DESIGN AND CONSTRUCTION OF BODY TEMPERATURE AND HEARTBEAT MONITORING DEVICE

BY

DATONG, AUGUSTINE CHINFON

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DEDICATION

This project is dedicated to my nieces Na'ankang Jordan Datong and Wallat Danielle Datong.

DECLARATION

I, Datong Augustine Chinfon, declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the Federal University of Technology, Minna.

Datong, Augustine Chinfon

(Name of student)

27/11/2010

(Signature and date)

Dr. Tsado Jacob

(Name of Supervisor)

25 11 2010.

(Signature and date)

Engr. A. G. Raji

(Name of H. O. D)

(Jan. 11, 2011)

(Signature and date)

Engr. Dr. G. I. Ighalo

(Name of External Supervisor)

1/12/10

(Signature and date)

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ABSTRACT

This project presents the design and construction of body temperature and heart beat monitoring device using a microcontroller. The microcontroller was programmed in assembly language and interfaced with a temperature measuring circuit (using temperature sensor (LM35) and an analog to digital converter (ADC0804), and heart beat measuring circuit (using Light Dependent Resistor (LDR), Light Emitting Diode (LED) and an op – amp (LM356) to measure the temperature and heart beat. The measured values are then displayed on the display unit (Liquid Crystal Display (LCD). The range of the temperature was found to be between zero and a hundred degree celcius (0 - 100 °C), while the heart beat range is between zero and a hundred and fifty beats per minute (0 – 150 bpm). This signifies the success of the project.

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CHAPTER ONE

1.0 Introduction

The world today is governed by science and technology, by way of inventions and modification of what already exist. It also seeks most importantly, to accomplish complex and multiple tasks within the shortest possible time, effectively and efficiently.

Prior to this project, human body temperature used to be measured through the use of digital thermometer and the mercury thermometer, distinct from measuring the heart rate (heart beat) using a separate device; where the two are combined, it is often complex and bulky.

However in this project, the function of both devices were combined into a single portable device, so that both body temperature and heart rate are simultaneously and continuously monitored and the result is displayed on the Liquid Crystal Display (LCD). This is made possible through the use of a programmable microcontroller, which permits flexibility in determining the functioning of the device.

The device finds its application not only in hospitals or clinics, but also for domestic use, most especially in the developing countries. It has lo operating voltage (5V) and operates on D. C power source which adds more value to it and makes it most suitable for countries like Nigeria, where electric power supply is not readily available, and when available, it is never stable.

1.1 Objectives

The objectives of this project are to design and construct a single electronic device that will:

- Continuously and simultaneously measure and monitor human body temperature and heart rate over a period of time.
- Be relatively cheap, accessible and affordable to all for both clinical and personal use especially in developing countries like Nigeria.

1.2 Scope of the Project

The device is meant to run on a d. c battery. It made up of four units, namely the heart rate monitoring unit (comprises of Light Dependent Resistor (LDR), a Light Emitting Diode (LED) and an operational amplifier (LM358)), the temperature sensing and conversion unit (LM35 and ADC0804), the central processing and storage unit (AT89S52 microcontroller), and finally the data display unit (LCD).

The device is limited to measuring body temperature and heart rate and the final results display on the LCD.

1.3 Sources of Materials

The materials used for this project have the internet as their primary source. Other sources include the Electrical and Computer Engineering Departmental lecture notes I used over the years during the period of my study.

All the components used for this project construction were bought from vendors in Lagos, Minna and Kaduna. The casing was constructed by a carpenter.

CHAPTER TWO

2.0 LITERATURE REVIEW

A thermometer is a medical device which is used for the measurement of temperature. Thermometers measure temperature, by using materials that change in some way when they are heated or cooled. In a mercury or alcohol thermometer the liquid expands as it is heated and contracts when it is cooled, so the length of the liquid column is longer or shorter depending on the temperature. Modern thermometers are calibrated in standard temperature units such as Fahrenheit or Celsius.

The first thermometers were called thermoscopes and while several inventors invented a version of the thermoscope at the same time, Italian inventor Santorio was the first inventor to put a numerical scale on the instrument. Galileo Galilei invented a rudimentary water thermometer in 1593 which, for the first time, allowed temperature variations to be measured. Gabriel Fahrenheit invented alcohol thermometer in 1709 and in 1714, he made the first mercury thermometer, which is the modern thermometer. Lord Kelvin took the whole process one step further with his invention of the Kelvin Scale in 1848. The Kelvin scale measures the ultimate extremes of hot and cold. Kelvin developed the idea of absolute temperature, what is called the "Second Law of Thermodynamics", and developed the dynamical theory of heat. [1]Today, the temperature scale has been replaced with the Celsius scale which is now widely used. The Fahrenheit scale is still in use but in few countries, such as the United States of America.

These thermometers have generally been analog in nature but with time, the digital thermometer came about. Unlike the analog thermometers which are highly

1.4 Constraints

The major constraints experienced during the course of this project lie with the non availability of the major components, the temperature sensor (LM35), the analog to digital converter IC, the operational amplifier IC (LM358), and the microcontroller IC (AT89S52).

1.5 Methodology

Heart Rate can be measured at different points on the human body, namely:

- Wrist and fingers (radial artery)
- Elbow (Brachial artery)
- Neck (Carotid artery)
- Groin (Femoral artery)

On the other hand, human body temperature is normally measured in the mouth (mostly in children) and under the armpit.

This project therefore, makes use of the radial artery mode of heart rate measurement (through the fingers), and the body temperature will be measured from under the armpit.

characterized by inaccuracy and in some cases assumptions, the digital thermometers have the advantage of being highly accurate and efficient such that the lowest and the highest imaginable temperatures can be measured, [2] thereby achieving the long conceived idea of "absolute temperature" by Lord Kelvin.

Temperature monitoring is particularly necessary especially to humans in order to maintain a healthy body. Generally, there is no body temperature value that can be called "normal" since it is dependent on the time of the day, the region in the world, and the circumstances a person finds himself in. However, the average value for normal body temperature for humans is set at 37°C [14] thus, any level above or below it is abnormal and may mean or lead to health problems. This is the value which is considered for this project, with limits between 25°C and 45°. [2]

The heart beat measuring device on the other hand, is used for checking the number of times a heart beats per minute, otherwise called the "Heart Rate (HR)".[3] This measurement has traditionally been done with the stethoscope. The use of this device for heart rate measurement is also inaccurate and in many cases, unreliable. This is because the accuracy depends on the person taking the measurement.

Just as in temperature measurement, there is no single value that is accepted as the general standard for heart rate measurement because it varies with age, sex, altitude (region) and on the situation that one finds himself in e.g. exercise. However, for a normal adult, the widely accepted range that can be considered normal is between 70 – 100 beats per minute. When resting, in adult, the heart beats at 70 bpm in males, 75 bpm in females and 120 bpm in children. [4] (Refer to appendix A for detailed range of values).

The Resting Heart Rate (RHR) defines the rate at which the heart beats per minute when a person is resting. This also determines the health status of a person. Some reference look-up tables are shown in index A for the standard for RHR for both males and females of different age brackets.

Exercise causes a normal person's HR to increase above the resting HR. As the physical activity increases, the HR increases the more. With vigorous exercise, a maximum HR can be reached (100 bpm). [4]

This project therefore, seeks to combine the dual functions into a single device and the measurement will be continuous and simultaneous.

2.1 Microcontroller

A microcontroller is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications.

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, and toys. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems. They generally have a low power operating capacity thereby making many of them well suited for long lasting battery applications. [5]

A microcontroller can be considered a self-contained system with a processor, memory and peripherals and can be used as an embedded system. The majority of microcontrollers in use today are embedded in other machinery, such as automobiles, telephones, appliances, and peripherals for computer systems. These are called embedded systems. While some embedded systems are very sophisticated, many have minimal requirements for memory and program length, with no operating system, and low software complexity. Typical input and output devices include switches, relays, solenoids, LEDs, small or custom LCD displays, radio frequency devices, and sensors for data such as temperature, humidity, light level etc. Embedded systems usually have no keyboard, screen, disks, printers, or other recognizable I/O devices of a personal computer, etc. [5]

2.2.1 List of components

2.2.2 operational amplifier (LM 358)

The LM158 series consists of two independent, high gain; internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage. Application areas include transducer amplifiers, dc gain blocks and all the conventional op amp circuits, which now can be more easily implemented in single power supply systems. For example, the LM158 series can be directly operated off of the standard +5V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional ±15V powersupplies. [6]

The operational amplifier (LM 358) is a available in 8-Bump micro SMD chip sized package, with internally frequency compensated for unity gain, a large dc voltage gain of 100 dB, and a wide bandwidth (unity gain) of 1 MHz (temperature compensated). It also has the characteristic advantage of having a wide power supply range (single supply: 3V to 32 V, or dual supplies: ±1.5V to ±16V), very low supply current drain (500 μA), low input offset voltage of 2 mV, a differential input voltage range equal to the power supply voltage, and a large output voltage swing.[6]

2.2.2 Light emitting diode (LED)

A light emitting diode is a type of diode that emits light while in operation. This must be forward biased before such light emission can be achieved. The color of light however, depends on the semiconducting materials used for its design. It is normally used as light indicator in circuits, as well as to provide some light intensity when used with light dependent resistors (LED).

2.2.3 Light Dependent Resistor (LDR)

This a special type of resistor whose resistance depends on the variation of light intensity that it senses. Its resistance is inversely proportional to the light intensity. External potentiometers or resistors are used to set the operating parameters for sensitivity, on-time, brightness, fade, daylight sensor and environment temperature correction. All signal processing is performed digitally.

LDRs are commonly used for outdoor and indoor motion sensor lights, high end lighting switches, automatic bedroom night lights, and energy saving circuits.[7]

2.2.4 ADC0804

This is a CMOS 8-bit successive approximation analog to digital (A/ D) converter that uses a differential potentiometric ladder. These A/Ds appear like memory locations or I/O ports to the microprocessor and no interfacing logic is needed. Differential analog voltage inputs allow increasing the common-mode rejection and offsetting the analog zero input voltage value. In addition, the voltage reference input can be adjusted to allow encoding any smaller analog voltage span to the full 8 bits of resolution.

The component has differential analog voltage inputs, works with 2.5V voltage reference on-chip clock generator, and 0V to 5V analog input voltage range with single 5V supply. It has 20-pin DIP package, 20-pin molded chip carrier or small outline package. It has an easy interface to all microprocessors, or operates "stand alone", with a conversion period of 100μs. [8]

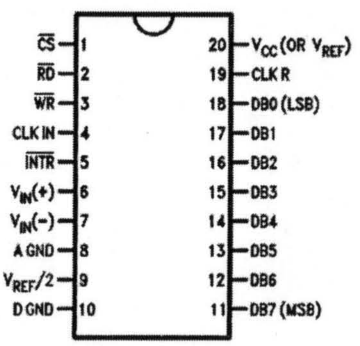

Fig. 1.0 Diagram of ADC0804 showing pin configuration

2.2.5 LM35

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4°C at room temperature and ±3⁄4°C over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 μA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a −55° to +150°C temperature range, while the LM35C is rated for a −40° to +110°C range (−10° with improved accuracy). The LM35 series is available packaged, in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

It is calibrated directly in ° Celsius (Centigrade), has linear + 10.0 mV/°C scale factor 0.5°C accuracy guaranteeable (at +25°C), rated for full −55° to +150°C range, suitable for remote applications, has low cost due to wafer-level trimming, operates from 4 to 30 volts, has, less than 60 μA current drain. It also has low self-heating (.08°C in still air) and a low impedance output (0.1 W for 1 mA load). [9]

2.2.6 Liquid Crystal Display (LCD)

This is an electro-optical amplitude modulator realized as a thin, flat display device made up of any number of color or monochrome pixels arrayed in front of a light source or reflector. [10] It is often utilized in battery-powered electronic devices because it uses very small amounts of electric power.

Each pixel of an LCD typically consists of a layer of molecules aligned between two transparent electrodes, and two polarizing filters, the axes of transmission of which are (in most of the cases) perpendicular to each other. With no liquid crystal between the polarizing filters, light passing through the first filter would be blocked by the second (crossed) polarizer.

The surfaces of the electrodes that are in contact with the liquid crystal material are treated so as to align the liquid crystal molecules in a particular direction. This treatment typically consists of a thin polymer layer that is unidirectional rubbed using, for example, a cloth.

The direction of the liquid crystal alignment is then defined by the direction of rubbing. Electrodes are made of a transparent conductor called Indium Tin Oxide (ITO). [10]

2.2.7 Microcontroller (AT89S52)

The AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The device has a high-density nonvolatile memory. It has an on-chip Flash allows the program memory to be hot or cool [11]. By combining a versatile 8-bit CPU with in-system programmable Flash on a monolithic chip, the microcontroller is made powerful to provide a highly-flexible and cost-effective solution to many embedded control applications. [5]

The AT89S52 provides the following standard features: 8K bytes of Flash, 256 bytes of RAM, 32 I/O lines, Watchdog timer, two data pointers, three 16-bit timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry. In addition, it is designed with static logic for operation down to zero frequency.

The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue functioning. The Power-down mode saves the RAM contents but freezes the oscillator, disabling all other chip functions until the next interrupt or hardware reset. [11]

It has a total of 32 pins set aside for the four ports (P0, P1, P3 and P4), where each port takes 8 pins. All the ports upon RESET are configured as input, ready to be used as input ports. When the first 0 is written to a port, it becomes an output. To configure it as an input, 1 must be sent to the port; this is done in the program.

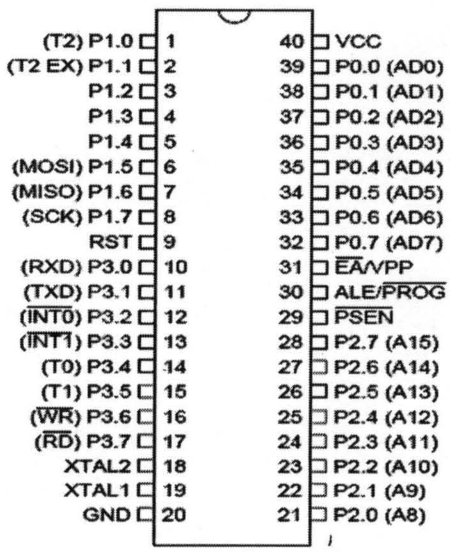

Figure 2.1 Diagram of AT89S52 microcontroller showing the pin configuration

Port 0 is an 8-bit open drain bidirectional I/O port. It is made with internal pull-ups and as well receives the code bytes during Flash programming and outputs the code bytes during program verification. External pull-ups are required during program verification.

Port 1 is an 8-bit bidirectional I/O port with internal pull-ups. When 1s are written to Port 1 pins, they are pulled high by the internal pull-ups and can be used as inputs. P1.0 and P1.1 can be configured to be the timer/counter 2 external count input (P1.0/T2) and the timer/counter 2 trigger input (P1.1/T2 EX), respectively, as shown in the following table. Port 1 also receives the low-order address bytes during Flash programming and verification.

Port 2 is an 8-bit bidirectional I/O port with internal pull-ups. When 1s are written to Port 2 pins, they are pulled high by the internal pull-ups and can be used as inputs. The port emits the high-order address byte during fetches from external program memory and during accesses to external data memory that uses 16-bit addresses. In this application, the port uses strong internal pull-ups when emitting 1s. During accesses to external data memory that uses 8-bit addresses, Port 2 emits the contents of the P2 Special Function Register (SFR). It also receives the high-order address bits and some control signals during Flash programming and verification.

Port 3 is an 8-bit bidirectional I/O port with internal pull-ups. When 1s are written to Port 3 pins, they are pulled high by the internal pull-ups and can be used as inputs. It also receives some control signals for Flash programming and verification. [5]

RST PIN

RESET pin is an input and is active high (normally low). Upon applying a high pulse to this pin, the microcontroller will reset and terminate allactivities. This is often referred to as a power-on reset activating a power-on reset will cause all values in the registers to be lost. [5]

ALE/PROG

Address Latch Enable (ALE) is an output pulse for latching the low byte of the address during accesses to external memory. This pin is also the program pulse input (PROG) during Flash programming. In normal operation, ALE is emitted at a constant rate of 1/6 the oscillator frequency and may be used for external timing or clocking purposes. If desired, ALE operation can be disabled and the disable will have no effect if the microcontroller is in external execution mode.

PSEN

Program Store Enable (PSEN) is used to read the external program memory. When the AT89S52 is executing code from external program memory, PSEN is activated twice each machine cycle, except that two PSEN activations are skipped during each access to external data memory.

EA/VPP (External Access Enable)

External Access (EA) must be strapped to GND in order to enable the device to fetch code from external program memory locations starting at 0000H up to FFFFH. EA is strapped to VCC for internal program executions.

XTAL (1 AND 2)

XTAL1 is the input to the inverting oscillator amplifier as well as to the internal clock operating circuit, while XTAL2 serves as the output from the inverting oscillator amplifier.

Memory Organization

Program Memory

If the EA pin is connected to GND, all program fetches are directed to external memory while its connection to VCC makes program fetches directed to the internal memory.

Watchdog Timer (WDT): (One-time Enabled with Reset-out)

The WDT is intended as a recovery method in situations where the CPU may be subjected to software upsets. The WDT consists of a 13-bit counter and the Watchdog Timer Reset (WDTRST) SFR. The WDT is defaulted to disable from exiting reset. When the WDT is enabled, it will increment every machine cycle while the oscillator is running. Its timeout period is dependent on the external clock frequency. There is no way to disable the WDT except through reset (either hardware reset or WDT overflow reset).

In Power-down mode the oscillator stops, which means the WDT also stops.

Oscillator Characteristics

XTAL1 and XTAL2 are the input and output, respectively, of an inverting amplifier that can be configured for use as an on-chip oscillator, as shown in Figures 8 and 9 below. Either a quartz crystal or ceramic resonator may be used. To drive the device from an external clock source, XTAL2 is left unconnected while XTAL1 is driven, as shown in Figure 8 and 9. There are no requirements on the duty cycle of the external clock signal, but minimum and maximum voltage high and low time specifications must be observed.

Idle Mode

In idle mode, the CPU puts itself to sleep while all the on-chip peripherals remain active. The mode is invoked by software. The content of the on-chip RAM and all the special functions registers (SFR) remain unchanged during this mode. The idle mode can be terminated by any enabled interrupt or by a hardware reset. However, when idle mode is terminated by a hardware reset, the device normally resumes program execution from where it left off, up to two machine cycles before the internal reset algorithm takes control.

On-chip hardware inhibits access to internal RAM in this event, but access to the port pins is not inhibited. To eliminate the possibility of an unexpected write to a port pin when idle mode is terminated by a reset, the instruction following the one that invokes idle mode should not write to a port pin or to external memory.

Power-down Mode

In the Power-down mode, the oscillator is stopped, and the instruction that invokes Power-down is the last instruction executed. The on-chip RAM and Special Function

Registers retain their values until the Power-down mode is terminated. Exit from Power-down mode can be initiated either by a hardware reset or by an enabled external interrupt. Reset redefines the SFRs but does not change the on-chip RAM. The reset should not be activated before VCC is restored to its normal operating level and must be held active long enough to allow the oscillator to restart and stabilize.[11]

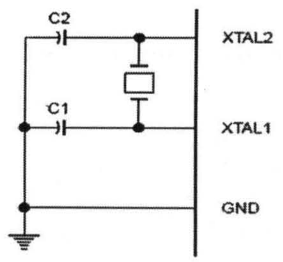

Figure 2.2.oscilator connection

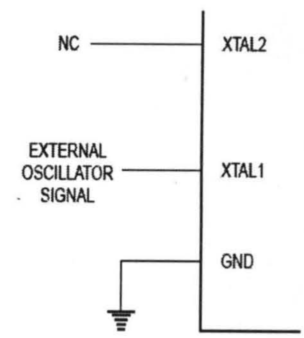

Figure 2.3.external clock drive configuration

2.3 PREVIOUS WORKS

The concept of this project was gotten from hbeonlabs.com. However, in their method, the device measures only for one instance at a time without any result storage. Thus once the measurement is taken, someone needs to be present to take the readings for record purpose.

Modifying the circuit, the AT89C2051 microcontroller is being replaced with the AT89S52 microcontroller which has a larger on-chip memory compared to the AT89C2051 used in the original device. The AT89C2051 has 2K bytes of reprogrammable Flash memory and 128 x 8-bit internal RAM, while AT89S52 has 8K byte Internal Flash memory and 128 x 8-bit RAM. With the AT89C2051 microcontroller, there is no room for future development, which is possible with the AT89S52.

CHAPTER THREE

3.0 Design and Implementation

3.1 Breadboarding

The required components were first tested and assembled on a breadboard in order to test for functionality of the entire circuit. This however, was carried out according to the different modules before being interfaced together.

After the certifying the circuit on the breadboard, the same setup was then transferred to the veroboard and soldered.

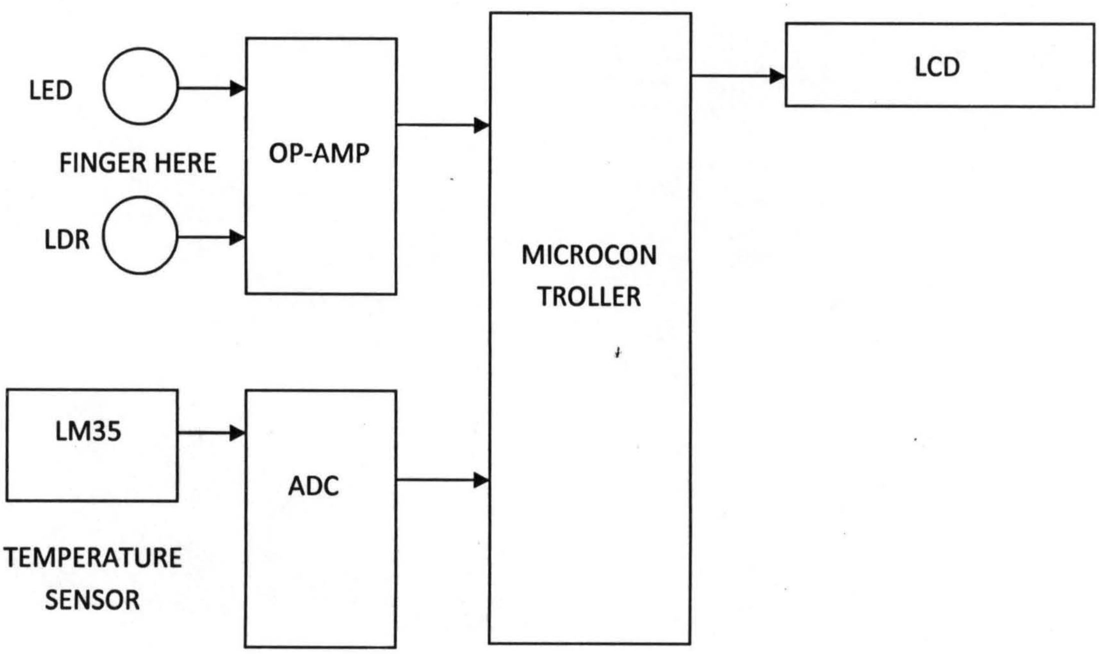

Fig. 3.1 block diagram of body temperature and heart beat monitoring device

3.2.0 **Modular Design**

The steps to designing the circuit was done according to the different modules that make up the circuit, as explained below.

3.2.1 Temperature Monitoring Unit

This comprises of a temperature sensor (LM 35) and an analog to digital converter (ADC 0804). They were used as shown below.

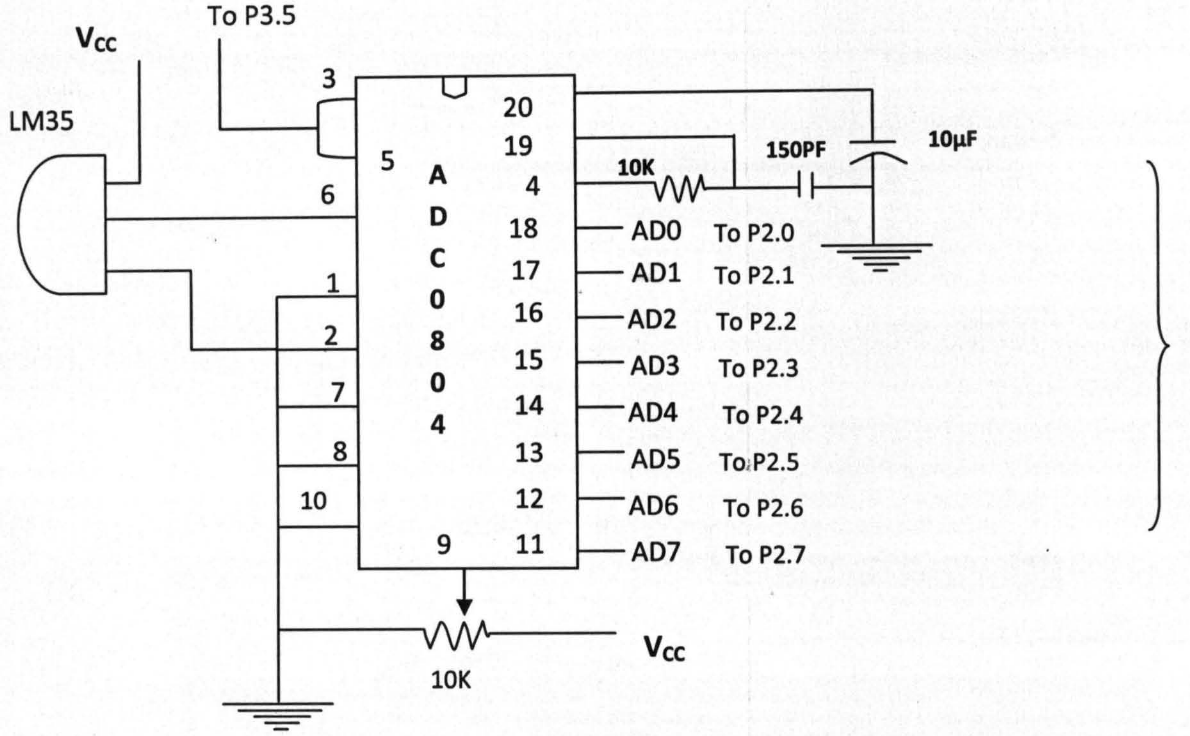

Fig. 3.2 Diagram of the temperature unit

A 5V supply is fed into LM35 via the emitter terminal of the transistor; the base is grounded while the collector supplies an output voltage that feeds the ADC 0804. Temperature is measured by the voltage drop between the base and the emitter (V_{be}) of the transistor. By precisely amplifying the voltage change, it is easy to generate an analog signal that is directly proportional to temperature. [12] Because this output is in analog form, ADC0804 is used to output its digital equivalent.

Pins 6 and 7 of ADC0804 are differential analog inputs. Pin 7 is connected to ground (–ve) while pind 6 is used as the analog input (+ve) to be converted. Pin 1 is an active Low input used to activate ADC0804. Pin 2 (RD) is the "output enable". When pulse goes from High to Low, the converted 8-bit digital data is sent out of ADC0804 to the microcontroller.

Pins 3 and 5 are "start" and "end" conversion respectively. When pin 3 makes a Low to High transition, the analog to digital conversion begins and when it is finished, pin 5 now sends message to the microcontroller that the conversion is over and the data is ready for use. Pins 4 and 19 are the "CLK IN" and "CLK R" (clock in and clock reset respectively). Both are connected together so that the internal clock generator can be used. This process is also called "self-clocking". They are being connected to a capacitor and a resistor and to determine the clock frequency is calculated thus:

$$f = \frac{1}{1.1RC} \quad \text{..........} 3.1$$

Therefore: $f = \frac{1}{1.1\ (10\ 000)(150\times10^{-6})} = 606$ KHz

Thus time (T) $= \frac{1}{f} = \frac{1}{606\ KHz} = 110\ \mu s$ 3.2

Pins 11 to 18 (D0 – D7) are the digital output pins. They are tri-state buffered. Converted data is only accessible when CS is Low and RD is forced to Low.

$$Vout = \frac{Vin}{step\ size} \quad \text{..........} 3.3$$

Where:

Vout = the digital output (in decimal)

Vin = the analog voltage

Step size = resolution = the smallest change (voltage drop measured between emitter and base (V_{be}))

Pins 8 and 10 are the analog and digital grounds respectively. These may be kept separate in order to achieve maximum accuracy. Pin 8 is connected to analog Vin and pin 10 to Vcc. [5]

3.2.2 **The Heart Rate Unit**

The circuit is powered by a 5V supply. This lights the LED that provides illumination to the flesh while the LDR serves as a detector which works based on the variance in light intensity due to blood flow in the finger. This blood flow is sensed by the LDR as a photo-current [13]. The photo-current is then converted into voltage and amplified by the operational amplifier IC LM 358. The detected signal is fed into the non-inverting input (pin 3) and its output (pin 1) is fed into another non-inverting input (pin 5) for squaring and amplification [13].

The output pin 7 then provides the detected heartbeats to the microcontroller. Preset VR1 is used for sensitivity, while the preset VR2 is used for trigger-level settings.

The output signal at pin 7 that represents the heartbeat is then converted into Heart Rate in beats per minute (bpm) using the following formula:

$$N = \frac{60n}{T} \quad \text{--} \quad 3.4$$

Where:

N = the number of beats per minute (bpm)

n = the number of cycles (wavelength) per pre-determined time (seconds)

T = the pre-determined time (in seconds) = 5seconds

60 = the number of seconds in a minute.

The LED used is a high intensity LED which takes a maximum voltage of 5V d.c when forward biased and will illuminate with 0.20mA of current flowing through it. The total voltage is given by:

$V_{in} = V_R + V_f$ --- 3.5

Where: V_R = voltage drop across resistor, and V_f = LED forward voltage (3.3V)

$5V = V_R + 3.3V$

Therefore: $V_R = 5 - 3.3 = 1.7$ (voltage drop across the limiting resistor)

The limiting resistor then is given by:

$R = \frac{V}{I}$ --- 3.6

Therefore: $R = \frac{1.7}{0.02} = 85\Omega$

However, 100Ω was used instead.

The gain of a non-inverting op-amp (A1) is given as:

$Av = 1 + \frac{Rf}{Rin}$ --- 3.7

But Rf = R3 + VR1

Therefore: $Av = 1 + \frac{(R3+VR1)}{R5}$ -- 3.8

But R3 = 100K, R5 = 1K and VR1 = 100K (for maximum gain, VR1 = 0)

Therefore: $Av = 1 + \frac{(100000+0)}{1000} = 100dB$ (which corresponds to the maximum gain with which the op-amp was designed). That is when the intensity is highest.

The output voltage of a non-inverting op-amp is given as:

Op-amp A2 is a comparator. It compares the voltage at pins 5 and 6 which determines the output voltage at pin 7.

The capacitor C2 is a filter, which serves the purpose of filtering any noise that may impeach into the op-amp. If however, the noise is to be reduced the more, a higher value of the capacitor may be used. C1 on the other hand, is a coupling capacitor.

The circuit diagram of the heart rate unit is given below.

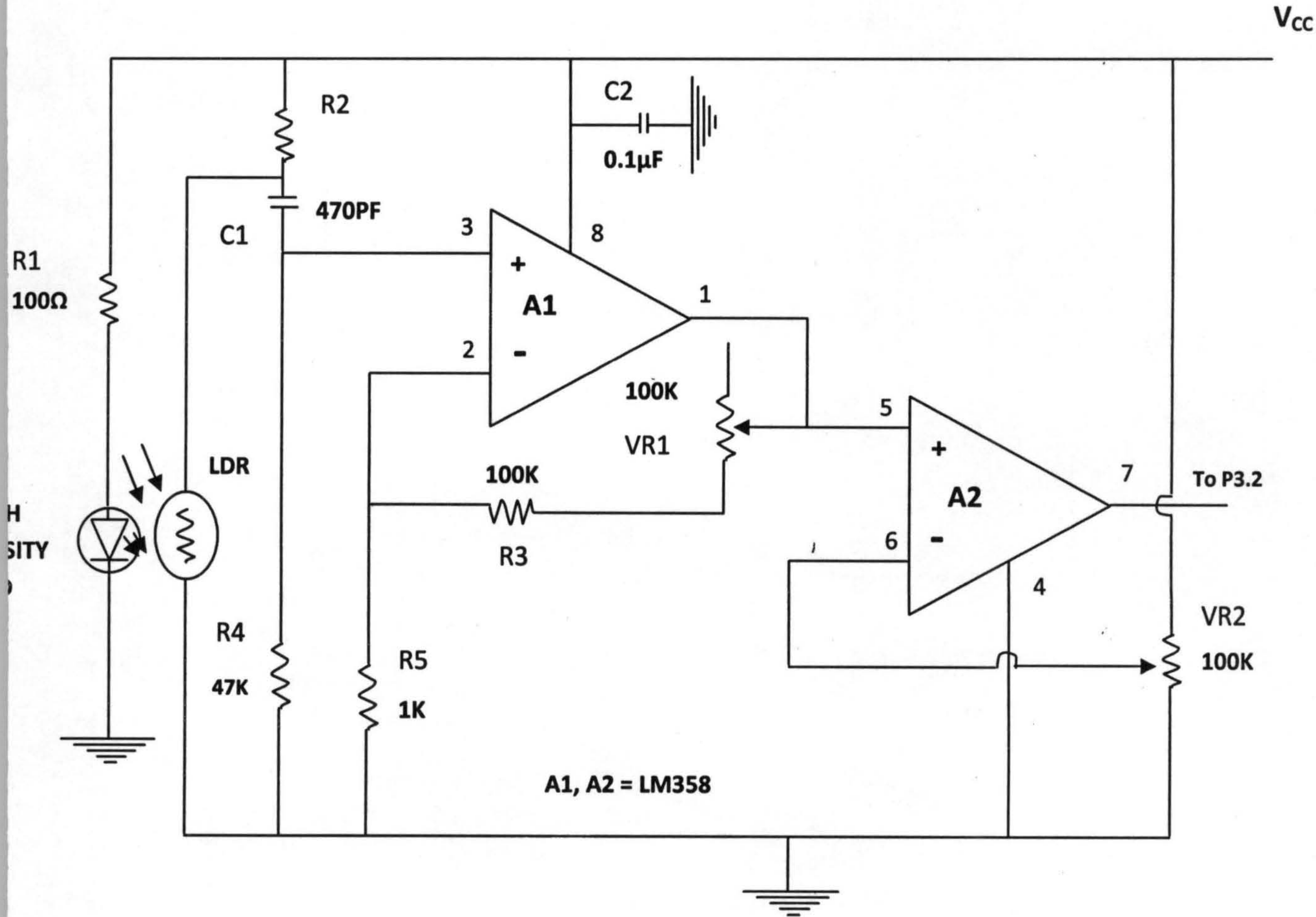

Figure 3.3 Heart Rate circuit diagram

3.2.3 **Microcontroller and Display Unit**

The microcontroller and the LCD display connection is as shown in figure 3.5 below. Connected to the crystal oscillator are two capacitors which are normally of the value 30pF $\pm$ 10. In the case of ceramic capacitors, it is of the value 40pF $\pm$ 10. The crystal oscillator has the machine cycle of 11. 0592 MHz, while the one connected to the controller is 12 MHz. The machine cycle is therefore given as:

$\frac{11.0592}{12}$ = 912. 6 KHz --- 3.10

Clock cycle = $\frac{921.6}{32}$ = 28.8 KHz -- 3.11

Where : 32 is a constant, since the microcontroller operates at the clock frequency as low as 32 KHz.

The LCD on the other hand, displays the output of the measured parameters (heart rate and temperature). The 10K variable resistor is used to vary the contrast of the LCD. The RS (pin 4) is used to send a reset instruction to the microcontroller, the E (pin 6) is an enable, used by the LCD to latch information presented to its data bus , while W/R (pin 5) is used by the microcontroller to read from or write data to the LCD. An 8-bit data line also exists (pins 7 – 14) to send information or instruction command codes to the LCD and to read the content of the LCD's internal register. [5]

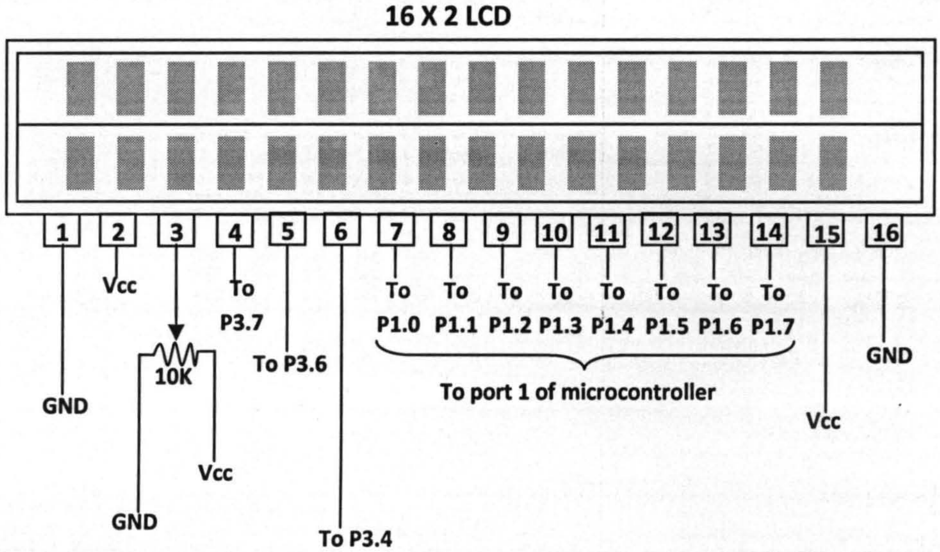

Figure 3.4 LCD pin configuration with microcontroller interface indications

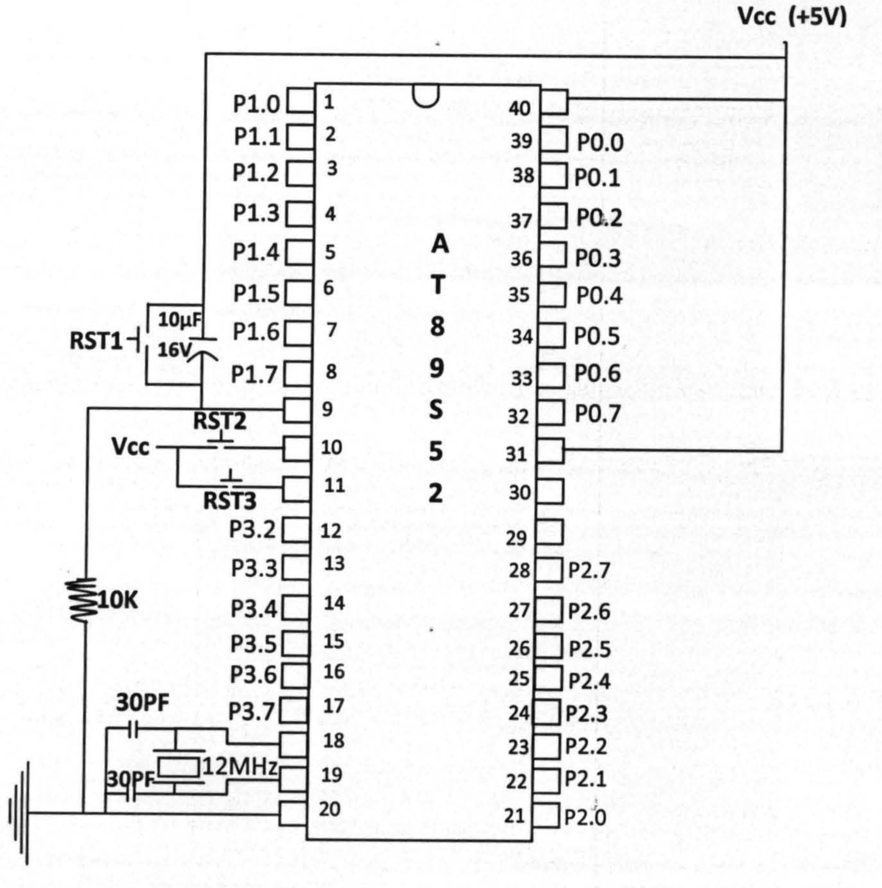

Figure 3.5 basic microcontroller pin configuration with interface indications

3.3 Programming

The program was written in assembly language. An assembly language is low level programming used to write codes or programs that instruct hardware to function in the manner in which the programmer so desires. Each microcontroller has a set of instructions which is called "instruction set"; this is what is used in writing the program. After writing the program using an assembler, the assembler converts the written codes into hexadecimal file which is the language a device called a burner is needed to load the written program in the microcontroller.

When the device is switched on, gives a welcome message on the display and then initializes for further functioning. The first line on the LCD reads the temperature while the second line displays the Heart Rate in beats per second (bpm).

When each sensor is set, their reset buttons **(RST2** and **RST3)** are pressed to begin measurement. The measured values are then displayed on the LCD. Each reset button is independent of the other thus, temperature can be reset **(RST2)** without affecting the Heart Rate unit (which is reset with **RST3)**, and vice-versa. When, on the other hand, the device reset button **(RST1)** is pressed, both temperature and heart rate units are affected and only the welcome message is displayed.

For each measurement, therefore, the corresponding reset button must be pressed.

CHAPTER FOUR

4.0 TEST AND RESULTS

The device was constructed and tested with the following the following observations and analysis recorded.

4.1 Temperature Unit

The temperature unite was tested and it was found out it is capable of measuring both atmospheric and body temperatures.

For body temperature test, the sensor is tucked under the armpit and the corresponding temperature is displayed on the LCD. A sample test was made on six (6) persons and the result obtained is thus:

Table 4.1 Temperature test result

S/N	NAME	TEMPERATURE
1	Suleiman Rilwan	$36^{o}C$
2	Kelechi Moneke	$38^{o}C$
3	Arika Ilyasu	$37^{o}C$
4	Jeffery Obasanjo	$39^{o}C$
5	Donald Angbas	$32^{o}C$
6	Philip Caleb	$36^{o}C$

It was also discovered that while open to the atmosphere, the temperature also reads. Therefore, for every test, the device must be reset (using the reset button), else, the result may not be reliable.

4.2 Heart Rate Test

When the device is switched on, the Light Emitting Diode (LED) in the sensor section lights up. At this stage, there will be no result yet because no finger is placed in the sensing unit. When a finger is placed between the LED and the LDR, the device begins to initialize and the then begins to measure the Heart Rate. The required result is then displayed on the LCD display.

It was tested with a stick, a pair of scissors and a ruler; the result was that the sensors initially recognize the presence of an object placed in-between and sends the output High, thus it begins to initialize. However, after testing for blood flow and senses nothing, the output goes Low and remains thus no result will be displayed. This therefore shows that the device clearly and distinctly senses blood movement in the finger.

Another observation was that though the sensors sense and measure the Heart Rate through the all fingers and the sensitivity was found to be highest on the thumb. For best result, however, the thumb should be placed with the nail facing the LDR, while the flesh faces the LED.

Care should be taken however, that while the thumb is in the sensor, it should be steady and motionless else, the devices keeps on resetting until there is stability in the blood flow pattern. This unit functioned accurately when tested prior to interfacing to the microcontroller but inaccuracy resulted after interfacing.

A test was conducted on six (6) persons before and after a rigorous exercise and the following result was achieved:

Table 4.2 Heart Rate test result

S/N	NAME	BEFORE EXERCISE	AFTER EXERCISE
1	Suleiman Rilwan	70 bpm	80 bpm
2	Kelechi Moneke	73 bpm	85 bpm
3	Arika Ilyasu	80 bpm	95 bpm
4	Jeffery Obasanjo	75 bpm	82 bpm
5	Donald Angbas	65 bpm	75 bpm
6	Philip Caleb	70 bpm	85 bpm

4.3 LIMITATIONS

The device has the following limitations:

1. The Heart Rate sensor unit casing is not good enough as it has to be supported with the other fingers for stable operation.
2. The device runs only on d.c supply with no battery monitoring, therefore, the battery may run down while in operation without warning.

3. It has no storage memory, therefore, once a measurement is taken, one has to be there to monitor the progress.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The aims and objectives of the project have clearly been achieved. The device performs the dual functions of a digital thermometer and a digital Heart Rate monitor, with both functions working simultaneously. It runs on a very low voltage power of 5V, with the results displayed on the LCD. It is also made to be portable and relatively cheap for the common man.

5.2 Recommendations

The following are recommended to improve the device:

1. It should be made to run on dual power supply, i.e., d.c and a.c supplies.
2. A battery charging and monitoring section can equally be incorporated.
3. It can also be made to be transmitting wirelessly.
4. An external memory unit can also be added so that older measured values could be stored in it and may be either copied, or recalled at any time.

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APPENDIX A

a. NORMAL HEART RATE RANGE FOR ALL AGES (MALES AND FEMALES)

RANGE	Age	BPM	AVERAGE
Newborn	Below 1	120-160	140
Toddlers	1-2	90 – 140	115
Pre-school	3-5	80 – 110	95
School-age	6-12	75 – 105	90
Adolescent	13 – 18	60 – 100	80
Adults	18 – 59	60 – 100	80
Seniors	Above 60	67 – 80	74

b. RESTING HEART RATE (RHR) CHART FOR WOMEN

Age	RHR FOR ATHLETES	EXCELLENT	GOOD	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	POOR
18-25	54-60	61-65	66-69	70-73	74-78	79-84	85+
26-35	54-59	60-64	65-69	69-72	73-76	77-82	83+
36-45	54-59	60-64	65-69	70-73	74-78	79-84	85+
46-55	54-59	61-65	66-69	70-73	74-77	78-83	84+
56-65	54-59	60-64	65-68	69-73	74-77	78-83	84+
65+	54-59	60-64	65-68	69-72	73-76	77-84	84+

c. RESTING HEART RATE (RHR) FOR MEN

Age	RHR FOR ATHLETES	EXCELLENT	GOOD	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	POOR
18-25	49-55	56-61	62-65	66-69	70-73	74-81	82+
26-35	49-54	55-61	62-65	66-70	71-74	75-81	82+
36-45	50-56	57-62	63-66	67-70	71-75	76-82	83+
46-55	50-57	58-63	64-67	68-71	72-76	77-83	84+
56-65	51-57	57-61	62-67	68-71	72-75	76-81	82+
65+	50-55	56-61	62-65	66-69	70-73	74-79	80+

APPENDIX B

Assembly language program code:

```
CLR A
TEMP_DATA   EQU P2
TEMP_CON   EQU P3.5
LCD_DATA EQU P1
HBIT   EQU P3.2
EN EQU P3.6
RW EQU P3.4
RS EQU P3.7
MOV R0,#00H
MOV R1,#00H
MOV R2,#00H
MOV R3,#00H
MOV R4,#00H
MOV R5,#00H
MOV R6,#00H
MOV R7,#00H
BOTTON  EQU P3.0
ORG 0000H
AJMP MAIN
ORG 000BH
INC R4
RETI
MAIN:       MOV TEMP_DATA, #0FFH
            LCALL HELLO
            CLR TEMP_CON
            CLR HBIT
            CLR BOTTON
AA:         JB HBIT,MAIN2
            JB BOTTON,MAIN1
            AJMP AA
MAIN1:      SETB BOTTON
            JB  BOTTON , $
            LCALL GET_TEMP
            LCALL CONV_TEMP
            LCALL CLR_LCD
            LCALL LOADING
            ACALL DELAY
            LCALL PLEASE
            ACALL DELAY
            LCALL T_RESULT
            AJMP AA
MAIN2:      MOV IE, #81H
            MOV R5, #60
MAIN21:     MOV R6, #195
MAIN22:     MOV R7, #254
            DJNZ R3,$
            DJNZ R2,MAIN22
            DJNZ R1,MAIN21
            MOV A,R4
            MOV B, #00H
            MOV B, #12
            MUL AB
            ACALL CONV_TEMP
            MOV LCD_DATA,#0C0H
        SETB EN
        CLR EN
        LCALL WAIT_LCD
            LCALL LOADING
            ACALL DELAY
            LCALL PLEASE
            ACALL DELAY
```

```
        LCALL H_RESULT
        AJMP AA

DELAY:  PUSH 00H
        PUSH 01H
        PUSH 02H
        MOV 00H,#12
BOLA: MOV 01H,#195
HERE: MOV 02H,#254
        DJNZ 02H,$
        DJNZ 01H,HERE
        DJNZ 00H,BOLA
        POP 02H
        POP 01H
        POP 00H
        RET
DELAY1: PUSH 00H
        PUSH 01H
        PUSH 02H
        MOV 00H,#02
BOLA1:  MOV 01H,#195
HERE1:  MOV 02H,#254
        DJNZ 02H,$
        DJNZ 01H,HERE1
        DJNZ 00H,BOLA1
        POP 02H
        POP 01H
        POP 00H
        RET
INIT_LCD:CLR RS
    MOV LCD_DATA,#48H
    SETB EN
    CLR EN
    LCALL WAIT_LCD
        CLR RS
        MOV LCD_DATA,#0EH
        SETB EN
        CLR EN
        LCALL WAIT_LCD
        CLR RS
        MOV LCD_DATA,#15H
        SETB EN
        CLR EN
        LCALL WAIT_LCD
        RET
CLR_LCD:CLR RS
        MOV LCD_DATA,#01H
        SETB EN
        CLR EN
        LCALL WAIT_LCD
        RET

HELLO:ACALL INIT_LCD
    LCALL CLR_LCD
    MOV A,#'H'
    LCALL WRITE_TEXT
    MOV A,#'E'
    LCALL WRITE_TEXT
    MOV A,#'L'
    LCALL WRITE_TEXT
    MOV A,#'L'
    LCALL WRITE_TEXT
    MOV A,#'O'
    LCALL WRITE_TEXT
    MOV A,#' '
    LCALL WRITE_TEXT
    MOV A,#'D'
    LCALL WRITE_TEXT
```

```
MOV A,#'A'
LCALL WRITE_TEXT
MOV A,#'T'
LCALL WRITE_TEXT
MOV A,#'O'
LCALL WRITE_TEXT
MOV A,#'N'
LCALL WRITE_TEXT
MOV A,#'G'
LCALL WRITE_TEXT
MOV A,#'.'
LCALL WRITE_TEXT
MOV A,#'.'
LCALL WRITE_TEXT
RET
GET_TEMP:   SETB TEMP_CON
            ACALL DELAY1
            CLR TEMP_CON
            ACALL DELAY1
            CLR A
            MOV A , TEMP_DATA
            RET
ORGANIZ:
    ONE:CJNE A, #00H, TWO
            MOV 20H, #00H
            RET
    TWO:CJNE A, #01H, THREE
            MOV 20H, #01H
            RET
THREE:CJNE A, #02H, FOUR
            MOV 20H, #02H
            RET
FOUR:CJNE A, #03H, FIVE
            MOV 20H, #03H
            RET
FIVE: CJNE A, #04H, SIX
            MOV 20H, #04H
            RET
SIX:    CJNE A, #05H, SEVEN
            MOV 20H, #05H
            RET
SEVEN:      CJNE A, #06H, EIGHT
            MOV 20H, #06H
            RET
EIGHT:      CJNE A, #07H, NINE
            MOV 20H, #07H
            RET
NINE:  CJNE A, #08H, TEN
            MOV 20H, #08H
            RET
TEN:   CJNE A, #09H, ELEVEN
            MOV 20H, #09H
            RET
ELEVEN:RET
LOADING:
            MOV A , #'L'
            ACALL WRITE_TEXT
            MOV A , #'O'
            ACALL WRITE_TEXT
            MOV A , #'A'
            ACALL WRITE_TEXT
            MOV A , #'D'
            ACALL WRITE_TEXT
            MOV A , #'I'
            ACALL WRITE_TEXT
            MOV A , #'N'
            ACALL WRITE_TEXT
            MOV A , #'G'
```

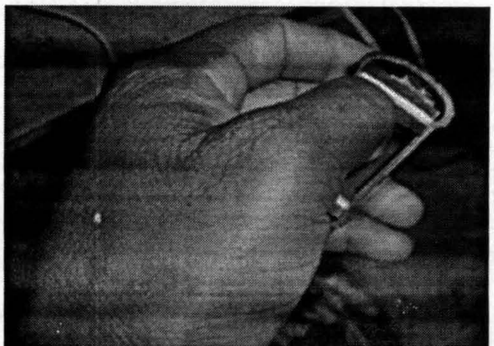
```
            ACALL  WRITE_TEXT
            MOV  A , #'.'
            ACALL  WRITE_TEXT

            MOV  A , #'.'
            ACALL  WRITE_TEXT
            MOV  A , #'.'
            ACALL  WRITE_TEXT
            RET
PLEASE:     MOV  A , #'P'
            ACALL  WRITE_TEXT
            MOV  A , #'L'
            ACALL  WRITE_TEXT
            MOV  A , #'E'
            ACALL  WRITE_TEXT
            MOV  A , #'A'
            ACALL  WRITE_TEXT
            MOV  A , #'S'
            ACALL  WRITE_TEXT
            MOV  A , #'E'
            ACALL  WRITE_TEXT
            MOV  A , #' '
            ACALL  WRITE_TEXT
            MOV  A , #'W'
            ACALL  WRITE_TEXT
            MOV  A , #'A'
            ACALL  WRITE_TEXT
            MOV  A , #'I'
            ACALL  WRITE_TEXT
            MOV  A , #'T'
            ACALL  WRITE_TEXT
            RET
T_RESULT:   LCALL CLR_LCD
            MOV  A , #'T'
            ACALL  WRITE_TEXT
            MOV  A , #'E'
            ACALL  WRITE_TEXT
            MOV  A , #'M'
            ACALL  WRITE_TEXT
            MOV  A , #'P'
            ACALL  WRITE_TEXT
            MOV  A , #' '
            ACALL  WRITE_TEXT
            MOV  A , #'='
            ACALL  WRITE_TEXT
            MOV  A , #' '
            ACALL  WRITE_TEXT
         LCALL ORG_1
            ACALL  WRITE_TEXT
            LCALL ORG_2
            ACALL  WRITE_TEXT
            LCALL ORG_3
            ACALL  WRITE_TEXT
            MOV  A , #0DFH
            ACALL  WRITE_TEXT
            MOV  A , #'C'
            ACALL  WRITE_TEXT

            RET
H_RESULT:   LCALL CLR_LCD
            MOV  A , #'H'
            ACALL  WRITE_TEXT
            MOV  A , #'.'
            ACALL  WRITE_TEXT
            MOV  A , #'R'
            ACALL  WRITE_TEXT
            MOV  A , #'.'
            ACALL  WRITE_TEXT
```

```
    MOV A , #' '
    ACALL  WRITE_TEXT
    MOV A , #'='
    ACALL  WRITE_TEXT
    MOV A , #' '
    ACALL  WRITE_TEXT
LCALL ORG_1
    ACALL  WRITE_TEXT
    LCALL ORG_2
    ACALL  WRITE_TEXT
    LCALL ORG_3
    ACALL  WRITE_TEXT
    MOV A , #' '
    ACALL  WRITE_TEXT
    MOV A , #'B'
    ACALL  WRITE_TEXT
    MOV A , #'P'
    ACALL  WRITE_TEXT
    MOV A , #'M'
    ACALL  WRITE_TEXT
    MOV A , #'.'
    ACALL  WRITE_TEXT
    RET
```

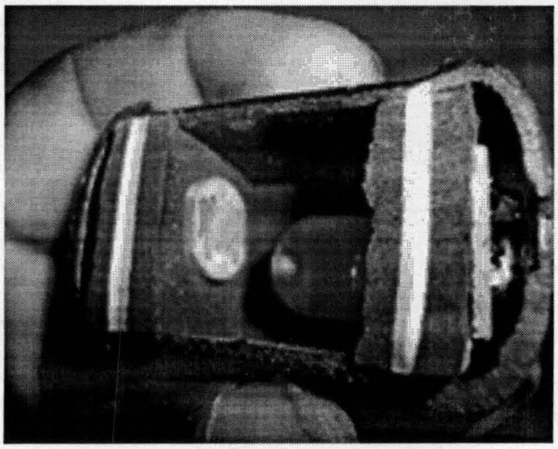
APPENDIX C

PICTORAL PRESENTATION OF THE PROJECT

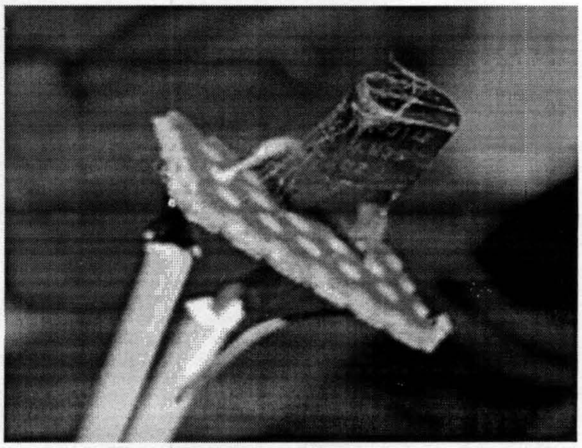
a. Welcome message on the LCD



b. Thumb inserted into the heart beat sensor

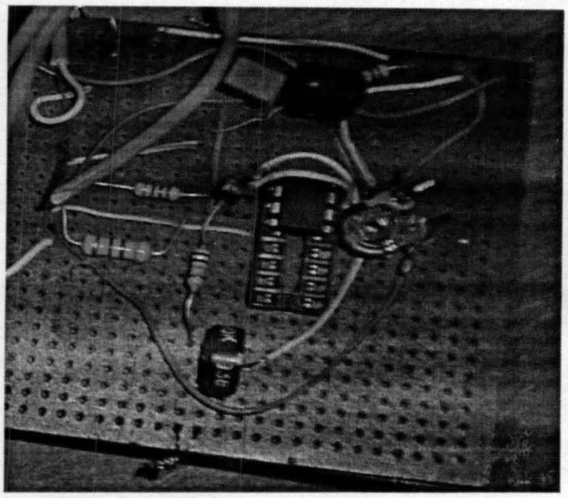


c. internal outlook of the heart beat sensor

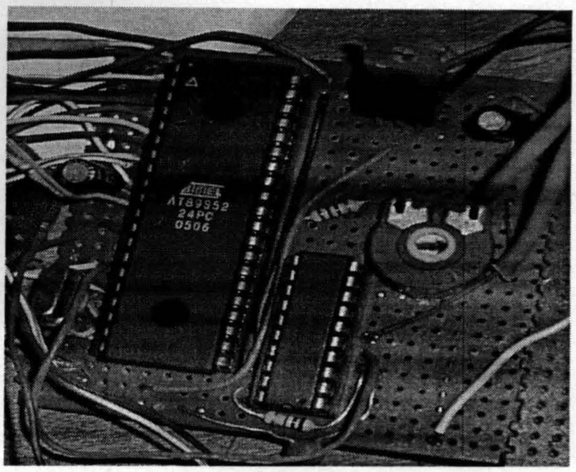


d. The temperature sensor

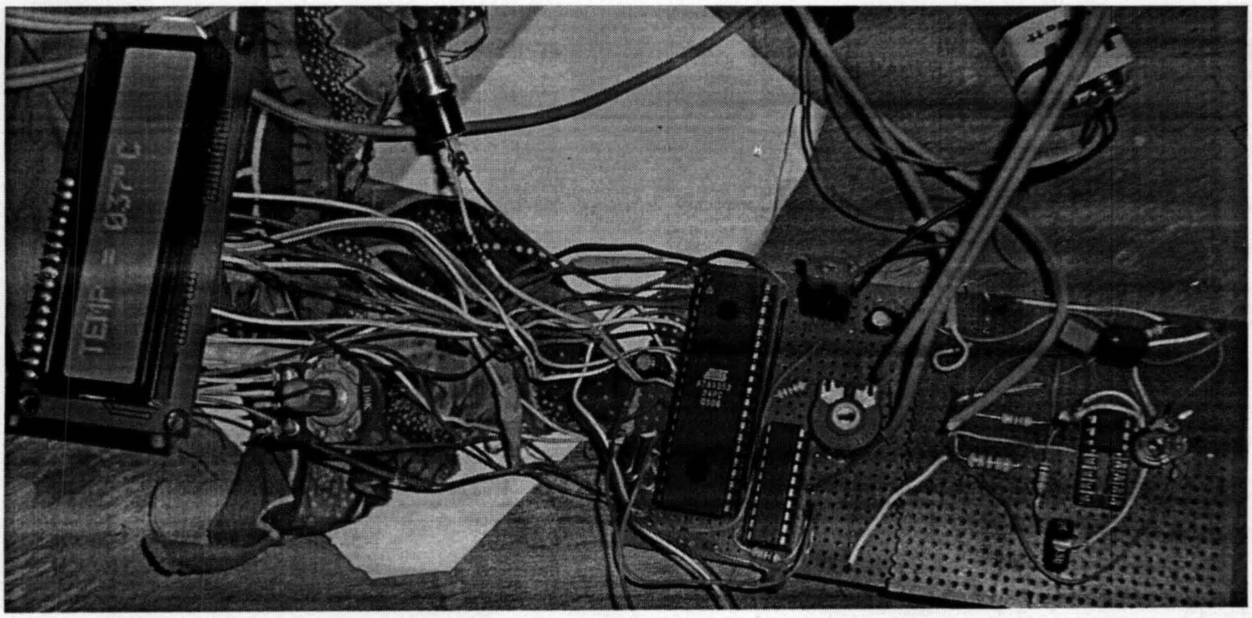
e. The completed device displaying sme measured values



f. **Heart Rate Unit**



g. Temperature unit interfaced to microcontroller



h. The complete circuit

i. A screen-shot of the assembly code using *EdSim51* assembler