Palestine Polytechnic University

College of Engineering

Electrical Engineering Department

Biomedical Engineering Program

Bachelor Thesis

Graduation Project

Design of a Body Temperature Regulation System

Project Team

Alaa Najjar

Amani Sweity

Wejdan Hroub

Project Supervisor

Dr. Ramzi Qawasma

Hebron – Palestine

2013

Palestine Polytechnic University

Hebron – Palestine

College of Engineering

Electrical Engineering Department

Design of a Body Temperature Regulation System

Project Team

Alaa Najjar

Amani Sweity

Wejdan Hroub

By the guidance of our supervisor, and by the acceptance of all members in the testing committee, this project is delivered to department of electrical engineering in the college of engineering and technology, to be as a partial fulfillment of the requirement of the department for the degree of B.sc.

Supervisor signature

....

Testing committee signature

....

The head of department signature

....

جامعة بوليتكنك فلسطين

الخليل – فلسطين

كلية الهندسة

دائرة الهندسة الكهربائية

Design of a Body Temperature Regulation System

فريق المشروع

آلاء نجار

أماني سويطي

وجدان حروب

بناءا على نظام كلية الهندسة والتكنولوجيا وإشراف ومتابعة المشرف المباشر على المشروع وموافقة أعضاء اللجنة المناقشة، تم تقديم هذا العمل إلى دائرة الهندسة الكهربائية. وذلك للوفاء بمتطلبات درجة البكالوريوس في هندسة الأجهزة الطبية.

توقيع المشرف

....

توقيع اللجنة المناقشة

....

توقيع رئيس اللجنة

....

الإهداء

إلى رموز المحبة والوفاء والعطاء

.........أمهاتنا اللواتي زرعن في نفوسنا حب العلم وسهرن كي يفتخرن بما نحن عليه الآن

إلى رموز التضحية والعطاء

..........آباؤنا الذين قاموا بتربيتنا بأحسن الأخلاق والذين تسري في عروقهم حب الخير للأمة

إلى رفقاء الطفولة وسند الشباب والكهولة

........كل من زملائنا في المدرسة و الجامعة التي تربطنا بهم علاقة المحبة والوفاء والإخلاص.

إلى رفقاء الدرب وظلال الروح الدافئة

..........أحبابنا ورفقاء العمر الذين ساهموا في رفع المعنويات طوال فترة العمل .

إلى كل من زادنا درجة في العلم بتواضع العالم وإخلاص المعلم

........إلى كل من علمنا حرفا(أساتذتنا).

إلى الذين رفضوا أن يكونوا في ذيل القافلة ...إلى الذين أبوا إلا أن يكونوا العنوان...إلى الذين

سخروا من عصا الجلاد وأيقنوا أن الأيام دول بين الناس ...إلى أبناء وأطفال فلسطين الباحثين

عن عالم لا يخلو من الإبداع والتطور والعلم.

آلاء، أماني ، وجدان

Acknowledgments

The project team express their thanks to all those who made this project a reality. Particular thanks go to the biomedical engineering stuff, including

Eng. Nabhan Ebia.

Eng. Ali Amro.

Eng. Shehda Zahda

Eng. Feda Ja'afrah.

And also thanks to

Eng. Ismail Zma'reh.

Amer Zaro

Youssuf Shweiki

Deya'a Qaimari

And specially thanks to **Dr. Ramzi Qawasma**, our graduation project supervisor for his support and good humor and encouragement.

We also thank our colleagues in Biomedical Engineering, "You are fantastic colleagues".

Always, we have had enormous support and understanding from our families and friends and our gratitude for their patience can be fully expressed.

Ala', Amani and Wejdan

This project provides a new system to regulate the temperature of the patient. This system is based on the patient's temperature regulation through the bed mattress by pumping water with appropriate temperature, The natural patient's temperature is used as a reference to the system and being without any medical intervention.

If body temperature less than the reference, the system will send a signal to the heating unit through PIC, which heats the water and then the pump pumps the heated water to the mattress through a special set of tubes.

If the patient's body temperature greater than the reference, the system will send a signal to the cooling unit and pump through PIC, which cools the water and pumps it to the mattress.

ملخص المشروع

هذا المشروع يتمحور حول تصميم نظام يعمل على تنظيم درجة حرارة المريض من خلال فرشة السرير، وباتخاذ درجة حرارة المريض الطبيعية كمرجع للنظام وذلك يجري دون أي تدخل طبي.

إذا انخفضت درجة حرارة جسم المريض فان النظام سوف يستشعر هذا الانخفاض، وبالتالي تصل الإشارة إلى قسم التدفئة الذي يقوم بدوره بتسخين الماء ومن ثم يعمل على ضخ الماء الساخن في الأنابيب الموجودة داخل الفرشة.

أما إذا ارتفعت درجة حرارة جسم المريض فان النظام يقوم باستشعار هذا الارتفاع في درجة حرارة الجسم فيعمل على ارسال إشارة إلى قسم التبريد الذي يقوم بدوره بتبريد الماء ومن ثم يعمل على ضخ الماء البارد في الأنابيب الموجودة داخل الفرشة.

هذا النظام سيبقى على اتصال طويل الأمد مع المريض فذلك يولد تغذية راجعة للنظام، ففي الوقت الذي سوف تعود فيه درجة حرارة المريض إلى معدلها الطبيعي، سوف يتوقف النظام عن ضخ الماء داخل الأنابيب في الفرشة.

Contents

Chapter One: Introduction

Chapter Two: Physiology of the Human Body Temperature

Chapter Three: System Design and Calculations

Chapter Three: System Implementation and Testing.

Chapter Five: Conclusion

List of Figures

List of Tables

CHAPTER ONE

Introduction

1.1Overview

Hyper-Hypothermia System is used to lower or to raise a patient's temperature and/or maintain a desired patient temperature through conductive heat transfer. This unit requires no field adjustments or calibrations in order to maintain the precise board measurement of temperature and temperature limits.

Distilled water is heated or cooled and pumped from the unit to a blanket. The blanket rests under and/or on top of the patient and is designed so that the water circulates through the blanket and returns to the unit.

If water that is at a lower temperature than the patient's temperature is circulated through the blanket, the desired effect is to reduce the patient's temperature. If water that is at a higher temperature than the patient's temperature is circulated through the blanket, the desired effect is to elevate the patient's temperature.

1.2 Project Objectives:

The main objectives of the project are:

1- This device is used primarily in hospital Intensive and Coronary Care Units, in Operating, Recovery and Emergency Rooms, this hyper-hypothermia system can be used with adult and pediatric patients to produce -normothermia by lowering a patient's elevated temperature or raising a patient's sub-normal temperature. It can also be utilized to maintain normal body temperature (normothermia) during surgical procedures.

2- Surgically, this system can be used to produce moderate to profound hypothermia for such procedures as amputations, cardiopulmonary by-pass surgery, vascular surgery, and intracranial surgery.

3- Medically this system can be used to decrease the rate of circulation, to reduce intracranial pressure, to control cerebral edema, and to reduce oxygen requirements.

4- This system is also used in the treatment of burns, shock, cardiac arrest, and gastrointestinal hemorrhage.

1.3 Literature Review:

NICE clinical guideline 65 ('Inadvertent perioperative hypothermia: the management of inadvertent perioperative hypothermia in adults', published April 2008) recommends that each patient undergoing anaesthesia should be assessed for risk of inadvertent perioperative hypothermia, and forced air warming used where indicated to keep patients warm. This medical technology guidance does not supersede the clinical guideline but addresses the case for adoption of the Inditherm patient warming mattress as an alternative to forced air warming.

The Inditherm patient warming mattress (Inditherm plc) uses flexible, carbonbased conductive polymer technology that aims to generate a uniform, direct heating surface. Reusable device that does not require disposable products.

The temperature of the mattress is maintained by a control unit and is user-selectable where appropriate. To prevent over-heating, there is an alarm and an automatic over-temperature shut-off. The control unit can be mounted on an intravenous infusion pole or an anaesthetic trolley.

The mattress polymer is combined with a viscoelastic foam pad which is designed to mould itself to the shape of the patient. The Inditherm mattress can be used on its own, with additional Inditherm blankets or with other warming methods such as forced air warming.

NICE clinical guideline 65 'Inadvertent perioperative hypothermia' recommends forced air warming should be used for all patients undergoing anaesthesia for longer than 30 minutes and for patients at higher risk of inadvertent perioperative hypothermia undergoing anaesthesia for less than 30 minutes.

The Committee concluded that the available clinical and cost evidence supported the case for adopting the Inditherm patient warming mattress in the NHS for patients undergoing operations which carry risk of inadvertent hypothermia.

1.4 Time Plan

Table 1.1: Project Time.

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
Collection of data & analysis																
Calculations																
Writing the documentation																
Build Project																
Delivery of the project.																

1.5 Project Cost

Table 1.2: Project Cost

Component	Cost
Equipments(Condenser ,valves, pumps, pipelines)	600 JD
PIC Microcontroller, AD620, resistors.	50 JD
Cooler/Heater	500 JD
Total	1150 JD

1.6 Project Contents

Chapter One: Introduction.

Chapter Two: Physiological Background.

Chapter Three: Schematic diagram and calculations.

Chapter Four: System Implementation and Testing.

Chapter Five: Conclusion.

Physiology of the Human Body Temperature

2.1 Normal human body temperature

Normal human body temperature, also known as normothermia or euthermia, is a concept that depends upon the place in the body at which the measurement is made, and the time of day and level of activity of the person. There is no single number that represents a normal or healthy temperature for all people under all circumstances using any place of measurement.

Different parts of the body have different temperatures. Rectal and vaginal measurements, or measurements taken directly inside the body cavity, are typically slightly higher than oral measurements, and oral measurements are somewhat higher than skin temperature. The commonly accepted average core body temperature (taken internally) is 37.0 °C. The typical oral (under the tongue) measurement is slightly cooler, at 36.8 ± 0.7 °C. Although some people think of these numbers as representing the normal temperature, a wide range of temperatures has been found in healthy people. In samples of normal adult men and women, the observed range for oral temperature is 33.2–38.2 °C, for rectal it is 34.4–37.8 °C, for the tympanic cavity it is 35.4–37.8 °C and for axillary it is 35.5–37.0 °C.

The time of day and other circumstances also affects 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.

2.2 Natural rhythms

Body temperature normally fluctuates over the day, with the lowest levels around 4 a.m. and the highest in the late afternoon, between 4:00 and 6:00 p.m. (assuming the person sleeps at night and stays awake during the day). Therefore, an oral temperature of 37.2 °C would, strictly speaking, be normal in the afternoon but not in the morning. An individual's body temperature typically changes by about 0.5 °C between its highest and lowest points each day.

Body temperature is sensitive to many hormones, so women have a temperature rhythm that varies with the menstrual cycle, called a circamensal rhythm. A woman's basal body temperature rises sharply after ovulation, as estrogen production decreases and progesterone increases. Fertility awareness programs use this predictable change to identify when a woman is able to become pregnant. During the luteal phase of the menstrual cycle, both the lowest and the average temperatures are slightly higher than during other parts of the cycle. However, the amount that the temperature rises during each day is slightly lower than typical, so the highest temperature of the day is not very much higher than usual. Hormonal contraceptives both suppress the circamensal rhythm and raise the typical body temperature by about 0.6 °C.

Temperature also varies with the change of seasons during each year. This pattern is called a circannual rhythm. Studies of seasonal variations have produced inconsistent results. People living in different climates may have different seasonal patterns.

Increased physical fitness increases the amount of daily variation in temperature. Table 2.1 shows different human body temperature measured from various regions for different categories of people. With increased age, both average body temperature and the amount of daily variability in the body temperature tend to decrease. Elderly patients may have a decreased ability to generate body heat during a fever, so even a somewhat elevated temperature can indicate a serious underlying cause in geriatrics.

Table 2.1: Normal body temperature ranges [9]

°C	0-2 years	3-10 years	11-65 years	>65 years
Oral	——	35.3 — 37.5	36.4 —37.5	35.8 — 37.9
Rectal	36.6 — 38	36.6 — 38	37— 38.1	36.2 — 37.3
Axillary	34.7 — 37.3	35.9 — 36.7	35.2 — 6.9	35.5 — 36.3
Ear	36.4 — 38	36.1 — 37.7	35.9 — 37.6	35.8 — 37.5
Core	36.4 — 37.8	36.4 — 37.7	36.8 — 37.9	35.9 — 37.1

2.3 Variations due to measurement methods

Different methods used for measuring temperature produce different results. Generally, oral, rectal, gut, and core body temperatures, although slightly different, are well-correlated, with oral temperature being the lowest of the four.

Oral temperatures are influenced by drinking, chewing, smoking, and breathing with the mouth open. Cold drinks or food reduce oral temperatures; hot drinks, hot food, chewing, and smoking raise oral temperatures. Axillary (armpit), tympanic (ear), and other skin-based temperatures correlate relatively poorly with core body temperature. Tympanic measurements run higher than rectal and core body measurements and axillary temperatures run lower. The body uses the skin as a tool to increase or decrease core body temperature, which affects the temperature of the skin. Skin-based temperatures are more variable than other measurement sites.

The peak daily temperature for axillary measurements lags about three hours behind the rest of the body. Skin Temperatures are also more influenced by outside factors, such as clothing and air temperature.

2.4 Variations due to outside factors

Many outside factors affect the measured temperature as well. "Normal" values are generally given for an otherwise healthy, non-fasting adult, dressed comfortably, indoors, in a room that is kept at a normal room temperature (22.7 to 24.4 °C), during the morning, but not shortly after arising from sleep. Furthermore, for oral temperatures, the subject must not have eaten, drunk, or smoked anything in at least the previous fifteen to twenty minutes, as the temperature of the food, drink, or smoke can dramatically affect the reading.

Temperature is increased after eating or drinking anything with calories. Caloric restriction, as for a weight-loss diet, reduces overall body temperature. Drinking alcohol reduces the amount of daily change, slightly lowering daytime temperatures and noticeably raising nighttime temperatures.

Exercise raises body temperatures. In adults, a noticeable increase usually requires strenuous exercise or exercise sustained over a significant time. Children develop higher temperatures with milder activities, like playing.

Psychological factors also influence body temperature: a very excited person often has an elevated temperature.

Wearing more clothing slows daily temperature changes and raises body temperature. Similarly, sleeping with an electric blanket raises the body temperature at night. Sleep disturbances also affect temperatures. Normally, body temperature drops significantly at a person's normal bedtime and throughout the night. Short-term sleep deprivation produces a higher temperature at night than normal, but long-term sleep deprivation appears to reduce temperatures. Insomnia and poor sleep quality are associated with smaller and later drops in body temperature. Similarly, waking up unusually early, sleeping in, jet lag and changes to shift work schedules may affect body temperature.

2.5 Specific temperature concepts

2.5.1 Fever

A temperature set point is the level at which the body attempts to maintain its temperature. When the set point is raised, the result is a fever. Most fevers are caused by infectious disease and can be lowered, if desired, with antipyretic medications.

An organism at optimum temperature is considered a febrile or a pyrexic, meaning "without fever". If temperature is raised, but the set point is not raised, then the result is hyperthermia.

2.5.2 Hyperthermia

Hyperthermia occurs when the body produces or absorbs more heat than it can dissipate. It is usually caused by prolonged exposure to high temperatures. The heat-regulating mechanisms of the body eventually become overwhelmed and unable to deal effectively with the heat, causing the body temperature to climb uncontrollably. Hyperthermia at or above about 40 °C (104 °F) is a life-threatening medical emergency that requires immediate treatment.

In a medical setting, mild hyperthermia is commonly called heat exhaustion or heat prostration; severe hyperthermia is called heat stroke. Heat stroke may come on suddenly, but it usually follows the untreated milder stage.

With fever, the body's core temperature rises to a higher temperature through the action of the part of the brain that controls the body temperature; with hyperthermia, the body temperature is raised without the consent of the heat control centers.

❖ **The causes of hyperthermia**

Hyperthermia, usually resulting from infection, certain drugs and medications, or head injury. Hyperthermia is sometimes created intentionally to treat diseases, especially some cancers.

❖ **The risk factors for hyperthermia**

- **Age:** Children under 5 years of age and older adults are at the greatest risk for and hyperthermia.
- **Genetic factors**: How well your body is able to withstand high temperatures. If, for example, your parents or grandparents have had difficulty with heat-related illnesses, that tendency may have been passed on to you.

- **Medications:** Such as beta-blockers, diuretics, anti-psychotics and vasoconstrictors may make the patient more prone to hyperthermia.

- **Diseases:** Heart, lung and kidney diseases, as well as any illness that causes general weakness or fever high blood pressure .

Lifestyle factors that can increase risk are:

- Unbearably hot living quarters.
- Transportation: Lack of transportation which prevents people from seeking respite from the heat in shopping malls, movie houses, and libraries.
- Overdressing: Older people may not dress appropriately in hot weather.
- Not understanding weather conditions: Older persons at risk should stay indoors on especially hot days.

Other factors include being substantially overweight or underweight, and drinking alcoholic beverages.

❖ The signs and symptoms of hyperthermia

Heat stress: occurs when a strain is placed on the body as a result of hot weather.

Heat fatigue: is a feeling of weakness brought on by high outdoor temperature. Symptoms include cool, moist skin and a weakened pulse. The person may feel faint.

Heat syncope: is a sudden dizziness experienced after exercising in the heat. The skin appears pale and sweaty but is generally moist and cool. The pulse is weakened and the heart rate is usually rapid.

Heat cramps: are painful muscle spasms in the abdomen, arms or legs. Heat cramps are caused by a lack of salt in the body.

Heat exhaustion: is a warning that the body is getting too hot. The person may be thirsty, giddy, weak, uncoordinated, nauseated and sweating profusely. The body temperature is normal and the pulse is normal or raised. The skin is cold and clammy.

Heat stroke: can be life-threatening and victims can die. A person with heat stroke usually has a body temperature above 104 degrees Fahrenheit. Other symptoms include confusion, combativeness, bizarre behavior, faintness, staggering, strong and rapid pulse, and possible delirium or coma. High body temperature is capable of producing irreversible brain damage.

❖ Treatments and drugs

If the victim is exhibiting signs of heat stroke, emergency assistance should be sought immediately. Without medical attention, heat stroke can be deadly.

- **First-aid care**

- Move the patient from hot to cool area.
- Shower the patient with cool water.
- Do not give the patient anything to eat or drink.
- Constantly keep a check on breathing and heart beat of the patient with the help of ABC test.
- Cold compressions are available which can be very useful in lowering the temperatures.
- Medications to reduce temperature shouldn't be given to the patient as it can further harm.
- If the casualty is unconscious than reduce the body temperature do not give a bath or else give it carefully.
- Continue the first aid treatment until the medical emergency is available.

- **Medical treatment**

Dantrium is used for treating Treating episodes of severe high body temperature. It is also used to prevent or reduce the risk of severe high body temperature in certain patients before or after surgery or anesthesia. It may also be used for other conditions as determined by your doctor.

Dantrium is a muscle relaxant. It works by restoring a normal level of calcium in the muscles, which helps to prevent or reduce severe high body temperature.

Do NOT use Dantrium if you are allergic to any ingredient in Dantrium.

2.5.3 Hypothermia

In humans, this is usually due to excessive exposure to cold air or water, but it can be deliberately induced as a medical treatment. Symptoms usually appear when the body's core temperature drops by 1-2 °C below normal temperature.

- **The causes of hypothermia**

Hypothermia most often occurs because of prolonged exposure to cold weather. Inadequate clothing for conditions may not provide enough insulation for the body to prevent heat loss.

Heat is lost more quickly in water than on land, and just a few minutes in cold water may be fatal , a water temperature of 10 °C (50 °F) often leads to death in one hour, and water temperatures hovering at freezing can lead to death in as little as 15 minutes. Water at a temperature of 26 °C (79 °F) after prolonged exposure, will lead to hypothermia.

Other causes of hypothermia include metabolic disorders like dysfunction of the thyroid, adrenal, or pituitary glands.

❖ The risk factors for hypothermia

There are numerous factors that increase the risk of hypothermia:

- **Age:** The very young and very old may be less able to generate heat. The elderly with underlying medical conditions such as hypothyroidism or Parkinson's disease that limit the ability of the body to regulate temperature. Infants with their relatively large head size compared to the body, they are at risk for increased heat loss by radiation.

- **Mental status:** Impaired judgment and mental function can lead to cold exposure. For example, Patients with Alzheimer's disease .

- **Substance abuse:** Alcohol and drug abuse increase the risk of hypothermia in two ways. First, impaired judgment can lead to cold exposure. Additionally, alcohol and similar drugs can dilate blood vessels near the skin, both of which decrease the body's ability to compensate for cold exposure.

- **Medical conditions:** Medical conditions can also lead to accidental hypothermia:

    1. Patients with hormonal abnormalities (thyroid, adrenal, pituitary) may be less able to feel the cold and generate a shivering response.
    2. Patients with spinal cord injuries, may not be able to adequately shiver.
    3. Patients who have suffered strokes or brain tumors may have impaired thermal regulation centers in the brain.
    4. People with diabetes who have very low blood sugar can appear unconscious and very cold.

- **Medications:** Limiting the shivering mechanism by some psychiatric medications , can increase the risk of hypothermia .

❖ The signs and symptoms of hypothermia

The body starts to slow as the temperature drops. Aside from the cold that is felt and the shivering that may occur, mental function is most affected initially, and since it affects thinking.

- Initial hunger and nausea will give way to apathy as the core body temperature drops.
- This is followed by confusion, lethargy, slurred speech, loss of consciousness, and coma.
- Often the affected person will lie down, fall asleep, and die.

The decrease in brain function occurs in direct relationship to the decrease in body temperature (the colder the body, the less the brain function). Brain function stops at temperature of 20 C (68 F).

Ventricular fibrillation, a disorganized rhythm in which the heart is unable to pump, may occur at core temperatures below 28 C (82.4 F). This is one type of cardiac arrest.

Table 2.2 shows the sign and symptoms of hypothermia.

Table 2.2: Hypothermia Symptoms by Body Temperature

Celsius	Description	Symptoms
37	No hypothermia	No hypothermia
Below 35	Definition of hypothermia	N/A
32 to 35	Mild hypothermia	Shivering Lethargy, apathy, confusion Rapid heart rate
28 to 32	Moderate hypothermia	Shivering stops Increased confusion or delirium Slowing heart rate; may be come irregular
Below 28	Severe hypothermia	Coma Ventricular fibrillation May appear deceased
20		Brain activity stops

- **Treatments and drugs:**

Seek immediate medical attention for anyone who appears to have hypothermia. Until medical help is available, follow these hypothermia treatment guidelines.

- **First-aid care**

- Move the person out of the cold to a warm, dry location if possible.
- Cut away wet clothing if necessary to avoid excessive movement.
- Cover the person with blankets , Cover the person's head, leaving only the face exposed.
- If the person's breathing has stopped or appears dangerously low or shallow, begin cardiopulmonary resuscitation (CPR) immediately if you're trained.
- Use a first-aid warm compress. Don't apply a warm compress to the arms or legs. Heat applied to the arms and legs forces cold blood back toward the heart. This can be fatal.
- Don't apply direct hot water to warm the person. The extreme heat cause irregular heartbeats so severe that they can cause the heart to stop.

- **Medical treatment**

Depending on the severity of hypothermia, emergency medical care for hypothermia may include one of following interventions to raise the body temperature:

- **Blood rewarming:** a common method of warming blood is the use of a hemodialysis machine. Blood may be drawn, warmed and recirculated in the body.
- **Warm intravenous fluids:** a warmed intravenous solution may be injected into a vein to help warm the blood.
- **Airway rewarming:** the use of humidified oxygen administered with a mask or nasal tube can warm the airways and help raise the temperature of the body.

2.5.4 Basal body temperature:

Basal body temperature is the lowest temperature attained by the body during rest (usually during sleep). It is generally measured immediately after awakening and before any physical activity has been undertaken, although the temperature measured at that time is somewhat higher than the true basal body temperature. In women, temperature differs at various points in the menstrual cycle, and this can be used for family planning.

Why is temperature control important?

Over the course of a year, or even over a single 24-hour period, environmental temperatures may vary considerably. Controlling the body temperature between narrow limits enables an organism to be independent of these fluctuations in environmental temperature. Enzymes are very sensitive to changes in temperature. In figure 2.1 the graph shows the effect of temperature on three different reactions in a mammal. These are controlled by enzymes. If the body temperature fell to, say, 20°C, the rates of reaction of these enzymes would be too slow to maintain the organism's metabolism. If the body temperature rose above 45°C, there would also be serious consequences for the animal. Some enzymes would be denatured but there is another problem as well. As can be seen on the graph, each enzyme is affected to a different extent by a rise in temperature. Such a rise could therefore upset the overall balance of metabolic reactions in the body.

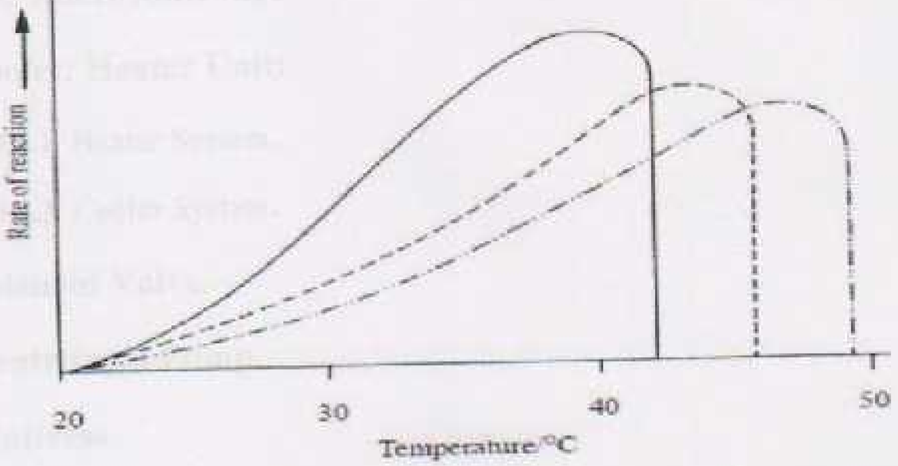


Fig 2.1: Temperature affects different enzymes in different way

Chapter Three

System Design and Calculations

3.1 Schematic Block Diagram.

3.2 Body Temperature Sensor.

3.3 Processing:

- **3.3.1 Wheatstone Bridge.**
- **3.3.2 Instrumentation Amplifier.**

3.4 PIC Microcontroller

3.5 Cooler/ Heater Unit:

- **4.5.1 Heater System.**
- **4.5.2 Cooler System.**

3.6 Solenoid Valve.

3.7 Centrifugal Pump.

3.8 Mattress.

3.9 Water Tank

3.10 Power Supply.

3.11 Switches.

3.1 Schematic Block Diagram:

- Block Diagram for a Design a body temperature regulation system

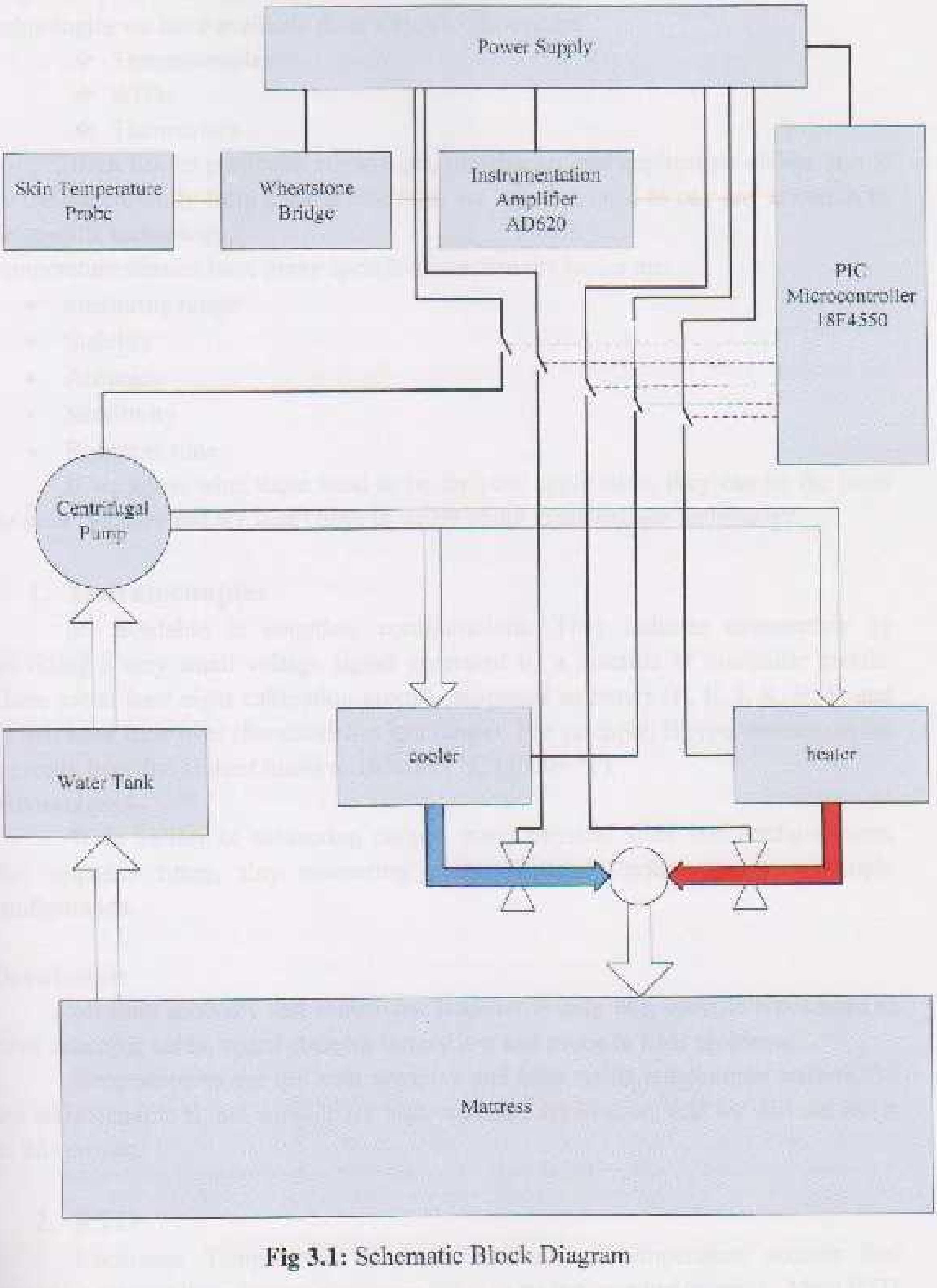


Fig 3.1: Schematic Block Diagram

3.2 Body Temperature Sensor:

One of the potentially challenging choices we may have to face is selecting a temperature measuring device. Like many things in the process industries, we have a range of options and there are tradeoffs that you need to balance. The three main technologies we have available from which to choose are

- ❖ Thermocouples
- ❖ RTDs
- ❖ Thermistors .

Each has its particular advantages, drawbacks, and application niches. But if we choose carefully from current offerings, we may not need to pay any attention to the specific technology.

Temperature sensors have many specifications, but the basics are:

- measuring range
- Stability
- Accuracy
- Sensitivity
- Response time.

If we know what these need to be for your application, they can be the basis for your decision and we won't have to worry about measurement technology.

1. Thermocouples

are available in countless configurations. They indicate temperature by providing a very small voltage signal generated by a junction of dissimilar metals. There are at least eight calibration groups, expressed as letters (B, E, J, K, R, S, and T) that have their own characteristics and ranges. For example, B type thermocouples typically have the highest limits at 1648.89+ °C (3000+ °F).

Advantages:-

Wide variety of measuring ranges, many physical sizes and configurations, fast response times, tiny measuring point, moderate price, and very simple configuration.

Drawbacks:

Medium accuracy and sensitivity, linearity is only fair, specific types have to have matching cable, signal strength is very low and prone to EMI problems.

thermocouples are the least sensitive and least stable temperature sensors, So the thermocouple is not suitable for high-accuracy application, and we will not use it in this project.

2. RTD

Resistance Temperature Detectors (RTDs) are temperature sensors that contain a resistor that changes resistance value as its temperature changes. Most RTD elements consist of a length of fine coiled wire wrapped around a ceramic or glass core. The element is usually quite fragile, so it is often placed inside a sheathed probe to protect it. The RTD element is made from a pure material whose resistance at various temperatures has been documented. The material has a predictable change in resistance as the temperature changes; it is this predictable change that is used to determine temperature.

RTDs have characteristics that compare well against thermocouples:

More stable, more accurate ,greater repeatability, better sensitivity and linearity, it is the most accurate and stable temperature sensor and is more linear than a thermocouple or thermistor.

Other RTD attributes don't compare as well against thermocouples:

Narrower measuring range, particularly at the high end, more expensive, require an external power source, slower response time, and at some temperatures, the reference voltage can actually heat the sensor and throw it off.

It fit precision applications where accuracy is critical while speed and cost are less important.

3. Thermistors

act in much the same way as RTDs, but use a semiconductor device to change resistance rather than a metallic element.

Advantages:-

Thermistors exhibit by far the largest parameter change with temperature and are the most sensitive temperature sensor, thermistors are also very small and respond quickly to temperatures changes.

Drawbacks:

The thermistors are an extremely non-linear device, are more expensive than thermocouples They also have smaller temperature ranges than thermocouples.

So what sensor is better?

It depends. Thermistors cost less than RTDs. Thermistors measure temperature to the same or better accuracies than RTDs. Thermistors do not need the extra cost of transmitters. RTDs have a much larger temperature measurement range than thermistors. Transmitters add at least $100 to the cost of an RTD

Based on the above. Finally, in this project we use the thermistor because it is the best of the all to use in measuring the value of the body temperature.

In this project we will use the skin temperature sensor LA003:

• Single patient use. Use for the length of stay of each infant. Cost-effective.

• 2 connector styles: Designed to fit Ohmeda or Air-Shields brands of warmers and incubators.

• Light weight medical grade wire: Lighter, more flexible than reusable probes.

• Molded construction and strain relief : High quality construction resists breakage.

•NeoGuard Reflectors: Each probe is packaged with a reflector.

Normal temperature ranges on the chest vary from 36.5°C to 37.5°C.

3.3 Processing:

3.3.1 Wheatstone Bridge.

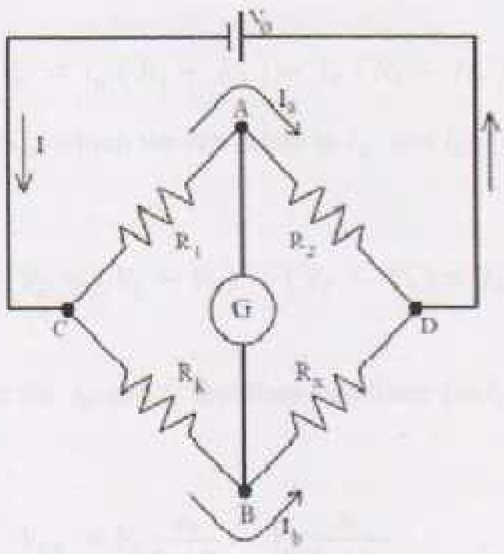


Fig 3.2: Schematic of a Wheatstone Bridge

The Wheatstone bridge is a very useful circuit. When the bridge is fully balanced, the right side resistors identical to the left side resistors (R1=R2, and R_k=R_x), the voltage across the bridge is zero.

R_x is the resistance of the thermistor. Change in temperature causes the thermistor's resistance to change accordingly. The relationship between this thermistor's resistance and temperature is non-linear. To measure this change in resistance, the circuit above is used. Four resistors are used in this configuration, one of them being the thermistor. When the thermistor's resistance changes due to change in temperature, the output voltage will change. The advantage of using a Wheatstone bridge is that it accurately measures small changes in resistances and produces a voltage output. This voltage output is sent to the instrumentation amplifier.

Since $V_{AB} = 0$, the voltage drop from C to A must equal the voltage drop from C to B, $V_{CA} = V_{CB}$. Likewise, we must have $V_{AD} = V_{BD}$. So we can write,

$$I_a R_1 = I_b R_k \qquad \dots (1)$$

$$I_a R_2 = I_b R_x \qquad \dots (2)$$

Dividing (2) by (1), we have

$$\frac{R_2}{R_1} = \frac{R_X}{R_K} \quad , \quad R_X = R_K \frac{R_2}{R_1} \dots (3)$$

Applying Kirchhoff's Voltage Law and Ohm's Law to the upper and lower arms of the bridge, we have

$$V_o = I_a (R_1 + R_2) = I_b (R_k + R_x) \qquad \dots (4)$$

We are trying to find V_{AB}, which we can relate to I_a and I_b.

$$V_{AB} = V_A - V_B = (V_C - V_B) - (V_C - V_A) = I_b R_k - I_a R_1 \qquad \dots (5)$$

We can use (4) to solve for I_a and I_b and then substitute for I_a and I_b in (5),

$$V_{AB} = V_o \frac{R_k}{R_k + R_x} - V_o \frac{R_1}{R_1 + R_2} \qquad \dots (6)$$

$$V_{AB} = V_o \left(\frac{R_k}{R_k + R_x} - \frac{R_1}{R_1 + R_2}\right) \qquad \dots (7)$$

3.3.2 Instrumentation Amplifier:

The instrumentation amplifier is a type of differential amplifier that has been outfitted with input buffers, which eliminate the need for input impedance matching and make the amplifier particularly suitable for use in test equipments.

2.5.5 Core temperature:

Core temperature, also called **core body temperature**, is the operating temperature of an organism, specifically in deep structures of the body such as the liver, in comparison to temperatures of peripheral tissues. Core temperature is normally maintained within a narrow range so that essential enzymatic reactions can occur. Significant core temperature elevation (hyperthermia) or depression (hypothermia) that is prolonged for more than a brief period of time is incompatible with human life.

Temperature examination in the rectum is the traditional gold standard measurement used to estimate core temperature (oral temperature is affected by hot or cold drinks and mouth-breathing). Rectal temperature is expected to be approximately one Fahrenheit degree higher than an oral temperature taken on the same person at the same time. Ear thermometers measure eardrum temperature using infrared sensors. The blood supply to the tympanic membrane is shared with the brain. However, this method of measuring body temperature is not as accurate as rectal measurement and has a low sensitivity for fevers, missing three or four out of every ten fevers in children. Ear temperature measurement may be acceptable for observing trends in body temperature but is less useful in consistently identifying fevers.

Until recently, direct measurement of core body temperature required surgical insertion of a probe, so a variety of indirect methods have commonly been used. While the rectal or vaginal temperature is generally considered to give Normal human body temperature 5 the most accurate assessment of core body temperature, particularly in hypothermia, its recording is disliked by patients and medical staff alike. In the early 2000s, ingestible thermistors in capsule form were produced, allowing the temperature inside the digestive tract to be transmitted to an external receiver; one study found that these were comparable in accuracy to rectal temperature measurement.

2.6 The Control of Body Temperature

There may be as many as 2000 different chemical reactions taking place inside a single living cell. Each of these is controlled by an enzyme and enzymes are very sensitive to changes in temperature. A constant internal temperature is an advantage because it may prevent fluctuations in the rates of these reactions. Body temperatures of most mammals change very little but many other organisms can also control their internal temperatures to some extent. Mammals and birds rely on complex physiological mechanisms; other animals such as reptiles and insects rely mainly on behavior.

An instrumentation amplifier is a closed-loop gain block that has a differential input and single-ended output. An instrumentation amplifier employs an internal feedback resistor network that is isolated from its signal input terminals. With the input signal applied across the two differential inputs, gain is either preset internally or is user set (via pins) by a gain resistor.

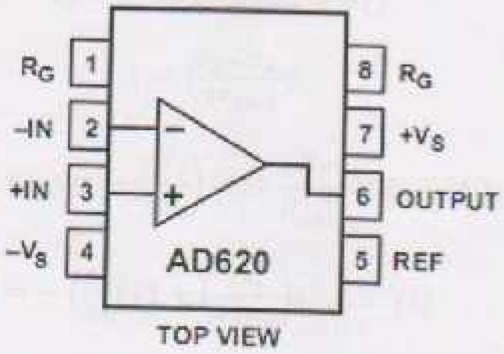


Fig 3.3: IC AD620.

Characteristics of instrumentation amplifier AD620 as shown in figure 3.3:

- Very low DC offset
- Low drift
- Low noise
- Very high open-loop gain
- Very high common-mode rejection ratio
- Very high input impedance.

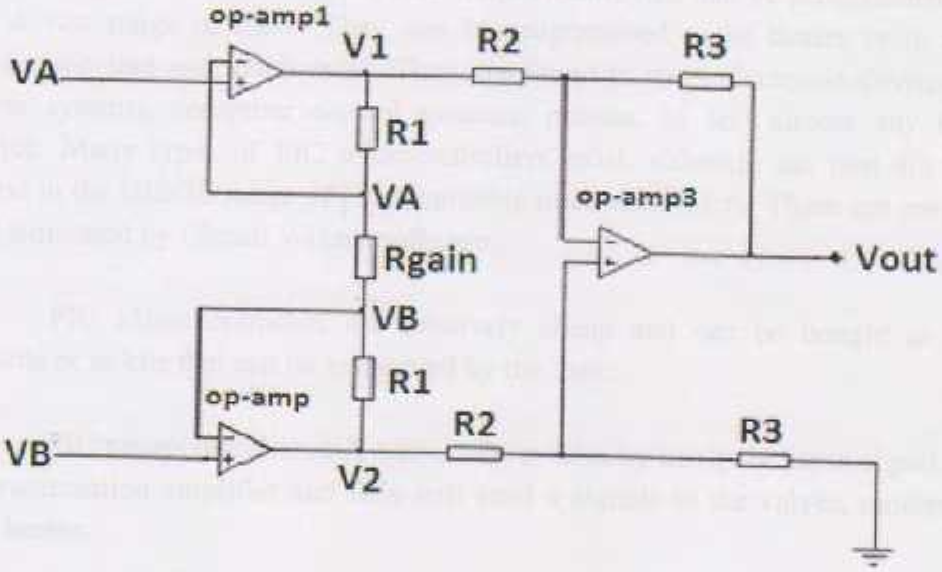


Fig3.4: The equivalent circuit for instrumentation amplifier.

$$V_{out} = -\left(\frac{R_3}{R_2}\right)(V_2 - V_1) \quad \dots (1)$$

$$V_2 - iR_1 - i\left(2R_{gain}\right) - iR_1 = V_1$$

$$V_2 - V_1 = 2i(R_{gain} + R_1)$$

$$i = \left(\frac{V_B - V_A}{2R_{gain}}\right)$$

$$V_{out} = -\left(\frac{R_3}{R_4}\right)\left(1 + \frac{R_1}{R_{gain}}\right)(V_B - V_A)$$

So $$G = -\left(\frac{R_3}{R_2}\right)\left(1 + \left(\frac{2R_1}{R_{gain}}\right)\right) \quad \dots\dots (2)$$

From data sheet of AD620:

$$G = \frac{49.4k}{R_{gain}} + 1 \quad \dots\dots\dots\dots\dots\dots\dots\dots (3)$$

3.4 PIC Microcontroller:

PIC controllers are a family of small risc controllers used in embedded applications. PIC controllers are produced by the company "Microchip".

PIC microcontrollers, are electronic circuits that can be programmed to carry out a vast range of tasks. They can be programmed to be timers or to control a production line and much more. They are found in most electronic devices such as alarm systems, computer control systems, phones, in fact almost any electronic device. Many types of PIC microcontrollers exist, although the best are probably found in the GENIE range of programmable microcontrollers. These are programmed and simulated by Circuit Wizard software.

PIC Microcontrollers are relatively cheap and can be bought as pre-built circuits or as kits that can be assembled by the user.

PIC microcontroller will control the system by using the input signal from the instrumentation amplifier and then will send a signals to the valves, motors, cooler, and heater.

PIC18F4550

Ideal for low power (nanoWatt) and connectivity applications that benefit from the availability of three serial ports. Large amounts of RAM memory for buffering and Enhanced Flash program memory make it ideal for embedded control and monitoring applications that require periodic connection with a (legacy free) personal computer via USB for data upload/download and/or firmware updates. Figure 3.5 shows the pins of PIC18F4550.

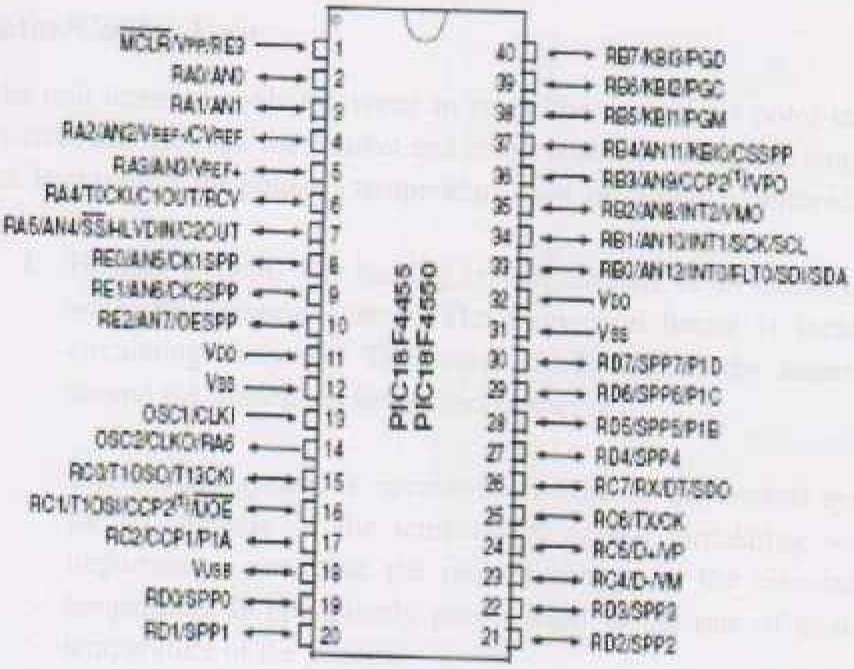


Fig ٣.5: Pins out of PIC18F4550

A microcontroller (also microcomputer, MCU or µC) is a small computer on a single integrated circuit consisting internally of a relatively simple CPU, clock, timer, I/O ports, and memory.

Microcontrollers are designed for small or dedicated applications. Thus, in contrast to the microprocessor used in personal computers and other high-performance or general purpose applications, simplicity is emphasized.

Some microcontrollers may use four-bit words and operate at clock rate frequencies as low as 4 KHz, as this is adequate for many typical applications, enabling low power consumption (mill Watts).

Choosing the PIC18F4550 type of microcontroller for following reasons:

1. 32768-bytes-program memory. This represents enough memory to perform the project.
2. 13 input channels, 10 bit analog-to-digital module that convert analog signal to digital.
3. Availability of PIC programming in the university.
4. Cheap.

3.5 Heater/Cooler Unit

The unit heats or cools the water to reach the desired set point temperature. The water circulates through the blanket and either raises or lowers the temperature of the patient. In this case, the patient's temperature must be closely monitored.

1. Heating System: The heating system consists of an immersion heater, water temperature control. The immersion heater is located in the circulating reservoir. The water circulating in the reservoir flows around the immersion heater and is warmed.

   The heating system is operational whenever the control system calls for an increase in the temperature of the circulating water. It is important to note that the rate of change in the circulating water temperature is not directly proportional to the rate of change in the temperature of the patient.

2. **Cooling System:** The cooling system is composed of a compressor, condenser, condenser fan, an evaporator coil, water temperature control, solenoid valve, hot gas by-pass valve, and two low temperature safety devices.

   The refrigerant of the cooling system flows through the evaporator coil located in the circulating reservoir. The water circulating in the reservoir flows over the evaporator coil and is cooled.

   The cooling system is operational whenever the control system calls for a decrease in the temperature of the circulating water. It is important to note that the rate of change in the circulating water temperature is not directly proportional to the rate of change in the temperature of the patient.

3.5.1 Heater System:

Electric water heaters supply hot water , that is usually consists of a tank, thermostats, two electric resistance elements (which are submerged inside the tank), and inlet and outlet pipes for cold and hot water. Internal thermostats regulate the temperature of the water. Fig 3.6 depicts the electrical water heater.

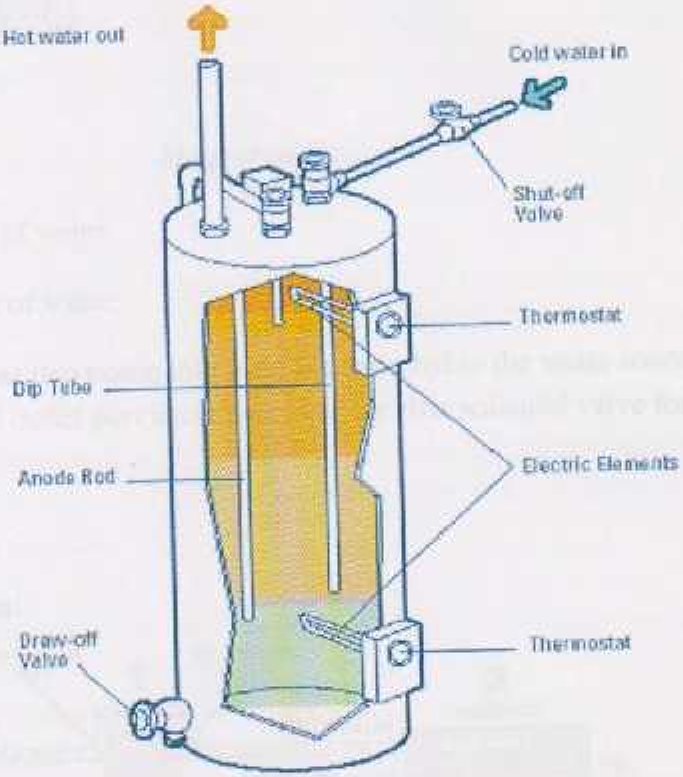


Fig 3.6: Electric Water Heater

Tanks are typically covered with foam insulation and lined on the inside with a ceramic glass layer. When cold water replaces the water withdrawn from the tank and the temperature of the water falls below a certain level, the elements are activated, reheating the water to the correct temperature. Essentially, electric hot water heaters are large closed electric kettles.

The submerged electric resistance heating elements in water heaters are very efficient, providing about 99 per cent of the available heat to the surrounding water.

The submerged electric resistance heating elements in water heaters are very efficient, providing about 99 per cent of the available heat to the surrounding water.

$$Q_1 = M_{tot} * C_v * \Delta T \ \ .... (3.1)$$

Q_1, Q_2 : amount of heat required to heat water.

M_{tot}: total mass of water.

C_v: specific heat.

ΔT: Temperature (T_f - T_i).

$$M_{tot} = \rho \vartheta$$

Where : ρ = density of water.

ϑ = volume of water.

The heater has two ports; inlet port is connected to the water source for enter the water , and outlet port is connected to the first solenoid valve for out the hot water.

3.5.2 Cooler System:

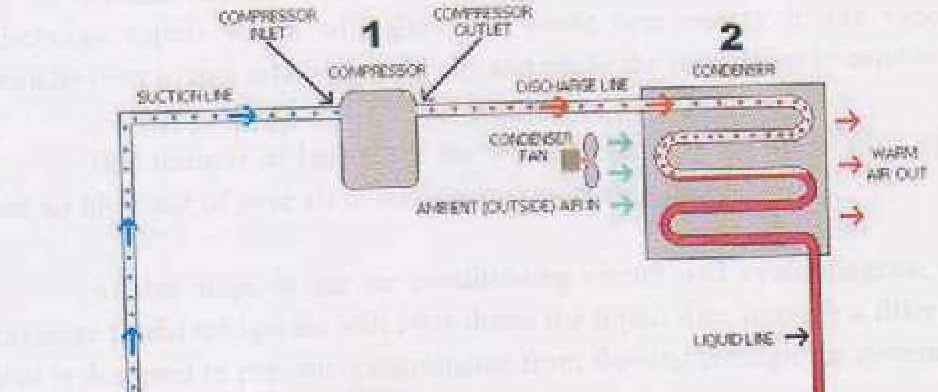


Fig 3.7: Air Conditioning Circuit and Cycle Diagram

The compressor is the heart of the system; it keeps the refrigerant flowing through the system at specific rates of flow, and at specific pressures. It takes refrigerant vapor in from the low pressure side of the circuit, and discharges it at a much higher pressure into the high side of the circuit, the rate of flow through the system will depend on the size of the unit, and the operating pressures will depend on the refrigerant being used and the desired evaporator temperature.

The component at #2 in this air conditioning circuit and cycle diagram is the condenser, the red dots inside the piping represent discharge vapor, the solid red color represents high pressure liquid refrigerant.

Most air cooled air conditioning and refrigeration systems are designed so that the refrigerant will condense at a temperature about 25 to 30 degrees above outside ambient air temperature.

When the hot refrigerant vapor discharged from the compressor travels through the condenser, the cool air flowing through the condenser coil absorbs enough heat from the vapor to cause it to condense.

If the outside air temperature is 80 degrees, the system is designed so that the temperature of the refrigerant, right at the point where it first condenses, will be about 105 to 115 degrees.

So that the air will be very cold relative to the temperature of the discharge vapor، which will allow the latent heat energy in the vapor to transfer over to that relatively cold air، and cause the refrigerant to condense

.

This transfer of heat from the vapor to the flowing air is what makes hot air blow out of your air conditioners condensing unit.

At this stage in the air conditioning circuit and cycle diagram, high pressure liquid refrigerant will flow down the liquid line, through a filter drier that is designed to prevent contaminants from flowing through the system, and on to the metering device.

The metering device, component #3 on this air conditioning circuit and cycle diagram, is the dividing point between the high pressure and low pressure sides of the system، and is designed to maintain a specific rate of flow of refrigerant into the low side of the system.

If the wrong capacity of metering device is used, or if there is a problem with the metering device، an incorrect quantity of refrigerant will flow into the evaporator.

When the refrigerant passes through the metering device, it drops from about 225 psi to about 70 psi, it also drops in temperature from about 110 degrees to about 40 degrees, it starts evaporating immediately, it's at a low pressure, so it's only boiling at about 40 degrees F.

And that brings us to the evaporator, component #4 in the air conditioning circuit and cycle diagram. There will be relatively warm air flowing over the evaporator coil, let's say about 80 degrees.

The air condition system is designed so that the refrigerant will evaporate in the evaporator at a temperature of about 40 degrees, so that it will be cold compared to the warm air flowing over it.

The system is designed so that the heat in the warm air flowing over the evaporator will be absorbed by the cold evaporating refrigerant

This cools the air flowing over the evaporator, and is the reason cold air blows out of your air conditioner.

The heater has two ports; inlet port is connected to the water source for enter the water , and outlet port is connected to the second solenoid valve for out the cold water .

3.6 Solenoid Valve:

A solenoid valve is an electromechanical device used for controlling liquid or gas flow. The solenoid valve is controlled by electrical current, which is run through a coil. When the coil is energized, a magnetic field is created, causing a plunger inside the coil to move. Depending on the design of the valve, the plunger will either open or close the valve. When electrical current is removed from the coil, the valve will return to its de-energized state. As shown in figure 3.8.

Fig 3.8: Solenoid Valve

In direct-acting solenoid valves, the plunger directly opens and closes an orifice inside the valve. In pilot-operated valves (also called the servo-type), the plunger opens and closes a pilot orifice. The inlet line pressure, which is led through the pilot orifice, opens and closes the valve seal.

The most common solenoid valve has two ports: an inlet port and an outlet port.

Solenoid valves make automation of fluid and gas control possible. Modern solenoid valves offer fast operation, high reliability, long service life, and compact design.

The illustration below depicts the basic components of a solenoid valve:

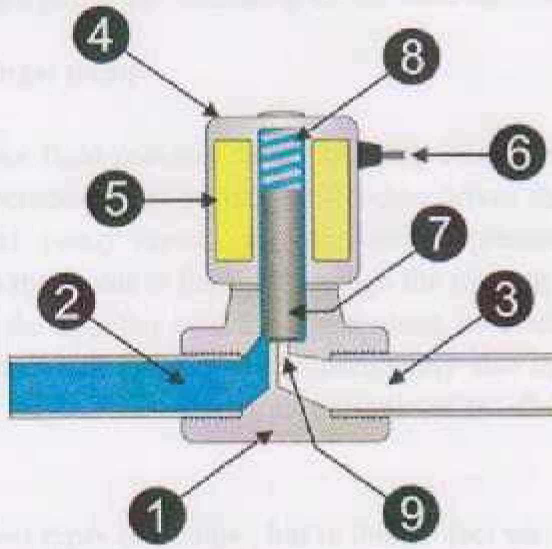


Fig 3.9: The basic components of a solenoid valve

1. Valve Body
2. Inlet Port
3. Outlet Port
4. Coil / Solenoid
5. Coil Windings
6. Lead Wires
7. Plunger
8. Spring
9. Orifice

The media controlled by the solenoid valve enters the valve through the inlet port (Part 2 in the illustration above). The media must flow through the orifice (9) before continuing into the outlet port (3). The orifice is closed and opened by the plunger (7).

The valve pictured above is a normally-closed solenoid valve. Normally-closed valves use a spring (8) which presses the plunger tip against the opening of the orifice. The sealing material at the tip of the plunger keeps the media from entering the orifice, until the plunger is lifted up by an electromagnetic field created by the coil.

In this project we will use two solenoid valves for control the flow of the hot and the cold water.

3.7 Centrifugal Pump:

The centrifugal pump is the most used pump type in the world. The principle is simple, well-described and thoroughly tested, and the pump is robust, effective and relatively inexpensive to produce. There is a wide range of variations based on the principle of the centrifugal pump and consisting of the same basic hydraulic parts.

Principle of the centrifugal pump

An increase in the fluid pressure from the pump inlet to its outlet is created when the pump is in operation. This pressure difference drives the fluid through the system. The centrifugal pump creates an increase in pressure by transferring mechanical energy from the motor to the fluid through the rotating impeller. The fluid flows from the inlet to the impeller centre and out along its blades. The centrifugal force hereby increases the fluid velocity and consequently also the kinetic energy is transformed to pressure. Figure 3.11 shows an example of the fluid path through the centrifugal pump.

There are different types of pumps , but in this project we will choose the TP pump because of several reasons. As shown in figure 3.10:

1. The TP pump is used for circulation of hot or cold water mainly in heating, cooling and air conditioning systems.
2. Is notable for its high levels of reliability and efficiency.
3. Quiet, highly-efficient IE3 motors are standard components.
4. TP pump is electro-coated to ensure high corrosion resistance.

Fig 3.10: The TP centrifugal pump.

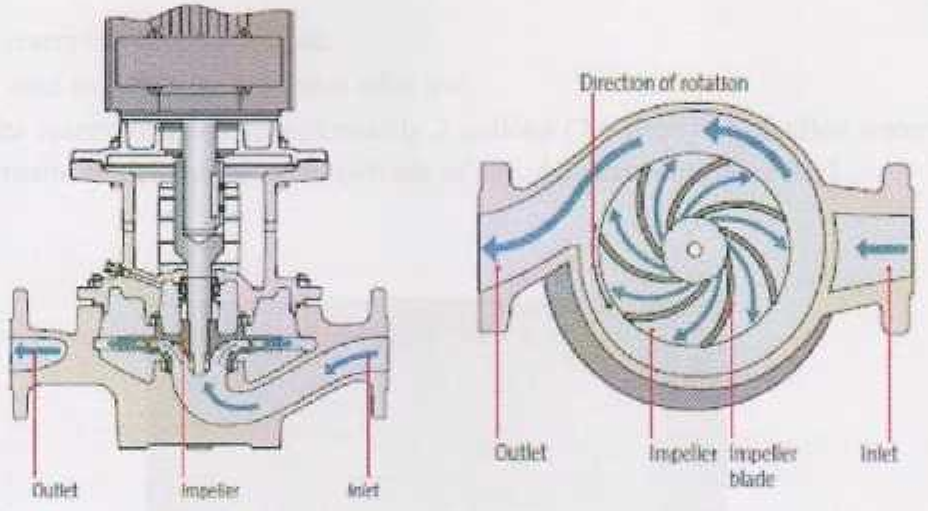


Fig 3.11: Fluid path through the centrifugal pump.

In this project we use one centrifugal pump to pump the hot or the cold water, when the inlet port is connected to the two solenoid valves by using T junction, and the outlet is connected to the pipelines in the mattress.

3.8 Mattress

Mattress is made of Polyurethane foam, is a unique material that offers the elasticity of rubber combined with the toughness and durability of metal. Because urethane is available in a very broad hardness range (eraser-soft to bowling-ball-hard), it allows the engineer to replace rubber, plastic and metal with the ultimate in abrasion resistance and physical properties.

This extra-strength material helps resist punctures and provides triple the seam strength of most other plastic blankets. Because of our irregular flow design it allows even temperature distribution and faster water circulation which results in better cooling and heating rates. Because it is nonporous, stains and debris can be easily wiped away with soap and water.

Fig 3.12: Medical Mattress

3.9 Water Tank:

- It reserves water to be used.
- It used to condense the water after use.
- The reservoir holds approximately 2 gallons (7.5 liters) of distilled water that remains in the unit between periods of use. As shown in figure 3.13.

Fig 3.13: Water tank

3.10 Power Supply:

In mains-supplied electronic systems the AC input voltage must be converted into a DC voltage with the right value.

There are many types of power supply are designed to convert high voltage AC mains electricity to a suitable low voltage supply for electronic circuits and other devices. A power supply can by broken down into a series of blocks, each of which performs a particular function.

Each of power supply circuit contain a four main components as figure 3.14 shown:

- Transformer - steps down high voltage AC mains to low voltage AC.
- Rectifier - converts AC to DC, but the DC output is varying.
- Smoothing - smoothes the DC from varying greatly to a small ripple.
- Regulator - eliminates ripple by setting DC output to a fixed voltage.

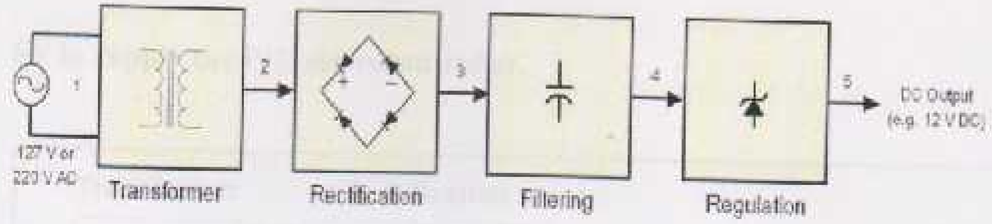


Fig 3.14: Power Supply Circuit

As shown in figure 3.15, output signal from each stage of power supply circuit.

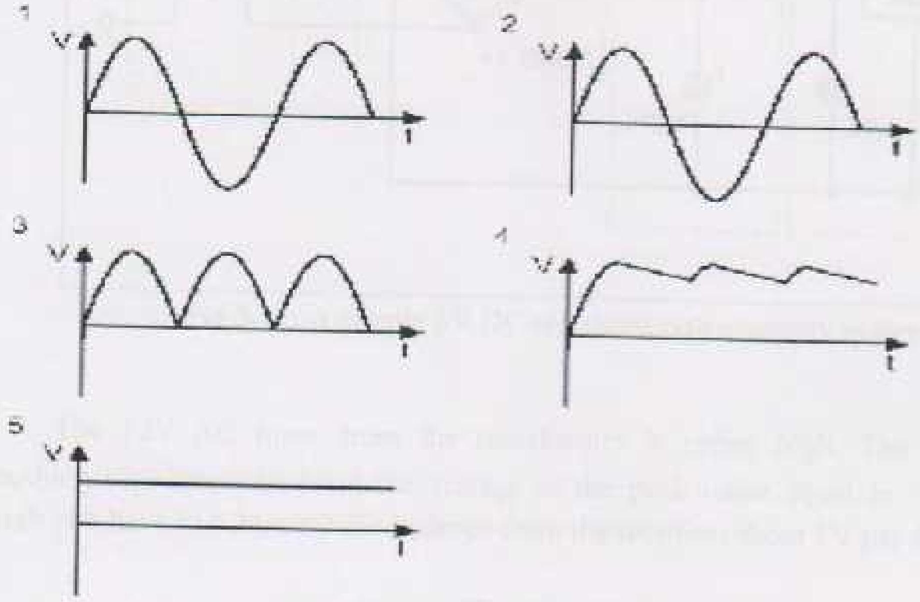


Fig.3.15: Output signal from each main component of power supply.

In this project we need to four power supply circuits for provide the system by suitable values of voltages, the four power supplies will convert the 220V AC voltage to three DC voltages:

1. 1V to supply the Wheatstone bridge.
2. 5V to supply the PIC microcontroller.
3. 12V and -12V to supply the instrumentation amplifier.
4. 220V to supply the centrifugal pump and the solenoid valve.

1. 1V to supply the Wheatstone bridge circuit.

We can get this value from the 5V DC regulated power supply system. By connect the output of the power supply with a 7801 regulator.

2. **5V to supply the PIC microcontroller.**

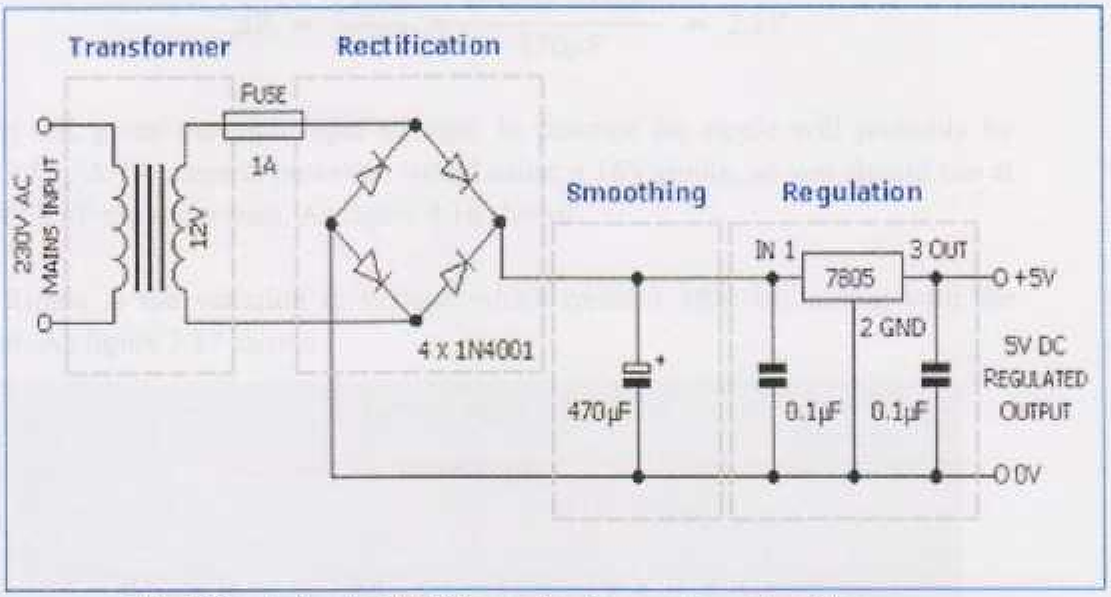


Fig 3.16: A simple 5V DC regulated power supply system.

The 12V AC input from the transformer is rather high. The rectifier + smoothing capacitor will level the voltage at the peak value equal to $\sqrt{2} * V_{RMS}$, though you have to subtract 2 diode drops from the rectifier, about 1V per diode. So

$$V_{IN} = \sqrt{2} * 12 - 2.1V = 15V$$

The 7805 can supply up to 1A, and then the dissipated power is

$$P_{REG} = (V_{IN} - V_{OUT}) * I = (15V - 5V) * 1A = 10W$$

That's a lot! Try to keep the dissipation low by having a lower input voltage. This should be at least 8V, then an 8V transformer should be fine. At 1A you'd still need a heat sink.

The smoothing capacitor's value depends on the load. Every half cycle of the mains voltage the capacitor will be charged to the peak value and start to discharge until the voltage is high enough to charge again. A simplified calculation gives

$$C = \frac{I \cdot \Delta T}{\Delta V}$$

where ΔT is half the mains cycle (e.g. 10ms in Europe, 8.33ms in the US). This formula assumes a linear discharge, which in reality often will be exponential, and also assumes a too long time, which often will be 70-80% of the given value. So, all in all, this is really worst case. Based on the above equation we can calculate the ripple voltage for a given current, like 100mA:

$$\Delta V = \frac{I \cdot \Delta T}{C} = \frac{100mA \cdot 10ms}{470\mu F} = 2.1V$$

which is OK given the high input voltage. In practice the ripple will probably be around 1.6V. A 1A current, however, would cause a 16V ripple, so you should use at least a 4700μF capacitor then. As figure 4.16 shown.

Ripple is the variation in voltage which remains after smoothing with the

3.11 Switches:

The PIC microcontroller will control the system by sending a signal to the switches that connected to each circuit that controlled by the PIC microcontroller, so the switch is an important item in the system.

Both these transistor regions are defined as:

❖ **Switch is on**

Transistor will become ON (saturation) when a sufficient voltage V is given to input. During this condition the Collector Emitter voltage Vce will be approximately equal to zero, ie the transistor acts as a short circuit. For a silicon transistor it is equal to 0.3v. Thus collector current Ic = Vcc/Rc will flows.

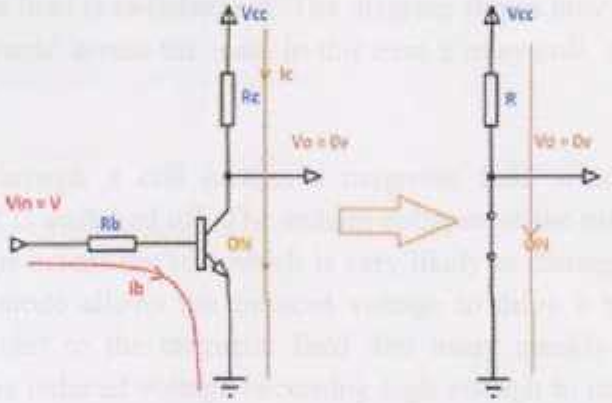


Fig 3.20: Saturation Region

❖ **Switch is off**

Transistor will be in OFF (cutoff) when the input Vin equal to zero. During this state transistor acts as an open circuit and thus the entire voltage Vcc will be available at collector.

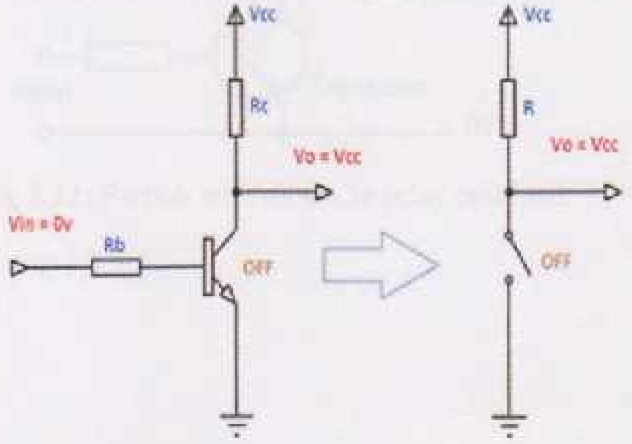


Fig 3.21: Cut-off Region

The power developed in a switching transistor is very small:

- In the OFF state: power = Ic × V_{CE}, but Ic = 0, so the power is zero.
- In the full ON state: power = Ic × V_{CE}, but V_{CE} = 0 (almost), so the power is
- very small.

This means that the transistor should not become hot in use and you do not need to consider its maximum power rating. The important ratings in switching circuits are the maximum collector current Ic(max) and the minimum current gain h_{FE}(min). The transistor's voltage ratings may be ignored unless you are using a supply voltage of more than about 15V.

If the load is a motor, relay or solenoid (or any other device with a coil) a diode must be connected across the load to protect the transistor from the brief high voltage produced when the load is switched off. The diagram shows how a protection diode is connected 'backwards' across the load, in this case a relay coil. As shown in figure 3.22.

Current flowing through a coil creates a magnetic field which collapses suddenly when the current is switched off. The sudden collapse of the magnetic field induces a brief high voltage across the coil which is very likely to damage transistors and ICs. The protection diode allows the induced voltage to drive a brief current through the coil (and diode) so the magnetic field dies away quickly rather than instantly. This prevents the induced voltage becoming high enough to cause damage to transistors and ICs.

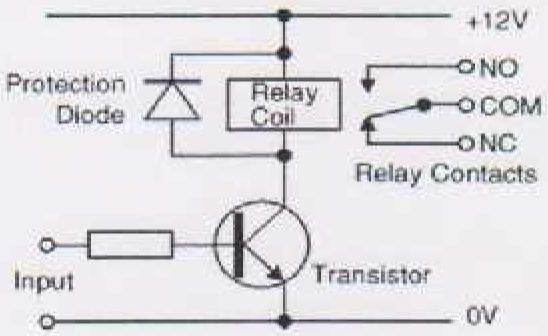


Fig 3.22: Switch with diode to relay coil load.

Chapter Four

System Implementation

4.1 Introduction.

4.2 System Implementation.

4.2.1 Electrical circuit components.

4.2.2 PIC Microcontroller.

4.2.3 Mechanical circuit components.

4.2.4 Mattress.

4.1 Introduction.

This chapter demonstrate the parts used to implement, test, and examine the system operation and behavior. System testing is an important step in implementing whole system.

The mechanical system implementation includes combining heater, cooler, infusion pump, solenoid valves, and switches the following picture shows mechanical system implementation.

4.2 System Implementation.

In this section the implementation of each stage will be included, the electrical circuit includes the design of all stages, these stages are: skin temperature sensor and Wheatstone Bridge, instrumentation amplifier, PIC Microcontroller, and the Mechanical stages like heater\cooler unit, pumps and valves.

4.2.1 Electrical circuit components

Skin Temperature sensor: it is measure the temperature of skin and we can put it on the chest.

Fig 4.1 Skin Temperature Sensor

Processing unit: consists of Wheatstone Bridge and instrumentation amplifier.

- **Wheatstone Bridge:** consist of skin temperature sensor, two resistances (12KΩ), and potentiometer for calibration (20KΩ).

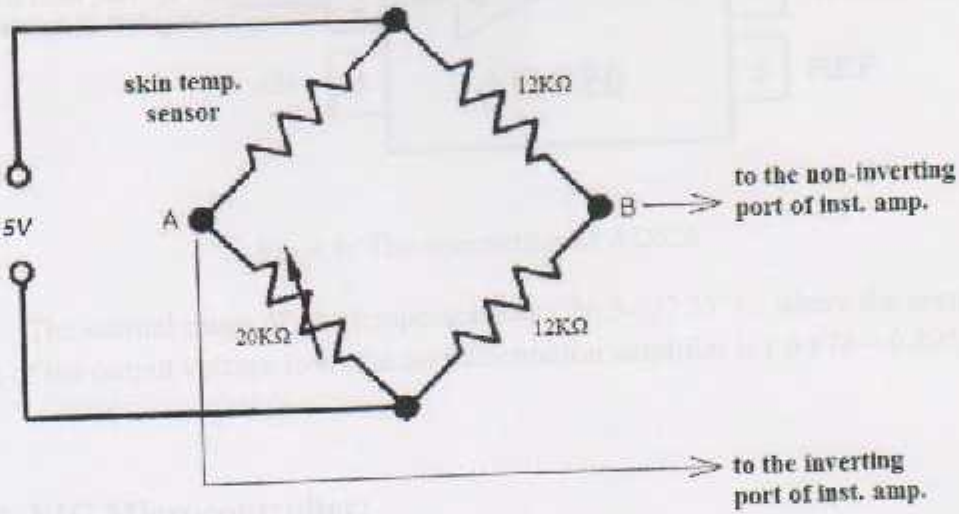


Fig 4.2: Wheatstone Bridge

- **Instrumentation amplifier (AD620):**

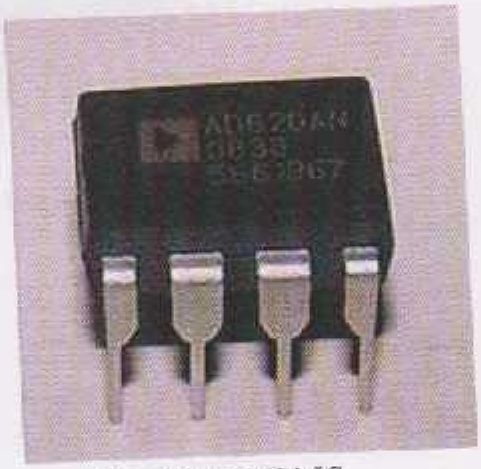


Fig 4.3: AD620 IC

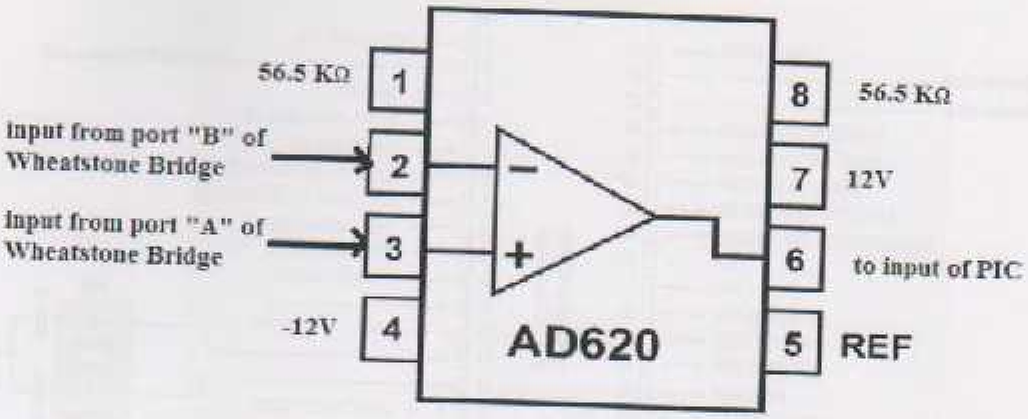


Fig 4.4: The connection of AD620.

The normal range of the temperature is (36.5– 37.5) °C, where the normal range of the output voltage from the instrumentation amplifier is (0.878 – 0.895) V.

4.2.2 PIC Microcontroller:

Fig 4.5: PIC18F4550.

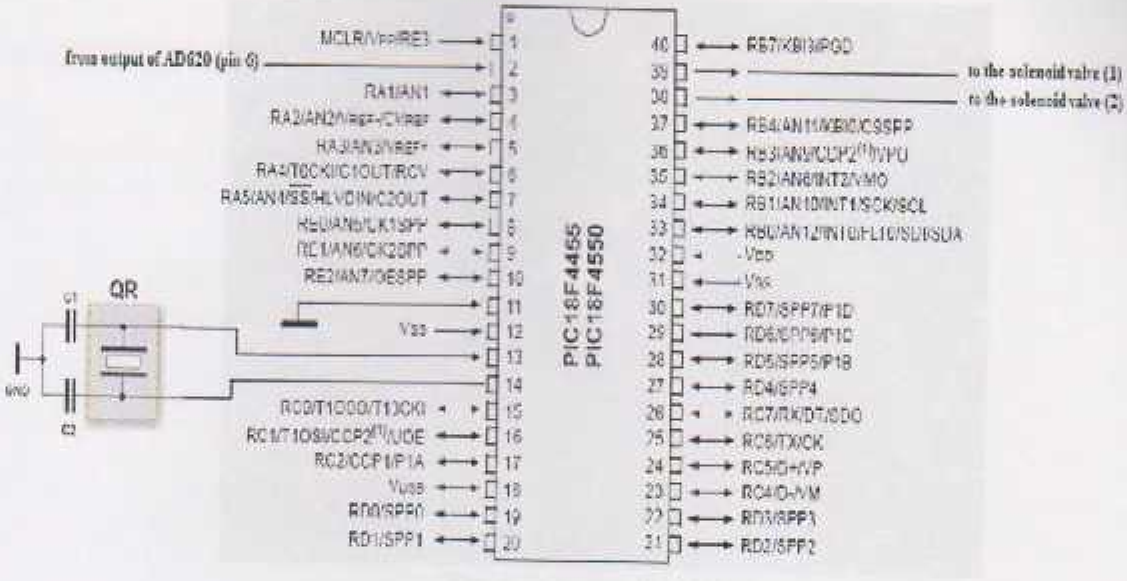


Fig 4.6: The connection of PIC Microcontroller

4.2.3 Mechanical Circuit Components:

4.2.3.1 Solenoid valve

In this project we need two valves The first solenoid valve to control the flow of the hot water, The second solenoid valve to control the flow of the cold water.

The solenoid valve has two ports: an inlet port and an outlet port for the hot or cold water, the inlet port is connected to the heater/cooler, and the outlet port is connected to the motor.

The value of the voltage that provide the solenoid valve is equal to 220V.

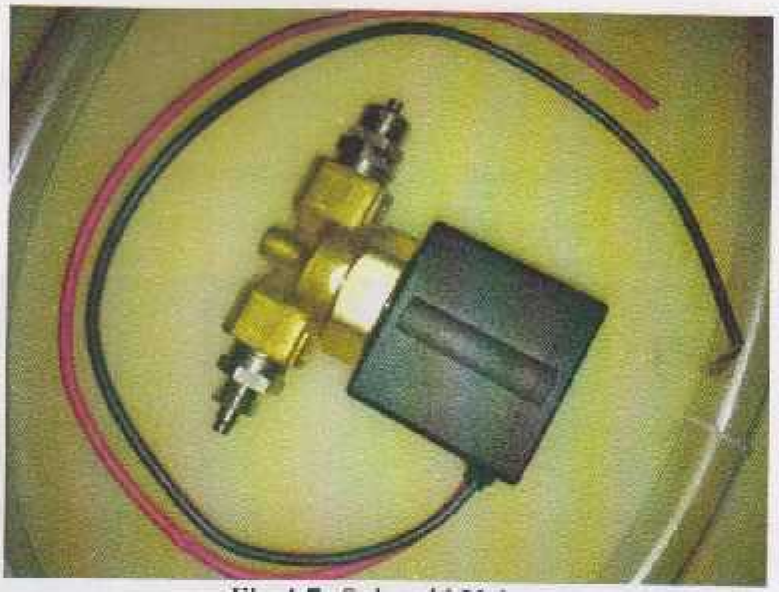


Fig 4.7: Solenoid Valve

4.2.3.2 Centrifugal pump

The centrifugal pump is used to pump the hot/cold water from the heater/cooler to the mattress through the pipelines, so we need one Centrifugal pump.

The value of the voltage that provide the Centrifugal pump is equal to 220V.

Fig 4.8: Centrifugal Pump

4.2.4 Mattress.

The mattress is made of Polyurethane foam, the pipelines are connected as shown in the figure 4.9.

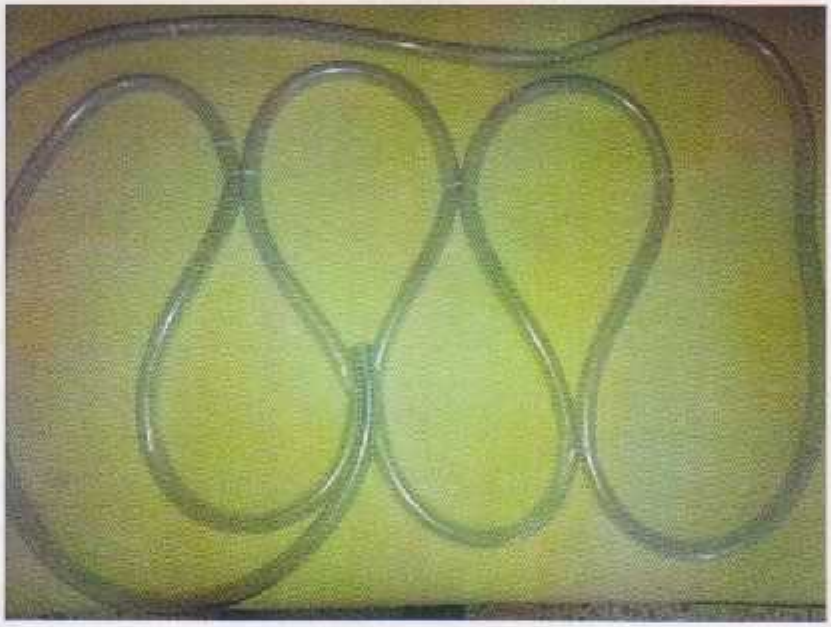


Fig 4.9: Mattress

Flow Chart for The System:

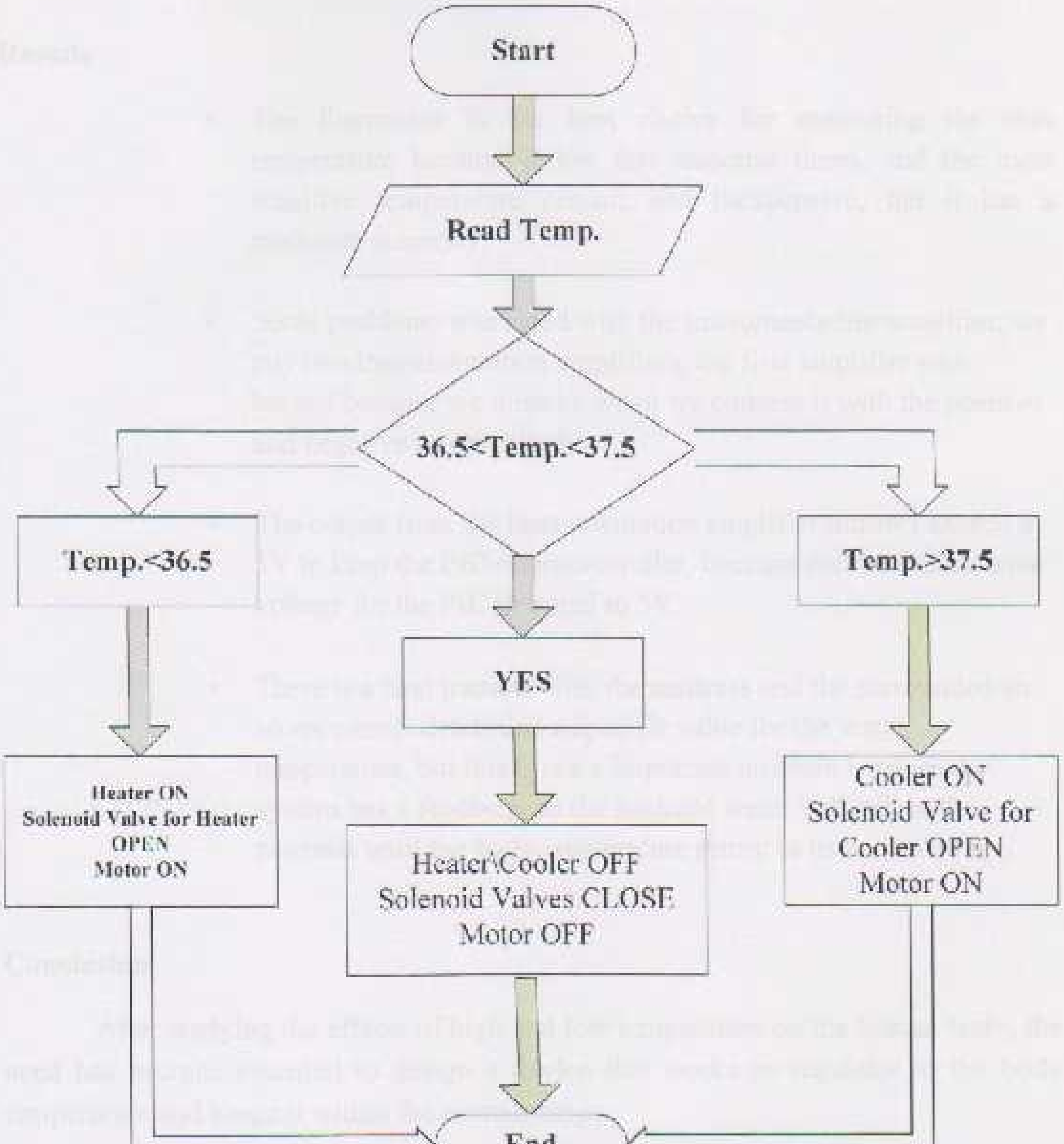


Fig 4.10 Flow Chart for the system

Chapter Five

Conclusion

Results

- The thermistor is the best choice for measuring the skin temperature because it has fast response times, and the most sensitive temperature sensor, and inexpensive, but it has a moderate accuracy.
- Some problems was faced with the instrumentation amplifier, we buy two instrumentation amplifiers, the first amplifier was burned because we mistake when we connect it with the positive and negative power supply.
- The output from the instrumentation amplifier mustn't exceed a 5V to keep the PIC microcontroller, because the maximum input voltage for the PIC is equal to 5V.
- There is a heat transfer with the mattress and the surrounded air so we cannot determine a specific value for the water temperature, but this is not a important problem because the system has a feedback so the hot/cold water will still in the mattress until the body temperature return to its normal range.

Conclusion

After studying the effects of high and low temperature on the human body, the need has become essential to design a device that works as regulator to the body temperature and keeps it within the normal range.

In this project electrical and mechanical parts were designed to control the human body temperature.

The design includes two main units one for cooling and the other for heating, these units are controlled by the PIC microcontroller to regulate the body temperature depending on the measured temperature values.

The theoretical data was analyzed in order to construct a modern body temperature regulation system. All the system parts and units in the project (hardware, PIC microcontroller, skin temperature sensor) was discussed and implemented in the second phase of the project.

The used PIC 18F4550 is very useful and programmable, easy to use and implement.

Future Work

1. Using rotors to pump the water inside the mattress to provide therapeutically effect .
2. Using a pneumatic proportional valves to control the flowing water volume to the mattress depending on the body temperature.
3. Using a keypad to allow the user to change the temperature range.

References

1. Blanketrol *III*, Operation and Technical Manual, Model 233 Hyper-Hypothermia Units.

2. Curriculum Press, Unit 305B, The Big Peg, 120 Vyse Street, Birmingham. B18 6NF researched by Bill Indge.

3. Dodd SR, Lancaster GA, Craig JV, Smyth RL, Williamson PR (April 2006). "In a systematic review, infrared ear thermometry for fever diagnosis in children finds poor sensitivity". J Clin Epidemiol 59 (4): 354–7. doi:10.1016/j.jclinepi.2005.10.004. PMID 16549256.

4. Heater Cooler System, Sorin 3T, Sorin Group USA, Inc., data sheet.

5. (http:/ / www. sciencedirect. com/ science?_ob=ArticleURL& udi=B6T94-4DDXMRG-H& _user=10& _rdoc=1& _fmt=& _orig=search& _sort=d& _docanchor=& view=c& _searchStrId=957411958& erunOrigin=google& _acct=C000050221& _version=1& _urlVersion=0& _userid=10& md5=6c571acbee07e8999b4c7774d3212dcc).

6. Kelly G (December 2006). "Body temperature variability (Part 1): a review of the history of body temperature and its variability due to site selection, biological rhythms, fitness, and aging". Altern Med Rev 11 (4): 278–93. PMID 17176167.

7. Kelly GS (March 2007). "Body temperature variability (Part 2): masking influences of body temperature variability and a review of body temperature variability in disease". Altern Med Rev 12 (1): 49–62. PMID 17397267.

8. Mackowiak, P. A.; S. S. Wasserman, M. M. Levine (1992-09-23). "A critical appraisal of 98.6 degrees F, the upper limit of the normal body temperature, and other legacies of Carl Reinhold August Wunderlich" (http:/ / jama. ama-assn. org/ cgi/ content/ bstract/ 268/ 12/ 1578). JAMA 268 (12): 1578–1580. doi:10.1001/jama.268.12.1578. PMID 1302471.Retrieved 2007-08-22.

9. Normal Body Temperature Ranges, welchallyn, CUSTOMER SERVICE For technical or clinical support.

10. Sund-Levander M, Forsberg C, Wahren LK (June 2002). "Normal oral, rectal, tympanic and axillary body temperature in adult men and women: a systematic literature review". Scand J Caring Sci 16 (2): 122–8. doi:10.1046/j.1471-6712.2002.00069.x. PMID 12000664.

11. http://www.circuitdiagram.org/12v-dual-power-supply-regulated.html
12. http://www.colorado.edu/physics/phys1140/phys1140_sm98/Experiments/E3/E3bridge.html

13. http://www.drugs.com/cdi/dantrium.html#zBiCmDHW6yfBUXa8.99
14. http://www.ehow.com/about_5108062_hyperthermia-risk-factors.html
15. http://www.ehow.com/about_6495494_kind-mattress-hospital-bed_.html
16. http://electronics.stackexchange.com/questions/21215/5v-power-supply-tutorial
17. http://www.electronics-tutorials.ws/transistor/tran_4.html4.
18. http://firstaid.ygoy.com/2010/05/28/hyperthermia-first-aid/
19. http://www.grundfos.com/content/dam/Global%20Site/Industries%20%26%20solutions/Industry/pdf/The_Centrifugal_Pump.pdf
20. http://www.healthscout.com/ency/1/271/main.html
21. http://www.medicinenet.com/hypothermia/page2.htm
22. http://www.medicalnewstoday.com/articles/182197.php
23. http://www.medicinenet.com/hypothermia/page3.htm
24. http://www.mayoclinic.com/health/hypothermia/DS00333/DSECTION=treatments-and-drugs
25. http://www.medicinenet.com/hypothermia/page4.htm
26. http://www.medicinenet.com/hypothermia/page6.htm
27. http://ww1.microchip.com/downloads/en/DeviceDoc/21895d.pdf
28. http://paginas.fisica.uson.mx/horacio.munguia/aula_virtual/Cursos/Instrumentacion%20I/Documentos/Reg%20de%20Voltaje%20SGS.pdf
29. http://oee.nrcan.gc.ca/equipment/heating/514
30. http://www.solenoid-valve-info.com/
31. http://www.testequity.com/documents/pdf/Correct_Temperature_Sensor.pdf

Appendix A

AD620

Low Cost Low Power Instrumentation Amplifier

ANALOG DEVICES

Low Cost Low Power Instrumentation Amplifier

AD620

FEATURES

Easy to use
- Gain set with one external resistor (Gain range 1 to 10,000)
- Wide power supply range (±2.3 V to ±18 V)
- Higher performance than 3 op amp IA designs
- Available in 8-lead DIP and SOIC packaging
- Low power, 1.3 mA max supply current

Excellent dc performance (B grade)
- 50 μV max, input offset voltage
- 0.6 μV/°C max, input offset drift
- 1.0 nA max, input bias current
- 100 dB min common-mode rejection ratio (G = 10)

Low noise
- 9 nV/√Hz @ 1 kHz, input voltage noise
- 0.28 μV p-p noise (0.1 Hz to 10 Hz)

Excellent ac specifications
- 120 kHz bandwidth (G = 100)
- 15 μs settling time to 0.01%

APPLICATIONS

Weigh scales
ECG and medical instrumentation
Transducer interface
Data acquisition systems
Industrial process controls
Battery-powered and portable equipment

Table 1. Next Generation Upgrades for AD620

Part	Comment
AD8221	Better specs at lower price
AD8222	Dual channel or differential out
AD8226	Low power, wide input range
AD8220	JFET input
AD8228	Best gain accuracy
AD8295	+2 precision op amps or differential out
AD8429	Ultra low noise

CONNECTION DIAGRAM

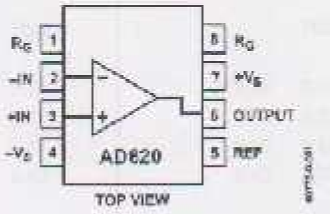


Figure 1. 8-Lead PDIP (N), CERDIP (Q), and SOIC (R) Packages

PRODUCT DESCRIPTION

The AD620 is a low cost, high accuracy instrumentation amplifier that requires only one external resistor to set gains of 1 to 10,000. Furthermore, the AD620 features 8-lead SOIC and DIP packaging that is smaller than discrete designs and offers lower power (only 1.3 mA max supply current), making it a good fit for battery-powered, portable (or remote) applications.

The AD620, with its high accuracy of 40 ppm maximum nonlinearity, low offset voltage of 50 μV max, and offset drift of 0.6 μV/°C max, is ideal for use in precision data acquisition systems, such as weigh scales and transducer interfaces. Furthermore, the low noise, low input bias current, and low power of the AD620 make it well suited for medical applications, such as ECG and noninvasive blood pressure monitors.

The low input bias current of 1.0 nA max is made possible with the use of SuperBeta processing in the input stage. The AD620 works well as a preamplifier due to its low input voltage noise of 9 nV/√Hz at 1 kHz, 0.28 μV p-p in the 0.1 Hz to 10 Hz band, and 0.1 pA/√Hz input current noise. Also, the AD620 is well suited for multiplexed applications with its settling time of 15 μs to 0.01%, and its cost is low enough to enable designs with one in-amp per channel.

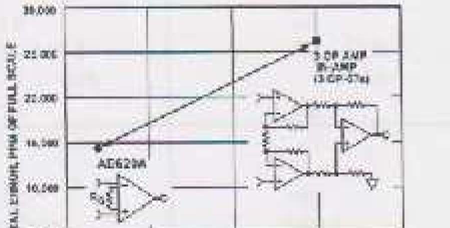


Figure 2. Three Op Amp IA Designs vs. AD620

Rev. H

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781.329.4700 www.analog.com
Fax: 781.326.8703

SPECIFICATIONS

Typical @ 25°C, V_S = ±15 V, and R_L = 2 kΩ, unless otherwise noted.

Table 2.

Parameter	Conditions	AD620A Min	AD620A Typ	AD620A Max	AD620B Min	AD620B Typ	AD620B Max	AD620S[1] Min	AD620S[1] Typ	AD620S[1] Max	Unit
GAIN	G = 1 + (49.4 kΩ/R_G)										
Gain Range		1		10,000	1		10,000	1		10,000	
Gain Error[2]	V_{OUT} = ±10 V										
G = 1			0.03	0.10		0.01	0.02		0.03	0.10	%
G = 10			0.15	0.30		0.10	0.15		0.15	0.30	%
G = 100			0.15	0.30		0.10	0.15		0.15	0.30	%
G = 1000			0.40	0.70		0.35	0.50		0.40	0.70	%
Nonlinearity	V_{OUT} = −10 V to +10 V										
G = 1–1000	R_L = 10 kΩ		10	40		10	40		10	40	ppm
G = 1–100	R_L = 2 kΩ		10	95		10	95		10	95	ppm
Gain vs. Temperature											
	G = 1			10			10			10	ppm/°C
	Gain >1[2]			−50			−50			−50	ppm/°C
VOLTAGE OFFSET	(Total RTI Error = V_{OSI} + V_{OSO}/G)										
Input Offset, V_{OSI}	V_S = ±5 V to ± 15 V		30	125		15	50		30	125	μV
Overtemperature	V_S = ±5 V to ± 15 V			185			85			225	μV
Average TC	V_S = ±5 V to ± 15 V		0.3	1.0		0.1	0.6		0.3	1.0	μV/°C
Output Offset, V_{OSO}	V_S = ±15 V		400	1000		200	500		400	1000	μV
	V_S = ± 5 V			1500			750			1500	μV
Overtemperature	V_S = ±5 V to ± 15 V			2000			1000			2000	μV
Average TC	V_S = ±5 V to ± 15 V		5.0	15		2.5	7.0		5.0	15	μV/°C
Offset Referred to the Input vs. Supply (PSR)	V_S = ±2.3 V to ±18 V										
G = 1		80	100		80	100		80	100		dB
G = 10		95	120		100	120		95	120		dB
G = 100		110	140		120	140		110	140		dB
G = 1000		110	140		120	140		110	140		dB
INPUT CURRENT											
Input Bias Current			0.5	2.0		0.5	1.0		0.5	2	nA
Overtemperature				2.5			1.5			4	nA
Average TC			3.0			3.0			8.0		pA/°C
Input Offset Current			0.3	1.0		0.3	0.5		0.3	1.0	nA
Overtemperature				1.5			0.75			2.0	nA
Average TC			1.5			1.5			8.0		pA/°C
INPUT											
Input Impedance											
Differential			10‖2			10‖2			10‖2		GΩ‖pF
Common-Mode			10‖2			10‖2			10‖2		GΩ‖pF
Input Voltage Range[3]	V_S = ±2.3 V to ±5 V	−V_S + 1.9		+V_S − 1.2	−V_S + 1.9		+V_S − 1.2	−V_S + 1.9		+V_S − 1.2	V
Overtemperature		−V_S + 2.1		+V_S − 1.3	−V_S + 2.1		+V_S − 1.3	−V_S + 2.1		+V_S − 1.3	V
	V_S = ± 5 V to ±18 V	−V_S + 1.9		+V_S − 1.4	−V_S + 1.9		+V_S − 1.4	−V_S + 1.9		+V_S − 1.4	V
Overtemperature		−V_S + 2.1		+V_S − 1.4	−V_S + 2.1		+V_S + 2.1	−V_S + 2.3		+V_S − 1.4	V

Parameter	Conditions	AD620A Min	AD620A Typ	AD620A Max	AD620B Min	AD620B Typ	AD620B Max	AD620S[1] Min	AD620S[1] Typ	AD620S[1] Max	Unit
Common-Mode Rejection Ratio DC to 60 Hz with 1 kΩ Source Imbalance	V_{CM} = 0 V to ± 10 V										
G = 1		73	90		80	90		73	90		dB
G = 10		93	110		100	110		93	110		dB
G = 100		110	130		120	130		110	130		dB
G = 1000		110	130		120	130		110	130		dB
OUTPUT											
Output Swing	R_L = 10 kΩ, V_S = ±2.3 V to ± 5 V	$-V_S$ + 1.1		$+V_S$ − 1.2	$-V_S$ + 1.1		$+V_S$ − 1.2	$-V_S$ + 1.1		$+V_S$ − 1.2	V
Overtemperature		$-V_S$ + 1.4		$+V_S$ − 1.3	$-V_S$ + 1.4		$+V_S$ − 1.3	$-V_S$ + 1.6		$+V_S$ − 1.3	V
	V_S = ±5 V to ± 18 V	$-V_S$ + 1.2		$+V_S$ − 1.4	$-V_S$ + 1.2		$+V_S$ − 1.4	$-V_S$ + 1.2		$+V_S$ − 1.4	V
Overtemperature		$-V_S$ + 1.6		$+V_S$ − 1.5	$-V_S$ + 1.6		$+V_S$ − 1.5	$-V_S$ + 2.3		$+V_S$ − 1.5	V
Short Circuit Current			±18			±18			±18		mA
DYNAMIC RESPONSE											
Small Signal −3 dB Bandwidth											
G = 1			1000			1000			1000		kHz
G = 10			800			800			800		kHz
G = 100			120			120			120		kHz
G = 1000			12			12			12		kHz
Slew Rate		0.75	1.2		0.75	1.2		0.75	1.2		V/μs
Settling Time to 0.01%	10 V Step										
G = 1–100			15			15			15		μs
G = 1000			150			150			150		μs
NOISE											
Voltage Noise, 1 kHz	*Total RTI Noise* = $\sqrt{(e^2_{ni}) + (e_{no}/G)^2}$										
Input, Voltage Noise, e_{ni}			9	13		9	13		9	13	nV/√Hz
Output, Voltage Noise, e_{no}			72	100		72	100		72	100	nV/√Hz
RTI, 0.1 Hz to 10 Hz											
G = 1			3.0			3.0	6.0		3.0	6.0	μV p-p
G = 10			0.55			0.55	0.8		0.55	0.8	μV p-p
G = 100–1000			0.28			0.28	0.4		0.28	0.4	μV p-p
Current Noise	f = 1 kHz		100			100			100		fA/√Hz
0.1 Hz to 10 Hz			10			10			10		pA p-p
REFERENCE INPUT											
R_{IN}			20			20			20		kΩ
I_{IN}	V_{IN+}, V_{REF} = 0		50	60		50	60		50	60	μA
Voltage Range		$-V_S$ + 1.5		$+V_S$ − 1.6	$-V_S$ + 1.6		$-V_S$ − 1.6	$-V_S$ + 1.6		$+V_S$ − 1.6	V
Gain to Output		1 ± 0.0001			1 ± 0.0001			1 ± 0.0001			
POWER SUPPLY											
Operating Range[4]		±2.3		±18	±2.3		±18	±2.3		±18	V
Quiescent Current	V_S = ±2.3 V to ±18 V		0.9	1.3		0.9	1.3		0.9	1.3	mA
Overtemperature			1.1	1.6		1.1	1.6		1.1	1.6	mA
TEMPERATURE RANGE											
For Specified Performance		−40 to +85			−40 to +85			−55 to +125			°C

[1] See Analog Devices military data sheet for 883B tested specifications.
[2] Does not include effects of external resistor R_G.
[3] One input grounded. G = 1.
[4] This is defined as the same supply range that is used to specify PSR.

Appendix B

PIC18F4550

28/40/44-Pin, High-Performance, Enhanced Flash, USB Microcontrollers with nanoWatt Technology

MICROCHIP

PIC18F2455/2550/4455/4550 Data Sheet

28/40/44-Pin, High-Performance, Enhanced Flash, USB Microcontrollers with nanoWatt Technology

MICROCHIP PIC18F2455/2550/4455/4550

28/40/44-Pin, High-Performance, Enhanced Flash, USB Microcontrollers with nanoWatt Technology

Universal Serial Bus Features:

- USB V2.0 Compliant
- Low Speed (1.5 Mb/s) and Full Speed (12 Mb/s)
- Supports Control, Interrupt, Isochronous and Bulk Transfers
- Supports up to 32 Endpoints (16 bidirectional)
- 1 Kbyte Dual Access RAM for USB
- On-Chip USB Transceiver with On-Chip Voltage Regulator
- Interface for Off-Chip USB Transceiver
- Streaming Parallel Port (SPP) for USB streaming transfers (40/44-pin devices only)

Power-Managed Modes:

- Run: CPU on, Peripherals on
- Idle: CPU off, Peripherals on
- Sleep: CPU off, Peripherals off
- Idle mode Currents Down to 5.8 μA Typical
- Sleep mode Currents Down to 0.1 μA Typical
- Timer1 Oscillator: 1.1 μA Typical, 32 kHz, 2V
- Watchdog Timer: 2.1 μA Typical
- Two-Speed Oscillator Start-up

Flexible Oscillator Structure:

- Four Crystal modes, including High-Precision PLL for USB
- Two External Clock modes, Up to 48 MHz
- Internal Oscillator Block:
  - 8 user-selectable frequencies, from 31 kHz to 8 MHz
  - User-tunable to compensate for frequency drift
- Secondary Oscillator using Timer1 @ 32 kHz
- Dual Oscillator Options allow Microcontroller and USB module to Run at Different Clock Speeds
- Fail-Safe Clock Monitor:
  - Allows for safe shutdown if any clock stops

Peripheral Highlights:

- High-Current Sink/Source: 25 mA/25 mA
- Three External Interrupts
- Four Timer modules (Timer0 to Timer3)
- Up to 2 Capture/Compare/PWM (CCP) modules:
  - Capture is 16-bit, max. resolution 5.2 ns ($T_{CY}/16$)
  - Compare is 16-bit, max. resolution 83.3 ns (T_{CY})
  - PWM output: PWM resolution is 1 to 10-bit
- Enhanced Capture/Compare/PWM (ECCP) module:
  - Multiple output modes
  - Selectable polarity
  - Programmable dead time
  - Auto-shutdown and auto-restart
- Enhanced USART module:
  - LIN bus support
- Master Synchronous Serial Port (MSSP) module Supporting 3-Wire SPI (all 4 modes) and I²C™ Master and Slave modes
- 10-Bit, Up to 13-Channel Analog-to-Digital Converter (A/D) module with Programmable Acquisition Time
- Dual Analog Comparators with Input Multiplexing

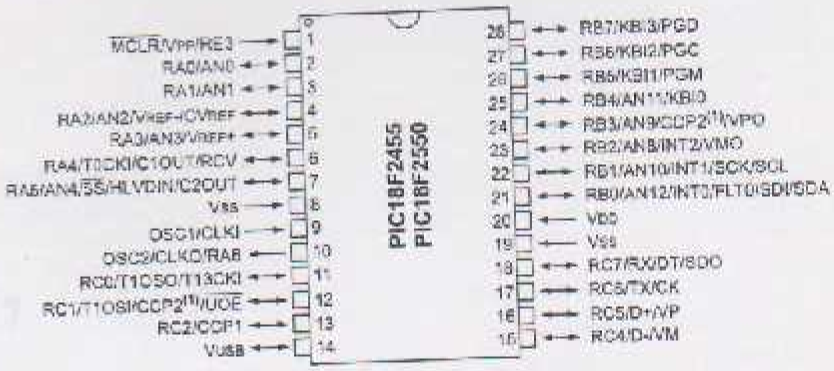
Special Microcontroller Features:

- C Compiler Optimized Architecture with Optional Extended Instruction Set
- 100,000 Erase/Write Cycle Enhanced Flash Program Memory Typical
- 1,000,000 Erase/Write Cycle Data EEPROM Memory Typical
- Flash/Data EEPROM Retention: > 40 Years
- Self-Programmable under Software Control
- Priority Levels for Interrupts
- 8 x 8 Single-Cycle Hardware Multiplier
- Extended Watchdog Timer (WDT):
  - Programmable period from 41 ms to 131s
- Programmable Code Protection
- Single-Supply 5V In-Circuit Serial Programming™ (ICSP™) via Two Pins
- In-Circuit Debug (ICD) via Two Pins
- Optional Dedicated ICD/ICSP Port (44-pin, TQFP package only)
- Wide Operating Voltage Range (2.0V to 5.5V)

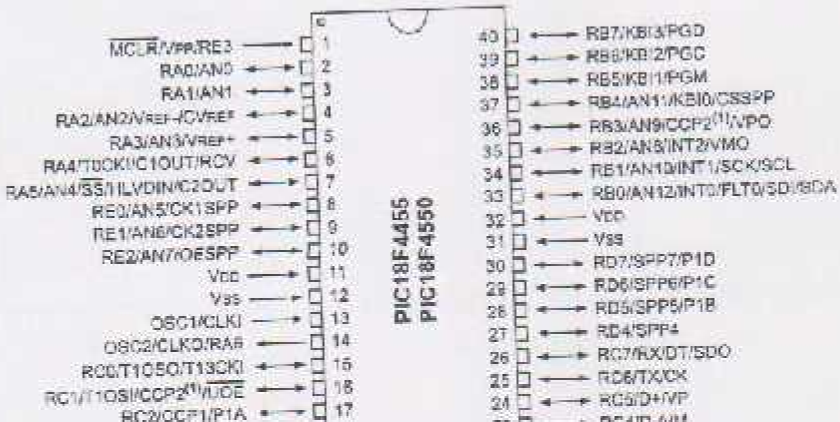
Device	Program Memory		Data Memory		I/O	10-Bit A/D (ch)	CCP/ECCP (PWM)	SPP	MSSP		EUSART	Comparators	Timers 8/16-Bit
	Flash (bytes)	# Single-Word Instructions	SRAM (bytes)	EEPROM (bytes)					SPI	Master I²C™			
PIC18F2455	24K	12288	2048	256	24	10	2/0	No	Y	Y	1	2	1/3
PIC18F2550	32K	16384	2048	256	24	10	2/0	No	Y	Y	1	2	1/3
PIC18F4455	24K	12288	2048	256	35	13	1/1	Yes	Y	Y	1	2	1/3
PIC18F4550	32K	16384	2048	256	35	13	1/1	Yes	Y	Y	1	2	1/3

Pin Diagrams

28-Pin PDIP, SOIC



40-Pin PDIP



Note 1: RB3 is the alternate pin for CCP2 multiplexing.

Appendix C

LM317

Three Terminal Adjustable Regulator

National Semiconductor

February 25, 2011

LM117/LM317A/LM317

3-Terminal Adjustable Regulator

General Description

The LM117 series of adjustable 3-terminal positive voltage regulators is capable of supplying in excess of 1.5A over a 1.2V to 37V output range. They are exceptionally easy to use and require only two external resistors to set the output voltage. Further, both line and load regulation are better than standard fixed regulators. Also, the LM117 is packaged in standard transistor packages which are easily mounted and handled.

In addition to higher performance than fixed regulators, the LM117 series offers full overload protection available only in IC®. Included on the chip are current limit, thermal overload protection and safe area protection. All overload protection circuitry remains fully functional even if the adjustment terminal is disconnected.

Normally, no capacitors are needed unless the device is situated more than 6 inches from the input filter capacitors in which case an input bypass is needed. An optional output capacitor can be added to improve transient response. The adjustment terminal can be bypassed to achieve very high ripple rejection ratios which are difficult to achieve with standard 3-terminal regulators.

Besides replacing fixed regulators, the LM117 is useful in a wide variety of other applications. Since the regulator is "floating" and sees only the input-to-output differential voltage, supplies of several hundred volts can be regulated as long as the maximum input to output differential is not exceeded, i.e., avoid short-circuiting the output.

Also, it makes an especially simple adjustable switching regulator, a programmable output regulator, or by connecting a fixed resistor between the adjustment pin and output, the LM117 can be used as a precision current regulator. Supplies with electronic shutdown can be achieved by clamping the adjustment terminal to ground which programs the output to 1.2V where most loads draw little current.

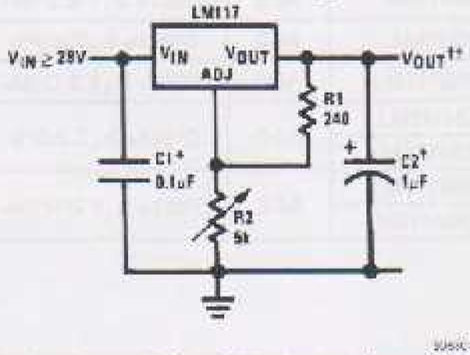
For applications requiring greater output current, see LM150 series (3A) and LM138 series (5A) data sheets. For the negative complement, see LM137 series data sheet.

Features

- Guaranteed 1% output voltage tolerance (LM317A)
- Guaranteed max. 0.01%/V line regulation (LM317A)
- Guaranteed max. 0.3% load regulation (LM117)
- Guaranteed 1.5A output current
- Adjustable output down to 1.2V
- Current limit constant with temperature
- P+ Product Enhancement tested
- 80 dB ripple rejection
- Output is short-circuit protected

Typical Applications

1.2V–25V Adjustable Regulator



Full output current not available at high input-output voltages

*Needed if device is more than 6 inches from filter capacitors.

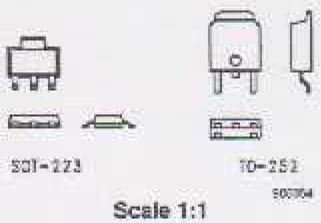
†Optional—improves transient response. Output capacitors in the range of 1µF to 1000µF of aluminum or tantalum electrolytic are commonly used to provide improved output impedance and rejection of transients.

$$^{\dagger\dagger}V_{OUT} = 1.25V\left(1 + \frac{R2}{R1}\right) + I_{ADJ}(R_2)$$

LM117/LM317A/LM317 Package Options

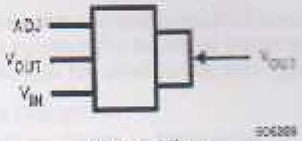
Part Number	Suffix	Package	Output Current
LM117, LM317	K	TO-3	1.5A
LM317A, LM317	T	TO-220	1.5A
LM317	S	TO-263	1.5A
LM317A, LM317	EMP	SOT-223	1.0A
LM117, LM317A, LM317	H	TO-39	0.5A
LM117	E	LCC	0.5A
LM317A, LM317	MDT	TO-252	0.5A

SOT-223 vs. TO-252 (D-Pak) Packages



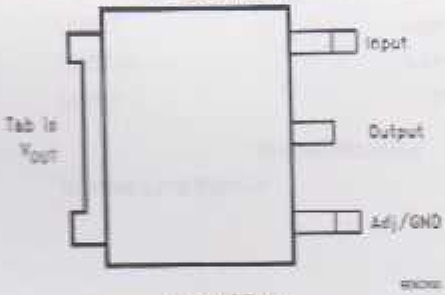
Scale 1:1

4-Lead SOT-223 (EMP)



Front View
NS Package Number MP04A

TO-252 (MDT)



Front View
NS Package Number TD03B

Ordering Information

Package	Temperature Range	Output Current	Order Number	Package Marking	Transport Media	NSC Drawing
TO-3 Metal Can (K)	$-55°C \le T_J \le +150°C$	1.5A	LM117K STEEL	LM117K STEEL P+	50 Per Bag	K02A
	$0°C \le T_J \le +125°C$	1.5A	LM317K STEEL	LM317K STEEL P+	50 Per Bag	
	$-55°C \le T_J \le +150°C$	1.5A	LM117K/883	LM117K/883	50 Per Bag	K02C
TO-220 3- Lead	$-40°C \le T_J \le +125°C$	1.5A	LM317AT	LM317AT P+	45 Units/Rail	T03B
	$0°C \le T_J \le +125°C$	1.5A	LM317T	LM317T P+	45 Units/Rail	
TO-263 3- Lead	$0°C \le T_J \le +125°C$	1.5A	LM317S	LM317S P+	45 Units/Rail	TS3B
			LM317SX		500 Units Tape and Reel	
SOT-223 4- Lead	$0°C \le T_J \le +125°C$	1.0A	LM317EMP	N01A	1k Units Tape and Reel	MP04A
			LM317EMPX		2k Units Tape and Reel	
	$-40°C \le T_J \le +125°C$	1.0A	LM317AEMP	N07A	1k Units Tape and Reel	
			LM317AEMPX		2k Units Tape and Reel	
TO-39 Metal Can (H)	$-55°C \le T_J \le +150°C$	0.5A	LM117H	LM117H P+	500 Per Box	H03A
	$-55°C \le T_J \le +150°C$	0.5A	LM117H/883	LM117H/883	20 Per Tray	
	$-40°C \le T_J \le +125°C$	0.5A	LM317AH	LM317AH P+	500 Per Box	
	$0°C \le T_J \le +125°C$	0.5A	LM317H	LM317H P+	500 Per Box	
LCC	$-55°C \le T_J \le +150°C$	0.5A	LM117E/883	LM117E/883	50 Units/Rail	E20A
TO-252 3- Lead D-Pack	$0°C \le T_J \le +125°C$	0.5A	LM317MDT	LM317MDT	75 Units/Rail	TD03B
			LM317MDTX		2.5k Units Tape and Reel	
	$-40°C \le T_J \le +125°C$	0.5A	LM317AMDT	LM317AMDT	75 Units/Rail	
			LM317AMDTX		2.5k Units Tape and Reel	

Absolute Maximum Ratings (*Note 1*)

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

Power Dissipation	Internally Limited
Input-Output Voltage Differential	+40V, −0.3V
Storage Temperature	−65°C to +150°C
Lead Temperature	
Metal Package (Soldering, 10 seconds)	300°C
Plastic Package (Soldering, 4 seconds)	260°C
ESD Tolerance (*Note 5*)	3 kV

Operating Temperature Range

LM117	$-55°C \le T_J \le +150°C$
LM317A	$-40°C \le T_J \le +125°C$
LM317	$0°C \le T_J \le +125°C$

Preconditioning

Thermal Limit Burn-In	All Devices 100%

LM117 Electrical Characteristics (*Note 3*)

Specifications with standard type face are for $T_J = 25°C$, and those with **boldface type** apply over **full Operating Temperature Range.** Unless otherwise specified, $V_{IN} - V_{OUT} = 5V$, and $I_{OUT} = 10$ mA.

Parameter	Conditions	LM117 (*Note 2*)			
		Min	Typ	Max	Units
Reference Voltage	$3V \le (V_{IN} - V_{OUT}) \le 40V$, $10 mA \le I_{OUT} \le I_{MAX}$ (*Note 3*)	**1.20**	**1.25**	**1.30**	V
Line Regulation	$3V \le (V_{IN} - V_{OUT}) \le 40V$ (*Note 4*)		0.01 **0.02**	0.02 **0.05**	%/V
Load Regulation	$10 mA \le I_{OUT} \le I_{MAX}$ (*Note 3, Note 4*)		0.1 **0.3**	0.3 **1**	%
Thermal Regulation	20 ms Pulse		0.03	0.07	%/W
Adjustment Pin Current			**50**	**100**	μA
Adjustment Pin Current Change	$10 mA \le I_{OUT} \le I_{MAX}$ (*Note 3*) $3V \le (V_{IN} - V_{OUT}) \le 40V$		**0.2**	**5**	μA
Temperature Stability	$T_{MIN} \le T_J \le T_{MAX}$		**1**		%
Minimum Load Current	$(V_{IN} - V_{OUT}) = 40V$		**3.5**	**5**	mA
Current Limit	$(V_{IN} - V_{OUT}) \le 15V$ K Package H, E Package	**1.5** **0.5**	**2.2** **0.8**	**3.4** **1.8**	A
	$(V_{IN} - V_{OUT}) = 40V$ K Package H, E Package	0.3 0.15	0.4 0.20		A
RMS Output Noise, % of V_{OUT}	$10 Hz \le f \le 10 kHz$		0.003		%
Ripple Rejection Ratio	$V_{OUT} = 10V$, f = 120 Hz, $C_{ADJ} = 0$ μF		65		dB
	$V_{OUT} = 10V$, f = 120 Hz, $C_{ADJ} = 10$ μF	**66**	80		dB
Long-Term Stability	$T_J = 125°C$, 1000 hrs		0.3	1	%
Thermal Resistance, θ_{JC} Junction-to-Case	K (TO-3) Package H (TO-39) Package E (LCC) Package		2 21 12		°C/W
Thermal Resistance, θ_{JA} Junction-to-Ambient (No Heat Sink)	K (TO-3) Package H (TO-39) Package E (LCC) Package		39 186 88		°C/W

Appendix D

The Software of PIC18F4550

```
unsigned volt=0;

void main() {

OSCCON=0x72;

ADCON1 = 0x0D;

trisb=0;

trisc=0;

trisa=255;

trisd=0;

porta=0;

portb=0;

portd=0;

portc=0;


while(1)

{

volt=adc_read(0);


if (volt<180)portb=0b00000011;

else if (volt>=183)portb=0b00000101;

else portb=0;
```