Real-time and Continuous Infant Health Monitoring System

by

Nuremelina Binti Abu Hassan Shaari

Dissertation Report submitted in partial fulfillment of
the requirements for the
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CERTIFICATION OF APPROVAL

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TRONOH, PERAK
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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.

(Nuremelina Binti Abu Hassan Shaari)

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ABSTRACT

Continuous monitoring of physiological parameters for infants is necessary because infants are very vulnerable and cannot feedback health complaints. Recent technological advances in sensors and low-power integrated circuits have enabled the design of low-cost, miniature, lightweight, and intelligent physiological sensor nodes. These nodes, capable of sensing, processing, and communicating one or more vital signs of human body, can be seamlessly integrated into a body network for health monitoring for infant. These networks promise to transform health care by allowing inexpensive, continuous, ambulatory health monitoring with almost real-time and continuous updates. The objective of this project is to come out with the conceptual system of the Real-Time and Continuous Wireless Infant Health Monitoring System and to translate the conceptual system into a working physical prototype. The prototype will consist of a transmitter node which is interfaced with temperature sensor which is placed at the infant, and a receiver node which receives data from the transmitter node and notify the parent or caregiver according to the predefined situations. The scope of study for this project will be divided into three main parts; Temperature Sensor and Microcontroller Implementation. The author has started the project with the preliminary research in order to gather all the information regarding the project. After that, the author proceeds to two of the main scopes of the project, which is to design the temperature sensor and heart rate sensor. The chosen temperature sensor to be used in the project is LM35D IC which has the accuracy of almost ± 0.25 °C. The signal from the temperature sensor is then amplified in order to provide better resolution and sensitivity of the analog to digital conversion. The next part of this project is to implement a transmitter node to the temperature sensor so that the data can be captured and transmitted almost real time to the receiving node. Asynchronous serial data communication is used as a way to communicate between the transmitter and receiver node.

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INTRODUCTION

1. INTRODUCTION

1.1. Background of Study

One of the ways to indicate the level of health in a country is through the infant mortality rate. According to the Central Intelligent Agency World Factbook, the infant mortality rate in Malaysia has decreased constantly, although not significantly over the last ten years [1]. The trend is global, which means that the number of infant mortality rate across the world is also decreasing in the last ten years. Until March 2011, the number of infant mortality rate in Malaysia is 15.02 deaths over 1000 live births and Malaysia has been ranked as the 119th country with the highest mortality rate [2]. The leading causes of infant death haven't changed in the last several years, despite advanced technology and increased focus on prenatal care. While most people would expect the rate of infant death to be decreasing rapidly, it has actually remained pretty stable since 2000 [3].

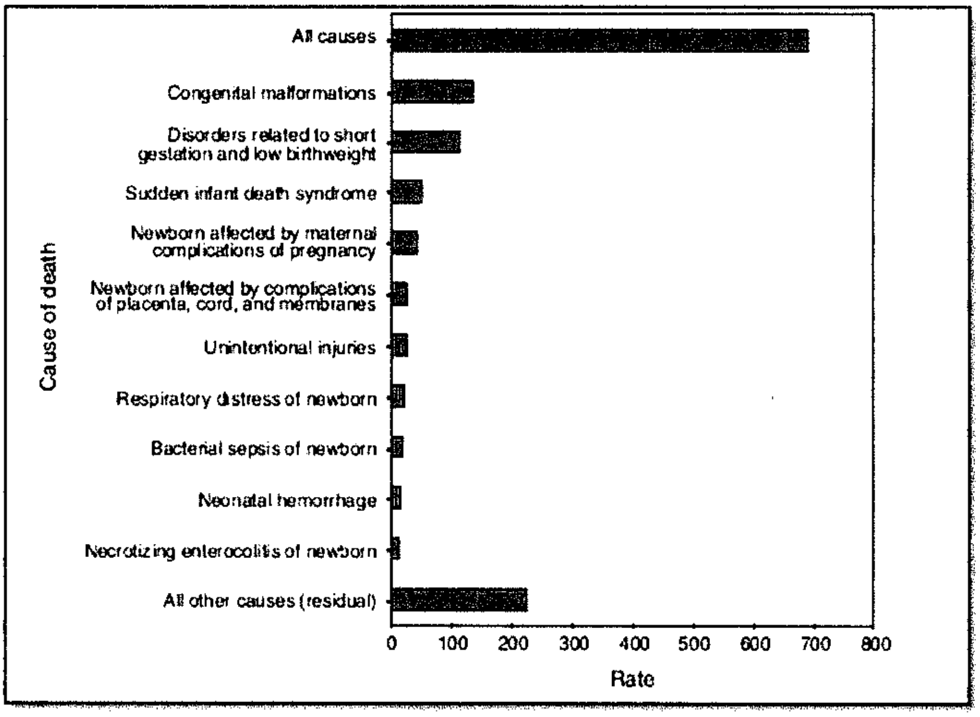


Figure 1: Ten leading causes for infants' death worldwide (CDC's (Center for Disease Control) National Center for Health Statistics, 2005).

All these statistics suggest that health care among infants needs a major shift toward a more proactive solutions. Restructuring infants' health care systems toward managing of wellness rather than illness, and focusing on prevention and early detection of disease and discomfort emerge as the answers to these problems. Wearable systems for continuous infants' health monitoring are a key technology in helping the transition to more proactive and effective healthcare. Wearable health monitoring systems will allow parent or caregiver to closely monitor changes in an infant's vital signs and provide feedback to alert parent or caregiver about the condition of the infant.

During the last few years there has been a significant increase in the number of various wearable health monitoring devices, ranging from simple pulse monitors [4] [5], activity monitors [6] [7], and portable Holter monitors [8], to sophisticated and expensive implantable sensors [9]. However, wider acceptance of the existing systems is still limited by the following important restrictions. Traditionally, personal medical monitoring systems, such as Holter monitors, have been used only to collect data. Data processing and analysis are performed offline, making such devices impractical for continual monitoring and early detection of medical disorders. In addition, individual sensors often operate as stand-alone systems and usually do not offer flexibility and integration with third-party devices. Finally, the existing systems are rarely made affordable. Having all these considerations, the author has come up with the idea of inventing the Real Time and Continuous Infant Health Monitoring System.

Recent technology advances in integration and miniaturization of physical sensors and embedded microcontrollers have enabled a new generation of health monitoring system. A number of physiological sensors that monitor vital signs of an infant (temperature, heartbeat, respiratory rate and electrocardiography) can be integrated into the Real-time and Continuous Infant Health Monitoring System. The system will consist of inexpensive, lightweight, and miniature sensors that can allow long-term, unobtrusive, ambulatory infant health monitoring with instantaneous feedback to the parent or caregiver about the current health status and real-time or near real-time updates of the infant. This system will utilize the use of serial data communication modules in the microcontroller in order to provide communications between the central monitoring device and the sensors.

In this report the author will describe about the conceptual system proposed for the Real-time and Continuous Infant Health Monitoring System. The prototype will consist of a temperature sensor that can be used to detect the infant's vital sign as well as the transmitter and receiver side that are used to send and receive continuous health information of the infant. The following sections in Chapter 1 will discuss about the problem statement, objectives, scope of study for the project. Chapter 2 will discuss about the literature review obtained during the preliminary research while Chapter 3 will discuss about the methodology proposed for completing the project. Chapter 4 will discuss about the results and analysis of the result and lastly, Chapter 5 will provide conclusion and recommendation for the project.

1.2. Problem Identification

The three leading causes of infant mortality which is congenital malformations, disorders related to short gestation and low birth weight, and Sudden Infant Death Syndrome (SIDS) are accounted for approximately 43% of all infant deaths in 2005 [9]. Here in this report the author will specifically focus on one of the causes of the infant death, which is Sudden Infant Death Syndrome (SIDS).

Sudden Infant Death Syndrome (SIDS) is defined as the sudden death of an infant younger than one year of age. If the child's death remains unexplained after a formal investigation into the circumstances of the death (including performance of a complete autopsy, examination of the death scene, and review of the clinical history), the death is then attributed to Sudden Infant Death Syndrome (SIDS) [10].

While congenital malfunctions and disorders related to short gestation and low birth weight can be prevented by taking early preventive measures during the pregnancy, Sudden Infant Death Syndrome (SIDS) is not predictable, therefore making it difficult for parent or caregiver to take preventive measures. The specific cause(s) of Sudden Infant Death Syndrome (SIDS) remains unknown until nowadays, but it is generally accepted that Sudden Infant Death Syndrome (SIDS) may be a reflection of multiple interacting factors, which are as follows:

- Infant development: A leading hypothesis is that Sudden Infant Death Syndrome (SIDS) may reflect a delay in the development of nerve cells within the brain that are critical to normal heart and lung function. Research examinations of the brain stems of infants who died with a diagnosis of Sudden Infant Death Syndrome (SIDS) have revealed a developmental delay in formation and function of several serotonin-binding nerve pathways within the brain (serotonin is an example of a brain chemical known as a neurotransmitter that is important for brain function). These pathways are thought to be crucial to regulating breathing, heart rate, and blood pressure responses.

- Rebreathing asphyxia: When a baby is facedown, air movement around the mouth may be impaired. This can cause the baby to re-breathe carbon dioxide that the baby has just exhaled. Soft bedding and gas-trapping objects, such as blankets, comforters, water beds, and soft mattresses, are other types of sleep surfaces that may impair normal air movement around the baby's mouth and nose when positioned facedown.

- Hyperthermia (increased temperature): Overdressing, using excessive coverings, or increasing the air temperature may lead to an increased metabolic rate in these infants and eventual loss of breathing control.

Until nowadays, there is currently no way to predict which infants are at risk for Sudden Infant Death Syndrome (SIDS). Sudden Infant Death Syndrome (SIDS) has been linked to certain infant specific and sleep- environment factors. Observing the precautions like infants' sleep position and sleep environment can reduced the risk of Sudden Infant Death Syndrome (SIDS) for many infants. Therefore, the author feels that there is a need to come up with an invention that can assist parent and caregiver in monitoring their infants' vital signs and notify them in case of abnormalities.

1.3. Objectives and Scope of Study

The project has a few objectives to be achieved upon the completion, which are as follow:

- To create a conceptual system of the Real-Time and Continuous Infant Health Monitoring System.
- To translate the conceptual system into a working physical prototype. The prototype will consist of a transmitter node which is interfaced with temperature sensor and is placed at the infant and a receiver node which receives data from

the transmitter node and notify the parent or caregiver according to the predefined situations.

- To come up with an organized documentation throughout the process of the project.

Two scopes of study are to be implemented throughout the project. They are Temperature Sensor Interface and Microcontroller Implementation, both for analog to digital conversion and serial data communication. For the prototype, circuit to measure temperature of the infant is built using selection of suitable sensors according to the predefined criteria set by the author. Apart from that, microcontroller is also used in this project in order to connect the sensor to the analog to digital converter and to perform the serial data communication.

1.4. Relevancy of the Project

According to the statistic provided, the infant mortality rate in Malaysia is 15.02 deaths over 1000 live births. In Malaysia, the birth rate has been estimated to be 21.08 births over 1000 population up until 2011. Until 2010, the population in Malaysia stood at 28.3 million. Therefore, we can deduce that the total of infant mortality in Malaysia is around 8960 deaths in a year. The number is significant, therefore making it possible for the author to come out with an innovation that can take preventive measures against some of the causes of infant mortality. Therefore, for this project, the author hope that the infant's health monitoring system can be used as a measure to prevent infant mortality caused by Sudden Infant Death Syndrome (SIDS).

1.5. Feasibility of the Project

The two scopes of study for the project which are Sensor Interface and Microcontroller Implementation are within the scope of study of the author, making it feasible for implementation. Apart from that, the execution of the project has been divided into several stages. Please refer to methodology chapter in page 20 for flowchart and page 27 for Gantt chart of the project. The project can be completed in the time allocated, given that the dateline of each procedure is followed according to the Gantt chart accordingly.

CHAPTER 2

LITERATURE REVIEW

2. LITERATURE REVIEW

2.1. Infant Vital Body Signs

2.1.1. 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.

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 (98.6 °F). The typical oral (under the tongue) measurement is slightly cooler, at 36.8±0.7 °C, or 98.24±1.26 °F [11] [12]. Although some people think of these numbers as representing the normal temperature, a wide range of temperatures has been found in healthy people [13].

The normal infant body temperature is around 36 °C to 37 °C. A slight increase around 37 °C to 37.5 °C is called the low grade temperature and is often caused by teething, overheated and overdressed. Temperature in the range of 37.5 °C to 38 °C is called elevated temperature and is still not considered as dangerous and do not require medicine. However, if the infant has temperature higher than 38 °C, they may have been infected by fever and medical attention is required.

2.1.2. Heart Rate

Heart rate measurement indicates the soundness of the human cardiovascular system [14]. Heart rate is the number of heartbeats per unit of time and is usually expressed in beats per minute (bpm). For infants (one to eleven months old), the normal heart beats rate is from 80 to 120 beats per minute during resting condition. The resting heart rate is directly related to the health and fitness of an infant and hence is important to know. You can measure heart rate at any spot on the body where you can feel a pulse with your fingers. The most common places are wrist and neck. The number of pulses within a certain interval can be counted, for example 15 seconds, and the heart rate in bpm can be easily determined.

2.1.3. Respiratory rate

Respiratory rate is the number of breaths a living being, such as a human, takes within a certain amount of time (frequently given in breaths per minute). The infant respiration rate is usually measured when an infant is at rest and simply involves counting the number of breaths for one minute by counting how many times the chest rises. Respiration rates may increase with fever, illness, or other medical conditions. When checking respiration, it is important to also note whether the infant has any difficulty breathing. The normal respiratory rate for infant below the age of one year old is around 30 to 40 breaths per minute.

2.1.4. Electrocardiography (ECG)

Electrocardiography is a transthoracic (across the thorax or chest) interpretation of the electrical activity of the heart over a period of time, as detected by electrodes attached to the outer surface of the skin and recorded by a device external to the body [15]. The recording produced by this noninvasive procedure is termed an electrocardiogram (also ECG). In infant, cardiac output is determined primarily by heart rate as opposed to stroke volume. With age, the heart rate decreases as the ventricles mature and stroke volume plays a larger role in cardiac output.

Table 1: Pediatric ECG: normal values by age.

Age	HR (bpm)	QRS axis (degrees)	PR interval (sec)	QRS interval (sec)	R in V1 (mm)	S in V1 (mm)	R in V6 (mm)	S in V6 (mm)
1st wk	90–160	60–180	0.08–0.15	0.03–0.08	5–26	0–23	0–12	0–10
1–3 wk	100–180	45–160	0.08–0.15	0.03–0.08	3–21	0–16	2–16	0–10
1–2 mo	120–180	30–135	0.08–0.15	0.03–0.08	3–18	0–15	5–21	0–10
3–5 mo	105–185	0–135	0.08–0.15	0.03–0.08	3–20	0–15	6–22	0–10
6–11 mo	110–170	0–135	0.07–0.16	0.03–0.08	2–20	0.5–20	6–23	0–7
1–2 yr	90–165	0–110	0.08–0.16	0.03–0.08	2–18	0.5–21	6–23	0–7
3–4 yr	70–140	0–110	0.09–0.17	0.04–0.08	1–18	0.5–21	4–24	0–5
5–7 yr	65–140	0–110	0.09–0.17	0.04–0.08	0.5–14	0.5–24	4–26	0–4
8–11 yr	60–130	–15–110	0.09–0.17	0.04–0.09	0–14	0.5–25	4–25	0–4
12–15 yr	65–130	–15–110	0.09–0.18	0.04–0.09	0–14	0.5–21	4–25	0–4
>16 yr	50–120	–15–110	0.12–0.20	0.05–0.10	0–14	0.5–23	4–21	0–4

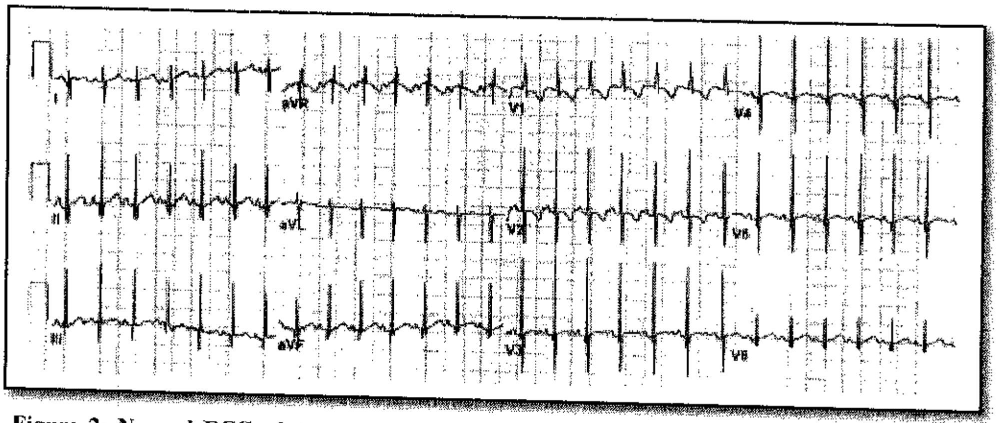


Figure 2: Normal ECG of 4-week-old infant. The ECG demonstrates right axis deviation and large R-wave amplitude and inverted T waves in the right precordial leads (V1 and V2) indicating right ventricular dominance normally seen in early infancy. Also note the fast heart rate, which is also normal for this age group.

2.2. Temperature Measurement

There are a few types of temperature sensors that can be used in order to perform temperature measurement. The author will provide basic theories and working principles behind every type of sensor in this section. The selection criteria for the temperature sensor that is going to be used in this project will be covered in the Methodology chapter.

2.2.1. LM 35

The LM35 is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature (in °C). The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The scale factor is 0.01V/°C. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full -55 to +150°C temperature range. Another important characteristic of the LM35DZ is that it draws only 60 micro amps from its supply and possesses a low self-heating capability. The sensor self-heating causes less than 0.1 °C temperature rise in still air. The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

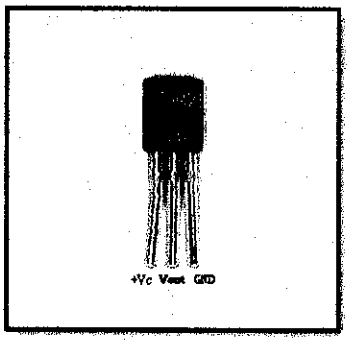


Figure 3: Example of LM35DZ IC.

In this section, the author will explain about the basic construction of temperature measurement circuit. The figure below shows the commonly used circuit for LM 35. In this circuit, parameter values commonly used are:

$$V_c = 4 \text{ to } 30V \text{ (5V or 12V are the typical values used).}$$

$$R_a = V_c / 10^{-6}$$

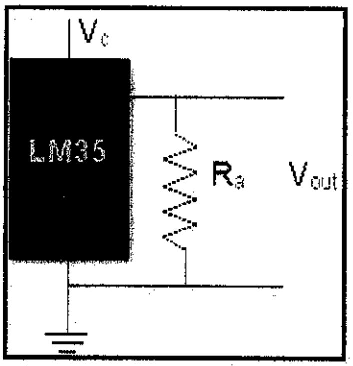


Figure 4: Electrical connection commonly used for LM35

The value for R_a can range from 80 Kohm to 600 Kohm, but most application will just use 80 Kohm. A voltmeter has to be used in order to sense V_{out}. The output voltage is converted to temperature by a simple conversion factor. The sensor has a sensitivity of 10mV / °C. Therefore, a conversion factor that is the reciprocal, which is 100 °C / V, is used. The general equation used to convert output voltage to temperature is:

$$T\ (^{\circ}C) = V_{out} * (100\ ^{\circ}C/V)$$

So if Vout is 1V , then, the temperature will be equal to 100 °C. The output voltage varies linearly with temperature.

2.2.2. Thermistor

Thermistors are temperature sensitive resistors. All resistors vary with temperature, but thermistors are constructed of semiconductor material with a resistivity that is especially sensitive to temperature. However, unlike most other resistive devices, the resistance of a thermistor decreases with increasing temperature. That is due to the properties of the semiconductor material that the thermistor is made from.

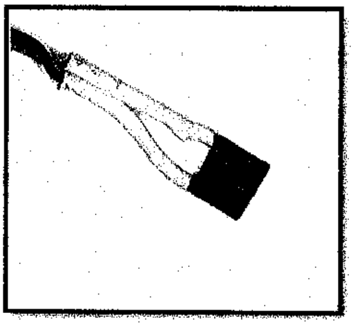


Figure 5: Example of a typical thermistor.

The Steinhart-Hart equation gives the reciprocal of absolute temperature as a function of the resistance of a thermistor. Using the Steinhardt-Hart equation, the temperature of the thermistor from the measured resistance can be calculated.The Steinhardt-Hart equation is:

$$1/T = A + B*\ln(R) + C*(\ln(R))^3, \text{ where R in W, T in } {}^\circ\text{K}$$

The constants, A, B and C can be determined from experimental measurements of resistance, or they can be calculated from tabular data. However, usually the thermistor vendor will provide the value for constants. Here are some data points for a typical thermistor from "The Temperature Handbook" [16].

Table 2: data points for a typical thermistor from "The Temperature Handbook" (Omega Engineering, Inc., 1989).

T (°C)	R (Ω
0	16 330
25	5000
50	1801

Using these values, the value for the coefficients A, B and C can be obtained through the Steinhardt-Hart equation. In this case, the computed value of the coefficients will be:

$$A = 0.001284$$

$$B = 2.364 \times 10^{-4}$$

$$C = 9.304 \times 10^{-8}$$

There are many circuits and measurement methods that can be used with a thermistor to determine the temperature. The simplest approach is to use a half-bridge circuit also known as a resistor divider, shown in figure below. The goal is to perform a ratiometric measurement such that the V_{REF} source voltage to the divider is the same as the reference to the ADC used to measure the voltage at V_T. The R_1 resistance is known.

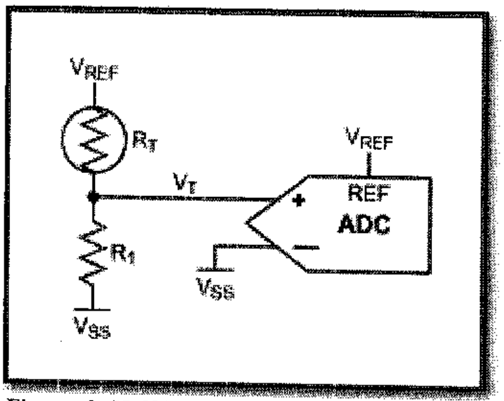


Figure 6: Half-bridge circuit connection using thermistor.

The value for R_T can be calculated by using the following equation:

$R_T = (\frac{2N}{ADC} - 1) \cdot R_1$, where ADC is the ADC result and N is the ADC resolution.

After the value for R_T is calculated, the temperature can then be calculated by using the Steinhardt-Hart equation. A plot of the thermistor is shown in figure below.

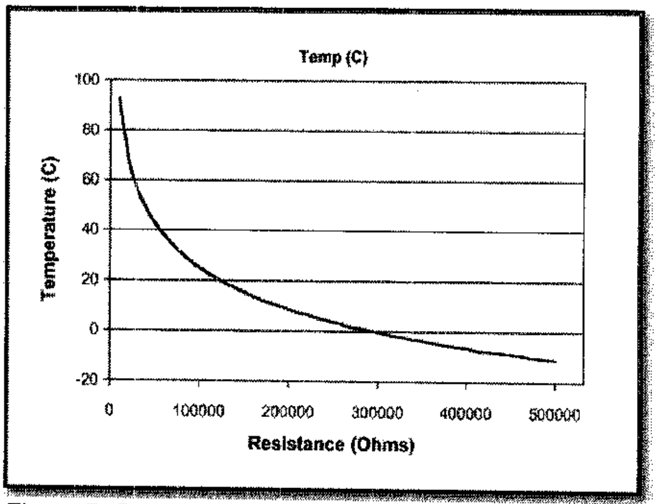


Figure 7: Plot of temperature versus resistance for typical thermistor.

2.2.3. Thermocouples

A thermocouple is based on the thermoelectric effect which occurs when two different metals are connected together – a voltage is produced that is dependent on the type of metals used and the temperature. In order for the thermal voltage to produce a current, the metals must be connected together at both ends so that a closed circuit is formed. If the temperature is the same at both ends, there is no flow of current. Thus, a thermocouple can only measure temperature differences. For this reason, the reference junction temperature must be known for an accurate measurement to occur. Since the reference temperature point is generally lower than the measured temperature – it is generally called the cold junction. At the "cold junction" or reference junction, a resistance temperature detector (RTD) or similar temperature sensor is used to have an accurate reference temperature. The voltage produced by a thermocouple is very small and amounts to only a few μvolts per degree Celsius. Thermocouples are generally not used in applications in the range of -30 to 50°C because the difference between the reference temperature and the measurement temperature is too small to get accurate noise-free signals. However, compared with other sensors – thermocouples offer the clear advantage of a higher upper temperature limit (up to several thousand degrees Celsius) and are therefore frequently used to measure temperatures in ovens, furnaces, etc.

The commonly used types of base-metal thermocouples are type T, type K and type N thermocouples.

- Type K (Ni-Cr/Ni-Al) thermocouples are also widely used in the industry. It has high thermopower and good resistance to oxidation. The operating temperature range of a Type K thermocouple is from -269 °C to +1260 °C. However, this thermocouple performs rather poorly in reducing atmospheres.
- Type T (Cu/Cu-Ni) thermocouples can be used in oxidizing of inert atmospheres over the temperature range of -250 °C to +850 °C. In reducing or mildly oxidizing environments, it is possible to use the thermocouple up to nearly +1000 °C.
- Type N (Nicrosil/Nisil) thermocouples are designed to be used in industrial environments of temperatures up to +1200 °C.

In the thermocouple, the sensing junction - produces a voltage that depends upon temperature. The two junctions where the thermocouple connects will produce a temperature dependent voltage. Those junctions are shown inside the yellow oval in the figure below.

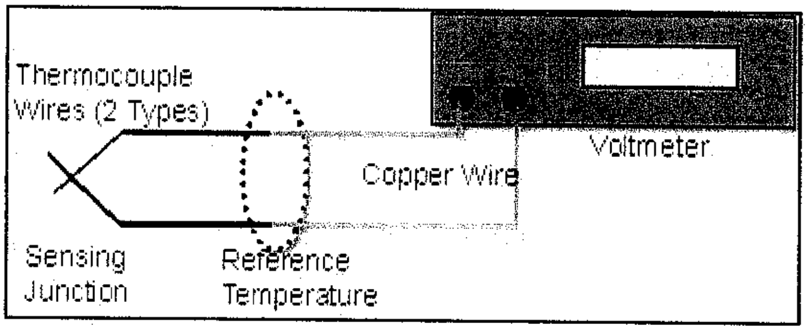


Figure 8: Typical connection used to measure voltage across two junctions of a thermocouple.

When using a thermocouple, the connections must be made at some standard temperature, or there might be a need to use an electronically compensated system that takes those voltages into account. If the thermocouple is connected to a data acquisition system, then chances are good that it is an electronically compensated system. Once the reading is obtained from a voltmeter, the measured voltage has to be converted to temperature. The temperature is usually expressed as a polynomial function of the measured voltage. Sometimes it is possible to get a decent linear approximation over a limited temperature range. The other way to convert the measured voltage to a temperature reading is to use the measured voltage as an input to a conversion circuit, either analog or digital.

The polynomial equation used to convert thermocouple voltage to temperature (°C) over a wide range of temperatures can be expressed in the equation below:

$$T = \sum_{n=0}^{N} a_n v^n$$

Table 3: NBS polynomial coefficients for a type K thermocouple. (T. J. Quinn, Temperature, Academic Press Inc.,1990)

Type K Polynomial Coefficients	
n	a_n
0	0.226584602
1	24152.10900
2	67233.4248
3	2210340.682
4	-860963914.9
5	$4.83506 \text{x} 10^{10}$
6	$-1.18452 \text{x} 10^{12}$
7	$1.38690 \text{x} 10^{13}$
8	$-6.33708 \text{x} 10^{13}$

2.3. Operational amplifier

An operational amplifier ("op-amp") is a DC-coupled high-gain electronic voltage amplifier with a differential input and, usually, a single-ended output. An op-amp produces an output voltage that is typically hundreds of thousands times larger than the voltage difference between its input terminals.

2.3.1. Non inverting operational amplifier

In this configuration, the input voltage signal, (Vin) is applied directly to the non-inverting (+) input terminal which means that the output gain of the amplifier becomes "Positive" in value in contrast to the "Inverting Amplifier" circuit whose output gain is negative in value. The result of this is that the output signal is "in-phase" with the input signal.

Feedback control of the non-inverting amplifier is achieved by applying a small part of the output voltage signal back to the inverting (-) input terminal via a Rf - R2 voltage divider network, again producing negative feedback. This closed-loop configuration produces a non-inverting amplifier circuit with very good stability, very high input impedance, Rin approaching infinity, as no current flows into the positive input terminal, (ideal conditions) and low output impedance, Rout as shown below.

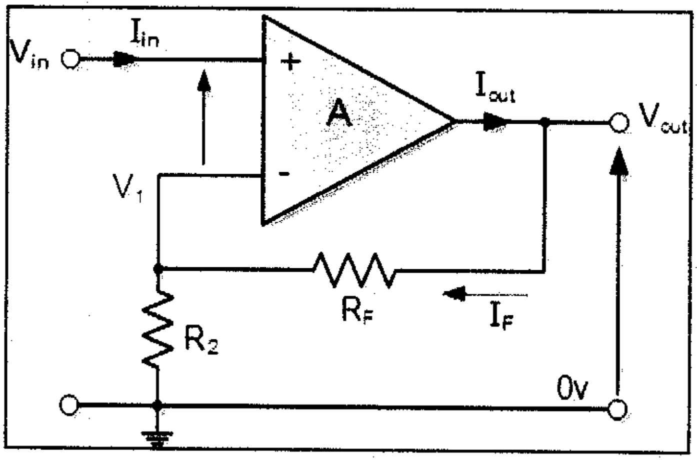


Figure 9: Non inverting operational amplifier

Then using the formula to calculate the output voltage of a potential divider network, we can calculate the closed-loop voltage gain (Av) of the Non-inverting Amplifier as follows:

$$V_1 = \frac{R_2}{R_2 + R_f} V_{out}$$

$$A_v = \frac{V_{out}}{V_1} = \frac{R_2 + R_f}{R_2}$$

$$A_v = \frac{V_{out}}{V_1} = 1 + \frac{R_f}{R_2}$$

2.4. Serial Data Communication

Serial communication is defined as the process of sending data one bit at a time, sequentially, over a communication channel or computer bus. This is in contrast to parallel communication, where several bits are sent as a whole, on a link with several parallel channels. The serial and parallel data communications are illustrated in the figures below.

Using the serial communication, the multi-bit word is transmitted bit after bit (when at any given moment only one bit will pass).

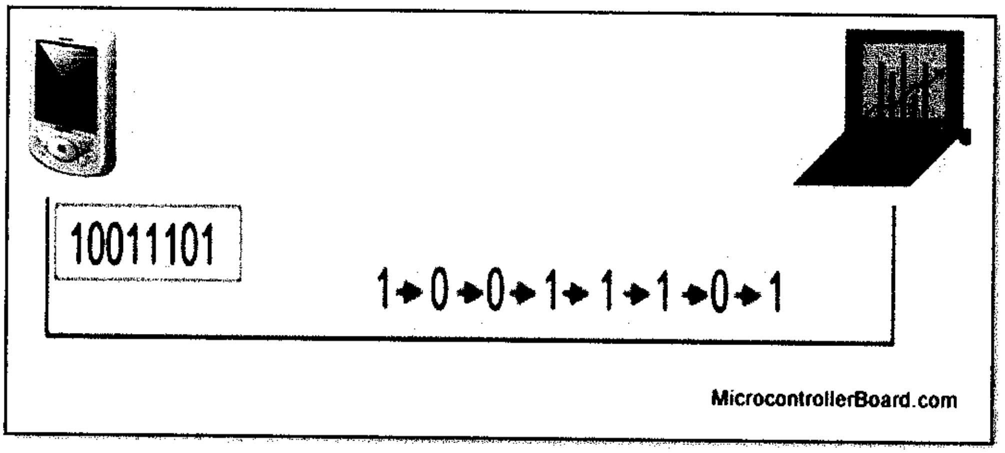


Figure 10: Serial data communication

However, using the parallel communication, the number of bits will be transmitted at once from one computer to the second computer.

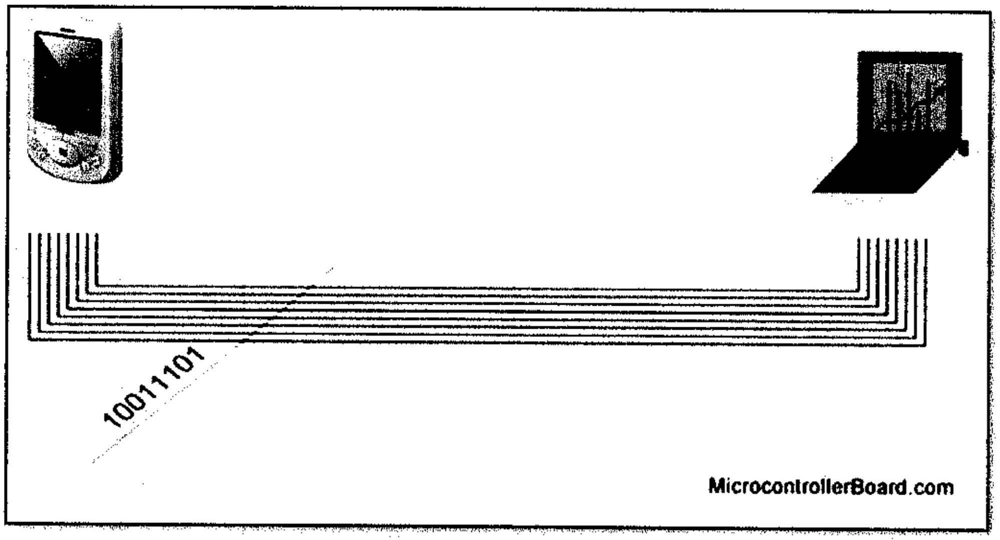


Figure 11: Parallel data communication

Serial data communication modules are often included in the PIC i.e. Universal Synchronous Asynchronous Receiver Transmitter (USART) Module and Master Synchronous Serial Port (MSSP) Module.

2.4.1. Universal Synchronous Asynchronous Receiver Transmitter (USART)

The Universal Synchronous Asynchronous Receiver Transmitter (USART) module is one of the two serial I/O modules. USART is also known as a Serial Communications Interface (SCI). The USART can be configured as a full duplex asynchronous system that can communicate with peripheral devices such as CRT terminals and personal computers, or it can be configured as a half duplex synchronous system that can communicate with peripheral devices such as A/D or D/A integrated circuits, serial EEPROMs etc.

The asynchronous method uses a start and stop bit protocol to synchronize the two ends. Each character byte is sent in a frame consisting of a start bit, followed by the character bits, followed (optionally) by a parity bit, and finalized by one or more stop bits. The sender and receiver have to be initialized to use the same data rate, number of data bits, and number of stop bits.

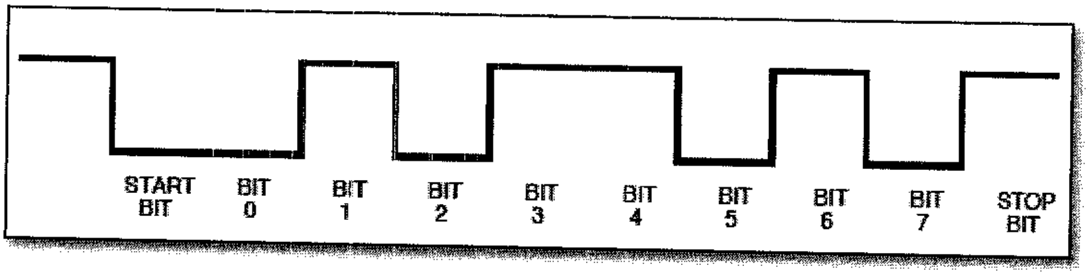


Figure 12: Example of 8-bit data transmission in asynchronous data transmission

In idle condition, the transmit output is at logic high. When the transmitter is ready to send a character byte, it signals the receiver by pulling the transmit line low for one clock period. This is the start bit and it tells the receiver that a frame follows. The receiver reads the number of character bits expected according to the adopted protocol until the line is pulled to logic high by the transmitter (one or more stop bits), and that is the end of the frame. The whole process is repeated every time the transmitter has to send a character byte. This form of serial transmission is called asynchronous because the receiver resynchronizes itself to the transmitter every time the data is sent using the start bit. However, within each frame the two parties are synchronized.

On the other hand, the synchronous serial communication transmits characters in blocks with no framing bits surrounding them. The transmitter and receiver are synchronized with a separate clock line or, in some cases, the clock signal is contained in the transmitted characters.

2.4.2. Master Synchronous Serial Port (MSSP) Module

The Master Synchronous Serial Port (MSSP) module is a serial interface, useful for communicating with other peripheral or microcontroller devices. These peripheral devices may be serial EEPROMs, shift registers, display drivers, A/D converters, etc. The MSSP module can operate in one of two modes:

- Serial Peripheral Interface (SPI)
- Inter-Integrated Circuit (I2C)

2.4.2.1. Serial Peripheral Interface (SPI)

SPI bus is a synchronous serial data link standard named by Motorola that operates in full duplex mode. Devices communicate in master/slave mode where the master device initiates the data frame. Multiple slave devices are allowed with individual slave select (chip select) lines.

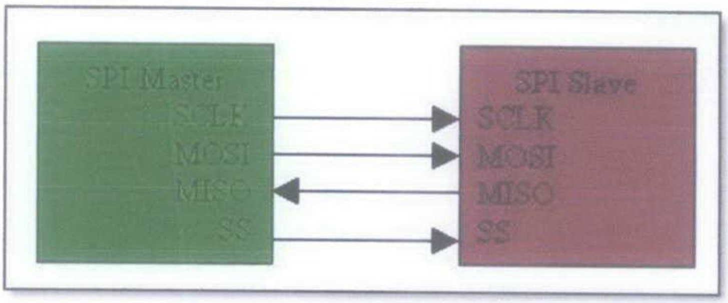


Figure 13: SPI block diagram

SPI usually has four lines and supports full duplex communication. The SCLK line is the clock line, the clock is generated by the master and drives the communication in both directions, and this line is an input to all slaves. The MOSI line is the master data output, slave data input, and it carries data from the master to the slave. The MISO line is the master data input, slave data output, and it carries data from the slave to the master. Finally the SS or sometimes known as the CS line is the slave select or chip select line, it is toggled to select a slave to be communicated with. There is also a 3-Wire version of SPI however it only supports half duplex communication. This set up uses a SISO line and this single bidirectional data line carries data in and out of the slave.

Usually the transfer sequence consist of driving the SS line low with a general I/O pin, sending X number of clock signals with the proper polarity and phase, driving the SS line high to end the communication. As the clock signals are generated, data is transferred in both directions, therefore in a "transmit only" system the received bytes have to be discarded and in a "receive only" system a dummy byte has to be transmitted. The clock polarity and clock phase control's on which edge of the clock signal the data is received and sent. This has to be set up to match between the master and the slave.

2.4.2.2. Inter-Integrated Circuit (I2C)

I2C is a multi-master serial single-ended computer bus invented by Philips that is used to attach low-speed peripherals to a motherboard, embedded system, cell phone, or other electronic device.

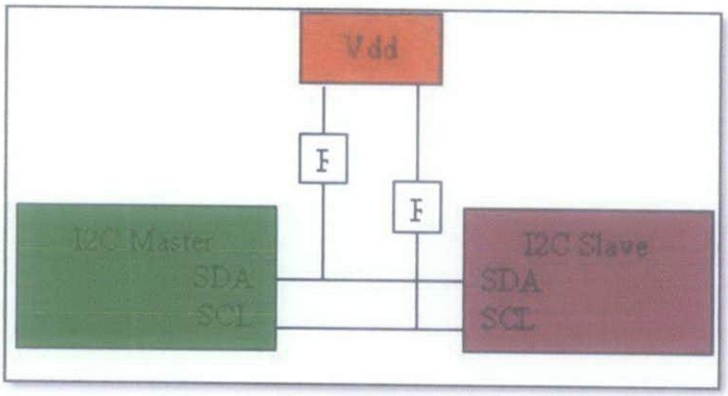


Figure 14: I2C block diagram

I2C bus has two lines: a serial data line (SDA) and a serial clock line (SCL). Any data sent from one device to another goes through the SDA line, whereas the SCL line provides the necessary synchronization clock for the data transfer. The devices on an I2C bus are either Masters or Slaves. Only a Master can initiate a data transfer and Slaves respond to the Master. It is possible to have multiple Masters on a common bus, but only one could be active at a time. It is also possible to have multiple slaves in I2C bus.

The standard I2C modules support a 7-bit slave address. The three types of messages that are defined by the I2C protocol are a single message where the master writes to a slave, a single message where the master reads from a slave, and a combined message where a master issues at least two reads and/or writes to one or more slaves.

The sequence of the communication begins with the master sending a start bit followed by the 7 or 10-bit slave address and finally a bit that selects if the operation is a write(0) or a read(1). At this point, if the slave address exists on the bus the slave will send an acknowledgment bit to the master. The data is then transferred on the SDA line in the direction that was specified by the master. An acknowledgment bit is sent at the end of each transferred byte by the receiving end of the transmission. The only exception is that when the master is in receive mode and the slave in transmit mode the master will not send an acknowledge bit after the very last bit received. Lastly the communication is stopped with the master sending a stop command. The start and stop commands are simply a transition from high to low (Start) on the SDA line with SCL high or low to high (Stop) on the SDA line with SCL high. Transitions for the data bits are always performed while SCL is low; the high state is only for the start/stop commands.

CHAPTER 3

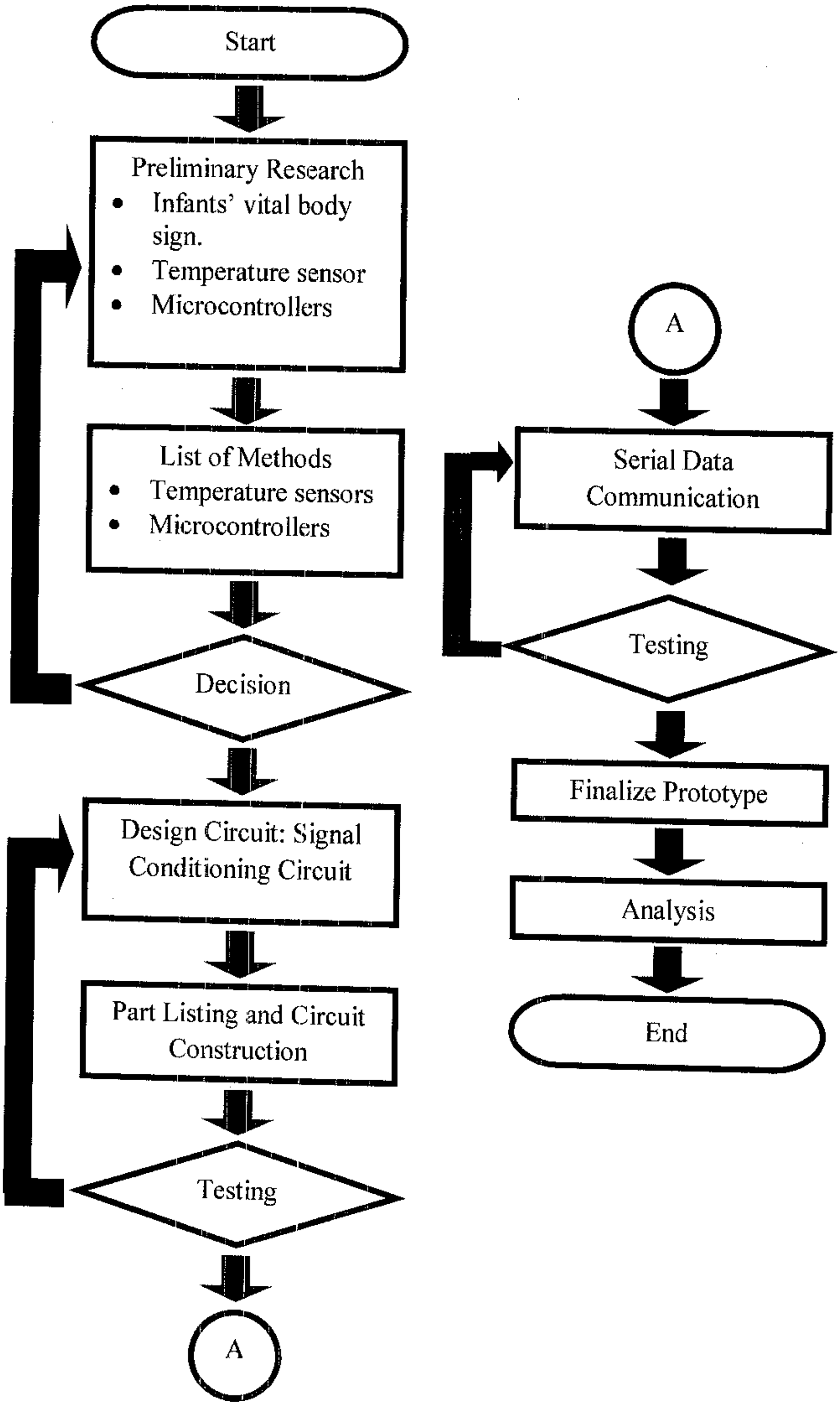
METHODOLOGY

3. METHODOLOGY

3.1. Research Methodology

This chapter will discuss the detail explanation of methodology that is used upon completing the project. This project is divided into a few stages to ensure a smooth flow.

3.1.1. Flowchart



3.2. Project Activities

All activities in this project are carried out according to the sequence in the flowchart. For this section, the author will give brief explanation regarding all of the activities listed in the flowchart.

3.2.1. Planning

Planning is the very first and vital part of a project. During the initial stage, the author has come up with the title, problem identification, objectives and scope of study of the project. With the limitation of requirements gathered regarding the project, the author will proceed to the next stage which is the preliminary research. This step can reduce the redundancy and unwanted information gathered during the preliminary research which can lead to waste of time and energy. Apart from that, the author has come up with a Gantt chart and flowchart in order to ensure smooth flow in completing the project.

3.2.2. Preliminary Research

Based on the project's requirement obtained in the previous stage, related materials are collected from a wide range of resources, namely journals, text books, research papers and internet articles. Apart from reading, the author also gains information through consultation and discussion with the supervisor of the project.

The author has divided the research into two parts, in which the first part is regarding the suitable vital signs that need to be measured, as precautions to Sudden Infants Death Syndrome (SIDS). From that, the author then determines the suitable sensors that need to be used for the project and consequently search for related circuit design. The second part of the research is related to PIC microcontroller; internal analog to digital converter (ADC) and serial data communications.

3.2.3. List of Methods

In this section, the author will discuss about the options available for hardware and methods in developing the prototype and this section is divided into two major decisions.

3.2.3.1. Temperature Sensors

There are three types of sensors that are most commonly used for measuring temperature. They are LM35 IC, thermistor and thermocouple. A comparison table is created to justify which method is practically the best solution with balance of performance and cost factor. Few criteria have been selected in order to choose the methods:

- Ability to complete the task
- Scale factor
- Accuracy
- Output voltage
- Cost

For this project, LM35 IC has been chosen by the author because it can perform the task, which is to measure the temperature, and has a small scale factor, which means that it can measure small deviation of temperature, which is an important feature since it is used to measure body temperature. Other than that, it also has a quite high accuracy (±¼°C at room temperature and ±¾°C over a full -55 to +150°C temperature range) and although the output voltage is not large enough, it can be amplified with the signal conditioning circuit. The most important feature is the lowest cost among all other sensors, which makes it affordable and easy to replace.

Table 4: Comparison between temperature sensors.

Type	**LM35**	**Thermistor**	**Thermocouple**
Feature	An IC sensor to measure temperature with an electrical output proportional to the temperature (in °C).	An electrical device that varies its electrical resistance with temperature (°K)	A junction between two different metals that produces a voltage related to a temperature difference.
Range	0 °C -100 °C	0 °C -200 °C	0 °C -1100 °C
Scale factor	10mV / °C	N/A	N/A
Accuracy	+/-0.25 °C	+/- 0.1 °C - 0.2 °C	+/- 1.5 °C
Output voltage	Large enough-no need for amplifier.	Small-need amplifier.	Small-need amplifier.
Cost	RM 7.65	RM 31.50	RM 139.00

3.2.3.2. Microcontroller

There are three types of approaches that can be used in order to perform the analog to digital conversion and the serial data communication in this project. They are PIC microcontroller, Atmel (Arduino) and Make Controller.

Based on the information gathered regarding all the three options, a comparison table is created in order to justify the chosen option, which represents the best solution among all options in term of performance and cost. Few criteria have been considered in choosing the options:

- Ability to complete the task
- Complexity of system
- Cost

All the methods available have the ability to complete the task thus allowing all of them to be qualified. The complexity of the methods proposed are almost the same; ranging from PIC (C/C++), followed by Make Controller(C/C++) and Arduino (Arduino-specific C/C++). However, PIC is the popular method available and the support for the PIC is wider in Malaysia, specifically. The final consideration and the most crucial is the cost factor. After taking account of these factors, the decision is to choose to use PIC as the author is familiar with the approach and the cost is the lowest among all. Table 5 below shows the comparison between options available.

Table 5: Comparison between PIC, Arduino and Make Controller

Feature	**PIC**	**Arduino**	**Make Controller**
Price	RM27.62	RM92.59	RM262.35
Digital IO	33 general purpose IO pins	14 general purpose IO pins.	4 dedicated analogue ins and 35 general purpose IOs.
Analogue Inputs	8 analog inputs with 10-bit resolution	6 analog inputs with 10-bit resolution.	8 analog ins with 10-bit resolution.
PWM Channels	2/4 PWM channels	6 PWM channels.	4 PWM channels.
Serial Ports	USART RX or TX (Synchronous Slave mode).	1 UART, shared with the USB connection.	2.5 - 2 full UARTs and a debug port, which has no hardware handshaking.
Processor / Memory	8K RAM	8-bit AVR. 2K RAM, 32K Flash.	32-bit ARM7. 64K RAM, 256K Flash.
Tools Support	MikroC	Arduino IDE - cross-platform easy to use editor, compiler and uploader.	Mcbuilder - cross-platform, easy to use editor, compiler, and uploader.
Programming Language	Standard C/C++	Arduino-specific C/C++	Standard C/C++

3.2.4. Designing and Testing the Circuit

After the methods to be used in building the prototype have been determined, the author will proceed to the design part of the circuit. In this stage, the overall design of the circuit will be completed using circuit design software. After that the author will then list the hardware and components needed and try to obtain them from UTP Electrical Store or from the nearest electrical store. The last part of this stage is to construct the circuit according to the design and perform circuit testing. If the expected result is obtained from the circuit testing, the author will proceed to the next stage. If not, the whole process of designing the circuit, part listing and constructing the circuit will have to be redone.

The signal conditioning circuit used to amplify the output voltage of the temperature sensor is designed and tested in the Pspice Schematics before it is constructed on a full-scale. The result from the simulation is shown in Chapter 4.

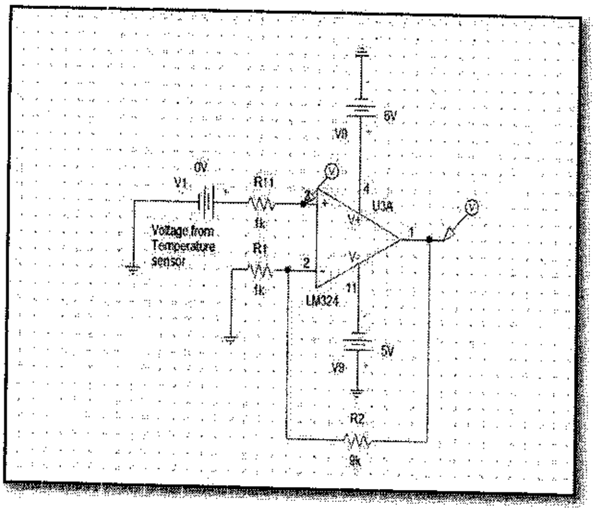
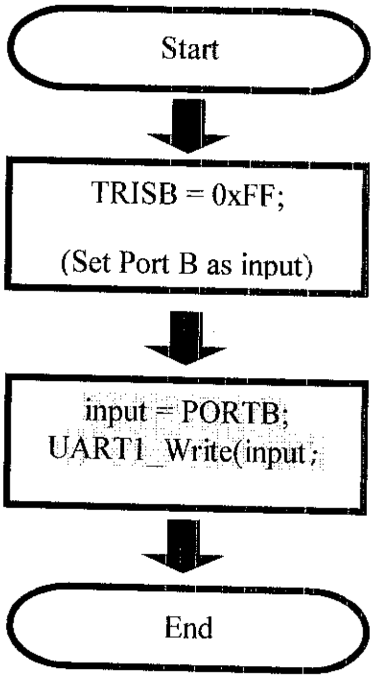
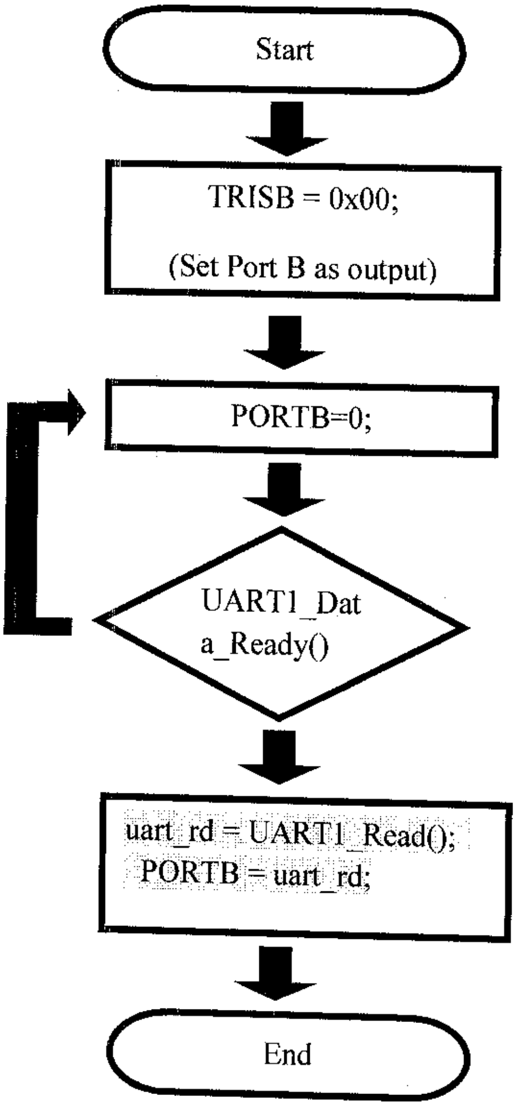


Figure 15: Design of the non-inverting amplifier in Pspice Schematics

The author has also done a software run test in order to test the USART module for serial data communication in the PIC. Software run test is a test carried out where a simple program is run in order to check whether the software programming is compatible with the circuit. In the test, Microcontroller is programmed with instructions in MikroC compiler to communicate between microcontrollers via its transmitting and receiving pin. When the test is successfully completed, it could be concluded that the system is ready for the real application. The following is the flow diagram for software run test at both side of microcontroller. The program code is attached in the Appendix section.





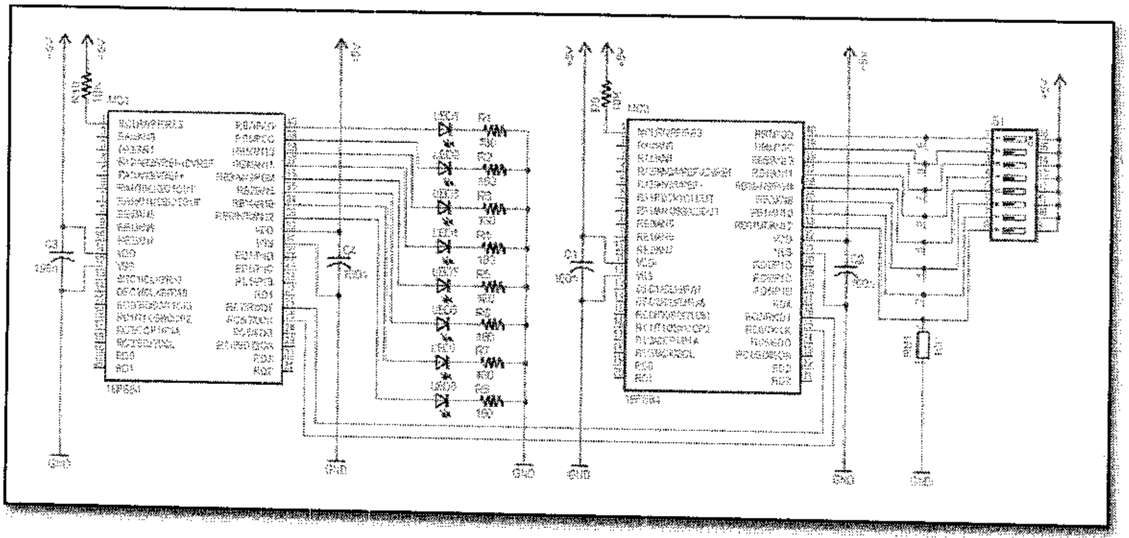


Figure 16: The schematics of the circuit used for software run test

3.2.5. Finalizing the Prototype

After the final testing of the prototype is done and the prototype is confirmed to be working perfectly, final touches are added to the prototype. This stage mainly involves with adding aesthetic value to the prototype, such as adding casing to the circuit, in order to make it more presentable for demonstration.

3.2.6. Analysis

Analysis will be done after the final testing of the prototype. In this stage, all possible observations are recorded for analysis of result. This is important as the result must be documented for evaluation. Apart from that, analysis is also done to distinguish between meaningful data and erroneous data.

3.3. Gantt Chart

Table 6: Gantt chart for FYP II

No	Details / Week / Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
		Sept		Oct				Nov				Dec				Jan			
1	Research Work Continues	■	■																
2	Circuit Testing		■	■	■	■													
3	Circuit Modification					■	■	■	■										
4	Progress Report (Due: 16/11/11)							✷	■	■									
5	Circuit Testing and Improvement									■	■	■							
6	Result and Analysis										■	■							

											■	■							
7	Poster Exhibition (Due: 21/12/11)											■	■	✸					
8	Dissertation Submission (Due: 27/12/11)														✸				
9	Oral Presentation (Due: 4/1/12)															✸			
10	Project Dissertation Submission (Due:23/1/12)															■	■	■	✸

Legend:

✸ Milestone

■ Duration

3.4. Tools and Preparation

Understanding the requirement and use of each tool is useful for project preparation. Table 7 below shows the list of the required tools which will be used in project construction.

Table 7: Tools needed for the project construction

No	Tool	Description
1	Soldering Iron	Soldering iron is used to solder the electrical components to circuit board. For electrical work a low-power iron with a power rating between 15 and 30 watts can be used. Other than that, temperature control and stand are also needed for the iron for best efficiency.
2	Solder	Solder is used to join together metal work pieces. The two most common alloys are 60/40 Tin/lead (Sn/Pb) which melts at 370 °F or 188 °C and 63/37 Sn/Pb used principally in electrical/electronic work.
3	Vacuum Desoldering Tool	Vacuum desoldering tool is used to remove the incorrect solder part on the circuit.
4	Multimeter	Multimeter is used to measure current, voltage and continuity.
5	Diagonal Cutter	Diagonal cutter is used to remove unwanted components like excessive leads and metals close to PCB.
6	Breadboard	Breadboard is used to construct mock circuit.
7	MikroC	MikroC is software used to program the microcontroller.
8	Pspice Orchad	Pspice Orchad is a software use to simulate the signal conditioning circuit.

3.5. Part Listing

Analyzing the requirement and priority of each part and material used are useful for project preparation. Table 8 shows the list of the required components and material which will be used in project construction.

Table 8: List of required components and material for the project

No	Tool	Description
1	LM35 Temperature Sensor	An integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature (in °C). Has a scale factor of 0.01V/°C.
2	PIC Microcontroller	The PIC used in this project is Microchip's 16f877A. Has a built in ADC and USART module.
3	Clock	To set the PIC clock. Usually in the range of 4 MHz.
4	Enhanced 40 pins PIC Start-Up Kit	Able to utilize the function of PIC by directly plugging in the I/O components in whatever way that is convenient to user
5	LED	As an indicator.
6	TL072CN	Operational amplifier used for building the non-inverting amplifier.
7	Resistor	Limits the current.
8	9V Battery	Supply voltage for the PIC and temperature sensor.
9	LM7805	A 9V to 5V voltage regulator. Used to regulate the power supply.
10	2x16 LCD Display	Used to display the measured temperature and give warning.

CHAPTER 4

RESULT AND DISCUSSION

4. RESULT AND DISCUSSION

4.1. Accuracy of the Temperature Sensor

4.1.1. Experiment 1

In order to determine the accuracy of the temperature sensor, the author has conducted a few experiments in order to determine how much the measured output voltage differs from the calculated value of the output voltage. The LM35D temperature sensor is operated as a standalone sensor with input voltage of 5V. The connection of the circuit can be seen in Figure 4 at page 12.

The author did not attempt to take measurement on body parts for the experiment, because of the unsuitable feature of the sensor (the sensor was mounted on the breadboard). Instead, room temperature was used as the measured variable in this experiment. Table 9 below shows the result of the experiment.

Table 9: Result obtained from Experiment 1

Trial	Measured/actual output voltage (mV)	Calculated/theoretical output voltage (mV)	|Output voltages difference| (mV)
1	290	270	20
2	285	275	10
3	313	286	27
4	300	295	5
5	290	290	0
6	295	300	5
7	295	296	1

The measured/actual output voltage is obtained from the digital thermometer that the author has managed to obtain off-the-shelf. It has an accuracy of ± 0.1 °C. The actual output voltage is determined by multiplying the temperature obtained from the digital thermometer by a scale of 10mV / 1 °C, considering the temperature obtained from the digital thermometer is the reference/actual temperature.

4.1.2. Experiment 2

The result that has been obtained from the first experiment showed a very unstable deviation from one point to another point. The reason for the deviations may be due to the settings of the experiments. Therefore the author has decided to conduct a follow up experiment in order to provide a more stable result and determine the accuracy of the temperature sensor.

The setup of the experiments is shown in the figure below. For the experiment, the author has used heated water as a medium to represent the human body temperature. The water is heated until it reached 36 °C. The output voltage of the temperature sensor is then recorded alongside with the increasing temperature. As in the first experiment, digital thermometer was used as a reference thermometer to record the actual temperature of the water. In order to get the actual output voltage, the temperature obtained from the digital thermometer by a scale of 10mV / 1 °C. Figure 17 below shows the experiment setup and Table 10 shows the result of the experiment.

Figure 17: Experiment setup

Table 10: Result obtained from Experiment 2

Trial	Measured/actual output voltage (mV)	Calculated/theoretical output voltage (mV)	|Output voltages difference| (mV)
1	360	362	2
2	365	365	0
3	370	371	1
4	375	378	3
5	380	380	0
6	385	382	3
7	390	390	0
8	395	392	3
9	400	403	3

4.2. Signal Conditioning Circuit

For this part, LM35D temperature sensor will only measure temperature in the range of 0 to 100 °C. The measurement of negative temperatures (below 0°C) requires a negative voltage source. Therefore, negative voltage source will not be needed for the circuit.

The output voltage from the sensor is converted to a 10-bit digital number using the internal analog to digital converter of the PIC16F877A. We are only interested in measuring infants' body temperature, which is in the range of minimum 36 °C to maximum 38 °C, and this temperature will produce am output voltage in the range of 0.36 V to 0.38 V only. The output voltage range is quite small; therefore there is the need to amplify it in order to obtain a more accurate conversion from analog signal to digital signal.

The author has proposed to use a non inverting operational amplifier with a gain of ten in order to amplify the output voltage range. After amplification, the output voltage range will be in the range of 3.6V to 3.8V which gives slightly higher difference range (3.8 V – 3.6 V = 0.2 V) instead of just 0.02 V. The non inverting operational amplifier will be built using the TL072CN Low Noise J-Fet Dual Operational Amplifiers. Figure 12 shows the basic circuit of a non inverting amplifier with gain of ten.

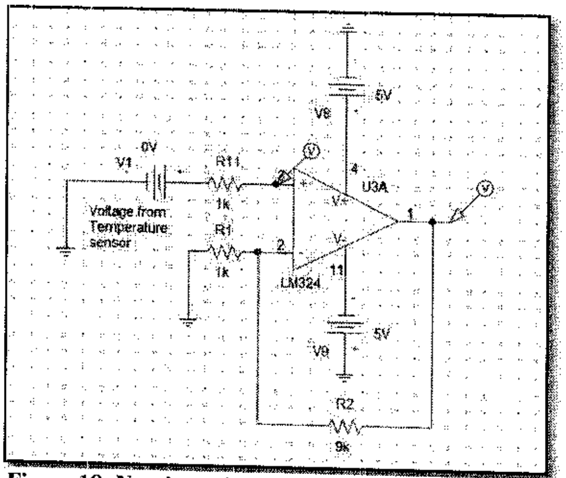


Figure 18: Non-inverting operational amplifier with gain 10

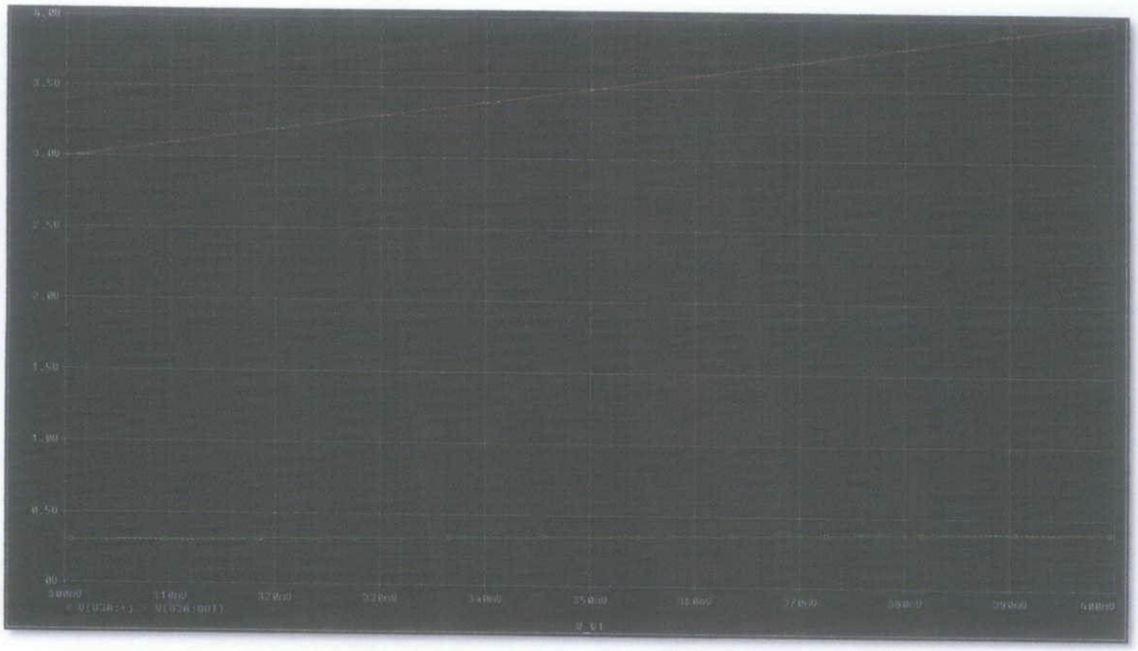


Figure 19: Simulation result for non-inverting amplifier in Pspice Schematics

The green curve in Figure 19 shows the output voltage of the temperature sensor while the red curve shows the amplified voltage output of the temperature sensor.

An external reference voltage to the internal ADC of PIC16F877A can be provided through RA1 I/O pin. The output from the LM35 sensor is read through RA2/AN2 ADC channel. The temperature is displayed on a 16×2 character LCD that is operating in the 4-bit mode. A 10K potentiometer is used to adjust the contrast level on the display.

4.3. Resolution of Temperature Sensor

With Vref = 5 V, the resolution of 10-bit A/D conversion would be 5/1024 ≈ 4.88 mV/count, which leads to:

Resolution of temperature measurement = 4.88 mV / (10 mV/°C) = 0.488 °C

The calculation to convert the 10-bit count obtained from ADC to temperature in °C below will be included in PIC programming.

I/P analog voltage = 4.88 x 10-bit count (mV)

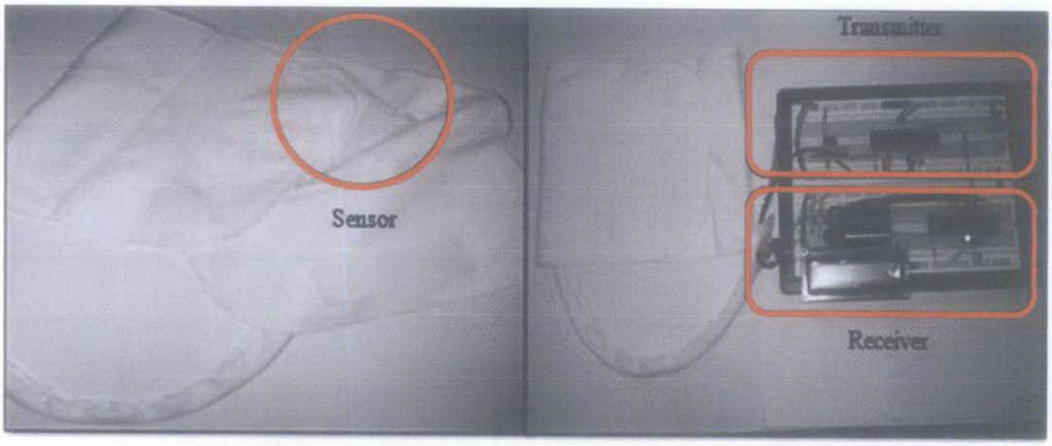
Measured temperature, T = (I/P analog voltage (mV) / (10 mV/°C)) /10

= 4.88 x 10-bit count/100 (°C)

= 0.0488 x 10-bit count (°C)

4.4. Prototype

After testing had been done, all of the elements i.e. temperature sensor, signal conditioning circuit and serial data communication are combined and implemented into one single prototype. The circuit is constructed on a development breadboard. Figure 20 below shows the circuit on the transmitter and receiver side together with the sensor which is located in the baby wrap.



(a) (b)

Figure 20: (a) The location of the sensor in baby wrap (b) Circuit on transmitter and receiver side

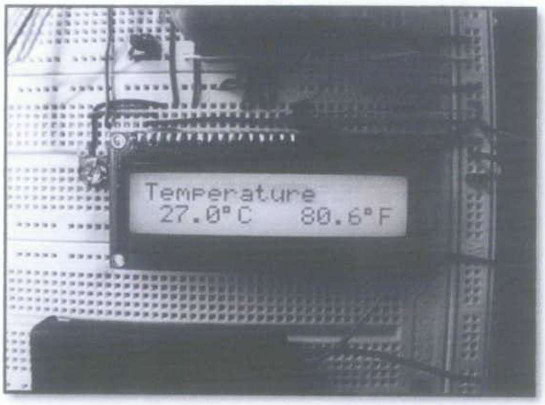


Figure 21: During testing

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The project achieved its objective, which is to create the conceptual system for infants' health monitoring system and translate it into o working physical prototype. The implementation Real Time and Continuous Infants Health Monitoring System can be used to assist people in monitoring the infants' vital signs in order to prevent SIDS. The system transmits the current temperature of the infants to the receiver and will trigger warning in the case of abnormalities. As per completion, the system consists of two main components;

- Transmitter which process the measured temperature in the PIC and transmit the data over an asynchronous serial data communication to the receiver
- Receiver which data received from transmitter and give warning in the case of abnormalities.

5.2. Recommendations

The author has also found out some suggested addition that can be done for future expansion and continuation of the project. One of them is to add other sensors that can monitor the other remaining vital infants' body sign e.g. heart rate, ECG and respiratory rate. Addition on wireless data transmission can also be done to replace the serial data communication between PIC for the upcoming continuation or expansion of this project. With growing interest in wireless sensor network every day, the author hopes that these modifications can be applied to ease everyday life.

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APPENDIX A

Sample code for the UART test circuit.

```
/*
Title: Transmitter program
Name: Nuremelina Binti Abu Hassan Shaari
Student ID: 10945
Final Year Project Infants Health Monitoring System
Supervisor: Dr. Fawnizu Azmadi Hussin
Copyright of MikroC
*/

char input;

void main() {

  TRISB = 0xFF;                       // set PORTB as input

  UART1_Init(9600);                   // Initialize UART module at
9600 bps
  Delay_ms(100);                      // Wait for UART module to
stabilize

  while(1){
            input = PORTB;
            UART1_Write(input);
            Delay_ms(100);
  }
}
```

Sample code for the UART test circuit.

```
/*
Title: Receiver program
Name: Nuremelina Binti Abu Hassan Shaari
Student ID: 10945
Final Year Project Infants Health Monitoring System
Supervisor: Dr. Fawnizu Azmadi Hussin
Copyright of MikroC
*/

char uart_rd;

void main() {

  TRISB = 0x00;
  PORTB = 0x00;                        // set PORTB as output

  UART1_Init(9600);                    // Initialize UART module at
9600 bps
  Delay_ms(100);                       // Wait for UART module to
stabilize

  while (1) {                          // Endless loop
    if (UART1_Data_Ready()) {          // If data is received,
      uart_rd = UART1_Read();          // read the received data,
      PORTB = uart_rd;                 // and send data via UART
    }
  }
}
```

APPENDIX B

Programming at the transmitter side:

```
/*
Title: Transmitter program
Name: Nuremelina Binti Abu Hassan Shaari
Student ID: 10945
Final Year Project Infants Health Monitoring System
Supervisor: Dr. Fawnizu Azmadi Hussin
Copyright @ Rajendra Bhatt
Nov 3, 2011
The code was referred and modified in order to suit the project
*/

 // LCD module connections
sbit LCD_RS at RC4_bit;
sbit LCD_EN at RC5_bit;
sbit LCD_D4 at RC0_bit;
sbit LCD_D5 at RC1_bit;
sbit LCD_D6 at RC2_bit;
sbit LCD_D7 at RC3_bit;
sbit LCD_RS_Direction at TRISC4_bit;
sbit LCD_EN_Direction at TRISC5_bit;
sbit LCD_D4_Direction at TRISC0_bit;
sbit LCD_D5_Direction at TRISC1_bit;
sbit LCD_D6_Direction at TRISC2_bit;
sbit LCD_D7_Direction at TRISC3_bit;
// End LCD module connections

// Define Messages
char message1[] = "Temperature:-";

// String array to store temperature value to display
char *tempC = "000.0";
char *tempF = "000.0";

// Variables to store temperature values
unsigned int tempinF, tempinC;
unsigned long temp_value;

void Display_Temperature() {
  // convert Temp to characters
  if (tempinC/10000)
   tempC[0] = tempinC/10000  + 48;
  else tempC[0] = ' ';
  tempC[1] = (tempinC/1000)%10 + 48;             // Extract tens digit
  tempC[2] =  (tempinC/100)%10 + 48;             // Extract ones digit

  // convert temp_fraction to characters
  tempC[4] =  (tempinC/10)%10 + 48;              // Extract tens digit
```

```
   // print temperature on LCD
   Lcd_Out(2, 1, tempC);
   if (tempinF/10000)
    tempF[0] = tempinF/10000  + 48;
   else tempF[0] = ' ';

   tempF[1] = (tempinF/1000)%10 + 48;      // Extract tens digit
   tempF[2] =  (tempinF/100)%10 + 48;
   tempF[4] =  (tempinF/10)%10  + 48;
   // print temperature on LCD
   Lcd_Out(2, 10, tempF);
 }
 #fuses HS, NOWDT, NOPROTECT, NOLVP, PUT
 #fuses NOBROWNOUT, CPD, NODEBUG, NOWRT
 #use delay(clock=10MHz)
 #use rs232(baud=1200, xmit=PIN_C6, bits=8, parity=N)

 void main() {
   //ANSEL = 0b11111111;  // RA2/AN2 is analog in*/put
   ADCON1 = 0b10000000; // ALL ANALOG INPUT, 10 BIT CONVERTER
   CMCON = 0x07 ;       // Disable comparators
   TRISC = 0b00000000;  // PORTC All Outputs
   TRISA = 0b11111111;  // PORTA All Input
   Lcd_Init();                           // Initialize LCD
   Lcd_Cmd(_LCD_CLEAR);                  // CLEAR display
   Lcd_Cmd(_LCD_CURSOR_OFF);             // Cursor off
   Lcd_Out(1,1,message1);                // Write message1 in 1st row
   // Print degree character
   Lcd_Chr(2,6,223);
   Lcd_Chr(2,15,223);
   Lcd_Chr(2,7,'C');
   Lcd_Chr(2,16,'F');

  do {
    temp_value = ADC_Read(2);
    temp_value = temp_value*244;
    tempinC = temp_value/10;
    tempinF = 9*tempinC/5 + 3200;
    Display_Temperature();
      s =   tempinC;
    putc(s);
    Delay_ms(1000);
  } while(1);
}
```

Programming at the receiver side:

```
/*
Title: Receiver program
Name: Nuremelina Binti Abu Hassan Shaari
Student ID: 10945
Final Year Project Infants Health Monitoring System
Supervisor: Dr. Fawnizu Azmadi Hussin
Copyright @ Rajendra Bhatt
Nov 3, 2011
The code was referred and modified in order to suit the project
*/

 // LCD module connections
sbit LCD_RS at RC4_bit;
sbit LCD_EN at RC5_bit;
sbit LCD_D4 at RC0_bit;
sbit LCD_D5 at RC1_bit;
sbit LCD_D6 at RC2_bit;
sbit LCD_D7 at RC3_bit;
sbit LCD_RS_Direction at TRISC4_bit;
sbit LCD_EN_Direction at TRISC5_bit;
sbit LCD_D4_Direction at TRISC0_bit;
sbit LCD_D5_Direction at TRISC1_bit;
sbit LCD_D6_Direction at TRISC2_bit;
sbit LCD_D7_Direction at TRISC3_bit;
// End LCD module connections

// Define Messages
char message1[] = "Temperature:-";

#fuses HS, NOWDT, NOPROTECT, NOLVP, PUT
#fuses NOBROWNOUT, CPD, NODEBUG, NOWRT
#use delay(clock=10MHz)
#use rs232(baud=1200, xmit=PIN_C6, bits=8, parity=N)

void main()
{
  //ANSEL = 0b11111111;  // RA2/AN2 is analog in*/put
  ADCON1 = 0b10000000; // ALL ANALOG INPUT, 10 BIT CONVERTER
  CMCON = 0x07 ;       // Disable comparators
  TRISC = 0b00000000;  // PORTC All Outputs
  TRISA = 0b11111111;  // PORTA All Input
  Lcd_Init();                        // Initialize LCD
  Lcd_Cmd(_LCD_CLEAR);               // CLEAR display
  Lcd_Cmd(_LCD_CURSOR_OFF);          // Cursor off
  Lcd_Out(1,1,message1);             // Write message1 in 1st row
  // Print degree character
  Lcd_Chr(2,6,223);
  Lcd_Chr(2,15,223);
```

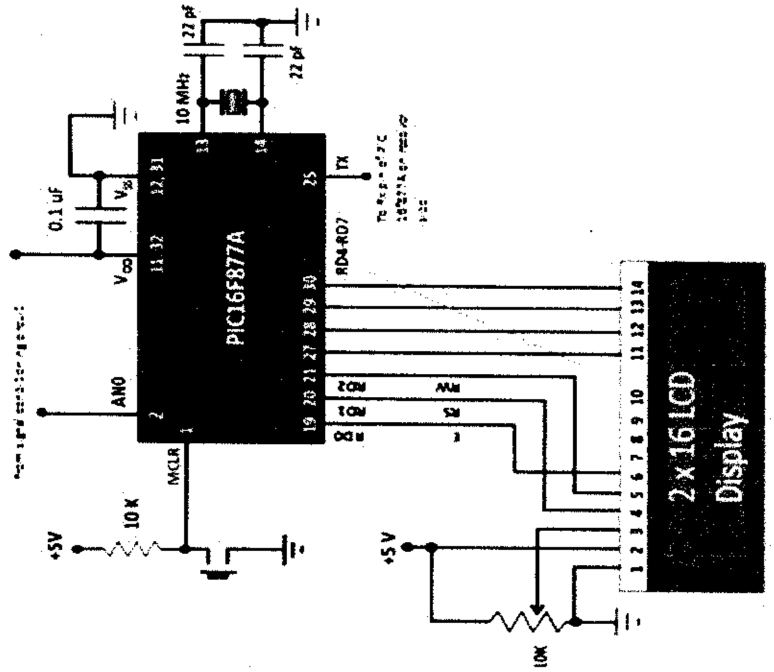
```
Lcd_Chr(2,7,'C');
  Lcd_Chr(2,16,'F');

do {
    c = getc();
Lcd_Out(2, 1, c);
    Delay_ms(1000);
  } while(1);
}
```

APPENDIX C

Circuit diagram for receiver and transmitter side.

Transmitter



Receiver