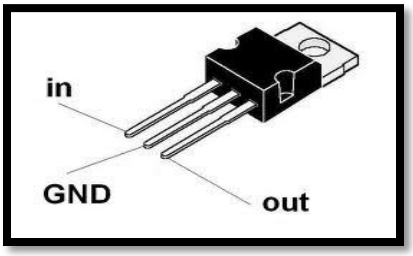


Figure (5.4): 78xx family Voltage regulator

5.5 Speaker

Speakers are usually used in circuit design to as an output option to let the person hear the voice. Therefore in this project this type of speaker was chosen as shown figure below.

Figure (5.5): Speaker

5.6 LEDs

The LED is a semiconductor that emits light when current is passed through it, here is it used as an indicator.

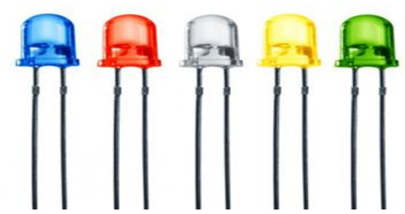


Figure (5.6): LEDs

5.7 ON-OFF Switch

The on/off switch is used to control the flow of the current. Figure (5.7) demonstrate the type of the on/off switch used in this project.

Figure (5.7): ON-OFF Switch

5.8 Conductive Thread

With conductive thread, you can add conductivity to any fabric, make conductive traces as easily as sewing and even use it as un-insulated low voltage wiring.

Figure (5.8): Conductive thread

5.9 Battery (9v)

The most common form of nine-volt battery is commonly called the transistor battery which was introduced for the early transistor radios. It has a rectangular prism shape with rounded edges and a polarized snap connector at the top. This type is commonly used in pocket radios, paintball guns, and small electronic devices.

They are also used as backup power to keep the time in certain electronic clocks. This format is commonly available in primary carbon-zinc and alkaline chemistry, in primary lithium iron disulfide, and in rechargeable form in nickel-cadmium, nickel-metal hydride and lithium-ion. Mercury oxide batteries in this form have not been manufactured in many years due to their mercury content. This type is designated NEDA 1604, IEC 6F22 and "Ever Ready" type PP3 (zinc-carbon) or MN1604 6LR61 (alkaline) [28].

Figure (5.9): Battery 9 Voltage

5.10 Summary

This chapter seeks to review recent literature on wearable flexible temperature devices. Several components that are integrated into fabric materials were introduced and discussed. Moreover, this chapter also introduced factors relating to components selection and material selection required for flexible fabric temperature monitoring device.

Therefore, based on the previous literature review, this research aimed to investigate the possibilities of designing, prototyping and testing a flexible wearable temperate monitoring device that small in size, flexible, portable and low in cost, which is capable on sensing the change in human body temperature.

CHAPTER SIX

SOFTWARE AND HARDWARE DESIGN

6.1 Introduction

In this chapter the work has been divided in three stages to be more simple and accurate. Stage one for the software design, Stage two for the simulation implementation and stage three for hardware design.

6.2 Design stages

6.2.1 Software Design

This part will discuss the software which the microcontroller is programmed with to calculate and display the temperature on the LCD after it was sensed. There are several types of programming languages available to program microcontrollers such as assembly, bascom and C/C++. We chose to program our microcontroller with bascom for AVR.

6.2.2 Simulation implementation

The purpose of this stage is to have a virtual representation of the circuit to make sure that if the circuit is to be implemented in real life it would actually work. The simulation will represent the processing stages and the sensor's output display on the LCD and the visual and sound indicators as depicted in figure (6.1).

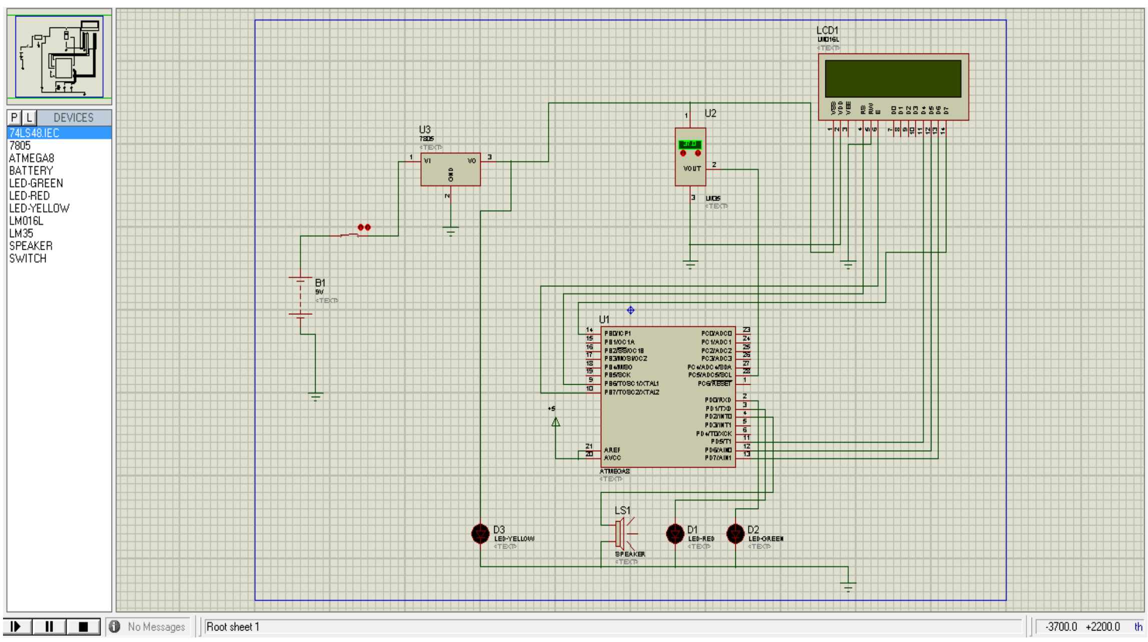


Figure (6.1) the simulation in general

6.2.2.1 Power

This part of the simulation will represent the power source of the circuit as shown in figure (6.2). A 9 volt battery was used as a power supply connected with a switch to enable the power entry/cutoff from the circuit. A voltage regulator was used to lower the voltage to 5 volt which is compatible with the circuit. Once the switch is closed, a led on the beginning of the circuit will light up indicating that the circuit is turned on.

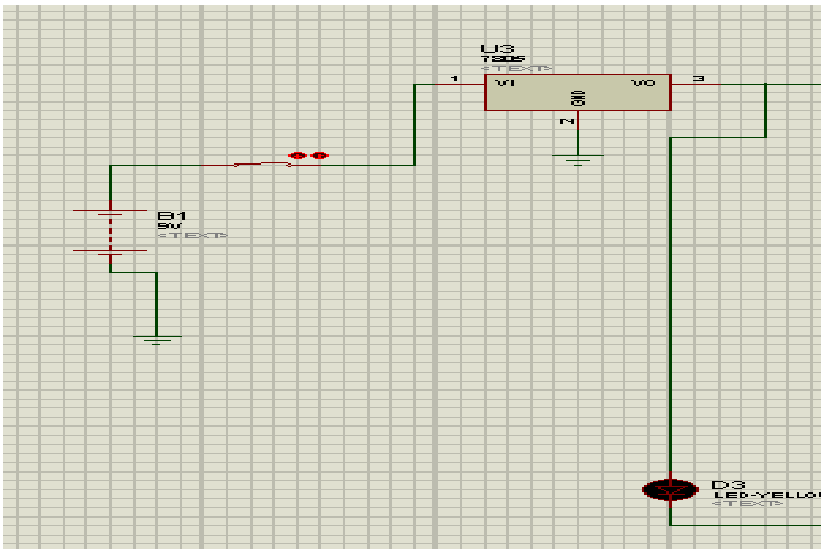


Figure (6.2) the power of the circuit

6.2.2.2 The processing part

This part shown in figure (6.3) Consist of an lm35 temperature sensor which senses the body temperature and its output is connected to the atmega8 microcontroller at port C5. The microcontroller processes the signals and calculates the temperature and sends the output to the visual and sound indicators. The green LED indicates normal temperature, red LED for increase in temperature and the sound speaker for extreme increase in temperature.

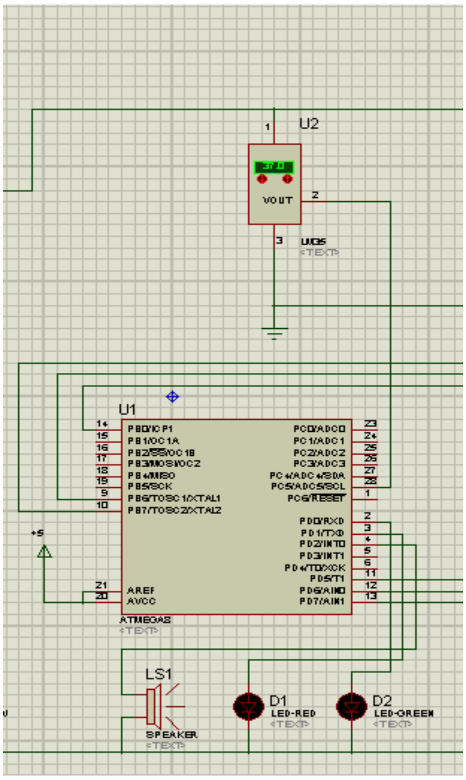


Figure (6.3) the processing

6.2.2.3 The LCD display

The 16x2 LCD was used to display the digital form of the microcontroller output which represents the temperature, shown in figure (6.4).

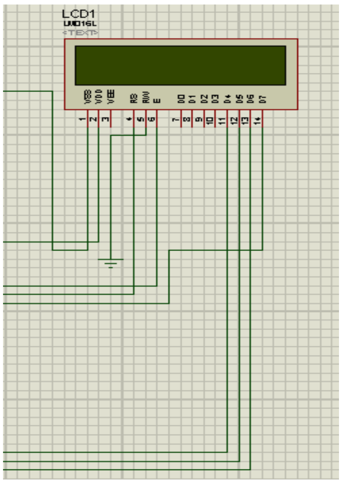


Figure (6.4) the LCD display

6.2.3 Hardware design

The main aim of this stage is to test the system to see if it can actually be implemented in real life and so all the components were placed on a test board, to check their performance. The final apperance of the circit as shown in figure(6.5)

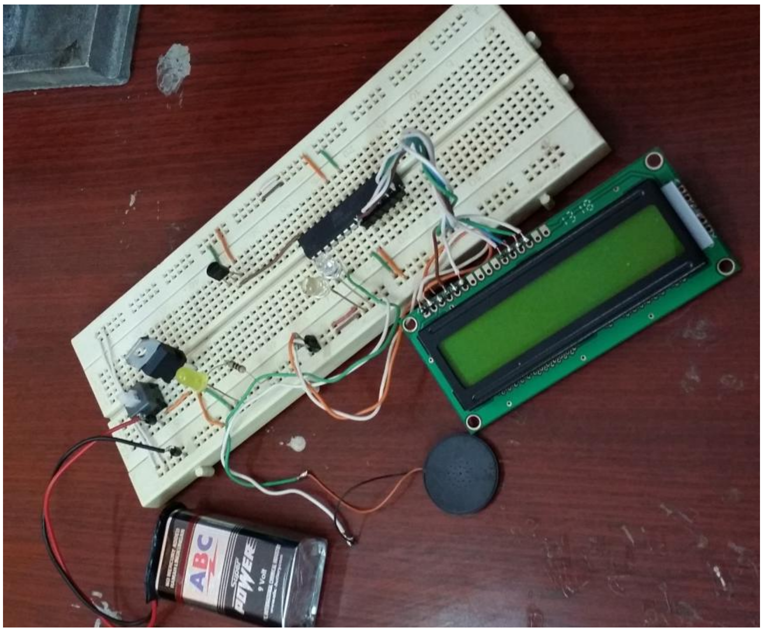


Figure (6.5) circuit design

CHAPTER SEVEN

RESULTS AND DISCUSSION

7.1 Introduction

After designing the software and hardware of the system, it is time to test the project in real environment. Thus, the system was tested on individuals in different weather conditions.

7.2 Testing the conducive material(preliminary result)

The conductive thread was used to join the LED to the power supply (battery) and the sensor which acts here as a switch they were all placed above the piece of fabric, the moment the finger blocked the sensor, the LED went on indicating flow of current in the circuit while when removed there was no flow and the LED remained off, the thread was of very good quality and there were no difficulties while using this thread.

Figure 7.1: Preliminary result OFF

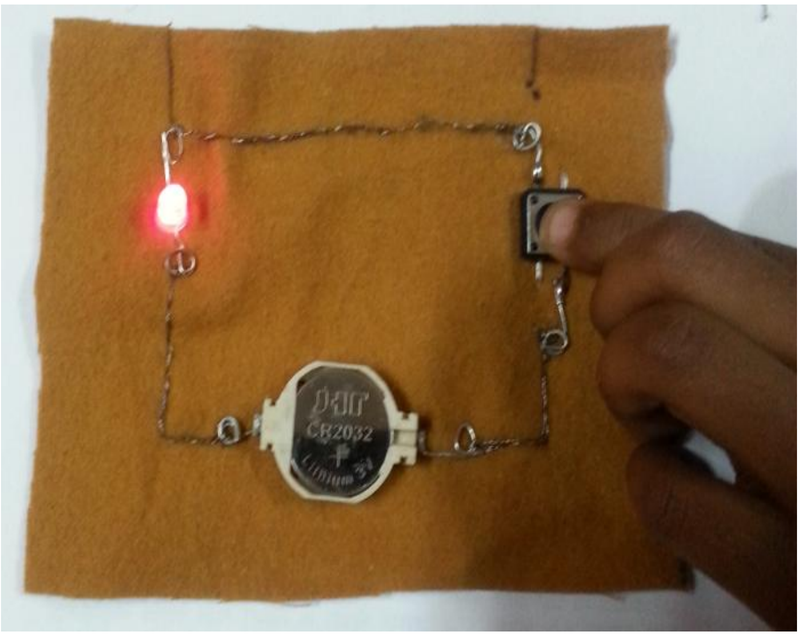


Figure 7.2: Preliminary result ON

7.3 Testing of hardware (stage II)

The system was tested in the normal situation; using the board for connecting the components. The program written was uploaded to the microcontroller; it worked successfully without any problem, numerical results were accurately displayed on the LCD, also indicators LEDs and speaker respond in sequence with the results.

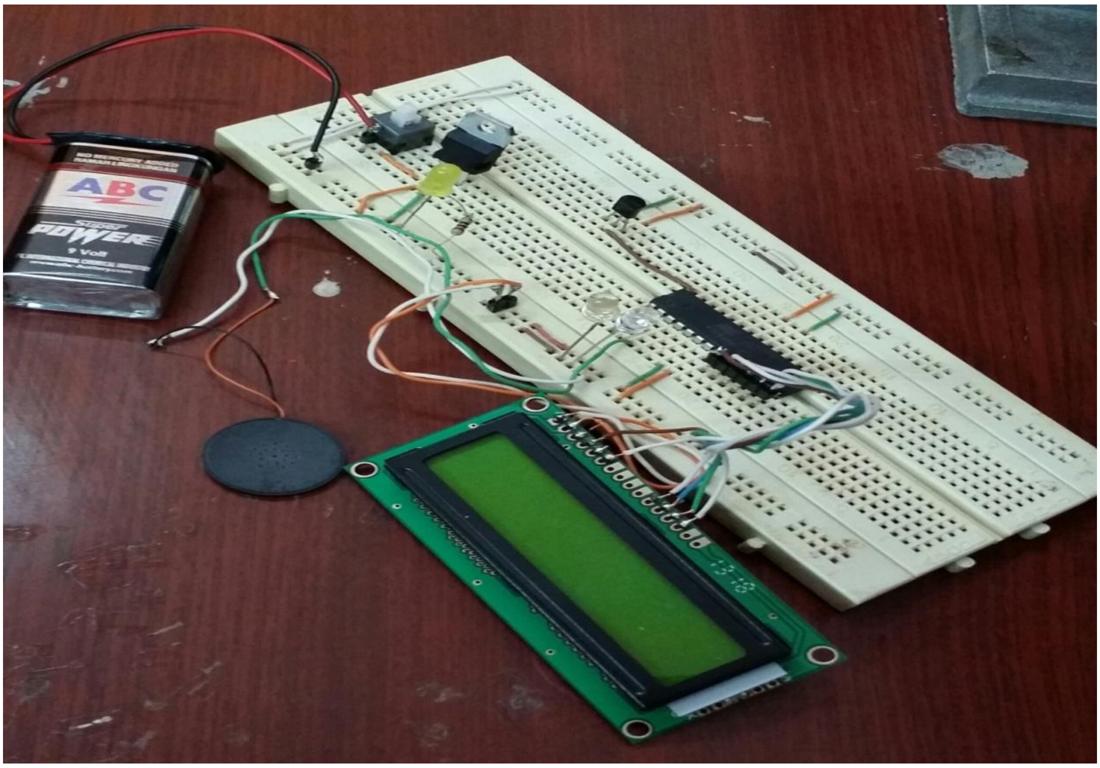


Figure 7.3: Hardware Result in circuit board

Table 7.1: Hardware Testing

Temperature(°C)	**Output**
35.5 – 37	Green LED
37.1– 39	Red LED
> 39	Red LED + alarm

The temperature ranges were chosen according to international standards.

7.4 Testing of stage III

In this stage the wire was replaced with the connecting thread, the output of this stage was the same as the previous stage and proved that the same result was generated, which proves that the thread and the wire have the same ability.

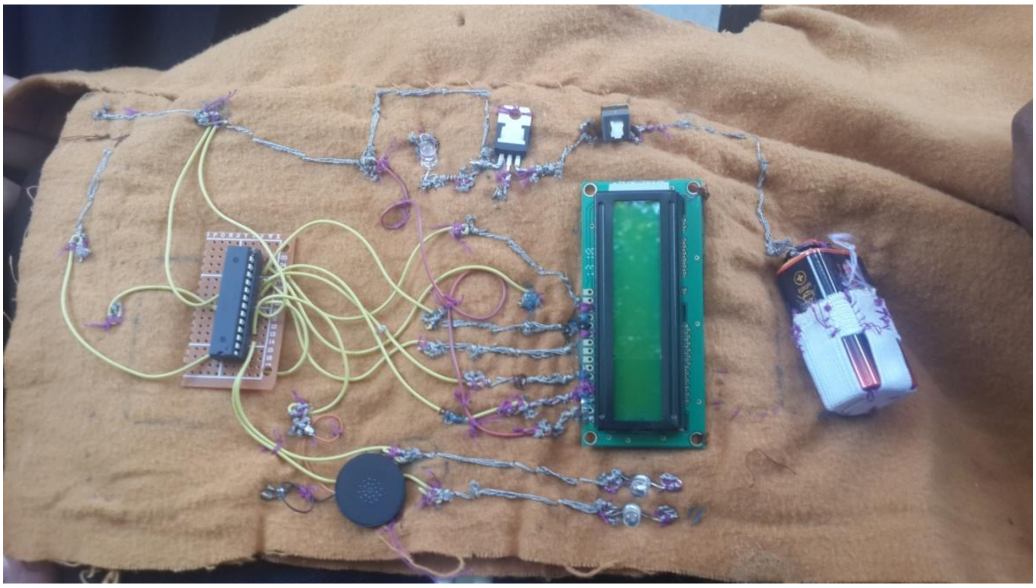


Figure 7.4: Final Fabrication Stage OFF

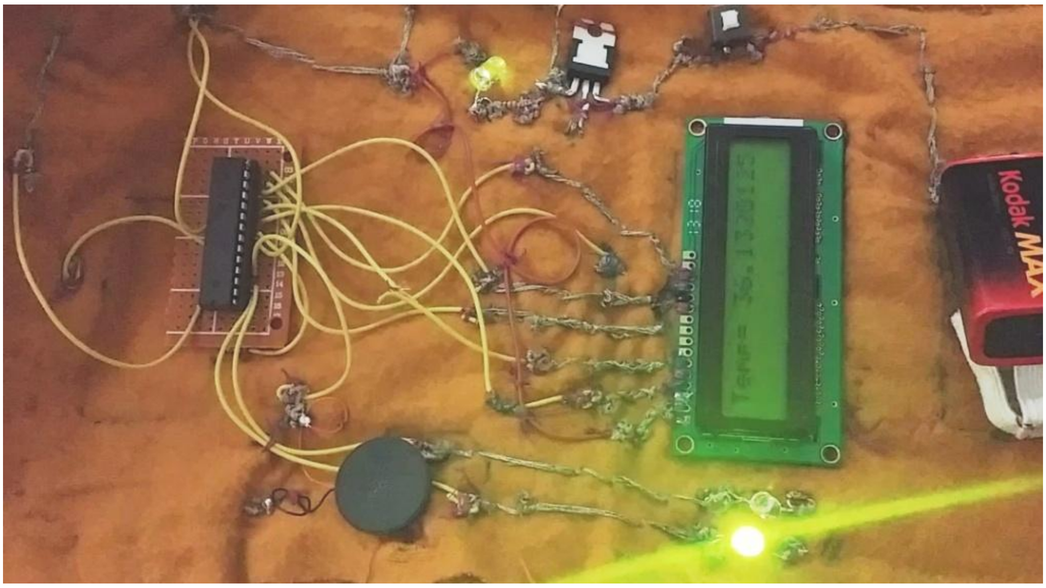


Figure 7.5: Final Fabrication Stage ON

The table below lists results estimated from the comparison between digital thermometer and our design.

Table 7.2: Final Fabrication Test

Digital Thermometer (°C)	**Wearable Temperature Sensing Device (**°C)
36.1	35.6
36.1	35.7
36.9	36.1
37.1	36.5
37.5	36
37.5	36.4
37.5	36.5
37.5	36.6
38	37.1
38	37.5

CHAPTER EIGHT

CONCLUSION AND RECOMMENDATION

8.1 Conclusion

- The device has been built and tested using rigid circuit board. The circuit performed successfully.
- The circuit has been built on fabric material as well as using conducting thread.
- Results indicated the suitability of using soft materials that replaced the rigid material effectively.
- According to the project objectives, our goals have been achieved, providing a device with low cost, accurate performance, flexible, portable, Small in size and Simple construction.

8.2 Recommendation

This project still has space for future development, with the development of the components and technology smaller and faster systems can be developed, some of the main concepts that are to be improved:

- Provide larger memory base for storing all temperature measurements for medical requirements.
- Using of a higher sensitivity temperature sensor capable of being isolated to avoid external influences.

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Appendix

Features

- High-performance, Low-power AVR® 8-bit Microcontroller
- Advanced RISC Architecture
  - 130 Powerful Instructions – Most Single-clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 16 MIPS Throughput at 16 MHz
  - On-chip 2-cycle Multiplier
- High Endurance Non-volatile Memory segments
  - 8K Bytes of In-System Self-programmable Flash program memory
  - 512 Bytes EEPROM
  - 1K Byte Internal SRAM
  - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
  - Data retention: 20 years at 85°C/100 years at 25°C[(1)]
  - Optional Boot Code Section with Independent Lock Bits
    In-System Programming by On-chip Boot Program
    True Read-While-Write Operation
  - Programming Lock for Software Security
- Peripheral Features
  - Two 8-bit Timer/Counters with Separate Prescaler, one Compare Mode
  - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
  - Real Time Counter with Separate Oscillator
  - Three PWM Channels
  - 8-channel ADC in TQFP and QFN/MLF package
    Eight Channels 10-bit Accuracy
  - 6-channel ADC in PDIP package
    Six Channels 10-bit Accuracy
  - Byte-oriented Two-wire Serial Interface
  - Programmable Serial USART
  - Master/Slave SPI Serial Interface
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - On-chip Analog Comparator
- Special Microcontroller Features
  - Power-on Reset and Programmable Brown-out Detection
  - Internal Calibrated RC Oscillator
  - External and Internal Interrupt Sources
  - Five Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, and Standby
- I/O and Packages
  - 23 Programmable I/O Lines
  - 28-lead PDIP, 32-lead TQFP, and 32-pad QFN/MLF
- Operating Voltages
  - 2.7 - 5.5V (ATmega8L)
  - 4.5 - 5.5V (ATmega8)
- Speed Grades
  - 0 - 8 MHz (ATmega8L)
  - 0 - 16 MHz (ATmega8)
- Power Consumption at 4 Mhz, 3V, 25°C
  - Active: 3.6 mA
  - Idle Mode: 1.0 mA
  - Power-down Mode: 0.5 µA

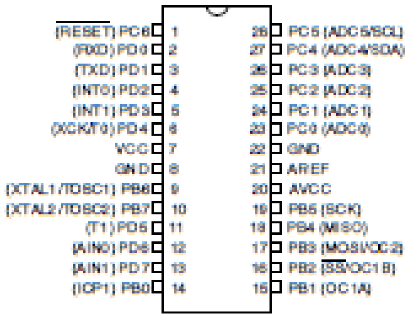
8-bit AVR® with 8K Bytes In-System Programmable Flash

ATmega8
ATmega8L

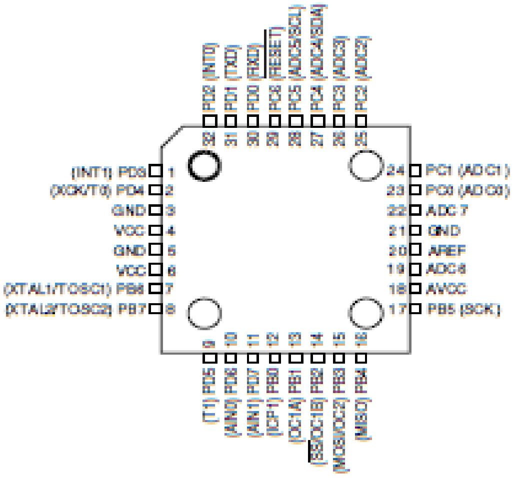
Summary

Pin Configurations

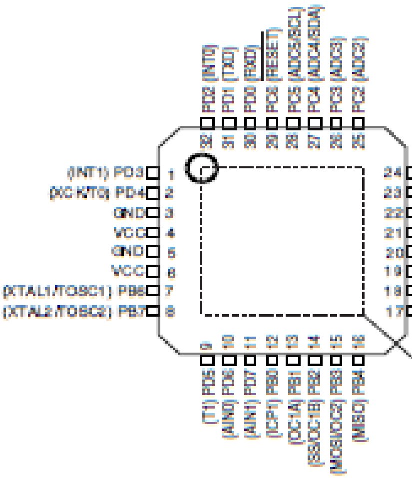
PDIP



TQFP Top View



MLF Top View



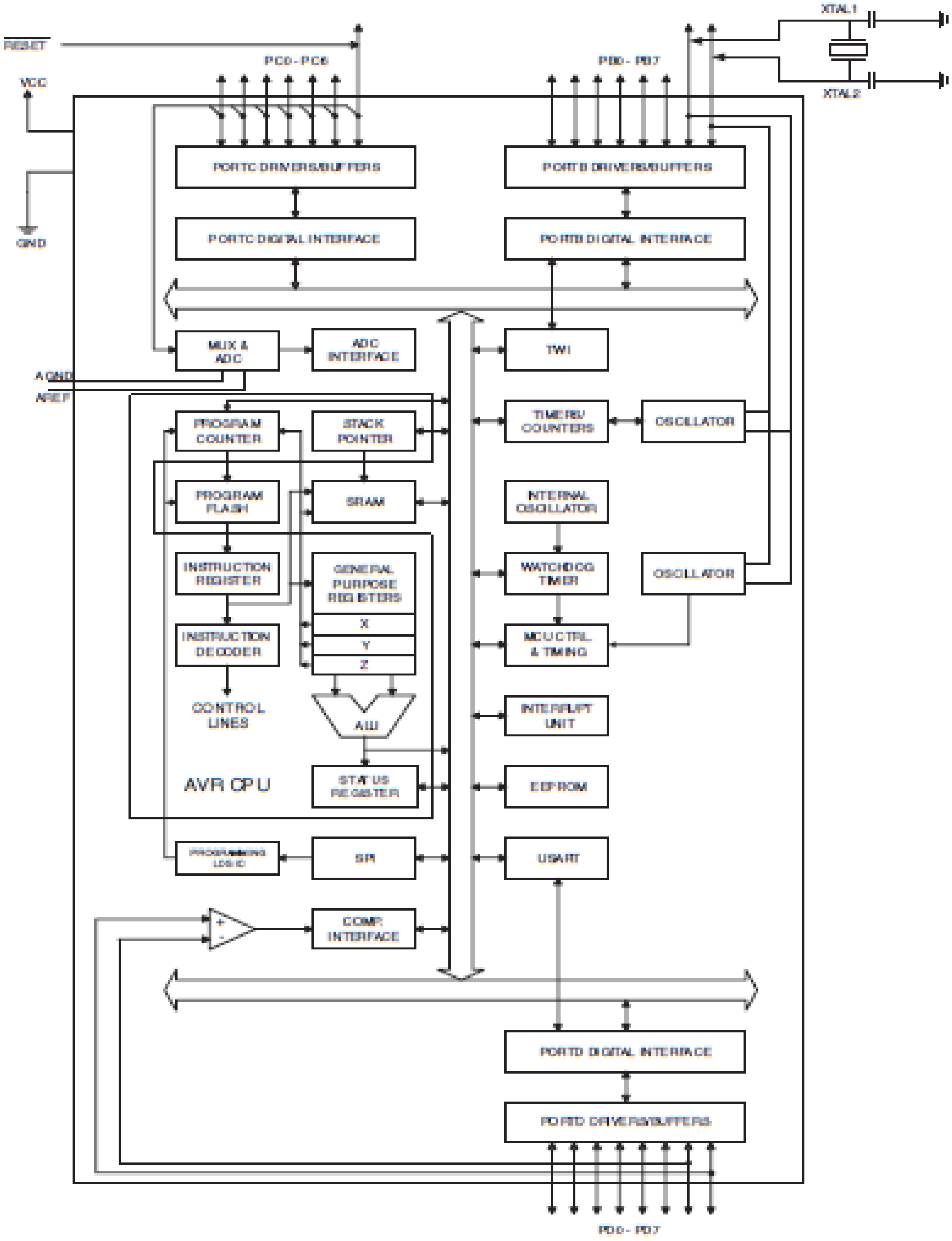
NOTE:
The large center pad underneath the MLF packages is made of metal and internally connected to GND. It should be soldered or glued to the PCB to ensure good mechanical stability. If the center pad is left unconnected, the package might loosen from the PCB.

Overview

The ATmega8 is a low-power CMOS 8-bit microcontroller based on the AVR RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega8 achieves throughputs approaching 1 MIPS per MHz, allowing the system designer to optimize power consumption versus processing speed.

Block Diagram

Figure 1. Block Diagram



National Semiconductor

November 2000

LM35
Precision Centigrade Temperature Sensors

General Description

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a −55° to +150°C temperature range, while the LM35C is rated for a −40° to +110°C range (−10° with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

Features

- Calibrated directly in ° Celsius (Centigrade)
- Linear + 10.0 mV/°C scale factor
- 0.5°C accuracy guaranteeable (at +25°C)
- Rated for full −55° to +150°C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 µA current drain
- Low self-heating, 0.08°C in still air
- Nonlinearity only ±¼°C typical
- Low impedance output, 0.1 Ω for 1 mA load

Typical Applications

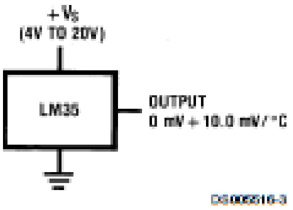
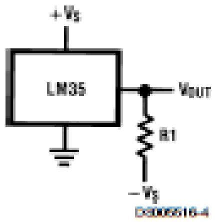


FIGURE 1. Basic Centigrade Temperature Sensor (+2°C to +150°C)

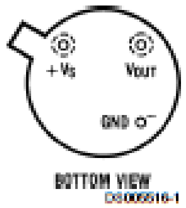


Choose $R_1 = -V_S/50\ \mu A$
V_{OUT}=+1,500 mV at +150°C
= +250 mV at +25°C
= −550 mV at −55°C

FIGURE 2. Full-Range Centigrade Temperature Sensor

Connection Diagrams

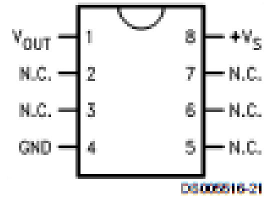
TO-46
Metal Can Package*



*Case is connected to negative pin (GND)

Order Number LM35H, LM35AH, LM35CH, LM35CAH or LM35DH
See NS Package Number H03H

SO-8
Small Outline Molded Package



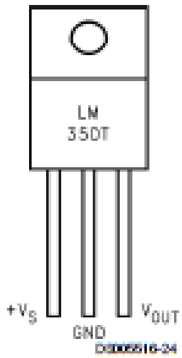
N.C. = No Connection

Top View
Order Number LM35DM
See NS Package Number M08A

TO-92
Plastic Package

Order Number LM35CZ, LM35CAZ or LM35DZ
See NS Package Number Z03A

TO-220
Plastic Package*



*Tab is connected to the negative pin (GND).

Note: The LM35DT pinout is different than the discontinued LM35DP.

Order Number LM35DT
See NS Package Number TA03F

Absolute Maximum Ratings (Note 10)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage	+35V to −0.2V
Output Voltage	+6V to −1.0V
Output Current	10 mA
Storage Temp.;	
TO-46 Package,	−60°C to +180°C
TO-92 Package,	−60°C to +150°C
SO-8 Package,	−65°C to +150°C
TO-220 Package,	−65°C to +150°C
Lead Temp.:	
TO-46 Package, (Soldering, 10 seconds)	300°C
TO-92 and TO-220 Package, (Soldering, 10 seconds)	260°C
SO Package (Note 12)	
Vapor Phase (60 seconds)	215°C
Infrared (15 seconds)	220°C
ESD Susceptibility (Note 11)	2500V
Specified Operating Temperature Range: T_{MIN} to T_{MAX} (Note 2)	
LM35, LM35A	−55°C to +150°C
LM35C, LM35CA	−40°C to +110°C
LM35D	0°C to +100°C

Electrical Characteristics

(Notes 1, 6)

Parameter	Conditions	LM35A			LM35CA			Units
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	(Max.)
Accuracy (Note 7)	T_A=+25°C	±0.2	±0.5		±0.2	±0.5		°C
	T_A=−10°C	±0.3			±0.3		±1.0	°C
	T_A=T_{MAX}	±0.4	±1.0		±0.4	±1.0		°C
	T_A=T_{MIN}	±0.4	±1.0		±0.4		±1.5	°C
Nonlinearity (Note 8)	T_{MIN}≤T_A≤T_{MAX}	**±0.18**		**±0.35**	**±0.15**		**±0.3**	°C
Sensor Gain (Average Slope)	T_{MIN}≤T_A≤T_{MAX}	**+10.0**	**+9.9, +10.1**		**+10.0**		**+9.9, +10.1**	mV/°C
Load Regulation (Note 3) 0≤I_L≤1 mA	T_A=+25°C	±0.4	±1.0		±0.4	±1.0		mV/mA
	T_{MIN}≤T_A≤T_{MAX}	**±0.5**		**±3.0**	**±0.5**		**±3.0**	mV/mA
Line Regulation (Note 3)	T_A=+25°C	±0.01	±0.05		±0.01	±0.05		mV/V
	4V≤V_S≤30V	**±0.02**		**±0.1**	**±0.02**		**±0.1**	mV/V
Quiescent Current (Note 9)	V_S=+5V, +25°C	56	67		56	67		µA
	V_S=+5V	**105**		**131**	**91**		**114**	µA
	V_S=+30V, +25°C	56.2	68		56.2	68		µA
	V_S=+30V	**105.5**		**133**	**91.5**		**116**	µA
Change of Quiescent Current (Note 3)	4V≤V_S≤30V, +25°C	0.2	1.0		0.2	1.0		µA
	4V≤V_S≤30V	**0.5**		**2.0**	**0.5**		**2.0**	µA
Temperature Coefficient of Quiescent Current		**+0.39**		**+0.5**	**+0.39**		**+0.5**	µA/°C
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, I_L=0	+1.5		+2.0	+1.5		+2.0	°C
Long Term Stability	T_J=T_{MAX}, for 1000 hours	±0.08			±0.08			°C

Electrical Characteristics

(Notes 1, 6)

Parameter	Conditions	LM35 Typical	LM35 Tested Limit (Note 4)	LM35 Design Limit (Note 5)	LM35C, LM35D Typical	LM35C, LM35D Tested Limit (Note 4)	LM35C, LM35D Design Limit (Note 5)	Units (Max.)
Accuracy, LM35, LM35C (Note 7)	T_A=+25°C	±0.4	±1.0		±0.4	±1.0		°C
	T_A=−10°C	±0.5			±0.5		±1.5	°C
	$T_A=T_{MAX}$	±0.8	±1.5		±0.8		±1.5	°C
	$T_A=T_{MIN}$	±0.8		±1.5	±0.8		±2.0	°C
Accuracy, LM35D (Note 7)	T_A=+25°C				±0.6	±1.5		°C
	$T_A=T_{MAX}$				±0.9		±2.0	°C
	$T_A=T_{MIN}$				±0.9		±2.0	°C
Nonlinearity (Note 8)	$T_{MIN}\le T_A\le T_{MAX}$	**±0.3**		**±0.5**	**±0.2**		**±0.5**	°C
Sensor Gain (Average Slope)	$T_{MIN}\le T_A\le T_{MAX}$	**+10.0**	**+9.8, +10.2**		**+10.0**		**+9.8, +10.2**	mV/°C
Load Regulation (Note 3) $0\le I_L\le 1$ mA	T_A=+25°C	±0.4	±2.0		±0.4	±2.0		mV/mA
	$T_{MIN}\le T_A\le T_{MAX}$	**±0.5**		**±5.0**	**±0.5**		**±5.0**	mV/mA
Line Regulation (Note 3)	T_A=+25°C	±0.01	±0.1		±0.01	±0.1		mV/V
	$4V\le V_S\le 30V$	**±0.02**		**±0.2**	**±0.02**		**±0.2**	mV/V
Quiescent Current (Note 9)	V_S=+5V, +25°C	56	80		56	80		μA
	V_S=+5V	**105**		**158**	**91**		**138**	μA
	V_S=+30V, +25°C	56.2	82		56.2	82		μA
	V_S=+30V	**105.5**		**161**	**91.5**		**141**	μA
Change of Quiescent Current (Note 3)	$4V\le V_S\le 30V$, +25°C	0.2	2.0		0.2	2.0		μA
	$4V\le V_S\le 30V$	**0.5**		**3.0**	**0.5**		**3.0**	μA
Temperature Coefficient of Quiescent Current		**+0.39**		**+0.7**	**+0.39**		**+0.7**	μA/°C
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, I_L=0	+1.5		+2.0	+1.5		+2.0	°C
Long Term Stability	$T_J=T_{MAX}$, for 1000 hours	±0.08			±0.08			°C

Note 1: Unless otherwise noted, these specifications apply: $-55°C\le T_J\le +150°C$ for the LM35 and LM35A; $-40°\le T_J\le +110°C$ for the LM35C and LM35CA; and $0°\le T_J\le +100°C$ for the LM35D. V_S=+5Vdc and I_{LOAD}=50 μA, in the circuit of *Figure 2*. These specifications also apply from +2°C to T_{MAX} in the circuit of *Figure 1*. Specifications in **boldface** apply over the full rated temperature range.

Note 2: Thermal resistance of the TO-46 package is 400°C/W, junction to ambient, and 24°C/W junction to case. Thermal resistance of the TO-92 package is 180°C/W junction to ambient. Thermal resistance of the small outline molded package is 220°C/W junction to ambient. Thermal resistance of the TO-220 package is 90°C/W junction to ambient. For additional thermal resistance information see table in the Applications section.

Note 3: Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

Note 4: Tested Limits are guaranteed and 100% tested in production.

Note 5: Design Limits are guaranteed (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

Note 6: Specifications in **boldface** apply over the full rated temperature range.

Note 7: Accuracy is defined as the error between the output voltage and 10mv/°C times the device's case temperature, at specified conditions of voltage, current, and temperature (expressed in °C).

Note 8: Nonlinearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the device's rated temperature range.

Note 9: Quiescent current is defined in the circuit of *Figure 1*.

Note 10: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions. See Note 1.

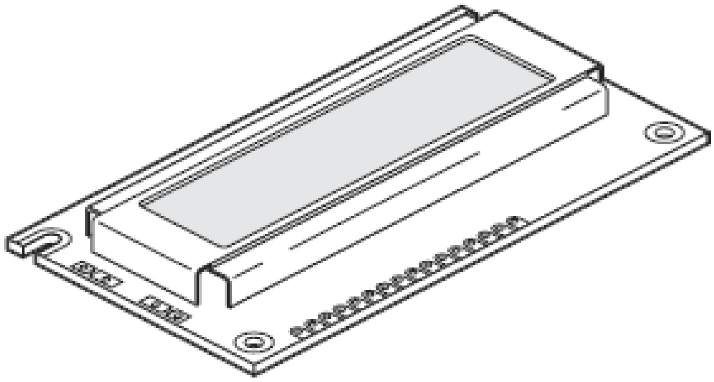
Note 11: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

Note 12: See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" or the section titled "Surface Mount" found in a current National Semiconductor Linear Data Book for other methods of soldering surface mount devices.

Alphanumeric LCD Display (16 x 2)

Order Code

LED008 16 x 2 Alphanumeric Display
FRM010 Serial LCD Firmware (optional)



Contents

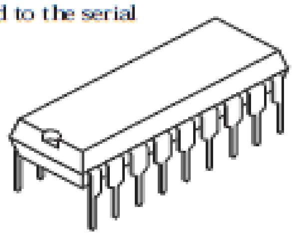
1 x 16x2 Alphanumeric Display
1 x data booklet

Introduction

Alphanumeric displays are used in a wide range of applications, including palmtop computers, word processors, photocopiers, point of sale terminals, medical instruments, cellular phones, etc. The 16 x 2 intelligent alphanumeric dot matrix display is capable of displaying 224 different characters and symbols. A full list of the characters and symbols is printed on pages 7/8 (note these symbols can vary between brand of LCD used). This booklet provides all the technical specifications for connecting the unit, which requires a single power supply (+5V).

Further Information

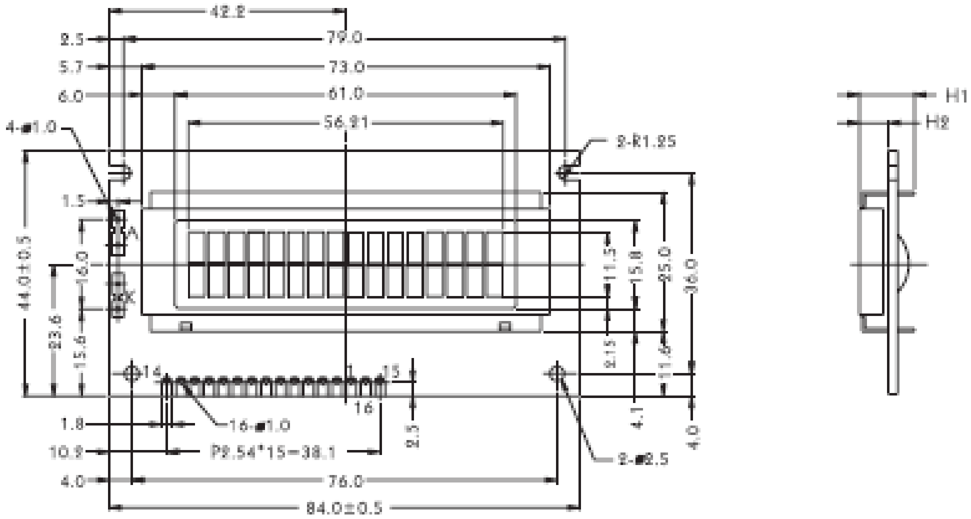
Available as an optional extra is the Serial LCD Firmware, which allows serial control of the display. This option provides much easier connection and use of the LCD module. The firmware enables microcontrollers (and microcontroller based systems such as the PICAXE) to visually output user instructions or readings onto an LCD module. All LCD commands are transmitted serially via a single microcontroller pin. The firmware can also be connected to the serial port of a computer.

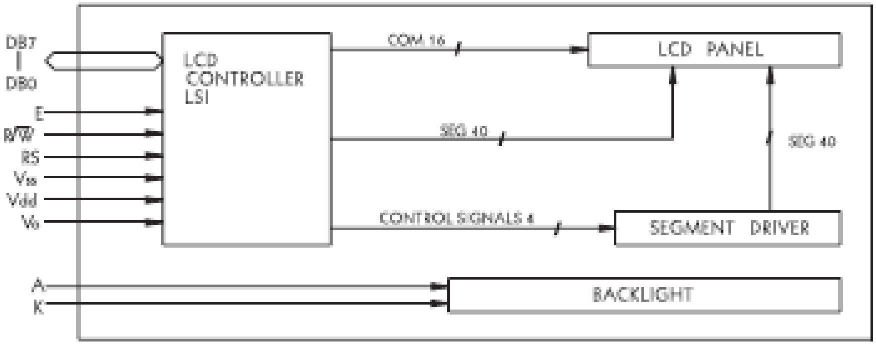


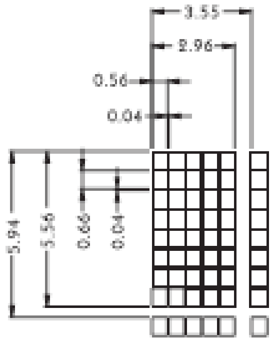
An example PICAXE instruction to print the text 'Hello' using the `serout` command is as follows:

```
serout 7,T2400,("Hello")
```

Outline Dimension and Block Diagram







The tolerance unless classified ±0.3mm

MECHANICAL SPECIFICATION			
Overall Size	84.0 * 44.0	Module	H2 / H1
View Area	61.0 * 15.8	W/O B/L	5.1 / 9.7
Dot Size	0.56 * 0.66	EL B/L	5.1 / 9.7
Dot Pitch	0.60 * 0.70	LED B/L	9.4 / 14.0

PIN ASSIGNMENT

Pin no.	Symbol	Function
1	Vss	Power supply (GND)
2	Vdd	Power supply (+5V)
3	Vo	Contrast Adjust
4	RS	Register select signal
5	R/W	Data read /write
6	E	Enable signal
7	DB0	Data bus line
8	DB1	Data bus line
9	DB2	Data bus line
10	DB3	Data bus line
11	DB4	Data bus line
12	DB5	Data bus line
13	DB6	Data bus line
14	DB7	Data bus line
15	A	Power supply for LED B/L (+)
16	K	Power supply for LED B/L (−)

ABSOLUTE MAXIMUM RATING

Item	Symbol	Conditions	Min.	Max.	Unit
Power Supply Voltage	Vdd−Vss	−	0	7	V
LCD Driving Supply Voltage	Vdd−Vee	−	0	13	V
Input Voltage	Vin	−	−0.3	Vdd+0.3	V
Operating Temperature	Topr	Nor.	0	50	℃
Storage Temperature	Tstg	Nor.	−20	+70	℃

ELECTRICAL CHARACTERISTICS (Vdd =+5V, Ta =25°C)

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
Logic Supply Voltage	Vdd	−	4.5	5	5.5	V
"H" Input Voltage	V_{IH}	−	2.2	−	−	V
"L" Input Voltage	V_{IL}	−	−	−	0.6	V
"H" Output Voltage	V_{OH}	−	2.4	−	−	V
"L" Output Voltage	V_{OL}	−	−	−	0.4	V
Supply Current	Idd	−	2	−	−	mA
LCD Driving Voltage	V_{LCD}	Vdd−Vo	4.3	−	4.8	V

Appendix b

Programming code

```
$regfile "m8def.dat"

$crystal = 1000000

Config PORTD = Output

Config PORTB = Output

Config ADC = Single , Prescaler = Auto , Reference = Avcc

Start ADC

Config Lcd = 16 * 2

Config Lcdpin = Pin , Db4 = PORTD.5 , Db5 = PORTD.6 , Db6 = PORTD.7 , Db7 = PORTB.0 , Rs = PORTB.6 , E = PORTB.7

Dim X As Word , Y As Single , T As Single , B As Single , A As Single

Cls

Do

X = Getadc(5)

Y = X * 5

Y = Y / 1024

T = Y * 100

Locate 1 , 1

Lcd "Temp= " ; T

Waitms 200
```

```
B = 0

A = 0

Do

X = Getadc(5)

Y = X * 5

Y = Y / 1024

T = Y * 100

B = B + T

Incr A

Wait 180

Loop Until A = 5

B = B / 5

Locate 2 , 1

Lcd "Avg= " ; B

Waitms 200

If B > 35.4 AND B < 37.1 Then

PORTD.0 = 1

PORTD.1 = 0

PORTD.2 = 0

End If

If B > 37.1 AND B < 39 Then
```

```
PORTD.0 = 0

PORTD.1 = 1

PORTD.2 = 0

End If

If B > 39 Then

PORTD.1 = 1

Sound PORTD.2 , 500 , 100

End If

If B < 36 Then

PORTD.0 = 0

PORTD.1 = 0

PORTD.2 = 0

 End If


Loop
```