MEDICINE/WATER DELIVERY SYSTEM WITH RESPONSE TO CHANGES IN PATIENT'S BODY

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FINAL REPORT

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CERTIFICATION OF APPROVAL

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Aida Nurnazifa bt Abdul Ghani

ABSTRACT

In many medical applications, the medicine or water needs to be infused over a period of time. The systems also need fully involvement from the physician to monitor the delivery rate and control the amount of rate by adjusting the device manually. Most of the delivery system is an open loop system where the rate is set basis of the past experience, mathematical computation and trial and error. This might lead to the human error with wrong collected data such as mistake in decimal place dose. Based on the problems, this project is done to replace and enhance the open loop systems by using the automated closed loop system. Basically, this project is to create a medicine delivery system with response to changes in patient's body. The change in patient's body is referred to the temperature. Basically, a thermistor sensor is used to detect the changes in the temperature by placing it at the human skin. Then, the signal from the sensor is sent to the PIC microcontroller to control the medicine delivery by automatically adjusting the pump movement. The microcontroller evaluates the received signal and displays the value in degree Celsius on the LCD display. The overall delivery system is fully automated controlled by the controller which depends on the human body temperature changes.

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LIST OF ABBREVIATIONS

RTD	Resistance Temperature Device
EMF	Electromagnetic Force
PTC	Positive Temperature Coefficient
NTC	Negative temperature Coefficient
PIC	Programmable Integrated Circuit
LCD	Liquid Crystal Display
PCB	Printed Circuit Board

CHAPTER 1
INTRODUCTION

1.1 Background of Study

A medicine or water delivery system is used to maintain appropriate fluid levels provided to patients. It can prevent fluid and electrolyte or nutritional imbalances in the patient by using the infusion devices. It is also commonly used to supply nutrients to maintain growth and in treating dehydration in pediatric patients. Basically, the water or fluid is delivered based on the measurement of vitals sign such as the temperature, blood pressure and also the pulse rate. The infusion devices is involved with the traditional intravenous infusion systems consist of a fluid container, administration set, and a clamp to control the flow from the set to the patient. The intravenous infusion therapy itself is a simple procedure which relies on gravity.

The existence systems need fully involvement of nurses and doctors to monitor the volume delivery and to ensure the actual volume being delivered with an accurate flow rate over period of time, which could be several minutes, hours and days. Usually, the rate of delivery is set by nurse or physician according to the past experience and observation, mathematical computation, or by trial and error as illustrate in **Figure 1**. The control action is taken manually either by adjusting the rate of infusion or by injecting the desired amount of the drug. Recently, the system was enhanced by using a computer to compute a recommended drug dosage and the infusion is done manually (**Figure 2**). However, the system was improved by the introduction of electronic drop counter that can determine the drip rate of IV delivery.

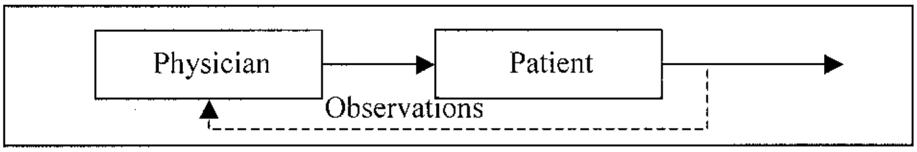

Figure 1 : Conventional method

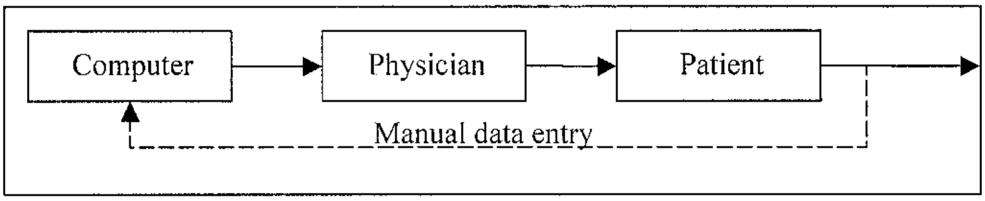

Figure 2 : Computer assisted therapy

Basically, the infusions systems consist of two components, which is a mechanism that delivers the drug and a means of controlling the rate of delivery. Overall, the most current systems or devices operate in open loop system with continuous infusion and limited control of input. The delivery is said to be open loop if the rate of infusion is set a-prior and it is not automatically altered by the patient's response. Due to the limitation of open loop systems, the closed loop systems are among of developing systems designed to automate the control of physiological variable. In the closed loop, the desired delivery rate is computed and set automatically according to the condition of patient monitored by appropriate transducers or sensors **(Figure 3).**

For example in measuring temperature, a mercury-in-glass thermometer is the most popular method which are slow, difficult to read and susceptible to contamination. Therefore, the electronic thermometers has become widely use for medical application due to its reliability and accuracy. The electronic thermometers might have various types of sensors for measuring. The accuracy must be addressed for patient safety concerns such as excessive delivery to avoid side effects occurs.

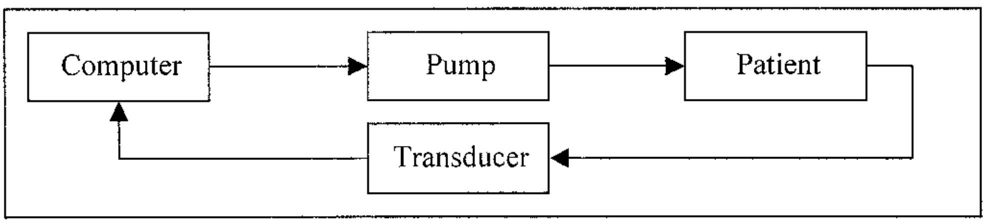

Figure 3 : Closed loop control

1.2 Problem Statement

1.2.1 Problem Identification

The current drug delivery apply the open loop system that requires frequent patient monitoring by the nurses and doctors to ensure an accurate flow rate with the current devices. Nurses and doctors need to gather the information during the monitoring to determine the correct amount of volume and also the timing for medicine/water to be delivered to the patient. Even with high tech pump systems, the patient still has to collect the data in order to adjust the pump rate and usually done manually by nurses or doctors. Therefore, the costs of medical care increase due to undivided attention from physician and nurse to manually control the infusion rate.

The calculations also are made based on the physician past experience, mathematical computation, or by trial and error. For most of the cases, due to the human error might lead to wrong collected data such as mistake in decimal place dose. Thus, it can affect the dose rate either to be excessive or insufficient. Besides that, the flow rate using the traditional intravenous systems cannot be accurately controlled as it is counted in drops rather than in volumetrically. The rate also is difficult to adjust and might change with time

1.2.2 Significant of the project

The development of the water delivery system with response to changes in patient's temperature body will require less monitoring from nurses or doctors. This is due to the device itself which can monitor and automatically react according to patient body's behavior changes or needs. Besides that, through the development of this project, the human error in collecting the data can be reduced as the measurement and calculation is done by the controller.

1.3 Objectives

The main purpose of the project is to introduce a delivery system that can supply medicine or water to patient with response to changes in the patient's body. The change described is in terms of body temperature of the patient. Another reason of this project implementation is to introduce the application of the closed loop system in delivery system.

The second objectives is to study the relationship between the human body changes; temperature with specific devices such as a sensor and to determine how the sensor can respond with human changes in controlling the medicine/water delivery system.

1.3.1 Feasibility of the Project within Scope and Time Frame

This project is categorized into two major phases. The first phase of the project concentrates more on research on the related topic while the second phase is more on the implementation of the project into a prototype. All the information about this project can be obtained from books in the library and journals from the Internet. The project is considered to be feasible within the time frame.

CHAPTER 2

LITERATURE REVIEW

In traditional drug delivery methods, drugs were delivered to the human body exclusively via oral and intravenous means [1]. Administration of intravenous infusion therapy has developed over the past 40 years from a comparatively simple procedure, relying on gravity, to the use of sophisticated multi-channel electronic pumps. These devices can calculate and administer multi-drug regimes and replace large volumes of fluid almost automatically [2].

Many hospital patients are likely to experience IV therapy, particularly following surgical procedures and during acute illness. It has been suggested that 63 per cent of surgical patients in Europe have an IV cannula inserted (Nystrom 1983) and at least 70 per cent of patients in acute care will receive IV therapy for at least part of their hospitalization (Feldstein 1986). A study conducted in a hospital in Wales indicated that approximately 16 per cent of all adult patients had IV therapy (Griffiths Jones 1990). This evidence clearly emphasizes the importance of IV maintenance (Bostrom-Ezrati 1990) [2].

Basically, the administration of intravenous infusion therapy must involve with the control of flow rate as for the safety factors. IV running too fast 'Over infusion' is one of the greatest risks that healthcare professionals will encounter when administering IV medication. Circulatory overload and speed shock may occur if an infusion is given too rapidly [2].

The existence flow-control devices are used to regulate the infusion at the prescribed administration. Basically, there are two types of flow control devices; manual flow-control devices and electronic infusion devices. The manual flow-control devices include roller, screw, slide or regulator clamps and also volume control devices such as Buretrol [3].

The administration set contains a manual-flow device such as a slide clamp, a roller (regulator) clamp or a screw to regulate a prescribed infusion rate as showed in **Figure 4**. In other words, these devices are used to controls drip rate. The number of drops falling per minute is determined manually by nurses or doctors. The level of drip rate depends on the adjustment of the regulator clamp.

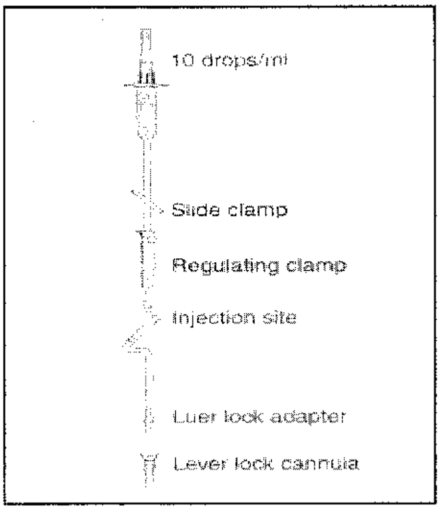

Figure 4 : Basic Administration Set [3]

Another type of manual-flow control is the Dial-a-Flo Regulation that uses a Dial-a-Flo regulator to regulate infusion of fluid at the desired rate. Like the previous method, the number of drip rate per minute is counted to ensure the accurate level of fluid being transferred. Gravitation is important to facilitate the drip rate. For the electronic infusion pumps such as controller infusion device is used to generate flow by gravity. The nurse sets the flow rate with the specific gravity with and the height of the bag to determine the maximum delivery pressure.

Electronic infusion devices are operated either by electricity or battery and are used to administer IV fluids and medications. There are two types of electronic infusion devices that are controllers and pumps. The controller infusion devices generate flow by gravity and are capable of maintaining a constant preset flow rate either by drop counting or volumetric delivery [3]. The flow rate and the specific gravity of the solution are set by physicians and the height of the bag determines the maximum delivery pressure.

Infusion pumps maintain the flow rate under positive pressure. Pump counter the effects of resistance in the delivery system and pressure fluctuations at the infusion site. Volumetric pumps use either pumping cassette or chamber to delivery a fixed volume over a specified period of time. Syringe infusion pumps rely on a syringe or cartridge to deliver the fluid at a specific set rate that is shown in **Figure 5**.

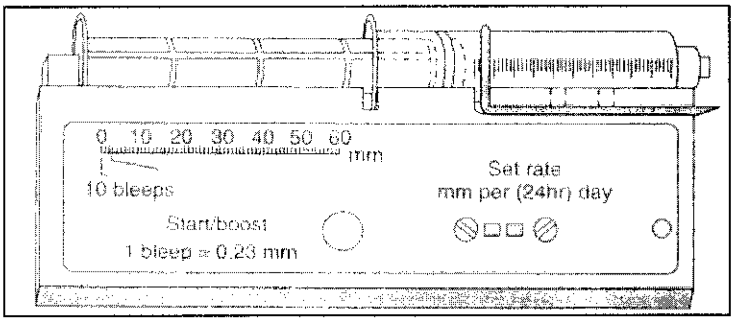

Figure 5 : Principle of Syringe Pump [4]

Most of the devices used are an open loop system and need frequent monitoring from nurses to collect the data in order to control the flow rate by adjusting the devices. This might lead to the human error in tracking the patient's data. Besides that, the major difficulty with traditional intravenous infusion systems is the flow rate cannot be controlled accurately (Crass and Vance, 1985). The flow rate is counted in drops rather than measured volumetrically. The rate is difficult to adjust and will change with time [4].

Many incidents associated with IV devices - of which there has been a significant number – have been attributed to 'user error' rather than 'machine failure' (Barker 1992, MDA 1995a). The fact that user error has been cited as the main problem has made it difficult to obtain reliable data regarding the causes of these incidents, perhaps because of the legal consequences which could result from the action or inaction of the staff involved [2].

2.1 Temperature Sensors

The stand-alone mercury-in-glass clinical thermometer was introduced from the early 20th century until recently [5]. It is accurate, stable enough, easy to use and inexpensive. However, it has slow response, difficult to read and susceptible to contamination. Therefore, it has been replaced by the electronic thermometers, widely used due to its reliability, accuracy and rapid response. The electronic thermometers have various types of sensors for measuring used for medical application such as the thermocouples, electrical resistance thermometer, RTD and thermistor.

2.1.1 Thermocouple

A thermocouple is made of two dissimilar metals are joined together at either end, forming two junctions. The junction at the higher temperature is termed the hot or measuring junction while at the lower temperature (0°C), is the cold or reference junction **(Figure 6)**. The thermocouple works by generating a small thermoelectric potential (emf) signal proportional to the temperature difference between the junctions of two metals. The thermocouple-based systems are simpler and are widely available.

However, in designing them into systems is complicated by the need for special extension wires and reference junction compensation. They are often difficult and time-consuming to set up. The systems also demand users who are experienced and knowledgeable with both thermocouple technology (and its eccentricities), temperature calibration methods and procedures. The thermocouples are normally used for measurements of surface skin temperature but generally measure relative temperature.

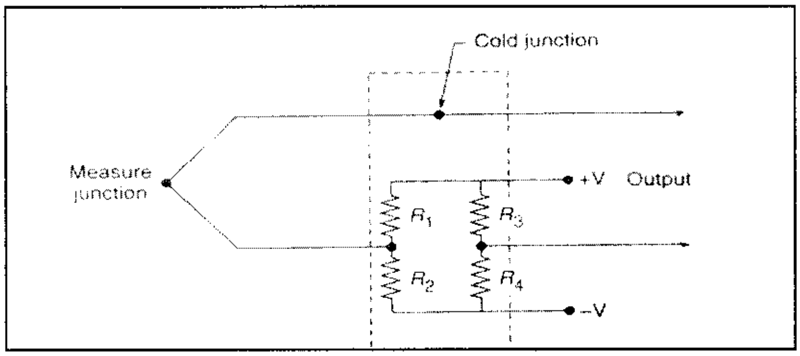

Figure 6 : Bridge type reference junction compensator [4]

2.1.2 Resistance Thermometer (RTDs)

Resistance thermometers or known as resistance temperature devices (RTDs), rely on the principle that the resistance of a metal varies with temperature. The metal normally used is either platinum or nickel, depends upon the linearity and sensitivity. Thermometers are constructed from a coil of these metals **(Figure 7).** Resistance temperature detector probes tend to be larger and to require more peripheral equipment [6]. Resistance thermometer is used for rectal and body temperature while small thermistor probes is suitable for oesophageal, rectal and intravenous measurements.

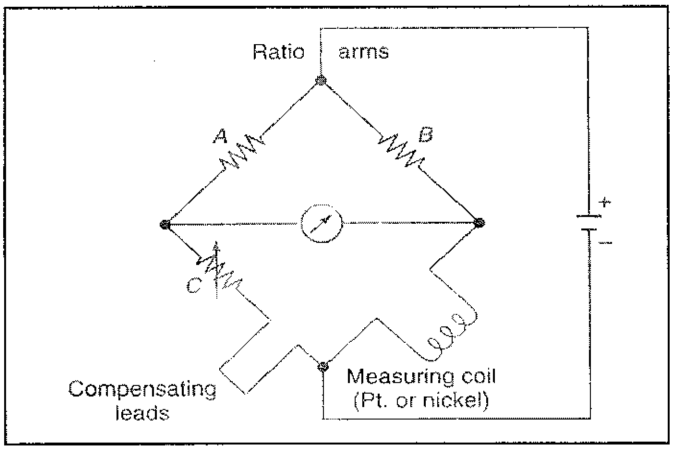

Figure 7 : Circuit arrangement of a metal resistance thermometer [4]

2.1.3 Thermistors

A thermistor is a resistive device made up of metal oxides that are formed into a bead and encapsulated in epoxy or glass. It is built by a high negative temperature coefficient (NTC) or positive temperature coefficient (PTC). NTC device decrease the resistance with increasing temperature and vice versa for the PTC device, causing a large voltage drop. NTC chip thermistor is one of the temperature sensors with high sensitivity response to temperature. The simplest circuit employing thermistors for temperature measurement is shown in **Figure 8**. Commercial thermistors are available with 25°C resistance of 100Ω, 300Ω, 10kΩ until 1MΩ.

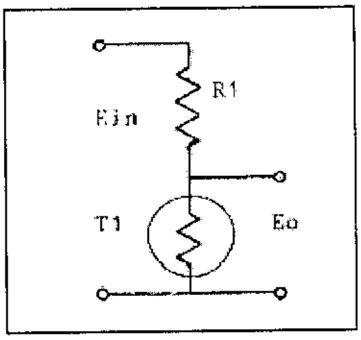

Figure 8 : Elementary Voltage Divider with Thermistor [7]

Typically, the thermistor has various packages types, from a normal size until the smallest size. The better choice of thermistor types is based on the application and the properties required from the sensor. However, all choices involve trade-offs. Basically, there are two common types of thermistor that are bead thermistors and disk thermistors.

In terms of size, the bead thermistors are made much smaller that discs. Besides, the bead thermistors are more stable result from the customary glass encapsulation. However, the stability of any thermistor depends upon the maximum temperature to which the sensor is exposed. Recently, the disks thermistors have been shown to approach the stability of the best beads with the advantage of interchangeability, which beads do not [7]. Reported stability for glass-coated disks is shown in **Table 1**.

Table 1 : Reported Stability for glass-coated disks for continuous operating temperature [7]

OP TEMP	1 MONTH	10 MONTH	100 MONTH
25°C	<0.01°C	<0.01C	<0.01°C
70°C	<0.01°C	<0.01C	<0.01°C
100°C	0.01°C	0.02C	0.01°C
150°C	0.03°C	0.05C	0.08°C
200°C	0.08°C	0.22C	0.60°C

The comparisons between these sensors are showed in **Table 2** below. These sensors have their own advantages and disadvantages. The perfect choice for the temperature sensor types is based on the application, properties required from the sensor and also involve with trade-off.

Table 2 : Comparison of temperature sensors [17]

	RTD	Thermocouple	Thermistor
Temperature range	-260 to 850°C	-270 to 1800°C	-80 to 150°C (typical)
Sensor Cost	Moderate	Low	Low
System Cost	Moderate	High	Moderate
Stability	Best	Low	Moderate
Sensitivity	Moderate	Low	Best
Linearity	Best	Moderate	Poor
Specify for:	General purpose sensing Highest accuracy Temperature averaging	Highest temperatures	Best sensitivity Narrow ranges(e.g. medical) Point sensing

2.2 Applications

The most common application of the thermistor is used in digital thermometer. It can be easily accomplished by interfacing a Wheatstone bridge, thermistor network and a digital voltmeter integrated circuit as illustrated in **Figure 9**. The IC consists of A/D converter and built-in LCD driver providing resolution 0.1°C. It can be interfaced with additional circuitry to provide a temperature control and digital display.

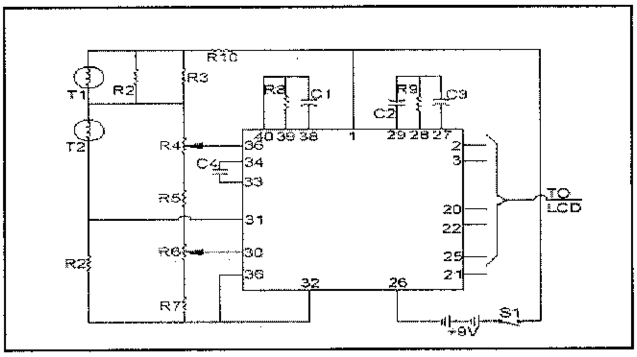

Figure 9 : Digital Thermometer [15]

CHAPTER 3
METHODOLOGY

3.1 Project Methodology

The first phase of this project involves a lot of researches regarding the existence drug delivery devices. The purpose is to understand the operation of these devices for drug delivery and problems related. Hence, the improvement of the system can be made based on the information of the existence devices. The second stage is to develop a details mechanism of the drug delivery system with diagram to illustrate the mechanism of the system effectively. The final stage is to identify the components or gadgets that will be used to construct the sensor, monitoring device, delivery device and the also controlling device. **Figure 10** below describes the summarization of the whole project methodology.

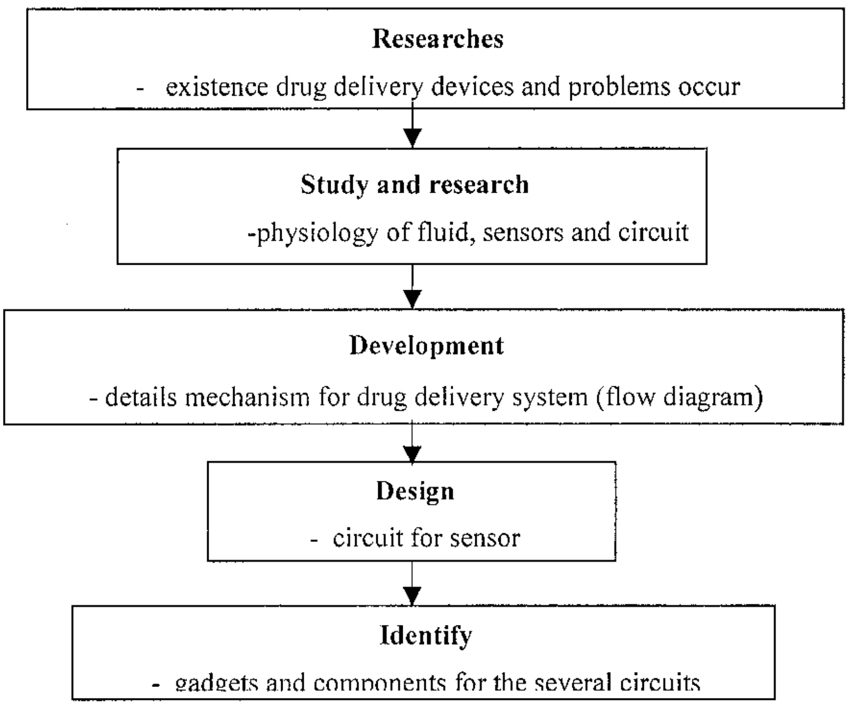

Figure 10 : Project methodology

3.1.1 Methodology Medicine/Water Delivery System

The project is focused more on the temperature sensors with the microcontroller system. The first step is to decide the type of temperature sensor that is suitable to use for the project as well as for medical application. Through some research from the Internet and books, thermistor provides the most suitable characteristic for patient's body temperature sensor.

Then, suitable circuit of the sensor is determined such as the Wheatstone bridge circuit. At this stage, all the components involve must be decided including the types of controller. This circuit will simulate using the Electronic Workbench (EWB) or the PSpice software to ensure the functionality of the circuit as well to get the exact result of the circuit. The sensor is calibrated with the bridge circuit to prove the linearity of this sensor circuit and to obtain the output voltage value correspond to the temperature.

Then, the sensor circuit (bridge circuit) is combined with the microcontroller to control the operation of the circuit. This step will involve some C programming of the microcontroller to control the whole system. Again, the process of simulation is done to prove the whole circuit is well function before testing it on circuit board.

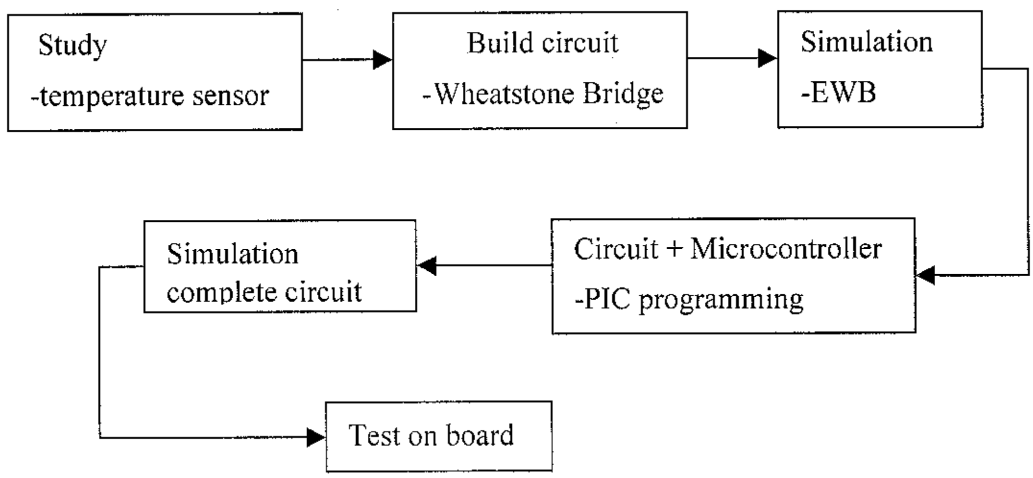

Figure 11 : Temperature sensor with controller system flow diagram

3.2 Tools

The main component, thermistor sensor that is needed for the project is not provided in the Lab and it is difficult to obtain. The components that are available in the Laboratory are PIC16F877, resistors, operational amplifier, LCD and the motor. Below **(Table 3)** is the list of the components and software that are used for this project.

Table 3 : Lists of Components and Software

Component	Thermistor Resistors PIC16F877 LCD Board Voltage Regulator 7508 Oscillator 4MHz
Software	Electronic Workbench (EWB) PSpice PICC Compiler (CSS)
Hardware	WRAP-13 board

CHAPTER 4
DISCUSSION

4.1 Findings

4.1.1 Thermistors Sensor

Thermistor sensor is selected due to the low cost and by using this sensor it will provide moderate cost for the whole system. For medical applications, thermistor are frequently taped to a patient's skin and used to control sensor for the temperature regulating system. Thermistors are electrically conductive elements that are designed to change electrical resistance in a predictable manner with changes in applied temperature. The quality of performance varies widely, in terms of interchangeability, stability, temperature range and others characteristics.

The NTC thermistor can be categorized into two major groups depending upon the method by which electrodes are attached to the ceramic body. The first group consists of bead types that include various types of glass beads and bare beads. The second group is thermistor that has metallized surface contacts such as disks and chips. The most suitable thermistor for medical application is the glass beads which is the most stable with higher accuracy and faster response compared to the second group. Besides, thermistor or the sensor must have higher sensitivity for at least one decimal place which can be obtained from the glass bead.

Usually, a normal range for body temperature is always remains in a range 35 to 40°C. While for skin temperature, it may vary much more widely when the skin is cooled or warmed externally. Therefore, a thermometer for skin measurement must have wider range for example 0 to 50°C. A temperature resolution of 0.1°C is required in body temperature measurement and absolute accuracy of 0.1°C is acceptable for most medical purpose. For medical requirement, thermistor has the accuracy of ±0.1°C and 4% change in resistance per degree centigrade. It is also has wider tolerance values range from ±0.05°C to ±0.2°C with high sensitivity of temperature changes.

However, the thermistor sensor obtained for this project does not meet the entire medical requirement. This NTC thermistor (Glass Bead) is a GM type that has resistance value of 4.7kΩ under reference temperature, 25°C. The lowest temperature of the thermistor is 25°C and the highest temperature is up to 125°C. Besides that, the resistance tolerances are quite large for medical application which is ±20%. Therefore, it is not suitable and practical for medical application. The thermistor datasheet is attached together in the **Appendix B**.

Table 4 : Thermistor Specification

Characteristic	Description
Type	Glass Bead NTC thermistor
Temperature range	25°C to 125°C
Resistance	4.7kΩ at 25°C
Tolerance	± 20%
Voltage Supply	1V to 6V

Most of the glass bead thermistor sensors provided is for the industrial consumer application with too low and too high operating temperature. These thermistors are manufactured for general temperature measurement and control purpose such as fluid level detection and flow measurement and control. Besides that, most of the sensors also are made from metal and alloy such as aluminums which is not suited for medical especially for skin temperature measurement. A table of resistance and its temperature can be referred to the graph nominal resistance versus temperature that is attached in the thermistor datasheet (**Appendix B**).

4.1.2 Wheatstone Bridge Circuit

The basic circuit applied for the sensor measurement is the Wheatstone bridge circuit where the sensor is connected in a voltage divider network (**Figure 12**). The thermistor sensor is placed with another three resistors. The circuit produces a voltage output that varies linearly with temperature as the thermistor is a nonlinear device. The value of thermistor resistance is usually depends on the environment temperature. However, for this circuit, the resistance of the thermistor is 4.7kΩ under the reference temperature which is 25°C. The output voltage for the circuit is the difference between the voltage drop across R_1 and R_2.

The voltage output of the voltage dividers can be very small (close to zero) if R_1 and R_2 are both small compared to the other resistors. While the voltage output of the voltage dividers can be very close to the supply voltage if R_1 and R_2 are both large compared to the other resistors. The value of the R_3 must be equal with the thermistor value,T. while the R_1 must equal with the R_2 in order to obtain a bridge output of zero volts. When the R_1 and R_2 values are larger, the voltage output is increase.

$$R_1R_2 = TR_3 = 0$$

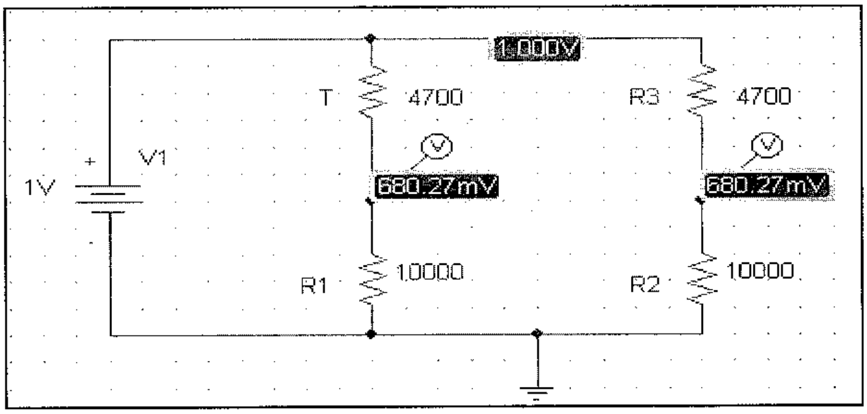

Figure 12 : Bride Circuit Simulation using PSpice (thermistor is replaced by normal resistor, T)

4.1.3 Calibration of Thermistor Sensor

According to the thermistor data sheet, the voltage supply can varies between 1V up to 6V. However, this circuit works fine with supplier of 5V. The resistors used for the circuit is $R_1 = R_2 = 10k\Omega$ and $T = R_3 = 4.7k\Omega$. In the circuit, the NTC thermistor is utilized as the active legs. As the temperature increases, the voltage output also will be increased.

This circuit is designed to produce 191mV at 30°C and 656mV at 45°C with the application of 4.7k ohm thermistor. For this project, the temperature ranges that will be considered are from 32°C to 40°C, suitable range for skin thermometer. The output from the bridge circuit is listed in the **Table 5** which is in a milivolts.

Table 5 : Output voltage (V_{out}) related to temperature

Resistance* kΩ	Temp (°C)	Simulation (mV)	Experiment (mV)	Graph (mV)
3.9	30	196	191.5	191.7
3.4	35	330	361.6	345
2.8	40	505	512.8	510
2.2	45	697	656.7	670

**Refer to the nominal resistance v temperature characteristic given in datasheet*

The output values obtained are plotted in the Microsoft Excel to attain the linearity of the output voltage (**Figure 13**). The purpose of this plotted graph is to figure out the V_{out} at certain temperature. The V_{out} must be determined correctly for microcontroller input for other controlling purpose. The graphs plotted showed that thermistor circuit is linear to the output voltage. As the temperature increase, V_{out} also increases. However, the output voltages at certain temperature between plotted graphs and measured from circuit are slightly different.

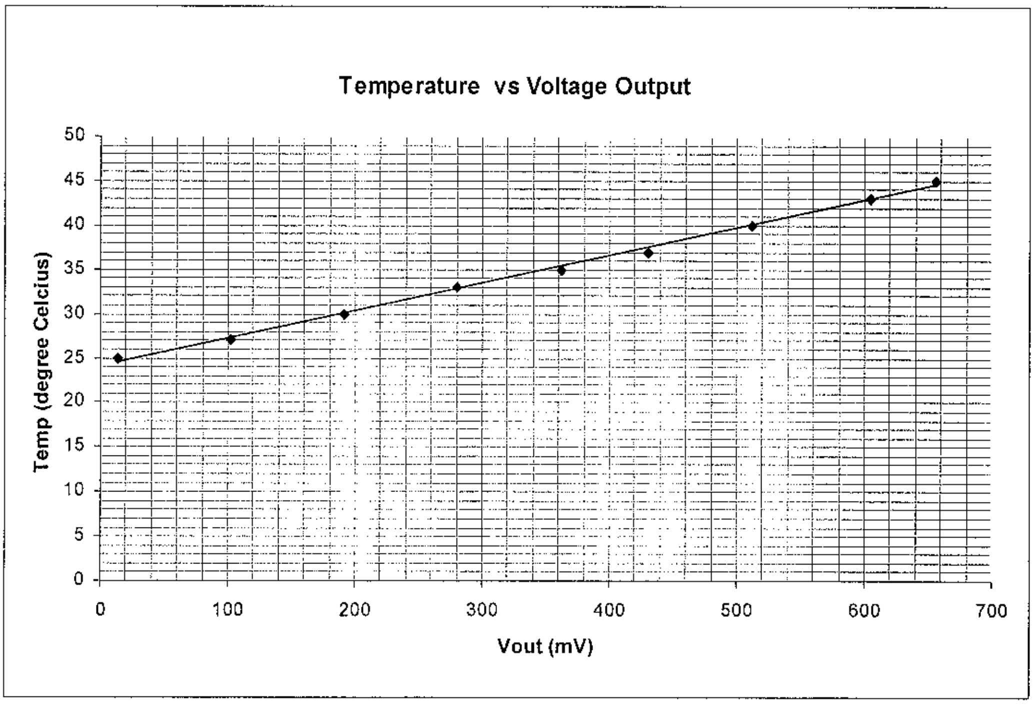

Figure 13 : Graph temperature versus voltage output

4.2 Discussion

Basically, this delivery system applies the closed loop systems where the patient's response is used to automatically adjust the infusion rate. The advantages of the closed loop are to improve patient care by delivering the right amount of agent for maximum effectiveness. The effectiveness is something that can be measured such as the body temperature. The second reason for using automated closed loop control is to reduce cost of medical care as the traditional system needs the physician attention and to manually control the infusion rate.

In fully automated system, the transducer or the sensor senses the control variable while the controller determines the infusion rate based on the discrepancy between the actual and desired variables and automatically computed infusion rate delivered by a pump. As a result, the system operates without human intervention until the delivery is completed or until malfunction of the system is detected.

The project is done for delivery system that has the feedback loop between the patients and the sensor. Basically the whole system is controlled by a microcontroller to control the mechanism of the pump according to the human body's temperature changes. The transducer or thermistor sensor is used to detect or to measure the changes of the patient's body temperature is connected by holding or wearing on wrist or attached to finger tips.

Thermistors are passive semiconductors which produce resistance values depend on temperature. The characteristics of this chip fulfill the requirement as the sensor device to detect the human physiology temperature. This sensor provides a narrow range of temperature which is between -80 to 150°C compared to other sensors.

The temperature of the human body will affect the thermistor and increase its temperature. The thermistor decrease in resistance as its temperature increase. By applying the Wheatstone bridge circuit, it will produce the equivalent output voltage according to the degree of temperature. The voltage produce is considered as the input for the microcontroller. The microcontroller is used to monitor the rate of medicine/water delivery by controlling the movement of the pump. The illustration of this closed loop delivery system is showed in **Figure 14**.

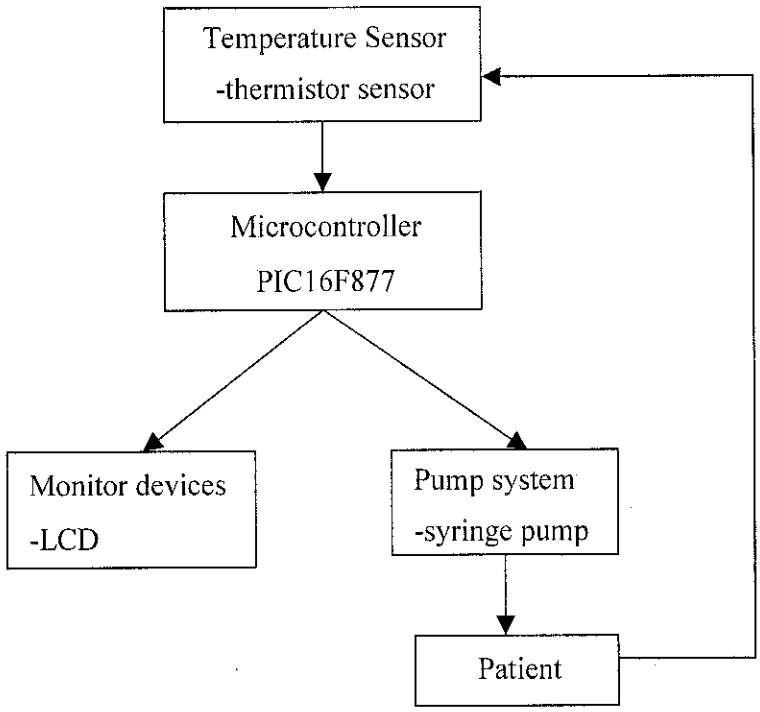

Figure 14 : Illustration of the Medicine/Water Delivery System

However, due to time constraint and limitation of the component, student only completed for the monitoring part which consist of microcontroller, LCD together with sensor circuit. For the pump system, the student managed to do the research part which will be discussed in the recommendation section.

4.2.1 Microcontroller System

In order to have a circuit that can monitor the temperature and control the delivery system, the Wheatstone bridge circuit is enhanced by adding it to the microcontroller system. Basically, the microcontroller will receive the input from the Wheatstone bridge circuit and the outputs are used to control the mechanism of the pump system and to display the current temperature value on the LCD.

The Wheatstone circuit will send the data or information in analogue to the controller which may involve some the calculation process. Then, this signal is sent to the pump system to control the mechanism that is operating in analogue system. The digital output of the microcontroller is connected to the LCD segments to display the temperature value.

The PICF877 that is chosen for this project has five ports of I/O; A, B, C, D and E. The pin description of this PIC is given in **Table 6**. This chip provides large data memory that is 368 bytes and has a large space for programming. The features and the information about PIC16F877 microcontroller is attached in **Appendix C**.

Table 6 : Pin description of PIC16F877

Pin	Description
1	Reset input and Vpp programming voltage of a microcontroller
2-7	PORT A pins
8-10	PORT B pins
11,32	Positive power supply
12,31	Ground of power supply
13-14	Pin assigned for oscillator
15-18, 23-26	PORT C pins
19-22, 27-30	PORT D pins
33-40	PORT B pins

This PIC16F877 provide built in successive-approximation A/D converter with 10 bit multi-channel where the conversation time faster than digital-ramp ADC. There will be 1023 possible steps for this converter. This A/D module has high and low voltage reference input in the software selectable to some combination of V_{DD}, V_{SS}, RA2 or RA3.

The A/D converter is assumed to have full scale (F.S) output of 5V. Therefore, the step size is 5mV.

$$\text{Step size} = \frac{F.S}{2^{10}-1} = \frac{5V}{1023} = 5mV$$

Resolution of A/D converter is the smallest unit of measure. The resolution is always equal to the weight of the LSB and also referred to as step size. The resolution percentage is 0.1%.

$$\frac{\text{Step size}}{F.S} \times 100\% = 0.1\%$$

4.2.2 Monitoring Device

The monitoring device is used to display the values or displays graph of the parameter such as human body's temperature. Liquid crystal displays (LCD) are preferred devices for display as they require very low current to operate with large screen size. It has 14-pin access with eight data lines, three control lines and three power lines. Pin 4, Register Select bit is used to select whether data or an instruction is being transferred between the controller and the LCD. If the bit is high, character data can be transferred to and from the module. When the line is low, data bytes transferred to the display and treated as commands.

For pin 5, this line is set to low in order to write commands and set to high to read status information from its register. Pin 6 is the Enable line, is used to initiate the actual transfer of commands between the module and the data lines. Pin 7-14 are the eight data bus lines. Data can be transferred to or from the display either by a single 8-bit byte or two 4-bit "nibbles". Only the upper four data lines are used for the latter case. The pin configuration for the LCD is given in **Table** 7.The LCD circuit is shown in **Figure 15**.

Table 7 : Pin Configuration for LCD

PIN	Description
1	Ground
2	VCC
3	Contrast Voltage
4	"R/S" Instruction/Register Select
5	"R/W" Read/Write LCD register
6	"E" Enable
7-14	Data I/O Pins

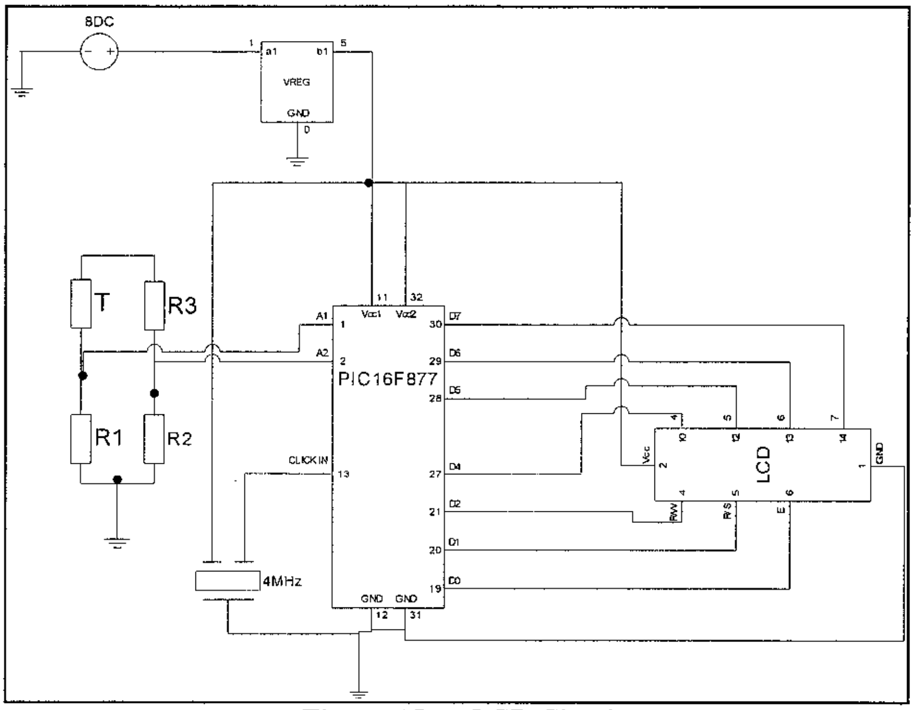

Figure 15 : LCD Circuit

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Relevancy to the Objectives

The main objectives in producing a delivery system that can supply medicine or water to patient with response to changes in their body have not been achieved yet. At this moment, the second objective regarding the relationship between the body temperature changes temperature with a sensor has been accomplished. Through some research, the thermistor is chosen as temperature sensor due to the low cost and the acceptable characteristic for medical application. However, the components itself is hard to find either from the lab or the electronic shops. The thermistor that is available is the PTC type, which is different in application and requirement of the project. The overall idea of the whole system has strongly established but the components are hard to obtain.

In overall, this project involves two major phases. The first phase of the project concentrates more on research on the related topic such as selection of temperature sensor as well as designing the whole system which has been completed. The second phase is focused more on the implementation of the project into a prototype. However, due to time constraint and limitation of the components, the second phase of the project is not fully completed. The main component, thermistor sensor is obtained in the middle of the semester. The student managed to complete this project until the LCD part. Therefore, the result of this project is only for the monitoring part that is used to monitor skin temperature and display the value on the LCD.

In order for this project to be possible, the knowledge of programming in both C and assembly language is crucial as to program the microcontroller and to control the overall operation of the circuit. However, the knowledge in the programming can be enhanced by reading materials and tutorials available on the microcontroller websites.

5.2 Suggested Future Work for Expansion and Continuation

5.2.1 Thermistor Sensor

The temperature sensor that is used for this project is not recommended and not practical for medical application. The sensor does not meet the medical requirement in terms of tolerance and accuracy. Therefore, for this project to be more practical for real medical application, the thermistor sensor that is used must meet the entire requirement and specification needed for the patient safety. The accuracy and higher resolution is the most major consideration in selecting the right sensor.

5.2.2 Motor System

As mentioned earlier, the project only completed until the LCD part. Therefore, for the future work suggestion, this project should be enhanced with motor circuitry in order to produce a complete closed loop delivery system. A stepper motor is suitable for the project application with rating voltage around 12 Volts. Basically, a stepper motor moves one step at a time. If the stepper motor is command to move some specific number of steps, it rotates incrementally that many number of steps and stops which is suitable to control the movement of the pump. Usually, the motor is connected to the worm gear which is used to control the pump movement. The infusion may be continuous or pulsatile. Besides that, several important factors are crucial in order to produce better performance such as the accuracy, speed, torque, and also execution time

5.2.3 Delivery and Monitoring Systems

The devices that are suitable to use for the medicine/water delivering is the syringe pump that has a worm gear mechanism and a holder for the syringe. A precision step motor will turn the worm gear and moving a push plate against the back of the syringe **(Figure 16).** The device is mainly for the applications that require the delivery of volumes limited by the syringe size. Control is achieved by varying the stroke length or the stroke rate. However, the system also can be implemented to other delivery devices instead of using the syringe pump for example controlling the valve opening for the administration of intravenous infusion therapy set.

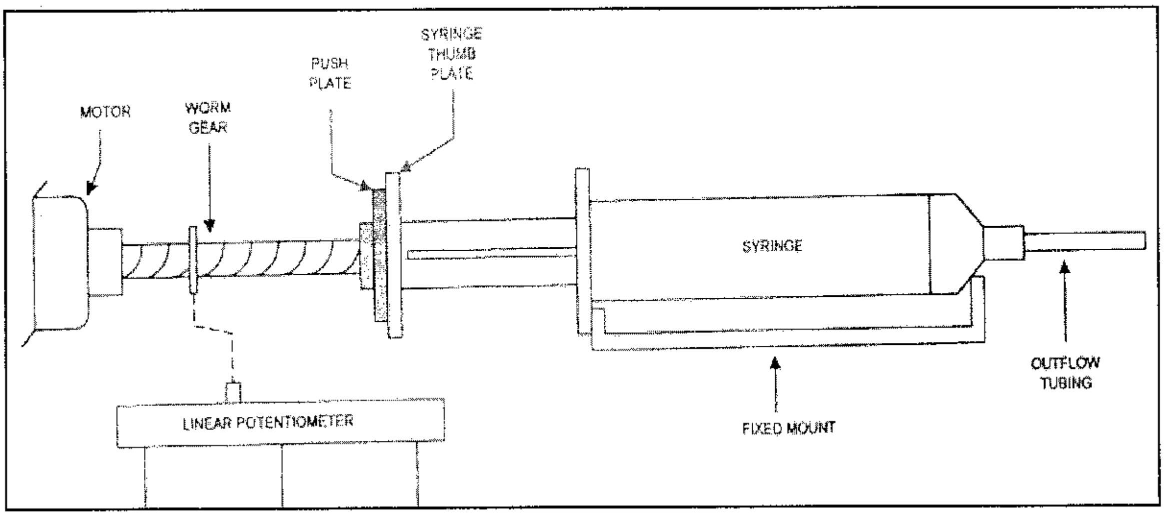

Figure 16 : Application of Syringe Pump and Motor

For the monitoring systems, other feature can be added by monitoring from the computer through serial communication port.

5.2.4 Fabrication on PCB

The circuitry can be enhanced by proper fabrication of the circuit and wiring system on the circuit board. The circuit can be improved by using PCB as to make the circuit more systematic. The trouble shooting problem will be easier if the PCB were utilized for this project.

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APPENDICES

APPENDIX A

PROJECT GANTT CHART

Gantt Chart: First Semester (February 2005 - May 2005)

No	Description	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
1	Briefing on FYP Background															
2	Topic assigned to students															
3	Research existance drug delivery system/devices/problems															
4	**Preliminary report**															
5	Research / Study															
	Temperature sensors															
6	Development delivery system/ mechanism															
7	**Progress Report**															
8	Research/design circuit for device/sensor															
9	Identify components															
10	**Interim Report**															
11	**Oral presentation**															

Gantt Chart: First Semester (July 2005 -Nov 2005)

No	Description	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
1	Identify temperature sensor															
2	Order Component															
4	**Progress Report 1**															
5	Calibration Sensor															
	Basic Design															
6	**Progress Report 1**															
7	Detail Design															
8	Implementation/ Design															
9	**Draft Report**															
10	**Final Report (soft copy)**															
11	**Technical Report**															
12	**Oral presentation**															
13	**Final Report**															

APPENDIX B
NTC THERMISTOR DATASHEET

BOWTHORPE THERMISTORS

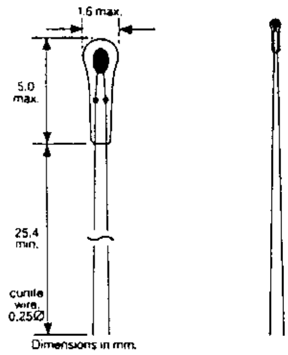
ISI-112
ISI-113

NTC Thermistors

INDUSTRIAL/CONSUMER

PROFESSIONAL

TYPE GM



Actual Size

Highly sensitive bead in solid glass pellet

Temperature Measurement & Control

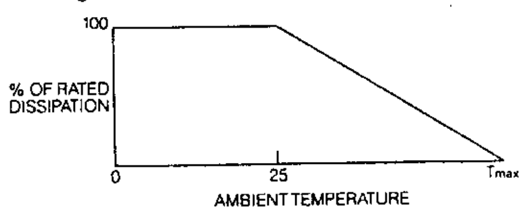
Fluid Level Detection
Flow Measurement & Control

Description

- Small size, fast response Typical applications include:
  - Temperature compensation of crystal oscillators
  - Control of industrial boiler temperature
  - Monitor of machine lubricant flow
- Approved to CECC 43 000
- Resistance tolerances ±20%, ±10%, ± 5% at reference temperature.
- B value tolerance ±3%
- Time constant (cooling) = 5s
- Dissipation factor = 0.75mW/°C
- Typical resistance change after 10,000 hours at 25°C <1%
- Weight = 0.1g
- Pack quantity = 25

Resistance Group	Code	Reference Resistance Ω	B Value K	∝ at 25°C %/°C	Reference Temperature °C	Tmax °C	Pmax at 25°C mW
LOW			25-85		25	125	75
	GM221	220	2655	−2.99			
	331	330	2725	−3.07			
	471	470	2780	−3.13			
	681	680	2845	−3.20			
	102	1k	2910	−3.27			
	152	1.5k	3010	−3.39			
	222	2.2k	3125	−3.52			
	332	3.3k	3240	−3.64			
	472	4.7k	3340	−3.76			
	682	6.8k	3445	−3.88			
MEDIUM			25-85		25	200	130
	103	10k	3555	−4.00			
	153	15k	3670	−4.13			
	223	22k	3780	−4.25			
	333	33k	3895	−4.38			
	473	47k	3940	−4.43			
	683	68k	3995	−4.49			
	104	100k	4045	−4.55			
	154	150k	4100	−4.61			
	224	220k	4145	−4.66			
	334	330k	4200	−4.72			
HIGH			100-200		100	300	205
	474	25k	4320	−4.86			
	684	35k	4[illegible]30	−4.93			
	105	50k	44[illegible]0	−5.04			

Derating



Coding Example

GM 47 3 Y

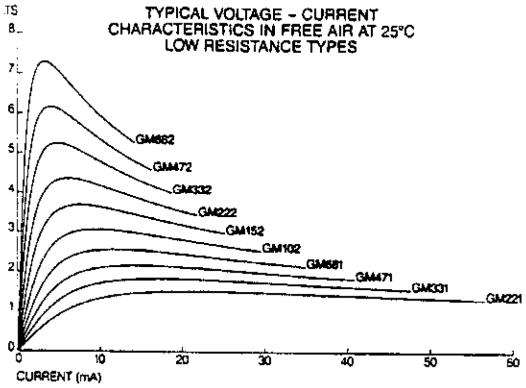
GM TYPE

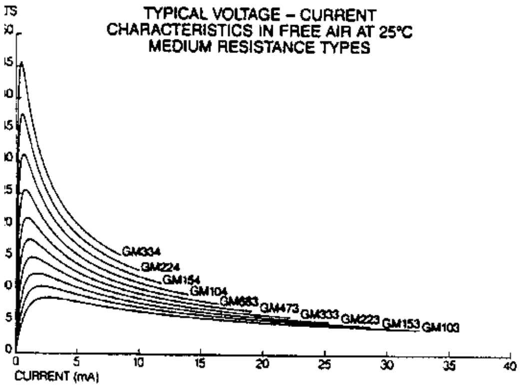
BASE RESISTANCE FACTOR AT 25°C

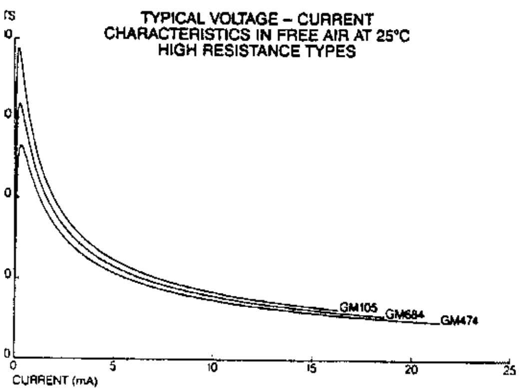
RESISTANCE MULTIPLIER
1 = 10^1
2 = 10^2
3 = 10^3
4 = 10^4
5 = 10^5

RESISTANCE TOLERANCE AT REFERENCE TEMPERATURE
W = ±20%
Y = ±10%
Z = ± 5%

eg. GM473Y = $47 \times 10^3 \Omega$
= 47KΩ ± 10% AT 25°C







NG:

's are designed to be intrinsically safe components provided
ɔerated within the rated voltages or currents and inside the
ded temperature range.

: :

ıl care required for electronic components should be exer-

L :

hazards are involved in disposal. Incineration of thermis-
recommended due to the emission of toxic fumes from
ted devices or the shattering of glass and/or ceramic with
ɜzard from hot jagged material.

PHYSICAL FORM :

The wire ends should not be bent nearer than 3mm to the glass body of the thermistor

PRODUCT SAFETY NOTES :

Although these devices are glass encapsulated no insulation properties are implied.
Some of the thermistors in this range, when operated at or near maximum rated dissipation in a self-heat mode, may require applied voltages capable of causing dangerous electric shock.

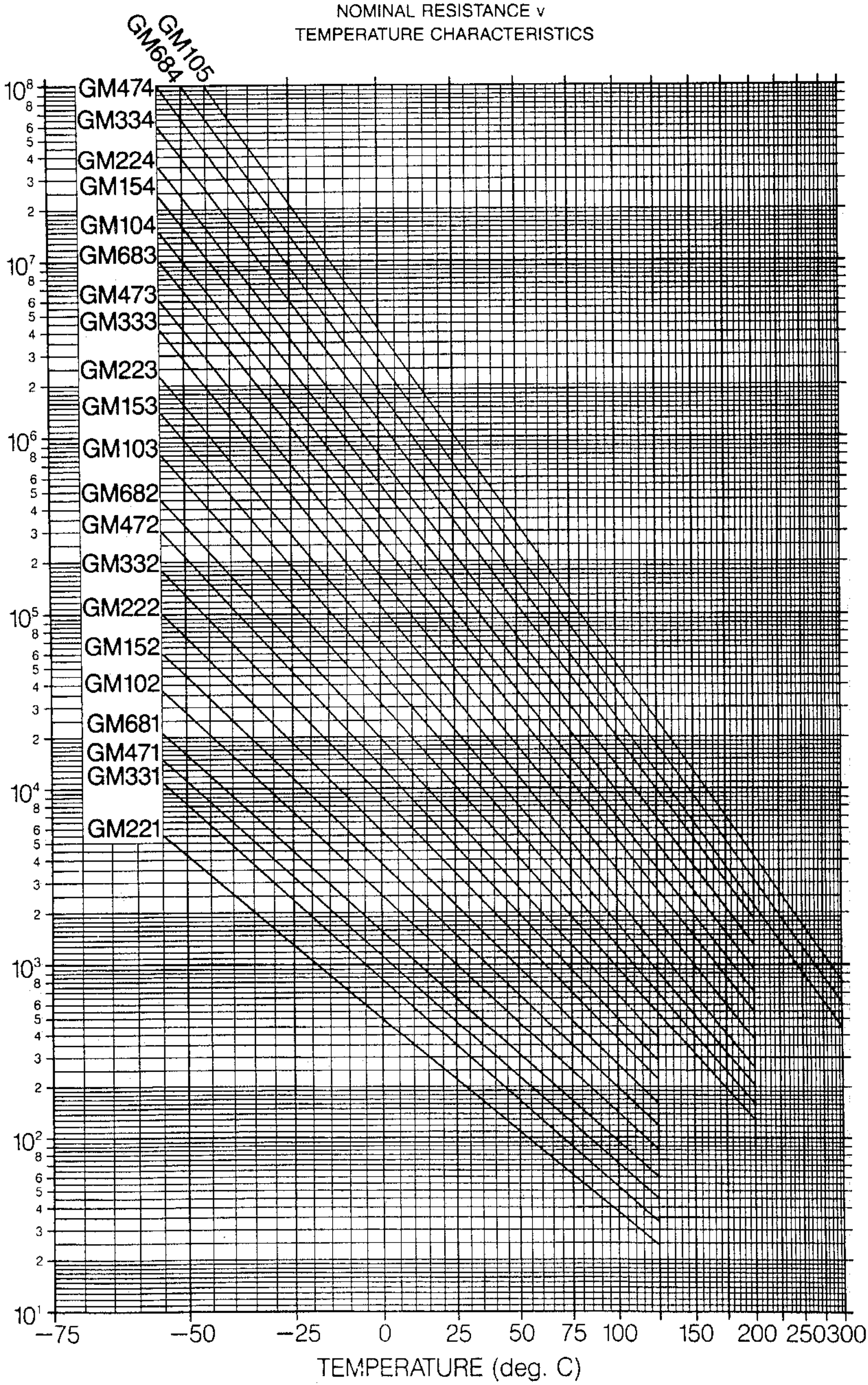
FLAMMABLE FLUIDS :

These devices attain high surface temperatures when used as liquid sensors. This precludes their direct use in flammable fluids; please contact the Technical Sales Department for further information.

BOWTHORPE THERMISTORS
CROWN INDUSTRIAL ESTATE
PRIORSWOOD ROAD
TAUNTON
SOMERSET TA2 8QY

TELEPHONE 0823 335200
TELEX 46748
FAX 0823 332637

NOMINAL RESISTANCE v
TEMPERATURE CHARACTERISTICS



APPENDIX C
PIC16F877 DATASHEET

MICROCHIP

PIC16F87X

28/40-pin 8-Bit CMOS FLASH Microcontrollers

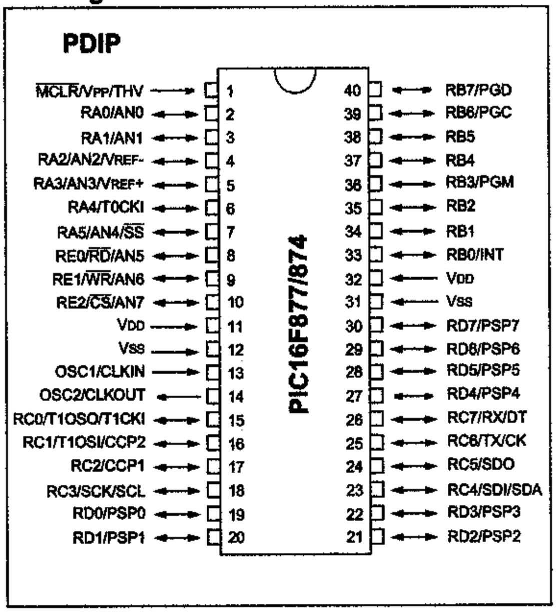
Devices Included in this Data Sheet:

- PIC16F873
- PIC16F874
- PIC16F876
- PIC16F877

Microcontroller Core Features:

- High-performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input
  DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory,
  Up to 368 x 8 bytes of Data Memory (RAM)
  Up to 256 x 8 bytes of EEPROM data memory
- Pinout compatible to the PIC16C73B/74B/76/77
- Interrupt capability (up to 14 sources)
- Eight level deep hardware stack
- Direct, indirect and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code-protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low-power, high-speed CMOS FLASH/EEPROM technology
- Fully static design
- In-Circuit Serial Programming™ (ICSP) via two pins
- Single 5V In-Circuit Serial Programming capability
- In-Circuit Debugging via two pins
- Processor read/write access to program memory
- Wide operating voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25 mA
- Commercial and Industrial temperature ranges
- Low-power consumption:
  - < 2 mA typical @ 5V, 4 MHz
  - 20 µA typical @ 3V, 32 kHz
  - < 1 µA typical standby current

Pin Diagram



Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI™ (Master Mode) and I²C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) 8-bits wide, with external RD, WR and CS controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

11.0 ANALOG-TO-DIGITAL CONVERTER (A/D) MODULE

The Analog-to-Digital (A/D) Converter module has five inputs for the 28-pin devices and eight for the other devices.

The analog input charges a sample and hold capacitor. The output of the sample and hold capacitor is the input into the converter. The converter then generates a digital result of this analog level via successive approximation. The A/D conversion of the analog input signal results in a corresponding 10-bit digital number. The A/D module has high and low voltage reference input that is software selectable to some combination of V_{DD}, V_{SS}, RA2 or RA3.

The A/D converter has a unique feature of being able to operate while the device is in SLEEP mode. To operate in sleep, the A/D clock must be derived from the A/D's internal RC oscillator.

The A/D module has four registers. These registers are:

- A/D Result High Register (ADRESH)
- A/D Result Low Register (ADRESL)
- A/D Control Register0 (ADCON0)
- A/D Control Register1 (ADCON1)

The ADCON0 register, shown in Register 11-1, controls the operation of the A/D module. The ADCON1 register, shown in Register 11-2, configures the functions of the port pins. The port pins can be configured as analog inputs (RA3 can also be the voltage reference) or as digital I/O.

Additional information on using the A/D module can be found in the PICmicro™ Mid-Range MCU Family Reference Manual (DS33023).

REGISTER 11-1: ADCON0 REGISTER (ADDRESS: 1Fh)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	U-0	R/W-0
ADCS1	ADCS0	CHS2	CHS1	CHS0	GO/$\overline{\text{DONE}}$	—	ADON
bit7							bit0

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n = Value at POR reset

bit 7-6: **ADCS1:ADCS0: A/D Conversion Clock Select bits**
00 = Fosc/2
01 = Fosc/8
10 = Fosc/32
11 = FRC (clock derived from an RC oscillation)

bit 5-3: **CHS2:CHS0**: Analog Channel Select bits
000 = channel 0, (RA0/AN0)
001 = channel 1, (RA1/AN1)
010 = channel 2, (RA2/AN2)
011 = channel 3, (RA3/AN3)
100 = channel 4, (RA5/AN4)
101 = channel 5, (RE0/AN5)(1)
110 = channel 6, (RE1/AN6)(1)
111 = channel 7, (RE2/AN7)(1)

bit 2: **GO/$\overline{\text{DONE}}$**: A/D Conversion Status bit
If ADON = 1
1 = A/D conversion in progress (setting this bit starts the A/D conversion)
0 = A/D conversion not in progress (This bit is automatically cleared by hardware when the A/D conversion is complete)

bit 1: **Unimplemented**: Read as '0'

bit 0: **ADON**: A/D On bit
1 = A/D converter module is operating
0 = A/D converter module is shutoff and consumes no operating current

Note 1: These channels are not available on the 28-pin devices.

REGISTER 11-2: ADCON1 REGISTER (ADDRESS 9Fh)

U-0	U-0	R/W-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0
ADFM	—	—	—	PCFG3	PCFG2	PCFG1	PCFG0
bit7							bit0

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n = Value at POR reset

bit 7: **ADFM: A/D Result format select**
1 = Right Justified. 6 most significant bits of ADRESH are read as '0'.
0 = Left Justified. 6 least significant bits of ADRESL are read as '0'.

bit 6-4: **Unimplemented: Read as '0'**

bit 3-0: **PCFG3:PCFG0**: A/D Port Configuration Control bits

PCFG3: PCFG0	AN7[1] RE2	AN6[1] RE1	AN5[1] RE0	AN4 RA5	AN3 RA3	AN2 RA2	AN1 RA1	AN0 RA0	VREF+	VREF-	CHAN / Refs[2]
0000	A	A	A	A	A	A	A	A	VDD	VSS	8/0
0001	A	A	A	A	VREF+	A	A	A	RA3	VSS	7/1
0010	D	D	D	A	A	A	A	A	VDD	VSS	5/0
0011	D	D	D	A	VREF+	A	A	A	RA3	VSS	4/1
0100	D	D	D	D	A	D	A	A	VDD	VSS	3/0
0101	D	D	D	D	VREF+	D	A	A	RA3	VSS	2/1
011x	D	D	D	D	D	D	D	D	VDD	VSS	0/0
1000	A	A	A	A	VREF+	VREF-	A	A	RA3	RA2	6/2
1001	D	D	A	A	A	A	A	A	VDD	VSS	6/0
1010	D	D	A	A	VREF+	A	A	A	RA3	VSS	5/1
1011	D	D	A	A	VREF+	VREF-	A	A	RA3	RA2	4/2
1100	D	D	D	A	VREF+	VREF-	A	A	RA3	RA2	3/2
1101	D	D	D	D	VREF+	VREF-	A	A	RA3	RA2	2/2
1110	D	D	D	D	D	D	D	A	VDD	VSS	1/0
1111	D	D	D	D	VREF+	VREF-	D	A	RA3	RA2	1/2

A = Analog input
D = Digital I/O

Note 1: These channels are not available on the 28-pin devices.
2: This column indicates the number of analog channels available as A/D inputs and the numer of analog channels used as voltage reference inputs.

The ADRESH:ADRESL registers contain the 10-bit result of the A/D conversion. When the A/D conversion is complete, the result is loaded into this A/D result register pair, the GO/$\overline{\text{DONE}}$ bit (ADCON0<2>) is cleared and the A/D interrupt flag bit ADIF is set. The block diagram of the A/D module is shown in Figure 11-1.

After the A/D module has been configured as desired, the selected channel must be acquired before the conversion is started. The analog input channels must have their corresponding TRIS bits selected as inputs. To determine sample time, see Section 11.1. After this acquisition time has elapsed, the A/D conversion can be started. The following steps should be followed for doing an A/D conversion:

1. Configure the A/D module:
   - Configure analog pins / voltage reference / and digital I/O (ADCON1)
   - Select A/D input channel (ADCON0)
   - Select A/D conversion clock (ADCON0)
   - Turn on A/D module (ADCON0)
2. Configure A/D interrupt (if desired):
   - Clear ADIF bit
   - Set ADIE bit
   - Set GIE bit
3. Wait the required acquisition time.
4. Start conversion:
   - Set GO/$\overline{\text{DONE}}$ bit (ADCON0)
5. Wait for A/D conversion to complete, by either:
   - Polling for the GO/$\overline{\text{DONE}}$ bit to be cleared

   OR

   - Waiting for the A/D interrupt
6. Read A/D Result register pair (ADRESH:ADRESL), clear bit ADIF if required.
7. For next conversion, go to step 1 or step 2 as required. The A/D conversion time per bit is defined as TAD. A minimum wait of 2TAD is required before next acquisition starts.

11.2 Selecting the A/D Conversion Clock

The A/D conversion time per bit is defined as TAD. The A/D conversion requires a minimum 12TAD per 10-bit conversion. The source of the A/D conversion clock is software selected. The four possible options for TAD are:

- 2Tosc
- 8Tosc
- 32Tosc
- Internal RC oscillator

For correct A/D conversions, the A/D conversion clock (TAD) must be selected to ensure a minimum TAD time of 1.6 μs.

Table 11-1shows the resultant TAD times derived from the device operating frequencies and the A/D clock source selected.

TABLE 11-1: TAD vs. MAXIMUM DEVICE OPERATING FREQUENCIES (STANDARD DEVICES (C))

AD Clock Source (TAD)		Maximum Device Frequency
Operation	**ADCS1:ADCS0**	**Max.**
2Tosc	00	1.25 MHz
8Tosc	01	5 MHz
32Tosc	10	20 MHz
RC(1, 2, 3)	11	Note 1

Note 1: The RC source has a typical TAD time of 4 μs but can vary between 2-6 μs.
2: When the device frequencies are greater than 1 MHz, the RC A/D conversion clock source is only recommended for sleep operation.
3: For extended voltage devices (LC), please refer to the Electrical Specifications section.

11.3 Configuring Analog Port Pins

The ADCON1, and TRIS registers control the operation of the A/D port pins. The port pins that are desired as analog inputs must have their corresponding TRIS bits set (input). If the TRIS bit is cleared (output), the digital output level (VOH or VOL) will be converted.

The A/D operation is independent of the state of the CHS2:CHS0 bits and the TRIS bits.

Note 1: When reading the port register, any pin configured as an analog input channel will read as cleared (a low level). Pins configured as digital inputs will convert an analog input. Analog levels on a digitally configured input will not affect the conversion accuracy.

2: Analog levels on any pin that is defined as a digital input (including the AN7:AN0 pins), may cause the input buffer to consume current that is out of the device specifications.