

# **Embedded System for Biofeedback Using Bio-Modalities**

**Thesis report submitted towards the partial fulfillment of  
requirements for the award of the degree of**

**Master of Engineering (Electronic Instrumentation & Control)**

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## **Declaration**

I hereby declare that the thesis report entitled “Embedded System for Biofeedback using Bio-modalities” is an authentic record of my own work carried out as requirements for the award of degree of M.E. (Electronics Instrumentation and Control) at Electrical and Instrumentation Engineering Department of Thapar Institute of Engineering and Technology (Deemed University), Patiala, is an authentic record of my own work carried out under the supervision of Mandeep Singh (Lecturer).

The matter presented in the thesis has not been submitted by me for the award of any other degree of this or any other university.

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Certified that the above statement made by the student is correct to the best of my knowledge and belief.

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## **Abstract**

Biofeedback is a means for gaining control of our body processes to increase relaxation, relieve pain, and develop healthier, more comfortable life patterns. The continuous recording of one or more of bio-modalities responses is done. The changes in the autonomic responses are noted by varying the environmental conditions, in this thesis by changing the type of music. It is required that the changes in the response be measured and that certain characteristics be signaled to the subject in a suitable way. This principle is called biological feedback or biofeedback.

Many physiological processes can be monitored for biofeedback applications. By using different sensors for different parameters the possibility of recording all parameters at a time can be achieved. Here three bio-modalities temperature, galvanic skin resistance and pulse rate are taken. The changes are measured. The modality, which is most sensitive i.e. the changes occur most rapidly due to change in environmental condition among these modalities, is taken for the feedback operation.

The embedded system is designed using AT89C51 microcontroller and program code is written in embedded-C using Keil compiler.

# Chapter 1

## Introduction

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### 1.1 The Beginning and Literature Survey of Biofeedback

Fire walking, more commonly known as walking on hot coals, is generally viewed as a paranormal phenomena. But it may be possible that fire walkers developed a way to combine biofeedback and various feedback methods hundreds of centuries ago, and used this knowledge to empower themselves to walk on embers without feeling pain.

The word “biofeedback” was coined in the late 1960s to describe laboratory procedures which were being used for experimental research, like alteration of brain activity, blood pressure, heart rate and other body functions that normally are not voluntarily controlled.[1]

In 1961, Neal miller, an experimental psychologist, suggested that autonomic nervous system responses could be brought under voluntary control. As a result of his experiments, he showed that such autonomic processes were controllable. This work led to the creation of feedback therapy. Miller’s work was further expanded by other researchers. Thereafter research performed in 1970s by UCLA researcher, Dr. Barry sterman, established that cats and monkeys could be trained to control their brainwave pattern.[2]

At that time, many scientists looked forward to that day when biofeedback would give a major degree of control over human body. Some believed that biofeedback would, one day, make it possible to dispense with drug treatment that often cause side effects in patients, like high blood pressure and other ailments.

D.A.Chrisdis has reported a research project to design, implement and standardize an EDR biofeedback device, using constant voltage method. To measure electro dermal resistance. With the use of microcontroller, it would be easy to calculate GSR. Along

with the changes in GSR, which occur as a result of training in “stress management strategies”[2]

EMIL, Amanda, Paul & Frank have reported robust scheme to monitor stress using a distributed wireless intelligent sensor system. This is based on measurement of Heart rate variability (HRV). By picking up the signal using ECG, it sent data to the doctor through internet (by linking to the PC and mobile gateway), using Bluetooth or WLAN. But that could only solve the purpose of chronically ill patients, require constant monitoring. Where as this instrument would solve both the purpose i.e. can be used independently by patient for regular treatment session and to have a look at the progress, for further improvement. Since it is micro controller based, if required can be modified and linked to server and hence act as WISE i.e. intelligent sensor, used for real time signal processing and data acquisition.

## **1.2 Biofeedback Instrumentation**

Although the activity of the autonomic nervous system cannot be controlled directly, it can be influenced in an indirect way by two mechanisms known as *conditioning* and *feedback*.

Biofeedback is a means for gaining control of our body processes to increase relaxation, relieve pain, and develop healthier, more comfortable life patterns.

Biofeedback gives us information about ourselves by means of external instruments. Using a thermometer to take our temperature is a common kind of biofeedback. Clinical biofeedback follows the same principle, using specialized instruments to monitor various physiological processes as they occur. Moving graphs on a computer screen and audio tones that go up and down "reflect" changes as they occur in the body system being measured. [1]

Experiments require the continuous recording of one or more of the autonomic responses. Sometimes the autonomic responses can be influenced by simply informing the subject when a change in the response occurs. This again requires that the response be

measured and that certain characteristics of it be signaled to the subject in a suitable way. This principle is called biological feedback or biofeedback.

Biofeedback training familiarizes us with the activity in our various body systems so we may learn to control this activity to relieve stress and improve health. Trying to change physiological activity without biofeedback is like playing dart while blindfolded - we can't see whether we are hitting the mark or not. Biofeedback lets us know precisely when we are changing our physiologies in the desired direction.

Biofeedback is not a treatment. Rather, biofeedback training is an educational process for learning specialized mind/body skills. Learning to recognize physiological responses and alter them is not unlike learning how to play the piano or tennis - it requires practice. Through practice, we become familiar with our own unique psycho physiological patterns and responses to stress, and learn to control them rather than having them controls us.

Using the biofeedback, we can learn to change the body's response, in a way that improves health, and this is done by using an electronic instrument that measures and indicates various things that are happening inside the body. A microcontroller based system is designed to pick up electrical signals from human body like Pulse, GSR and Temperature etc, to condition it according to the requirement and display the patient's condition.

### **1.3 Needs of Biofeedback**

When we are confronted with different stressful situations - anything from a sudden stop in traffic to being interviewed for a job - our bodies respond in much the same way, with the "fight or flight response." We automatically prepare either to fight the stressor or to run from it. Our pulse rate increases, muscles tense, breathing becomes shallower, we start to sweat, our minds race, etc. But this very old, unconscious pattern, which once provided human beings with the responses necessary for self-protection in a challenging physical environment, is today the root of many stress-related illnesses and a

reduced quality of life. Throughout our lives, as we confront the various stressors that occur every day, we respond by constantly tensing and relaxing. Eventually, after each instance of tensing, we cease to return to our original level of physiological relaxation. Thus, through the years we establish a stair-step pattern. We adapt to increasing levels of physiological activity. In so doing, we lose familiarity with deeper levels of relaxation and get used to greater levels of tension as the norm. This habituation to unnecessary physiological activity has a wearing effect and can cause such conditions as high blood pressure, headaches, digestive problems, and other illnesses. This technique is used in controlling variables like heart rate, blood pressure and the occurrence of certain patterns in electroencephalogram.[3]

## **1.4 The Bio Integrator and Bio-Integration**

The Bio Integrator, a biofeedback instrument, represents a dramatic breakthrough in the measurement and feedback of EEG and body measures. The Bio Integrator makes it possible to see right- and left-brain activity, while at the same time watching peripheral blood flow, respiration, heart rate, electro dermal activity, and skeletal muscle activity. The displays include vivid, full-color graphs, nature scenes, and games. The Bio Integrator was designed to enhance client learning by providing beautiful, intuitive, and adaptable displays. A wide variety of audio feedback can accompany the visual displays, surrounding the client in an audiovisual feedback envelope that promotes rapid learning.[4]

Bio Integrator is a specialized training protocol of multi-modality biofeedback. The client is trained to regulate many physiological systems in concert to achieve an appropriate mix of activation for various life situations. Just as in an orchestra, where each instrument must play in harmony with all the others, clients training learn to regulate various systems of the body to work in harmony with each other to achieve and maintain optimal health. Bio Integration links internal (physiological) and external (environmental) life events so that the individual can choose how to respond as these events occur instead of relying on automatic habitual patterns.

For example, you may notice as you are driving your car that your shoulders are starting to hurt. Not only does this inhibit your ability to drive comfortably, it indicates that you are unconsciously using more muscles and effort than you need to use for the task at hand. Bio Integration allows you to be aware of how much effort is needed in each physiology for each task, and promotes an economy of use.

The Bio Integrator Plus represents a dramatic breakthrough in the measuring and feeding back of psycho physiological measures. It is designed to provide feedback tailored to the client's needs and learning style, while providing maximum ease and flexibility.

The Bio Integrator Plus features 8-channel high-performance front ends, e.g.:

- 2 EEGs
- 2 EMGs
- Temp
- SCL
- Heart Rate
- Respiration

The bio integrator instrument's output can be seen through different ways. One can choose the different system for the output. The output can be simple displays, Bar graph. Audio sounds etc as explained below:-

### **1.4.1 Dazzling Feedback Displays**

Clients watch their physiological measures driving vivid, full-color graphs, nature scenes, games, works of art, and puzzles. Thousands of combinations of beautiful line graph, fill graph, spectral and live 3D displays can be shown as full-screen, two-per-screen or four-per-screen displays.

## **1.4.2 Extremely Rich Audio Feedback**

Audio feedback can be assigned to all measures with any of 60 voices, from calliope to violin. You may have up to four individual measures playing separate voices.

## **1.4.3 Bar-graphs**

The bar-graphs are the best display medium as here comparison with some standard or with the previous output can be done. For this display PC interfacing is done.

## **1.4.4 Professional Color Printing**

High resolution professional color printouts are standard with the Bio Integrator Plus. Printing is as simple as pressing a single key. You can print full-page, two-per-page, or four-per-page data displays, for single sessions and for multiple sessions with longitudinal review.

## **1.4.5 Powerful and Graceful Integration of EEG and Body Measures**

The Bio Integrator Plus offers the smoothest integration of EEG and body measures available today. In many systems, one can have an over-emphasis on EEG at the expense of body measures, or vice versa. The Bio Integrator Plus provides a very powerful and exciting mixture of EEG, EMG, Temp, Heart Rate/Cardiovascular, SCL, and Respiration for feedback and research.

The EEG measures are powerful and very flexible, allowing the clinician to choose among amplitude, power, percent power, and synchrony. Dazzling real-time, smooth-animation spectral and 3D displays allow for the observation of very subtle brain wave shifts. EEG as a measure is difficult to implement. Bio Integrator Plus provides extraordinary data collection and feedback.

The Bio Integrator Plus was designed over a 7-year period with the goal of creating a more powerful and effective bio system that accelerates the client's learning process and is very easy and exciting to use.

## **1.5 Biofeedback Assembly**

In a typical biofeedback assembly, the client settles into a comfortable chair and is hooked up to the biofeedback instrument with sensors attached to the surface of the skin at various locations on the body (usually the shoulders, fingers, back, and head). Electrical impulses from these locations are recorded and reflected on a computer monitor in the form of graphs or other visual displays such as mandalas. Additionally, the client may receive auditory feedback reflecting increases and decreases in body system activity in the form of higher and lower musical tones.

Before beginning training, the client's measures in the various modalities are recorded without feedback to give the clinician a picture of the client's overall psycho physiological state. The client may be directed to pay particular attention to one physiology, while information on the other body systems is monitored by the clinician. While the client is observing the activity of a particular system onscreen, audio feedback in the form of musical tones is also being presented, reflecting activity in the same system or a different one.[5]

Every individual exhibits a unique set of characteristic psycho physiological patterns that reflect the various accommodations to stress that he or she has made over the years. The goal of biofeedback training is to gain self-regulatory skills with which to adjust the activity in various systems to optimal levels for the task at hand.

## **1.6 Biofeedback Modalities**

Many physiological processes can be monitored for biofeedback applications. By using different sensors for different parameters the possibility of recording all parameters at a time can be achieved. There are many parameters which can be included in bio-

integrator instrument the complexity depend upon the number of parameters. In designing the biofeedback instrument one should take care that each biofeedback modality must have different display clearly specified, so that one should not get confused. Some of the more common modalities are given below.

### **1.6.1 Temperature**

Temperature is measured by sensors placed on the ring fingers. The temperature modality indicates the contraction of the smooth muscles surrounding the blood vessels, which determines how much blood reaches the fingertips. When these muscles are contracted (tense), the temperature is cooler because less blood reaches the fingers. We experience this coldness in our hands when we are stressed - for example, when going to a job interview and shaking hands with a prospective boss. It is not uncommon for people's temperature readings to be as low as 70 to 80 degrees Fahrenheit, nor is it uncommon to see a difference of five or ten degrees between right and left hand measures. The brain is organized so that the right hemisphere is associated with activity in the left side of the body, and the left hemisphere is associated with activity in the right side of the body. Some clinicians believe that when one hand is significantly colder than the other, this represents an imbalance in the activity of the right and left hemispheres of the brain. This is also thought to be the case for other bilateral measures (e.g., EMG and BSR). The sensors for the temperature measurement are Thermister, Thermocouple, Resistance temperature detectors etc. The sensor type is depending upon the requirements.[6]

### **1.6.2 EMG (electromyography)**

Muscle activity is measured by the EMG, which detects the electrical activity occurring within certain muscles, typically the trapezius (shoulder) and temporalis (jaw and scalp) muscles. Muscle tension indicates stress. For example, it is common for people to react to the stress of anger by clenching their teeth and generally tensing up. To measure EMG, the skin is cleaned and adhesive sensors with a conductive gel are attached to the shoulder muscles. The jaw and scalp sensors placed on the outer forehead

are small silver discs held in place by an elastic headband. Muscle activity is measured in micro volts, and it is not uncommon for levels to range from 5 to 40 micro volts.

### **1.6.3 GSR (Galvanic skin response)**

Galvanic skin response (GSR) is a measure of sweat gland activity. Most people are familiar with having cold, clammy hands under stressful circumstances, such as meeting new people or having to perform before an audience. The coldness comes from constriction of the smooth muscles surrounding the blood vessels (measured by hand temperature), while the dampness is caused by eccrine gland activity. The eccrine glands secrete a salty solution in response to emotional and stress stimuli. BSR sensors are attached with elastic bands to the first and second fingers of the right and left hands. [6]

### **1.6.4 Pulse Rate**

Pulse rate is usually described in terms of its rate, which is no. of beats per minute. Faster heart rates are often caused by stress. Our hearts may race and pound when we are afraid. Other kinds of stress, such as depression, may result in lower heart rates. To measure heart rate, we place a sensor on a finger to detect each beat of the heart. We also measure heart rate variability and train toward specific beneficial cardiovascular patterns. This technique is known as RSA training.[7]

### **1.6.5 Respiration Rate**

Respiration is measured in breaths per minute, typically by a strain gauge worn around the stomach. Respiration becomes faster, shallower, and uneven when we are stressed, for example, when we gasp in surprise or feel short of breath when frightened. It is not unusual for people to have a breath rate of between 16 and 30 breaths per minute prior to training.

### **1.6.6 Neurofeedback (EEG)**

Brain waves are measured by the electroencephalograph (EEG). EEG is comprised of several bandwidths: Theta (4-7 Hz), Alpha (8-12 Hz), Beta (13-20 Hz), and

Gamma (21+).[1] The overall purpose of EEG training is to develop range of motion among bandwidths, so that the client knows what each bandwidth feels like and how to use each state for its characteristic benefits. Speaking very generally, beta and gamma are useful for directed activity and getting things done; alpha is useful in situations where relaxed vigilance is called for (such as meditation); and theta is useful for creative, day-dreamy generation of imagery (theta is sometimes called the gateway to the unconscious). [6]

In biofeedback instrument brain wave measurements are recorded through silver discs placed at three locations: center forehead, the base of the scalp to the right of center (occipital 1), and the base of the scalp to the left of center (occipital 2).

## 1.7 Biofeedback Training



Imagine having hands so sensitive to cold that each winter they would swell and split open, so that just grabbing a carton of milk out of the refrigerator makes them whiten and throb with pain. Then imagine learning to raise the temperature in your hands to the extent that you could hold the carton of milk and do it without any pain.[8]

This is an example of what biofeedback training can accomplish for certain medical problems such as Raynaud's disease, a circulatory disorder that can cause its victims extreme discomfort and debilitation. Several decades of clinical experience and hundreds of published studies support the use of biofeedback training in many common medical problems, such as [9]

§ Fecal or urinary incontinence.

§ Anxiety.

- § Essential hypertension.
- § Stress-related disorders.
- § Migraine and tension headaches.
- § Circulatory problems.
- § Irritable bowel syndrome.
- § Pain control.
- § Bed wetting.
- § Chronic pain temporomandibular joint (TMJ) disorders.
- § Digestive disorders.
- § Abnormal heart rhythms (cardiac arrhythmias).
- § Addiction, including alcohol addiction.

## **1.8 Advantages and Disadvantages**

The major advantages of biofeedback are:

- § Noninvasive.
- § Has virtually no side effect.
- § It is effective over the long-term.

The major disadvantage for some is that:

- § It requires effort
- § Commitment and
- § Involvement of patients.

With biofeedback, you do the work rather than having it done to you. If you are ready and willing to do the work, it can be incredibly powerful. Usually, the results are satisfying, quick, and very reinforcing.

## 1.9 Working of Biofeedback

Every time you scratch an itch, grab a snack when you're hungry, or use the bathroom when you feel the urge, you are responding to biofeedback cues from your body about your physiologic state.

With biofeedback training, however, you are cued by sensors attached to your body. These sensors measure pulse rate, the temperature of your extremities, the muscle tension in specific muscle groups, or, in neurofeedback, the kinds of brain waves you are emitting. This information is conveyed by visual displays or sounds. Using imagery and mental exercises, you learn to control these functions, using the feedback provided by the sensors as a gauge of success. With practice, you can learn to "tune in" without instrumentation, and control these functions at will during ordinary life.

For example, in a biofeedback training session for headache, temperature sensors first attached to your hands, then to your feet, and finally to your forehead, if needed. Your goal would be to increase blood flow away from the brain by raising the temperature in your hands and feet and eventually lowering it in your temples. Other sensors might monitor your electro dermal or galvanic skin response how easily you sweat or get "Goosebumps" because this affects your ability to alter your skin temperature.

To warm up your hands and feet, you might imagine basking in the sun on a beach while listening to a script like "I feel warm...my hands are growing warm and heavy..." Both the image and the script would be modified to you personally to evoke a vivid and relaxing mental image. After your training session, you'd be sent home with this script on audiotape and small thermometers to use for your daily practice. The patient's data is fed to the software, which displays the person's information on computer screen or on other display media. [10]

## **1.10 Effectiveness of Biofeedback**

The type of problem being treated and the motivation of the patient are often the key determinants of biofeedback success. For problems like bed wetting in children, biofeedback has shown some effectiveness, but success rates vary widely. Success rates for established biofeedback protocols for incontinence, anxiety, headaches, and hypertension vary, but most studies report significant improvement in many participants.

The benefits of biofeedback therapy are usually permanent, but success is predicated on the fact that most patients must consciously continue practicing what they have learned. Any biofeedback treatment program should involve your primary health care provider and relevant specialists, such as urologists, cardiologists, or neurologists. The training is often most effective when integrated with other types of therapy, such as medication or cognitive behavioral therapy. Sometimes, as was found in one study of patients with essential hypertension, biofeedback therapy can allow you to substantially cut back or even eliminate some medications.

# Basic Biomedical Instrumentation system

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## 2.1 Introduction of Biofeedback Instrumentation

The primary purpose of medical instrumentation system is to measure or determine the presence of some physical quantity that may some way assist the medical personnel to make better diagnosis and treatment, as shown in Fig.6.1. Any medical instrument would comprise of the following. [11]

### (a) Measurand

The physical quantity or condition that the instrumentation system measure is called measurand. The source for the measurand is the human body which generates a variety of signals.

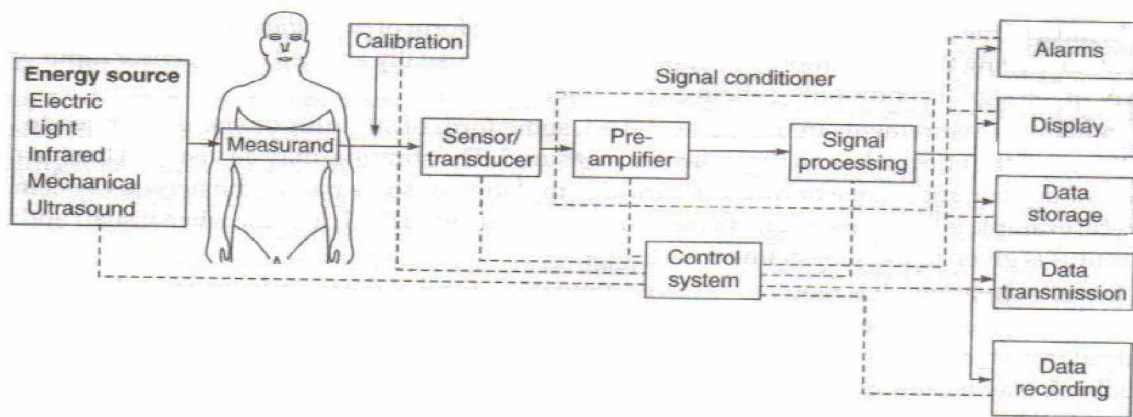
### (b) Transducer/Sensor

A transducer convert's one form of energy to another. The primary function of the transducer is to provide a usable output in response to the measurand which may be a specific physical quantity, property or condition. Basically, the sensor converts a physical measurand to an electrical signal. Depending on the transducer, the output produced is in the form of voltage, current, resistance, or capacitance. The sensor should be minimally invasive and interface with the living system with minimum extraction or energy. The primary function of the transducer is to provide a usable output in response to the measurand.

### (c) Signal Conditioner

For interfacing analog signals to the microprocessor/ micro controller, use is made of some kind of data acquisition system. The function of the system is to acquire and digitize data, often from hostile clinical environments, without any degradation in the resolution or accuracy of the signal. Signal conditioner converts the output of the transducer into an electrical quantity suitable for operation of the display or recording

system or control purposes. Signal conditioning usually include functions such as amplification, conversion analog to digital or signal transmission circuitry. Buffer amplifier helps in increasing the sensitivity of instruments by amplification of the original signal or its transduced form. The A/D converter carries out the process of the analog to digital conversion. The higher the no. of bits, higher the precision of conversion. Since software costs generally far exceed the hardware costs, the analog/digital interface structure must permit software effective transfers of data and command and status signals to avail of the full capability of the micro controller.



**Fig. 2.1 Block diagram of biomedical instrumentation system**

**(d) Display System**

Provides a visible representation of the quantity. It may be on the chart recorder, or on the screen of a cathode tube or in numeric form or LCD display.

**(e) Alarm System**

With upper and lower adjustable thresholds to indicate when the measurand goes beyond present limits.

**(f) Data transmission**

Standard interface connections can be used so that the information obtained may be carried to other parts of an integrated system or to transmit from one location to another.

### **(g) Data Storage**

To maintain the data for future reference. It may be a hard copy on a paper or on magnetic or semiconductor memories.

### **(h) Control System**

It controls all the operations of the instrument. It consists of a microprocessor or a micro-controller and software stored inside it to provide the necessary controls. The control logic provides the necessary interface between the microprocessor system and the elements of the acquisition unit in providing the necessary timing control. It has to ensure that the correct analog signal is selected, samples data at correct time, initiate the A/D conversion process and signals to the microcontroller or microprocessors on completion of conversion.

## **2.2 Working of Biofeedback Instrumentation**

Patients who are keen to benefit from biofeedback are advised, first and foremost, to relax and modify their attitude and social behavior. Scientists are of the firm belief that relaxation is a key component in biofeedback treatment for many disorders, particularly those created by stress.

Stressful events trigger strong emotions, which arouse certain quick physical responses. Many of these responses are controlled by a sympathetic nervous system. The human network of nerve tissues helps body to meet eventual emergencies, So as to “flight or fight” the circumstance.

Normally, people calm down when a stressful event is over, especially if they have done something to cope with it. For instance, imagine your own reactions, if you are walking in a dark street and hear someone rushing towards you. You get scared and your body has prepared and fore warned you of the attacker. So your response is to run fast to get away. When you escape, you gradually relax.

Feedback of physical responses such as skin, temperature, and muscle tension throw hints to help patients realize a relaxed state of mind. The feedback signal may also

act as a kind of reward for reducing tension. It's like a piano teacher, whose frown turns to a smile when a trainee musician finally plays a tune properly.

## **2.3 Sources of biomedical signals**

Biomedical signals are those signals which are used primarily for extracting information on a biological system under consideration. Biomedical signals given in Figure originate from a variety of sources such as [11]

### **2.3.1 Bioelectric signals**

They are generated by nerve cells and muscle cells. Their basic source is the cell membrane potential, which under certain conditions may be excited to generate action potential. The electric field generated by the action of many cells constitutes the bioelectric signals. For eg. ECG and EEG signals.

### **2.3.2 Bioacoustics signals**

Typical acoustic signal is generated by flow of blood in the heart, through the heart's valves and flow of air through the upper and lower airways and in the lungs.

### **2.3.3 Biomechanical signals**

These signals originate from some mechanical function of the biological system. They include all types of motion and displacement signals, pressure and flow signals etc. for eg. The movement of chest wall in accordance with the respiratory activity.

### **2.3.4 Biochemical signals**

These signals are obtained as a result of chemical measurement from the living tissue for eg. Concentration of various ions in the blood, measurement of partial pressure of carbon dioxide.

### **2.3.5 Bio-magnetic signals**

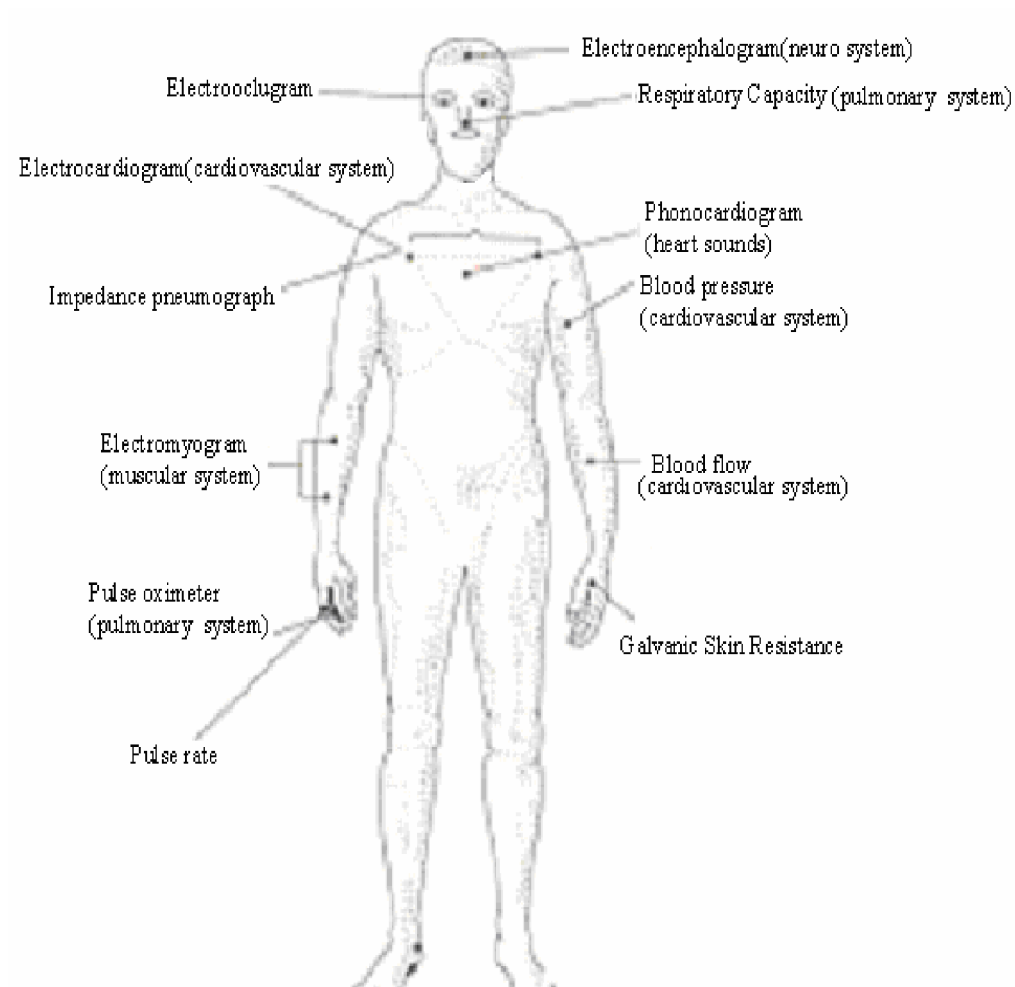
Extremely weak magnetic fields are produced by various organs such as the brain, heart and lungs for e.g. Magneto-encephalograph signals from brain.

### 2.3.6 Bio optical signals

The signals which are obtained as result of optical functions of the biological systems, occurring either naturally or induced by measurement process for eg. Blood oxygenation may be estimated by measuring the transmitted/ reflected light from a tissue at different wave lengths.

### 2.3.7 Bio-impedance signals

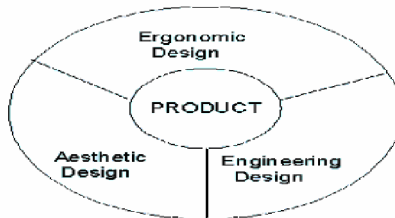
The bio impedance signal is obtained by injecting sinusoidal current in the tissue and measuring the voltage drop generated by the tissue impedance for eg. measurement of galvanic skin resistance.



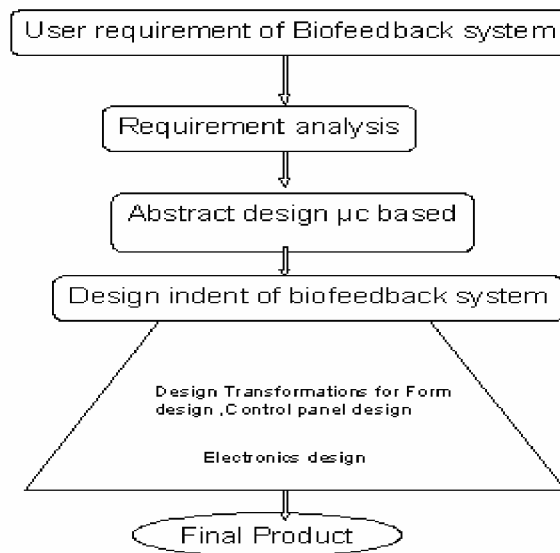
**Fig.2.2 Sources of biomedical signal**

## 2.4 Designing of Biofeedback System

If any one wants to design a biofeedback system he/she must keep in mind that designing is the heart of any equipment. Design and quality are an integral part of a product. Taking example of microcontroller based system, so while designing the microcontroller based biofeedback equipment, ergonomics, aesthetic and engineering parameter have been considered simultaneously as part of design process as shown in Fig. 2.3 flow chart shown in Fig. 2.4 describes the design steps for the design of the standalone biofeedback system.



**Fig.2.3 System Design Process**



**Fig. 2.4 Product Design of the Biofeedback system**

## **2.5 Product Design Considerations**

During product design the following design parameters are considered.

### **2.5.1 Operating Ease**

The product must be designed with user friendly control panel in mind and which provides control and display in a natural and easy to understand way. This aspect can be duly incorporated by using only a single input connector for each of the parameters, systematically programmed and developed user interface which include LCD display, bar graph and other control switches.

### **2.5.2 Aesthetics**

It is the outward out look of a product; the attention must be paid to the aesthetics both in form design and control panel.

### **2.5.3 Reliability**

The functional reliability of the system and the electronic control can be increased substantially by the use of an intelligent  $\mu$ c, well calibrated and standardized sensors and conditioning processes.

### **2.5.4 Maintainability**

To ensure easy maintenance of the system, the design must incorporate easy removability of different parts so that the various parts can be re-assembled quickly for carrying routine repairs. For easy maintainability the system cards must be designed in a modular form with standard reliable connectors.

### **2.5.5 Climatic factors**

The system must be properly packed, so that it may become resistant to corrosive effect of water and humid environment.

### 3.1 Description of the Microcontroller AT89C51

The AT89C51 is a low power, high performance CMOS 8-bit microcontroller with 4Kbytes of Flash Programmable and Erasable Read Only Memory (PEROM). This device is compatible with the industry standard 8051 instruction set and pin-out. The on-chip Flash allows the program memory to be quickly reprogrammed using a nonvolatile memory programmer. By combining an industry standard 8-bit CPU with Flash on a monolithic chip, the AT89C51 is a powerful microcomputer which provides a highly flexible and cost effective solution to many embedded control applications.



**Fig.3.1 Atmel Microcontroller AT89C51**

#### 3.1.1 Hardware features

- § 40 pin Ic.
- § 4 Kbytes of Flash.
- § 128 Bytes of RAM.
- § 32 I/O lines.
- § Two 16-Bit Timer/Counters.
- § Five Vector.
- § Two-Level Interrupt Architecture.

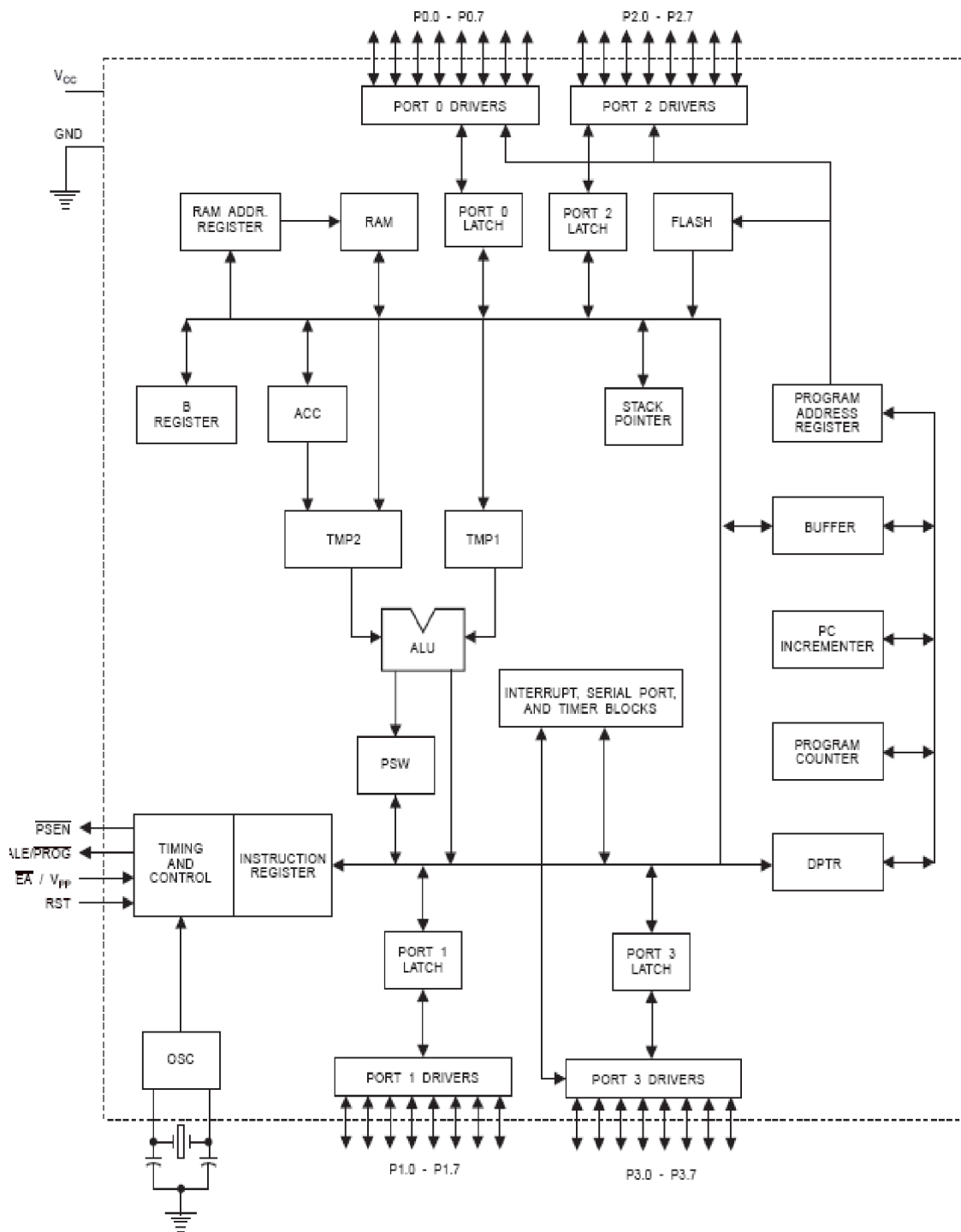
- § Full Duplex Serial Port.
- § On Chip Oscillator and Clock Circuitry.

### **3.1.2 Software features**

- § Bit Manipulations
- § Single Instruction Manipulation
- § Separate Program And Data Memory
- § 4 Bank Of Temporary Registers
- § Direct, Indirect, Register and Relative Addressing.

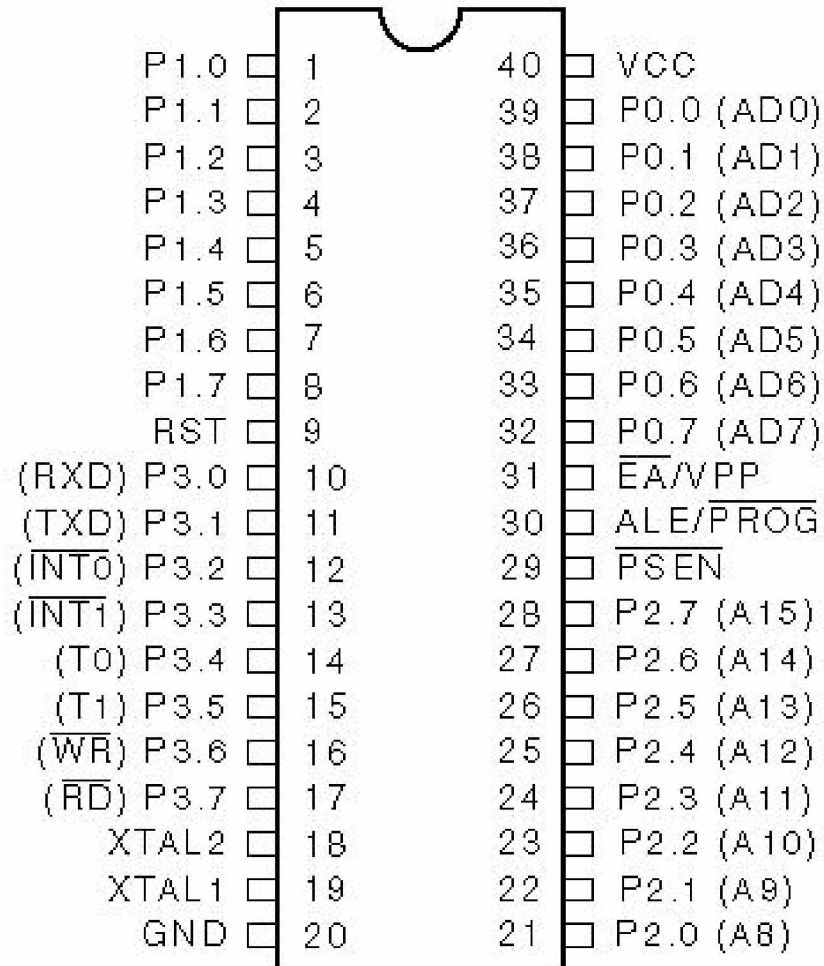
In addition, the AT89C51 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port and interrupt system to continue functioning. The Power down Mode saves the RAM contents but freezes the oscillator disabling all other chip functions until the next hardware reset. [12]

The Atmel Flash devices are ideal for developing, since they can be reprogrammed easy and fast. If we need more code space for our application, particularly for developing 89Cxx projects with C language. Atmel offers a broad range of microcontrollers based on the 8051 architecture, with on-chip Flash program memory.



**Fig. 3.2 Internal Architecture of AT89C51**

### 3.1.3 Pin Configurations of AT89C59



**Fig. 3.3 Pin-diagram**

**VCC** Pin 40 provides supply voltage to chip of +5V d.c. .

**GND** Pin 20 is Ground.

**I/O Ports** 0, 1, 2 and 3 are an 8-bit bi-directional I/O port. Port 3 also receives some control signals for programming.

**RST** Reset input. A high on this pin for two machine cycles while the oscillator is running resets the device.

**ALE/PROG** Address Latch Enable 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.

**PSEN** Program Store Enable is the read strobe to external program memory.

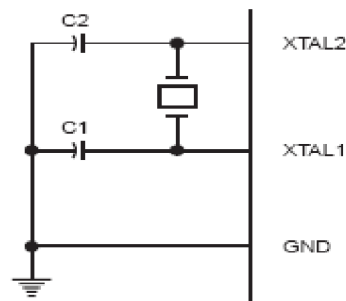
**EA/VPP** External Access Enable.

**XTAL1** Input to the inverting oscillator amplifier and input to the internal clock operating circuit.

**XTAL2** Output from the inverting oscillator amplifier.

### 3.1.4 Oscillator Characteristics

XTAL1 and XTAL2 are the input and output, respectively, of an inverting amplifier which can be configured for use as an on-chip oscillator, as shown in Figure. Either a quartz crystal or ceramic resonator may be used. To drive the device from an external clock source, XTAL2 should be left unconnected while XTAL1 is driven as shown in Figure.



**Fig. 3.4 Oscillator Connections**

## 3.2 LCD Module

### 3.2.1 Terminal Functions [10]

Pin No.	Symbol	Level	Function
1	VSS	-	Ground for LCD
2	VDD	-	Power Supply for LCD (+5V)
3	Vo	-	Power Supply for LCD
4	RS	H/L	Register Selection H: Display Data L: Instruction Code
5	R/W	H/L	Read/Write Selection H: Read Operation L: Write Operation
6	E	H,H→L	Enable Signal. Read data when E is "H", write data at the falling edge of E.
7	DB0	H/L	In 8-bit mode, used as low order bi-directional data bus. In 4-bit mode, open these terminals.
8	DB1	H/L	
9	DB2	H/L	
10	DB3	H/L	
11	DB4	H/L	In 8-bit mode, used as high order bi-directional data bus.
12	DB5	H/L	
13	DB6	H/L	In 4-bit mode, used as both high and low order data bus.
14	DB7	H/L	
15	LEDA	--	Power supply for Backlight
16	LEDK	--	Ground for Backlight

**Table-1**

### 3.2.2 LCD Command Code

Code (HEX)	Command to LCD Instruction Register
1	Clear the display screen
2	Return home
4	Decrement cursor(shift cursor to left)
6	Increment cursor(shift cursor to right)
7	Shift display right
8	Shift display left
9	Display off, cursor off
A	Display off, cursor on
C	Display on, cursor off
E	Display on, cursor blinking
F	Display on, cursor blinking
10	Shift cursor position to left
14	Shift cursor position to right
18	Shift the entire display to left
1C	Shift the entire display to right
80	Force cursor to the beginning of 1 <sup>st</sup> line
C0	Force cursor to the beginning of 2nd line
38	2 line and 5×7 matrix

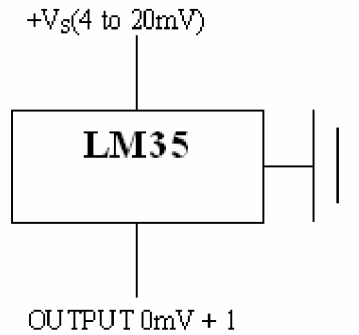
**Table-2**

### 3.3 Sensor for temperature measurement (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 Centi-grade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of  $\pm 1/4^{\circ}\text{C}$  at room temperature and  $\pm 3/4^{\circ}\text{C}$  over a full  $-55$  to  $+150^{\circ}\text{C}$  temperature range. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. [13]

#### Features

- Calibrated directly in ° Celsius (Centigrade).
- Linear + 10.0 mV/°C scale factor.
- 0.5°C accuracy guarantee able (at +25°C).
- Rated for full  $-55^{\circ}$  to  $+150^{\circ}\text{C}$  range.
- Suitable for remote applications.
- Operates from 4 to 30 volts.
- Low self-heating.
- Low impedance output, 0.1  $\Omega$  for 1 mA load.

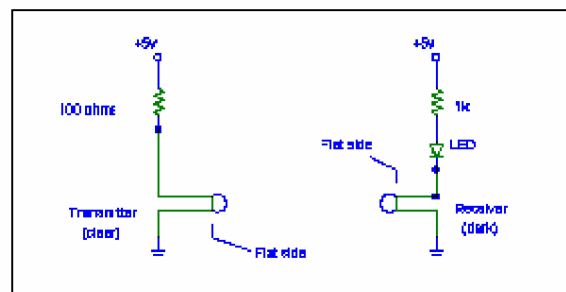


**Fig. 3.5 Basic centigrade Temperature sensor Ic**

### 3.4 Sensor for Pulse Rate an Infrared Communication Link

The infrared transmitter and receiver look like small LEDs: the transmitter is clear and the receiver is the dark-colored device. The transmitter will produce a beam of infrared light when current flows through it. The transmitter is energized all of the time. The receiver will conduct current when it receives the infrared signal from the transmitter. We will detect the received signal by observing an LED. Finally, we will connect the binary counter to the receiver circuit.

1) Construct the transmitter and receiver circuits shown in Fig. 1. Place the transmitter as close to the 555 timer as you can, and place the receiver about half an inch away from the transmitter. The transmitter and receiver should be pointing at each other. The LED on the receiver side should light when the infrared beam is received and go out (maybe not completely) when the beam is interrupted. [14]



**Fig. 3.6 The Infrared Transmitter and Receiver**

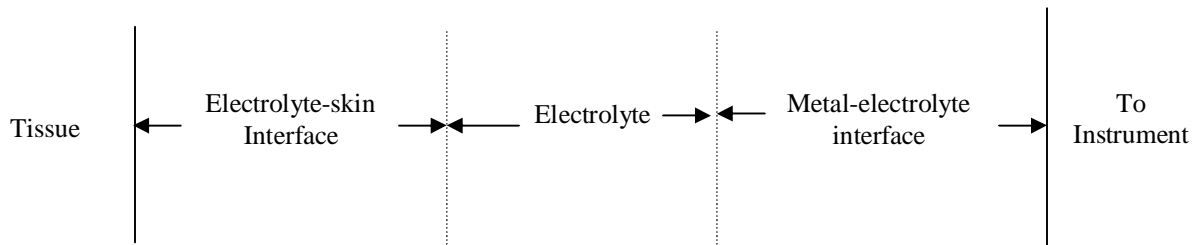
IR diodes start working at 2.2VDC, so at least 3V should be applied to the IR version devices. The microcontrollers can work on voltages 2-5.5VDC, lower voltages result in smaller current consumption and longer battery life. The receiver modules (RF and IR) usually take fixed +5VDC, this is already shown on the RF/IR schematics.

### 3.5 Sensors for GSR Measurement

Extremely pure silver electrodes, having silver with purity of 99.999% is used to measure the GSR. Pure silver is cut into pieces of 3 cm square and .4 mm thickness and drawn in cup shape to manufacture silver electrodes.

#### a) Electrodes

A surface electrode used for GSR measurement is composed of a metal electrode and attached to the surface of the body through an electrolyte. An electrolyte or electrode paste is usually employed as an interface between the electrodes and the surface of the source of the event. Figure 3.3 represents the electrode tissue interface.[11]



**Fig.3.7 Electrode - tissue interface**

Characteristic of a surface electrode depends upon the condition at the metal electrolyte interface, the electrolyte skin interface and the quality of the electrolyte.

i) **Metal electrolyte interface:** All the metal electrolyte transition, there is a tendency for each electrode to discharge ions into the solution and for ions in the electrolyte to combine with each electrode.

The net result in the creation of a change provident (difference in potential) at each electrode.

ii) **Electrolyte skin interface:** In electrolyte skin interface, skin may be assumed to act as a diaphragm arranged between two solutions i.e. electrolyte and body fluids, of

different counteractions containing the same ions which are bound to give potential difference.

Voltage presented to the measuring instrument consists of two main components. One is the contact potential and the other is the biological signal to interest.

### **3.6 Signal Conditioning for Temperature Modality**

As the output signal from the transducer LM35 is in analog form and the data can be fed to the controller in digital form only so an analog to digital converter is to be used. The A/D conversion is a quantizing process where by an analog signal is represented by equivalent binary states. A/D converter can be classified into two groups based on conversion technique. One technique involves comparing a given analog signal with the internally generated equivalent signal. This group includes Successive approximation Register, counter and Flash type converters. The second technique involves changing an analog signal into time or frequency and comparing these parameters to known values. This group includes Integrator and Voltage to Frequency Converters. First type is used for data loggers and instrumentation, while the second type is used in digital meters, panel meters and monitoring system. To give ADC clock we attach 555 timer with it.

#### **3.6.1 Successive Approximation A/D converter (ADC0808)**

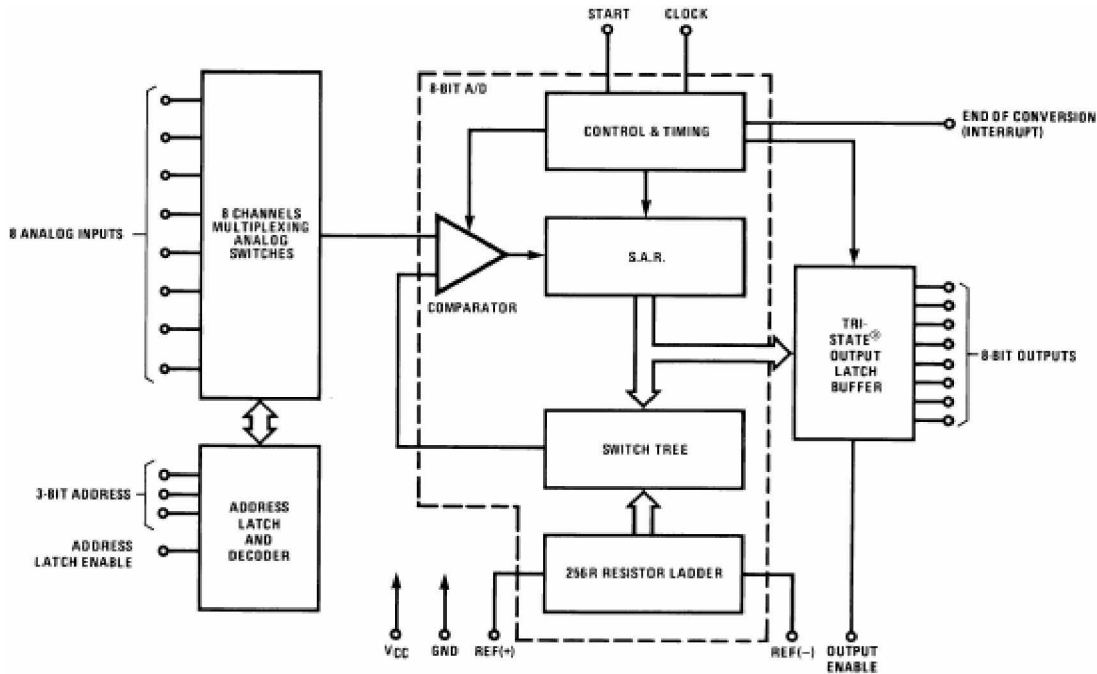
This is the most popular method of analog to digital conversion. It has an excellent compromise between accuracy and speed. An unknown voltage  $V_{in}$  is compared with a fraction of reference voltage,  $V_r$ . For n-bit digital output, comparison is made in times with different fractions of  $V_r$  and the value of a particular bit is set to 1, if  $V_{in}$  is greater than the set fraction of  $V_r$ . It includes three major elements. [15]

- § The D/A converter.
- § The successive Approximation Register.
- § The comparator.

The ADC0808 data acquisition component is a monolithic CMOS device with an 8 bit analog-to-digital converter, 8-channel multiplexer and microprocessor compatible control logic. The 8-bit A/D converter uses successive approximation as the conversion technique. The converter features a high impedance chopper stabilized comparator, a voltage divider with analog switch tree and a successive approximation register. The 8-channel multiplexer can directly access any of 8-single-ended analog signals. The device eliminates the need for external zero and full –scale adjustments. Easy interfacing to microprocessors is provided by the latched and decoded multiplexer address inputs and latched TTL TRI-STATE outputs.

The design of the ADC0808 has been optimized by incorporating the most desirable aspects of several A/D conversion Techniques. The ADC0808, ADC0809 offers high speed. High accuracy, minimal temperature dependence, excellent long-term accuracy and repeatability, and consumes minimal power. These features make this device ideally suited to applications from process and machine control to consumer and automotive applications. The key specifications of ADC0808 are as below:-

- § Easy interface to all microprocessors.
- § Operates with 5 V DC.
- § Adjusted voltage reference.
- § No zero or full scale adjusts required.
- § 8-channel multiplexer with address logic.
- § 0V to 5V input range with single 4V power supply.
- § Outputs meet TTL voltage level specifications.
- § Resolution 8 Bits.
- § Total Unadjusted Error =  $\frac{1}{2}$  LSB.
- § Single supply 5 V DC.
- § Low Power 15m W, conversion time 100 $\mu$ s.



**Fig. 3.8 Architecture of ADC0808**

### 3.6.2 Clock input in Astable Mode

The clock input to the ADC is provided by using a 555 TIMER. The LM555 is a highly stable device for generating accurate time delays or oscillation. Additional terminals are provided for triggering or resetting if desired. For astable operation as an oscillator, the free running frequency and duty cycle are accurately controlled with two external resistors and one capacitor. The circuit may be triggered and reset on falling waveforms, and the output circuit can source or sink up to 200mA or drive TTL circuits.[16]

If the circuit is connected as shown in Figure (pins 2 and 6 connected) it will trigger itself and free run as a multi-vibrator. The external capacitor charges through  $R_A + R_B$  and discharges through  $R_B$ . Thus the duty cycle may be precisely set by the ratio of these two resistors. In this mode of operation, the capacitor charges and discharges between  $1/3 V_{CC}$  and  $2/3 V_{CC}$ . The time during which the capacitor charges from  $1/3 V_{CC}$  to  $2/3 V_{CC}$  is equal to the time the output is high and is given by:

$$t_c = 0.69 (R_A + R_B)C \quad \dots\dots\dots 1$$

Where  $R_A$  and  $R_B$  are in ohms and  $C$  is in farads. Similarly, the time during which the capacitor discharges from  $2/3 V_{cc}$  to  $1/3 V_{cc}$  is equal to the time the output is low is given by:

$$t_d = 0.69 (R_B)C \quad \dots\dots\dots 2$$

$t_c$  and  $t_d$  is the charging time and discharging time of the capacitor respectively. As in the triggered mode, the charge and discharge times, and therefore the frequency are independent of the supply voltage.

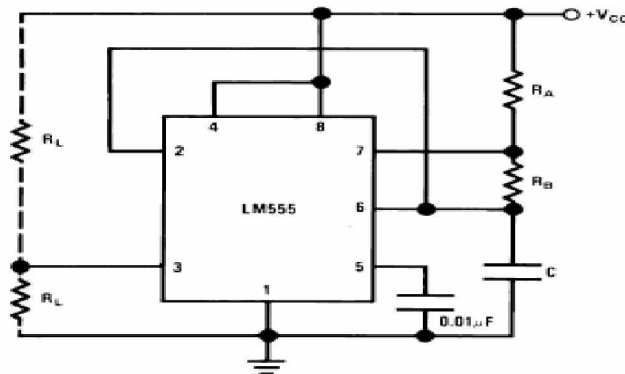
Thus the total period is

$$T = t_c + t_d = 0.69 (R_A + 2R_B) C \quad \dots\dots\dots 3$$

The frequency of oscillation:

$$f = \frac{1}{T} = \frac{1.44}{(R_A + 2R_B)C} \quad \dots\dots\dots 4$$

The duty cycle is the ratio of the time during which the output is high to the total time period  $T$ .



**Fig.3.9 Diagram of 555 timer in astable mode**

### 3.7 Signal Conditioning for Pulse Rate

To increase the sensitivity of an instrument an amplifier is used. In the circuit designed for the pulse amplifies the signal LM 324 have been used. The LM324 consists of four 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. The LM 324 can be directly operated of the standard +5V power supply voltage. [17]

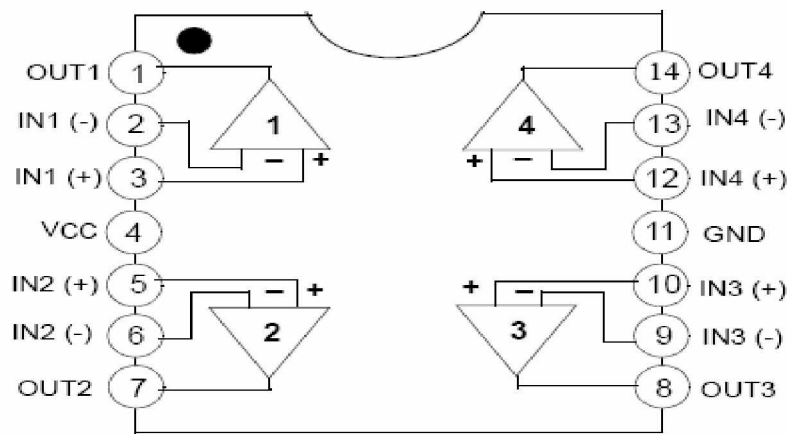


Fig. 3.10 Pin diagram of LM324

### 3.8 Description of the system

The various components used in the circuit are described in this section in detail:

#### a) Power supply

The first block of every circuit is power supply unit. It is the most essential part of a circuit to run its constituent IC's, these ICs can run only on D.C. power. Hence, the required D.C. supply has to be generated.

#### b) Temperature sensor

The LM 35 series sensor used in the circuit is precision integrated circuit temperature sensors whose output voltage is linearly proportional to the Celsius temperature. The LM 35 requires no external calibration since it is internally calibrated. It

outputs 10 mV for each degree of centigrade temperature. It has three terminals: input voltage ( $V_{in}$ ), output voltage ( $V_{out}$ ) and ground.

**c) Pulse sensor**

The LED phototransistor- photoplethysmography transducer consists of a GA-AS infrared emitting diode (F5D1) and a photo transistor (L14P) in a compact package measuring 6.25x4.5 x 4.75 mm. The peak spectral emission of the LED is at .94  $\mu\text{m}$  with a 0.707 peak bandwidth of 0.04 $\mu\text{m}$ . The phototransistor is sensitive to radiation between 0.4 and 1.1  $\mu\text{m}$ .

**d) GSR electrodes**

Extremely pure silver electrodes are used to measure the GSR. Pure silver is cut into pieces of 3 cm sq and .4 mm thickness and drawn in cup shape to manufacture silver electrodes.

**e) Signal amplification**

Since the ADC 0808 has 8 bit resolution with a maximum of 256 ( $2^8$ ) steps and the LM 35 produces 10 mV for every degree of temperature change. In the ADC 0808 if  $V_{ref} (-) = \text{GND}$  and  $V_{ref} (+) = 5\text{v}$ , the step size is  $5\text{V}/256 = 19.53 \text{ mV}$ . Therefore the output of LM 35 is amplified to eight times its value, using amplifier LM 324, same would be used for pulse and GSR.

**f) Signal conversion (ADC)**

Analog to digital converter translate the analog signal to digital numbers so that the microcontroller can read them. It work with +5 V and has a resolution of 8 bit and allow us to monitor up to 8 different transducers using only a single chip. The 8 analog input channels are multiplexed and selected using 3 address pins A, B and C.

- **Clock generation**

As in the ADC 0808 there is no self clocking and the clocking and the clock must be provided from an external source. So a 555 timer is used for clock generation. The 555 timer is connected for astable operation (i.e. self triggered mode). It generates a frequency of 470 kHz.

### **g) Microcontroller**

It is the heart of the system; it is a 40 pin IC with RAM, ROM, and CPU serial port, 4 parallel ports and timer, all packed in a single IC. It monitor the switches, read the ADC, manages the display and control the operation of relay, all this is done in accordance with a program written in its ROM. The microcontroller used in the circuit is Atmel 89C51.

### **h) Switches**

There are 3 micro switches in the circuit, connected to the microcontroller, these switches work for Mode select i.e. to select one parameter out of three i.e. GSR, pulse and temperature and to reset the system.

### **i) Display**

LCD display will be interfaced to microcontroller, to display the value of Pulse, Temperature and GSR.

### Developing the Circuits of the System

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Development of electronics circuit comprises of following modules:

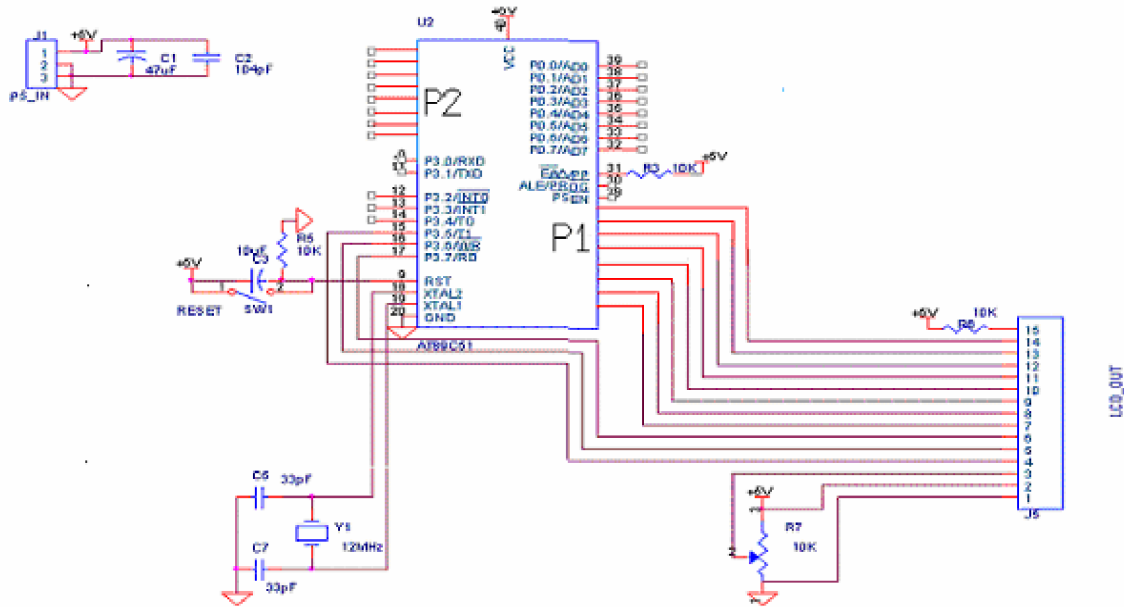
1. Interfacing of microcontroller with LCD.
2. Temperature card development.
3. Pulse card development.
4. GSR card development.
5. Interfacing of microcontroller with switches.

After them PCB layout is done.

#### **4.1 Interfacing of Microcontroller with LCD**

2 lines, 5×7 dots/char LCD display is used to display the value of current temperature and its changes with respect to normalized value.

The LCD display is connected to port 1 of the  $\mu\text{c}$  and Register select (RS), read/write (R/W), and enable (E) are connected to port pin p3.5 to p3.7. The LCD display used is 16×2 line.  $V_{CC}$  pin is connected to +5v and  $V_{SS}$  is connected to gnd. Supply to  $V_{EE}$  pin is varied using a 10k pot to control contrast as shown in Figure, but in the circuit we have it ground to achieve maximum contrast.



**Fig. 4.1 Interfacing of microcontroller with LCD**

## 4.2 Temperature Card Development

The development of Temperature card can be divided in to five parts.

- § Power supply.
- § Signal conditioning.
- § Interfacing to microcontroller.
- § Microcontroller circuit.
- § Interfacing of microcontroller to control switches.

### 4.2.1 Power supply

The first block of every circuit is power supply unit. It is the most essential part of a circuit to run its constituent IC's. These ICs can run only on D.C. power. Hence, the required D.C. supply has to be generated. The main parts of power supply unit and their function are as follows:

## Transformer

The function of the transformer is to step down the voltage level from the available A.C. 220V to the desired voltage. The rating of the transformer depends upon the requirements of the IC's in the circuit. A 9-0-9 transformer is used. The secondary has centre tapping which forms the neutral terminal.

## Full wave Center Tap Rectifier

The function of the rectifier is to convert the alternating voltage signal in to unidirectional one. This function is provided by semiconductor diode connected to bridge configuration. Diode IN4007 would be used for the rectifier.

## Ripple rejection

The output of the diode is unidirectional but pulsating. A 1000  $\mu\text{f}$  capacitor is used for ripple rejection.

## Regulation

To obtain a constant voltage specific IC's are used as voltage regulator. LM7805 is used to obtain a +5v supply. This IC has three terminals, an input, an output and a ground terminal.

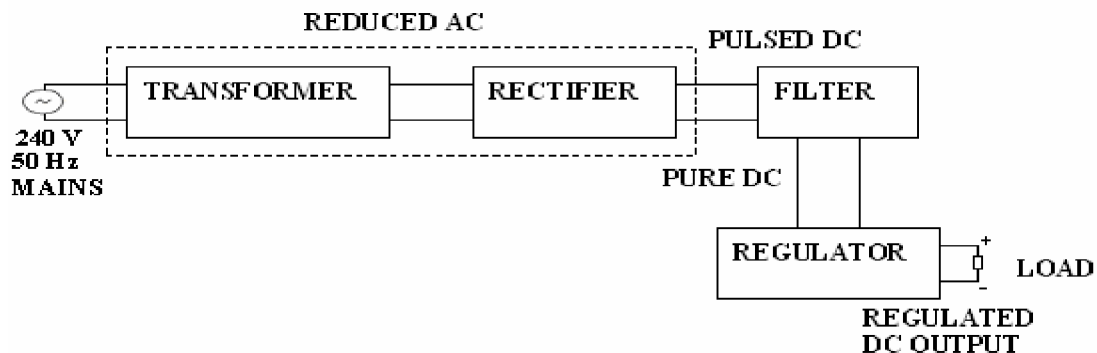


Fig. 4.2 Power Supply Circuit

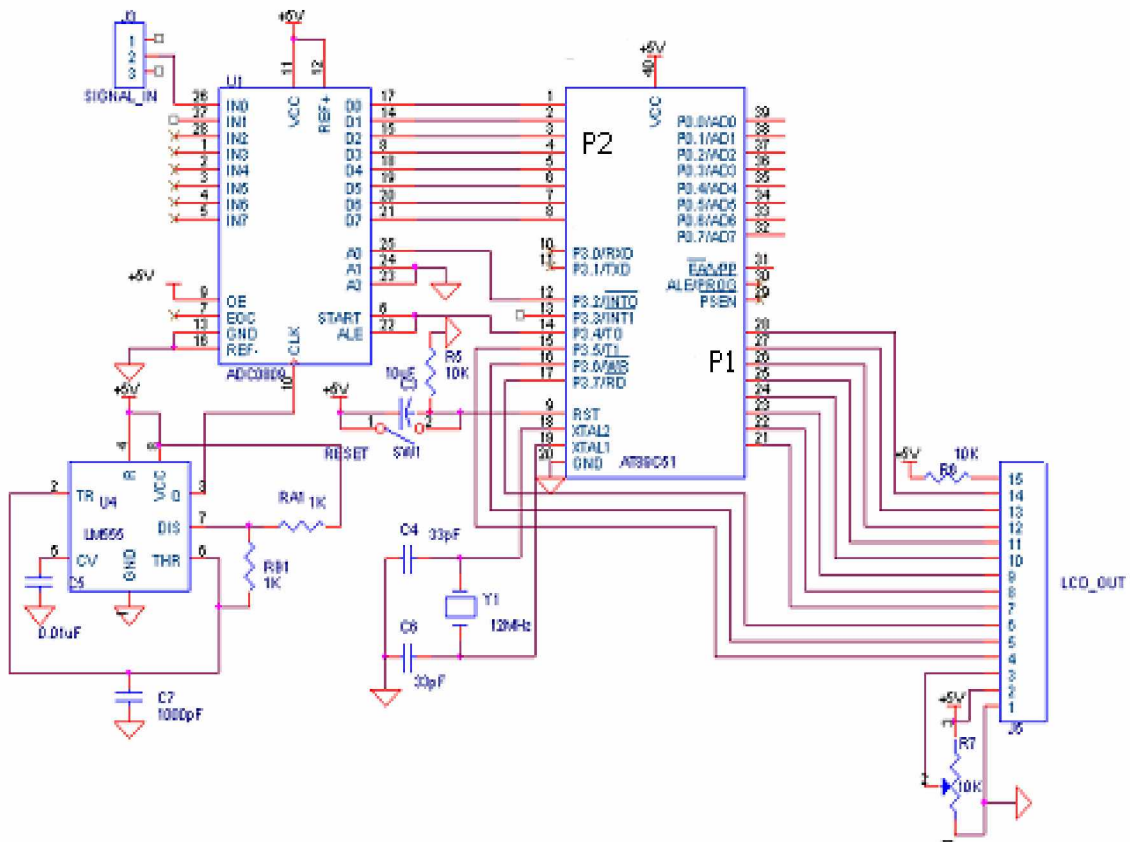
## 4.2.2 Interfacing to microcontroller

The ADC converts the analog signal to the digital data to be read by the  $\mu\text{c}$ . The address line  $A_0$  is connected to the  $\mu\text{c}$  pin p3.2. Address lines  $A_1$  and  $A_2$  are shorted together and connected to ground. If  $A_0$  is 0 input channel IN0 is selected. Address latch enable (p22) is connected to port pin p3.4 of the  $\mu\text{c}$ . Start of conversion is shorted with ALE.  $V_{\text{ref}+}$  is shorted with  $V_{\text{cc}}$  and  $V_{\text{ref}-}$  is shorted with ground to give step size of 19.56 mV, as shown in Figure 4.4.

To provide clock pulse to the ADC a 555 timer has been used. It provides a clock frequency of 470 kHz to ADC, as shown in Figure

## 4.2.3 Microcontroller circuit

In the micro controller circuit, the +5V is given to the capacitor (10 $\mu\text{F}$ ) which will get charged to the same value and reset pin 9 of the  $\mu\text{c}$  become high. After this RST pin is grounded through the resistor of 10K. RST switch is connected between pin 9 and  $V_{\text{cc}}$ . +5V is given to the external enable pin no.31 through resistor  $R_b = 10\text{K}$ . In the crystal circuit, Pin XTAL1 and XTAL 2 are connected to resonant network, the resonant network consist of a 12 MHz quartz crystal and 2 ceramic capacitor's (33 pf each) .this circuit is necessary to generate the clock which is used for synchronizing purposes.



**Fig. 4.3 Interfacing of microcontroller with Temperature out**

### 4.3 Pulse card development

The development of Pulse card can be divided in to six parts

1. Power supply
2. Signal capturing
3. Signal conditioning
4. Interfacing to microcontroller
5. Microcontroller circuit
6. Interfacing of microcontroller to both the three outputs and control switches.

### 4.3.1 Working of Pulse card

#### 1. Power supply

Same as in section 4.2.1(1)

#### 2. Signal capturing

Sensor section: the LED emits infrared rays which when pass through the finger gets attenuated due to the volume of blood inside the vessels. This attenuated wave is detected by photo transistor, as shown in Figure 4.4

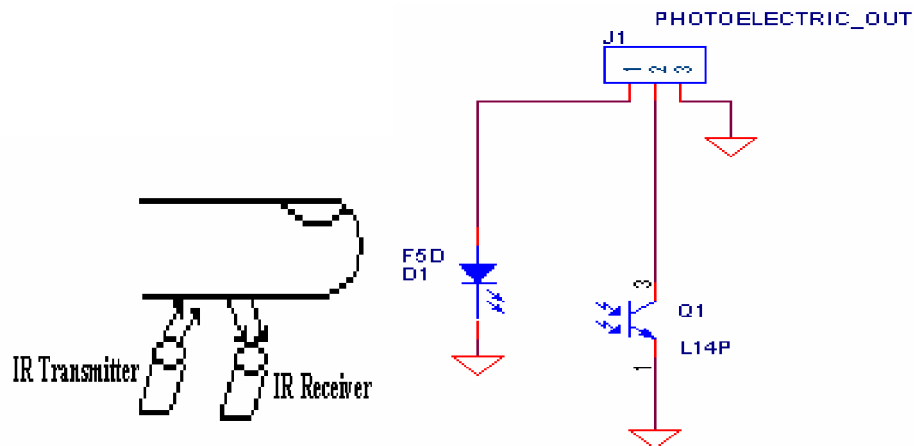


Figure 4.4 Pulse capture

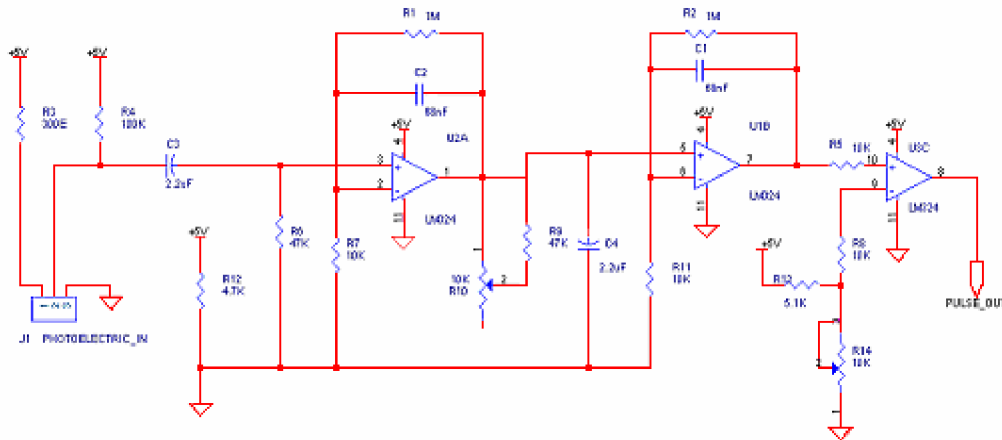
LED Driver: It amplifies the current input to the transducer i.e. infrared LED.

#### 3. Signal conditioning

The amplifier uses two opamps of an LM 324 quad opamp to provide two identical broadly tuned band pass stages with gain of 100. The signal frequencies are boxed in by movement artifacts at the low end and at the top end by main human interference. The circuit runs from a single 5V power supply, as shown in figure 4.5. This is convenient for interface with a 0-5 V I/P. The potentiometer allows the over all gain to be adjusted, so as to prevent clipping of large signal. Components are not critical but the two 2.2  $\mu$ F capacitors must be able to stand some reverse bias.

Pulse shaping: As the microcontroller can measure only square pulses, the amplified O/p of the photo transistor, i.e. ac is converted to square wave in a single step using the 3<sup>rd</sup> opamp of lm324 as non inverting comparator.  $V_{ref}$  (2-2.5 V) is applied to the

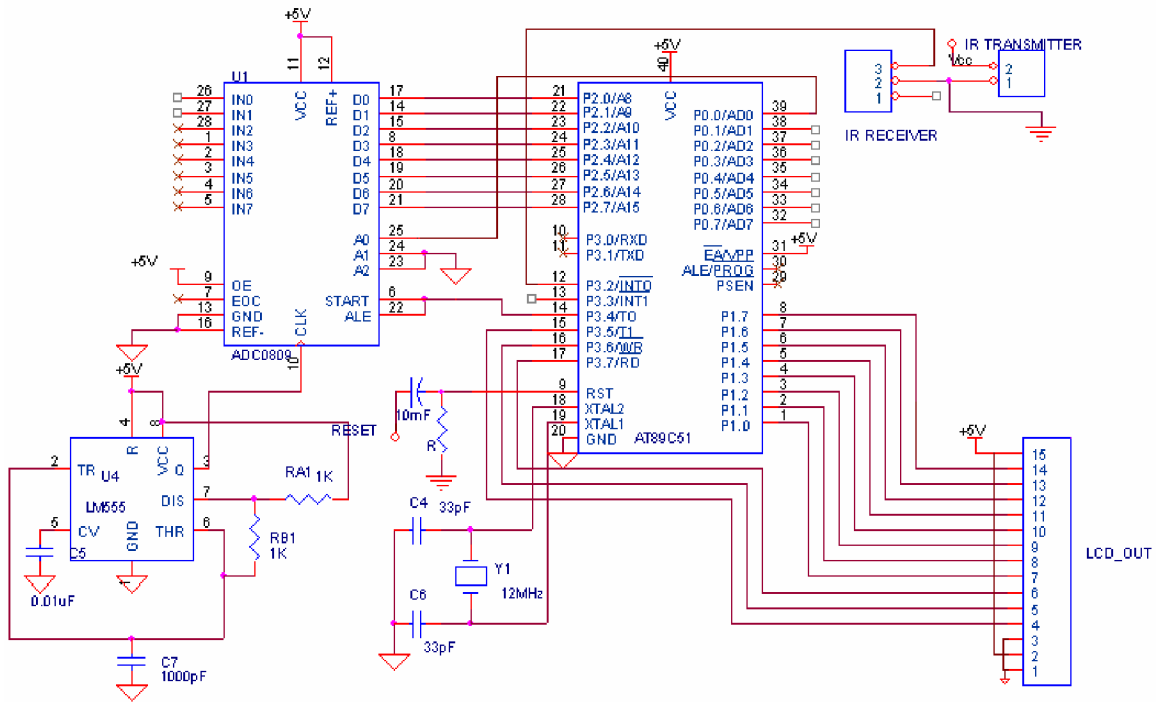
(-) I/P and  $V_{in}$  is applied to the (+) I/P. when  $V_{in}$  is less than  $V_{ref}$ , the out put voltage  $V_o$  is at  $-V_{sat}$ . On the other hand, when  $V_{in}$  is greater than  $V_{ref}$ ,  $V_o$  goes to  $+V_{sat}$ .  $V_{ref}$  is selected just below the average Maximum height of PQR wave.[18]



**Figure 4.5 Pulse conditioning**

#### 4. Microcontroller circuit

The O/P voltage  $V_o$  of the comparator is fed to the external interrupt pin p3.3/INT1 of the  $\mu c$ , as shown in Fig.4.6. The  $\mu c$  timer  $T_1$  is used to count the pulses, whenever signal on INT1 goes high to low.



**Fig.4.6 Interfacing of Pulse\_out to microcontroller**

## 4.4 GSR card development

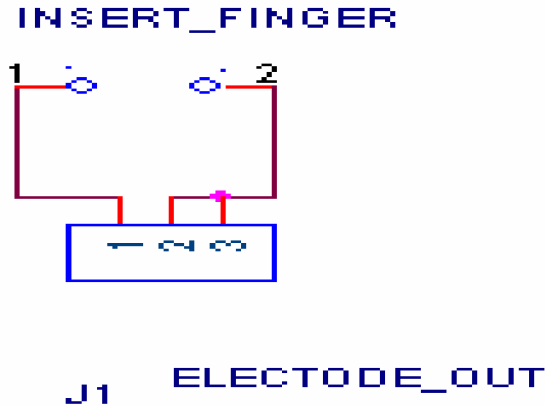
The development of GSR card can be divided in to five parts

- 1 Power supply
2. Interfacing to microcontroller
3. Microcontroller circuit

### 4.4.1 Working of GSR card

#### 1 Power supply

Same as in section 4.2.1(1)



**Fig.4.7 GSR\_capture**

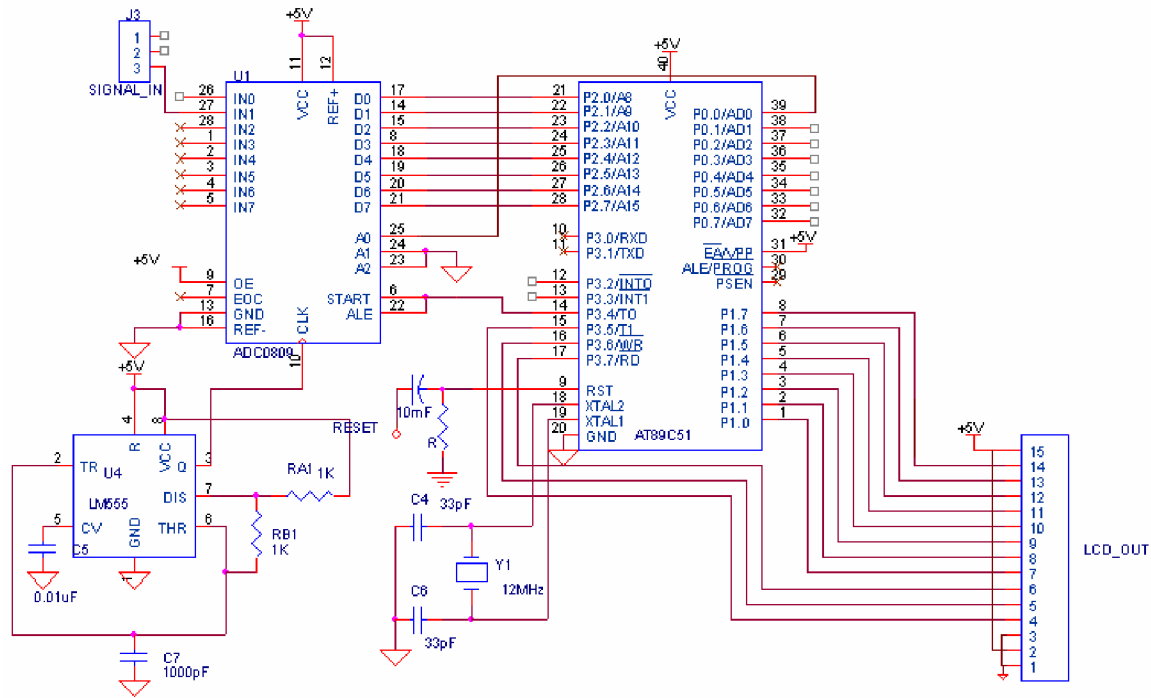
$$V_o = (1 + R_f / R_3) (1 + R_1 / R_2) \times V_{ref} \dots\dots\dots 4.2$$

$V_{ref} = 20 \text{ mV}$ ,  $R_3 = 5\text{K}$ ,  $R_1 = 1 \text{ K}$ ,  $R_2 = 1\text{K ohms}$

**2. Interfacing to microcontroller**

The ADC converts the analog signal to the digital data to be read by the  $\mu\text{c}$ . The address line  $A_0$  is connected to the  $\mu\text{c}$  pin p3.2. Address lines  $A_1$  and  $A_2$  are shorted together and connected to ground. If  $A_0$  is 1 input channel IN1 is selected. Address latch enable (p22) is connected to port pin p3.4 of the  $\mu\text{c}$ . Start of conversion is shorted with ALE.  $V_{ref+}$  is shorted with  $V_{cc}$  and  $V_{ref-}$  is shorted with ground to give step size of 19.56 mV, as shown in Figure 4.6.

To provide clock pulse to the ADC a 555 timer has been used. It provides a clock frequency of 470 kHz to ADC, as shown in Figure 4.8.



**Fig.4.8 Interfacing of GSR\_out to microcontroller**

### 3. Microcontroller Circuit

In the micro controller circuit, the +5V is given to the capacitor (10 $\mu$ F) which will get charged to the same value and reset pin 9 of the  $\mu$ c become high. After this RST pin is grounded through the resistor of 10K. RST switch is connected between pin 9 and V<sub>cc</sub>. +5V is given to the external enable pin no.31 through resistor R<sub>b</sub> =10K. In the crystal circuit, Pin XTAL1 and XTAL 2 are connected to resonant network, the resonant network consist of a 12 MHz quartz crystal and 2 ceramic capacitor's (33 pf each) .this circuit is necessary to generate the clock which is used for synchronizing purposes.

### 4.5 Interfacing of switches with microcontroller

There are three micro switches in the circuit connected to the microcontroller pin no. p0.5 to p0.7. One end of each switch is grounded and other is connected to the microcontroller port with a 10K pull-up, as in Fig.4.4. When switch is pressed that

particular port is grounded. The microcontroller always monitors these switches in real time (i.e. in continuous mode)

The configuration of the micro switches is as follows:

- § Switch1 ( $S_1$ ): Temperature
- § Switch2 ( $S_2$ ): GSR
- § Switch3 ( $S_3$ ): Pulse Rate

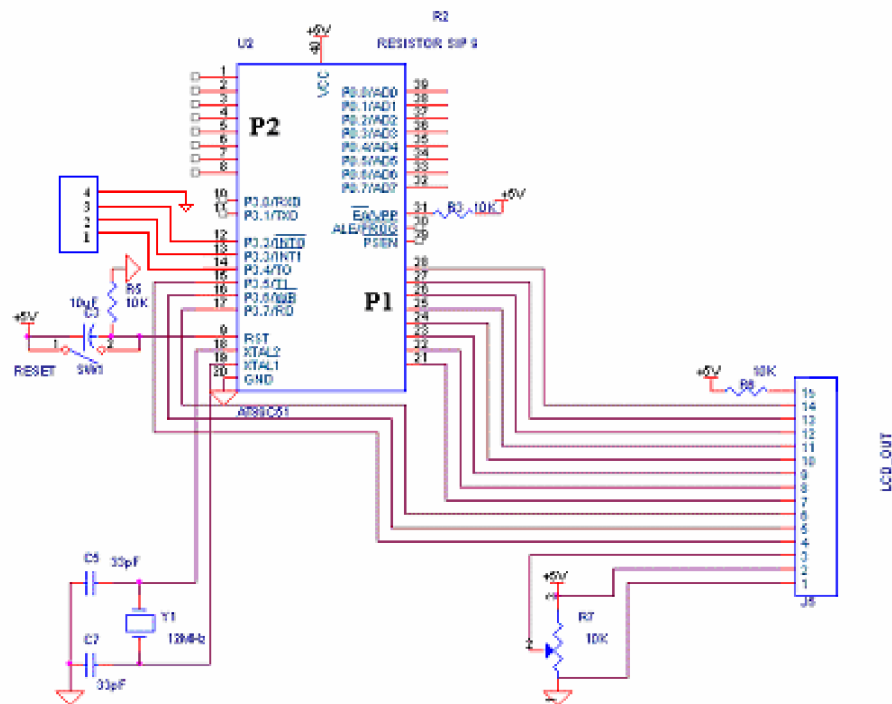


Fig. 4.9 Interfacing of Switches with  $\mu C$

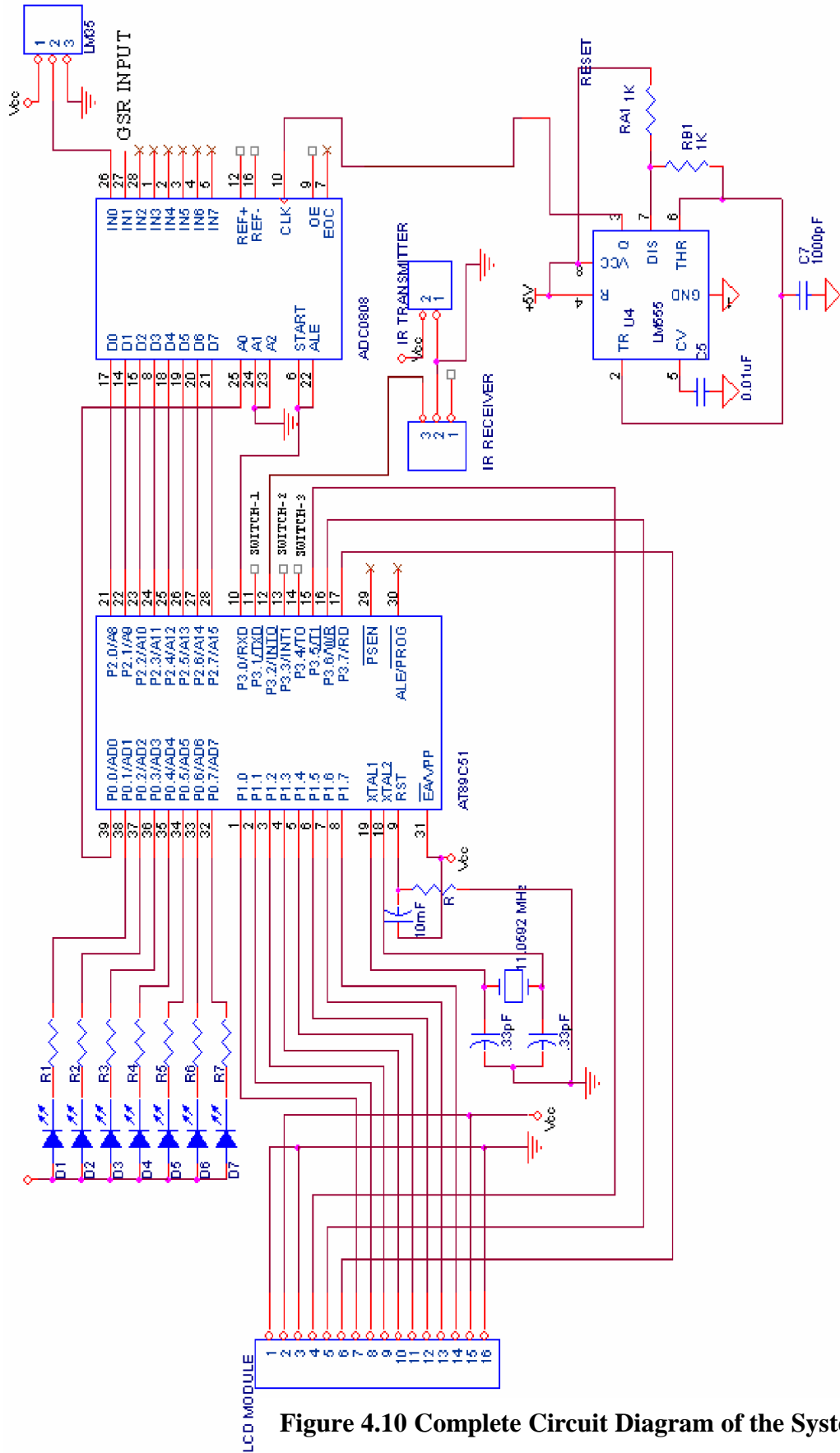


Figure 4.10 Complete Circuit Diagram of the System

### Software Functions of the System

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The microcontroller along with its various interfaces requires software. The logic involved in achieving the desired operation has been carefully prepared and is noted down in the form of flow chart for easy reference.

The functioning of the Biofeedback system is shown through a flow chart. As soon as the power is switched on the microcontroller starts performing its initial jobs and displays the selected parameter.

#### 5.1 Programming structure

As it is a very lengthy project the main strategy was to divide the whole project in to small modules, which are described as follows

##### 1. LCD initialization

##### 2. User interface

- BIOFEED BACK SYSTEM
- CHOOSE PARAMETER

1. Temperature      2. GSR      3. Pulse

##### 3. FOR TEMPERATUPE

Temperature taken by sensor converted in voltage and after that digitalized using ADC. The ADC output is again converted in to corresponding temperature value through programming and displayed on LCD module.

##### 4. FOR GSR

Body resistance is taken through silver electrodes is directly displayed on the LCD module i.e. without signal conditioning. Through programming the GSR is taken from third channel of the ADC.

##### 5. FOR PULSE

Pulse rate is taken as pulses per minute and in the program there is one interrupt counter is running and simultaneously one timer is running. The timer is set to run for 60 seconds and counter counts the number of interrupts in those 60 seconds.

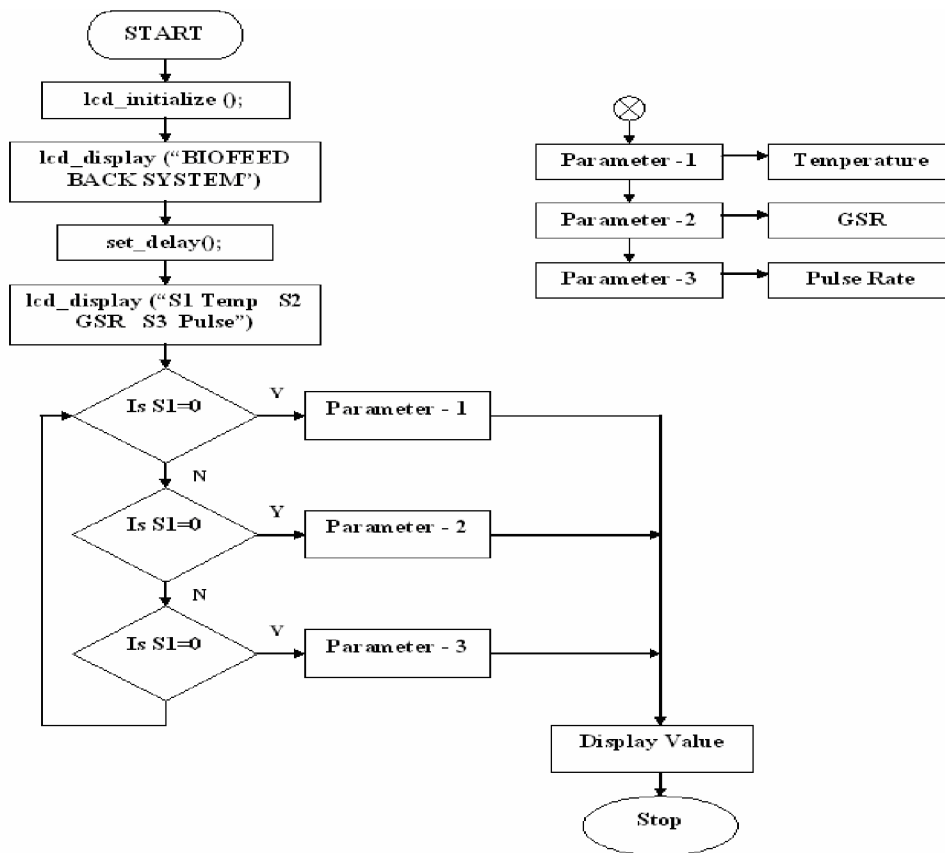
Switch1 ( $S_1$ ): Temperature

Switch2 ( $S_2$ ): GSR

Switch3 ( $S_3$ ): Pulse Rate

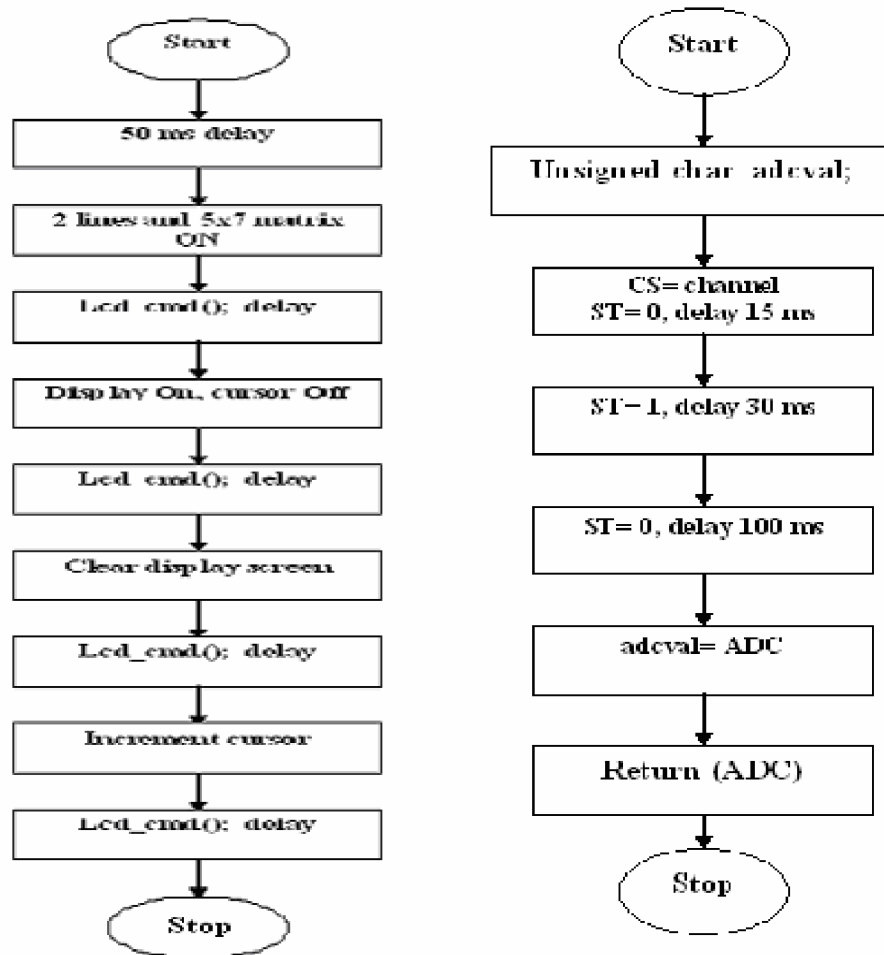
## a. Flow Charts

The whole software is divided into small modules. There are different functions, which are used in the program and are explained here using flow charts.



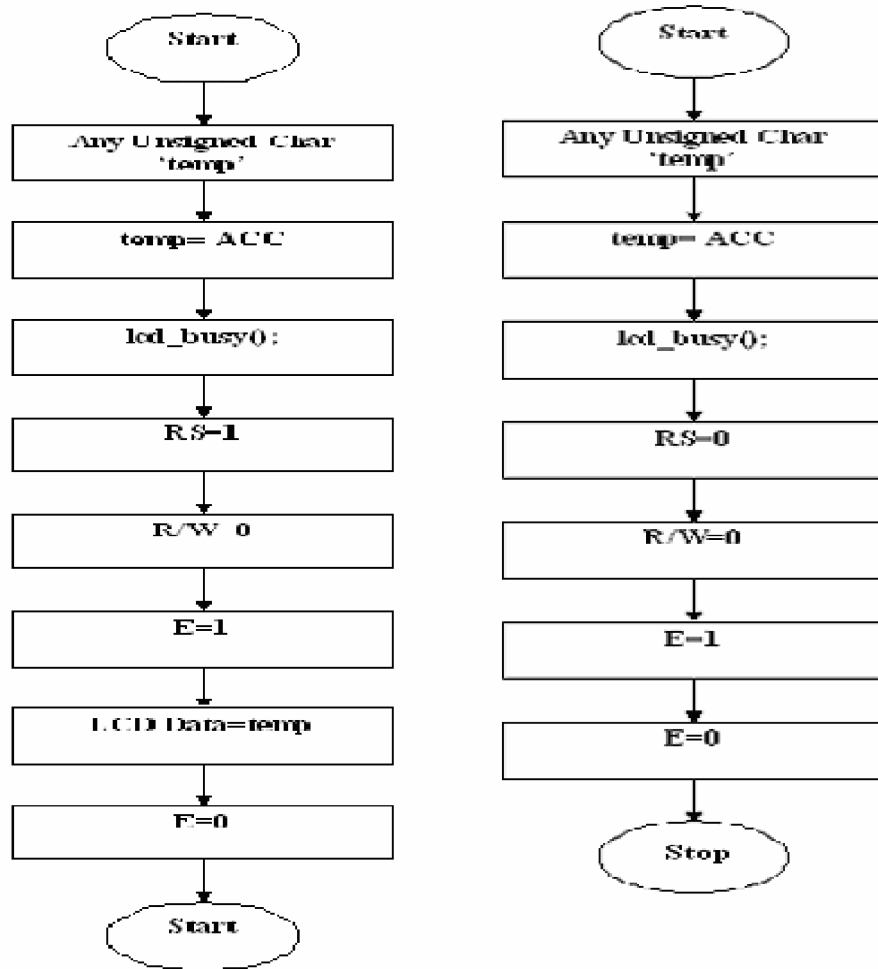
**Fig. 5.1 User Interface**

In first flowchart the steps involved for user interface are shown. When system is powered on the LCD gets initialized and message given in the flow chart displayed. Then after some time system ask for choosing parameter and according to the parameter chosen by the user the readings are taken and results are displayed.



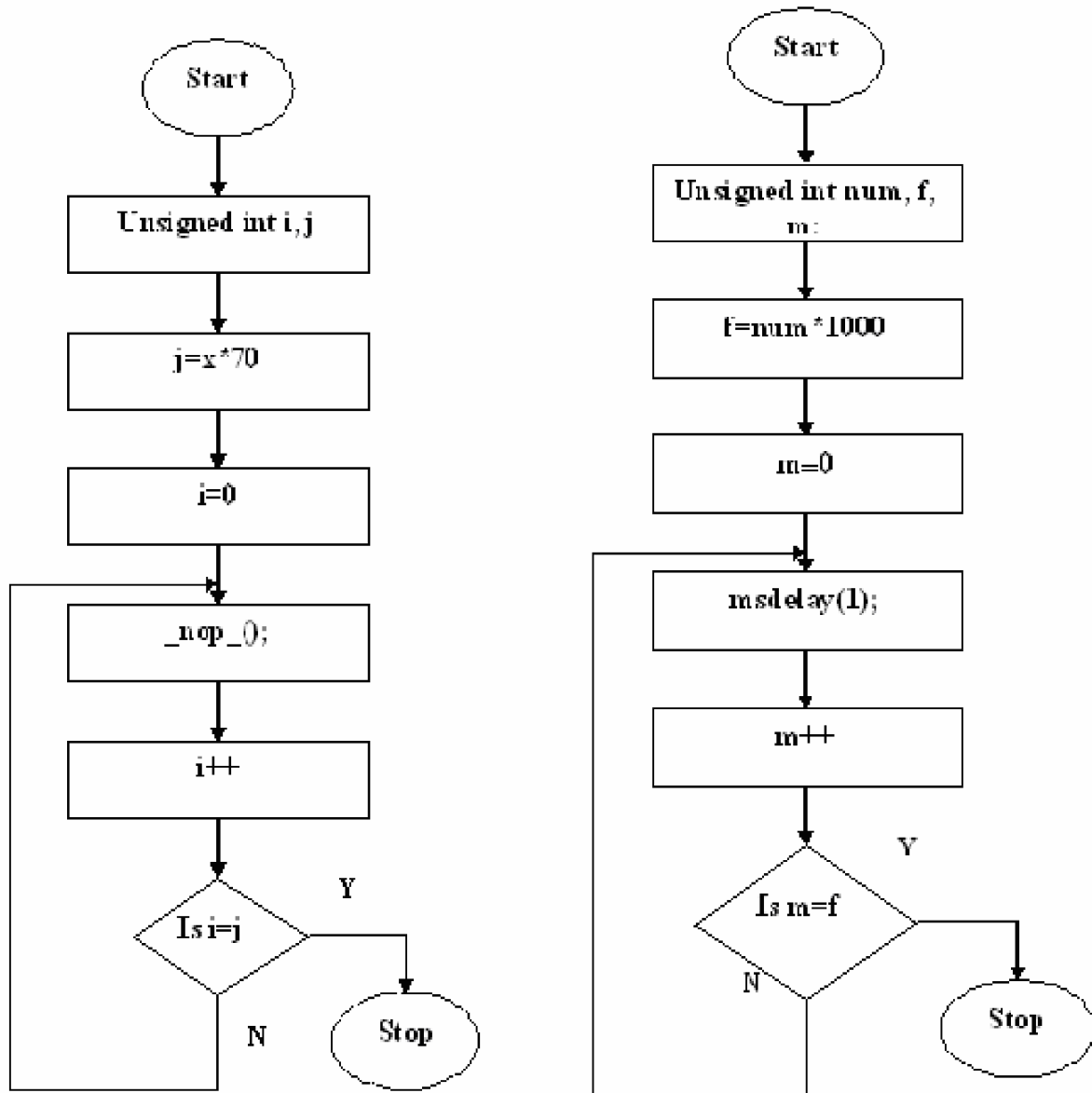
**Fig. 5.2 LCD Initialize and Get value from ADC**

In these flow charts the LCD initialization steps are shown. The steps can vary according to programming needs. Here 2 lines, 5x7 matrix is initialized and the screen is cleared and cursor is off when display is on. All the time the display is on in system therefore the cursor is done off in this function and it is called in the program when required. In the other flow chart of the figure the steps involved in getting value from the ADC are shown. Any unsigned character is taken ADC channel is selected and start of conversion is cleared initially and after that a high to low signal is given at the start of conversion pin. During this the ADC output at that particular channel is taken.



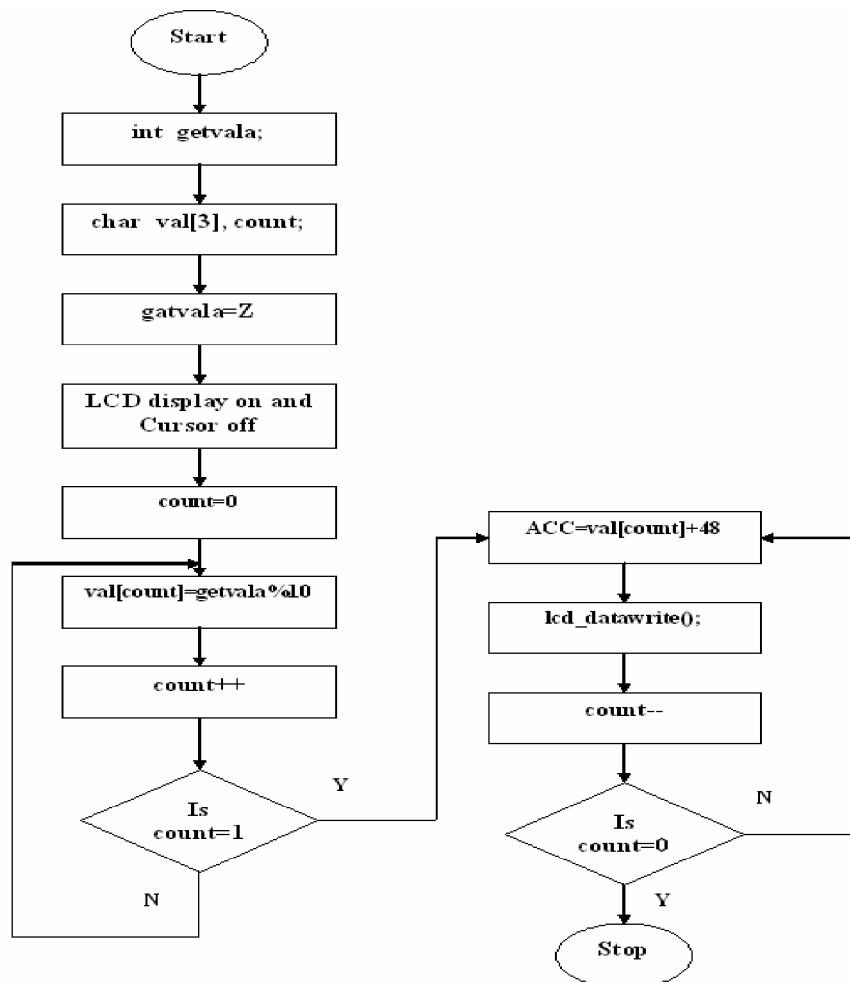
**Fig. 5.3 LCD Command and LCD Data Modes**

LCD work in two modes one is command mode and the other is data mode In the flowcharts of the third figure the LCD's two modes are shown. There are three control pins of LCD module register select (RS), read/write (R/W), Enable (E). To get LCD in command mode the RS and E are made high and R/W is made low. To get LCD in data mode RS is made low, E is made high and R/W is again made low.



**Fig. 5.4 Milli-Second Delay and Second Delay**

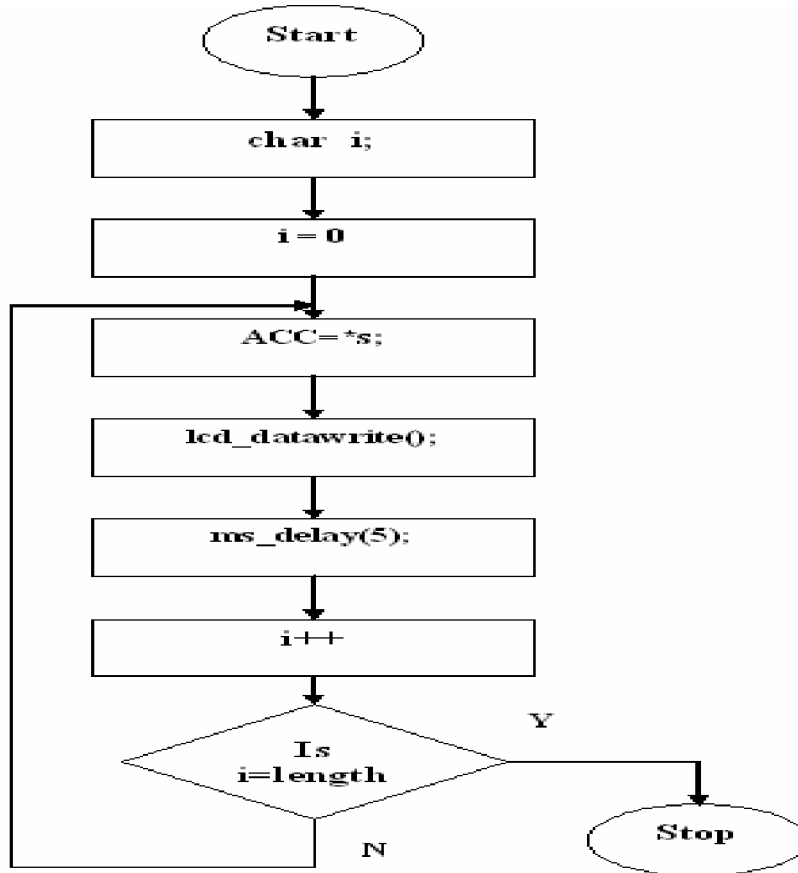
In the flow charts shown above the delay functions are made for making a milli-second delay an instruction `_nop_()`; is executed number if times, we require that delay. And for making second delay the milli-second delay subroutine is executed 1000 times.



**Fig. 5.5 Display value of any unsigned character Z**

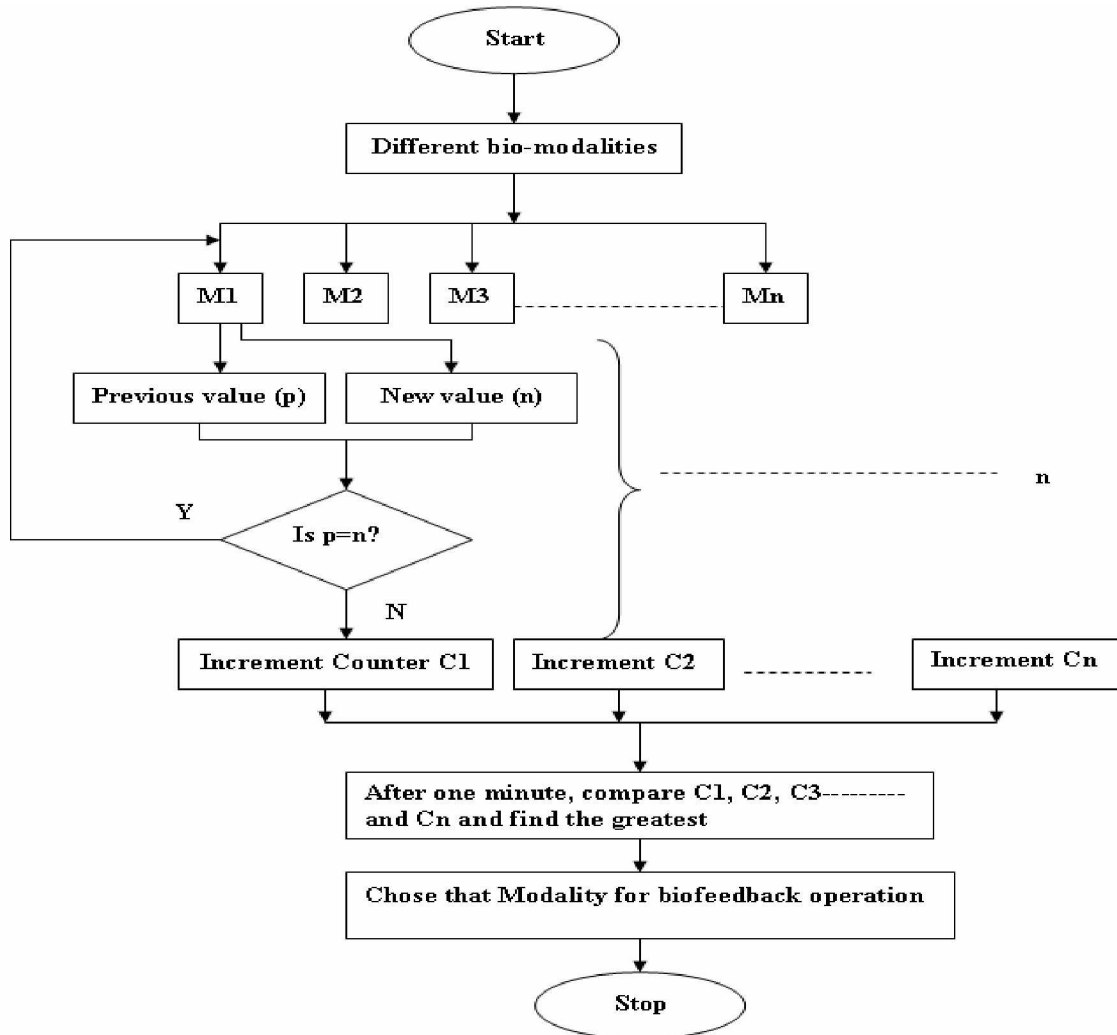
In the above flow chart, the steps involved, in displaying any unsigned integer value, are shown. The integer is taken as getvala and here the integer taken is placed in the form of array of 3 elements on the LCD module. A character count is taken to place the integer at that particular array index on LCD module and we reach at the next array index by incrementing the count. LCD display is made on and Cursor is made off. The count begins from zero and the number is divided by 10. We add 48 to the remainder to make it ASCII code. The LCD understands the ASCII code and the code is given to LCD and the

number is displayed on the LCD at that particular location. The whole procedure is repeated for the quotient until all the numbers are displayed.



**Fig. 5.6 lcd\_display (char \*s, char length)**

The above shown flow chart tells the steps involved in writing comments or we can say the characters on the LCD module. The character to be displayed on the LCD is taken in the string data type it is placed in inverted commas and the length of the string is defined. After that the function for writing the data is called. And that string is displayed on LCD module.



**Fig. 5.7** Flow chart for the working of the system

Above shown is the flow chart, which tells about the concept behind the system working. Here  $n$  number of different modalities are taken. Each new value of each modality is compared with the previous one. And checked whether the change is occurred or not. If there is change in the value recorded then the counter associated with that particular modality is incremented by one. This procedure is repeated with each modality. Now the number of changes in each modality in one minute i.e. the numeric value stored in the corresponding counter are compared. The modality, which changes maximum times, is chosen for the feedback operation.

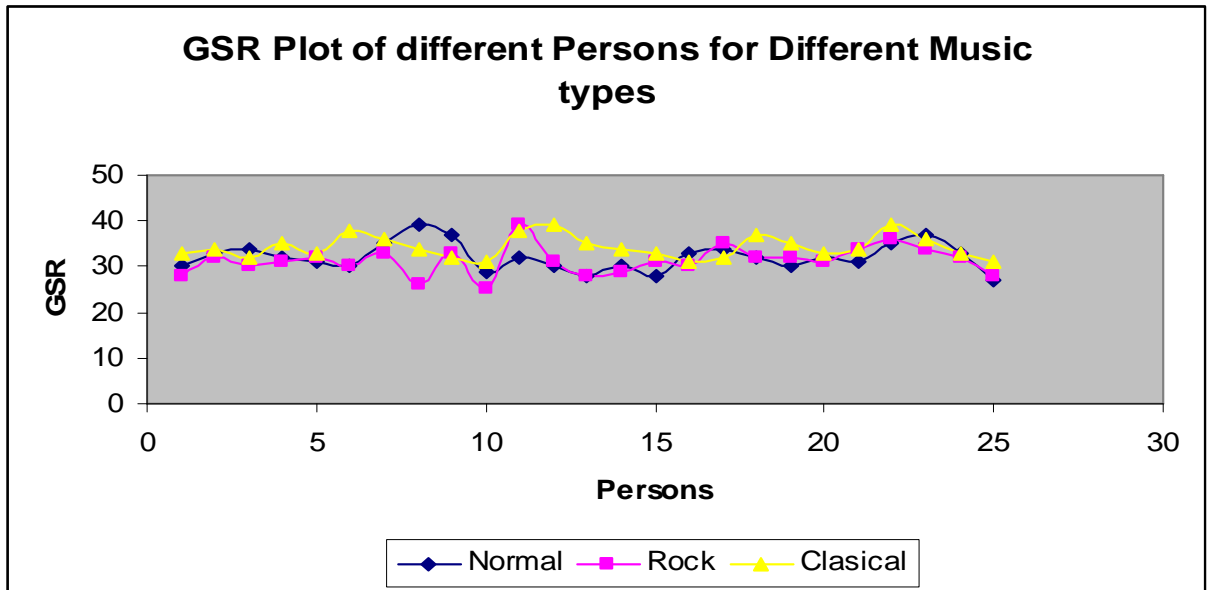
#### 6.1 Results

In this system the pulse rates changes most rapidly due to dynamic musical background. As the type of music change we experience changes in mood, tension and arousal which impact on pulse rate signals. With appropriate biofeedback, individuals can learn to control their biopotentials, such as pulse rate, to some degree.[19] However, an individual's pulse rate responds quickly to external events. More specifically, it responds to actions and events created by other people during communication. Music is an appealing medium for the display of bio-signals because it has the ability to elicit emotional responses while remaining in the background, allowing the listener to focus on it. We chose different music types such as classical and rock music due to their strong and well-understood effects on tension. We have presented the system, which uses music to express heartbeat information. Interesting variables can be derived from the change between the two pulse rate signals. Through this work we develop general techniques for controlling pulse rate through music.

Table- 3, 4, 5 give the GSR, Pulse Rate and Temperature measures respectively of 25 different peoples under different conditions. These different conditions are achieved by different music types. As we take a look at the plots, it is noticed that the pulse rate variations are more than the temperature and GSR variations. Therefore I have taken pulse rate as main biofeedback modality and the feedback system is designed for this modality. The assembly of four green and three red LEDs serve as visual feedback of a persons pulse rate. As the pulse rate is decreasing from the normal pulse rate we can say that the person is relaxing then green LEDs glow. In other case if pulse rate increases from the normal pulse rate the red LEDs begin to glow and green will be off.

**Table-3 Values of GSR of different people**

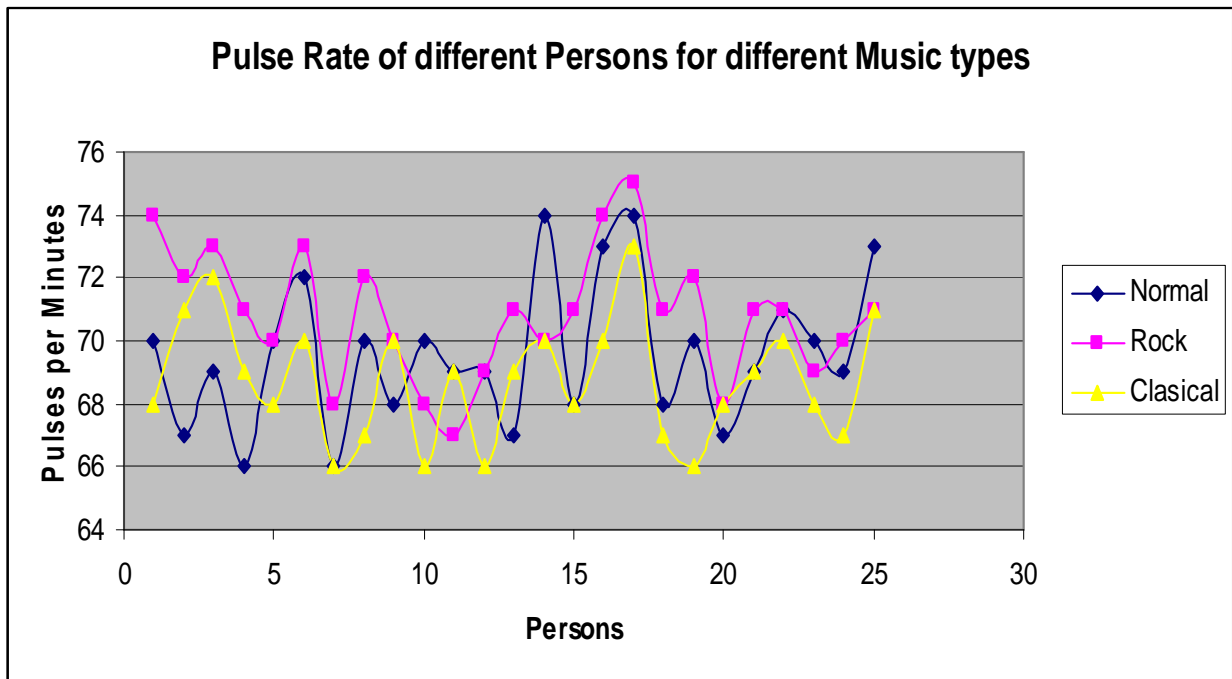
S.No.	Person	Normal	Rock Music	Classical
1.	x1	30	28	33
2.	x2	33	32	34
3.	x3	34	30	32
4.	x4	32	31	35
5.	x5	31	32	33
6.	x6	30	30	38
7.	x7	35	33	36
8..	x8	39	26	34
9.	x9	37	33	32
10.	x10	29	25	31
11.	x11	32	39	38
12.	x12	30	31	39
13.	x13	28	28	35
14.	x14	30	29	34
15.	x15	28	31	33
16.	x16	33	30	31
17.	x17	34	35	32
18.	x18	32	32	37
19.	x19	30	32	35
20.	x20	32	31	33
21.	x21	31	34	34
22.	x22	35	36	39
23.	x23	37	34	36
24.	x24	33	32	33
25.	x25	27	28	31



**Fig.6.1 GSR plot**

**Table-4 Values of pulse rate of different people**

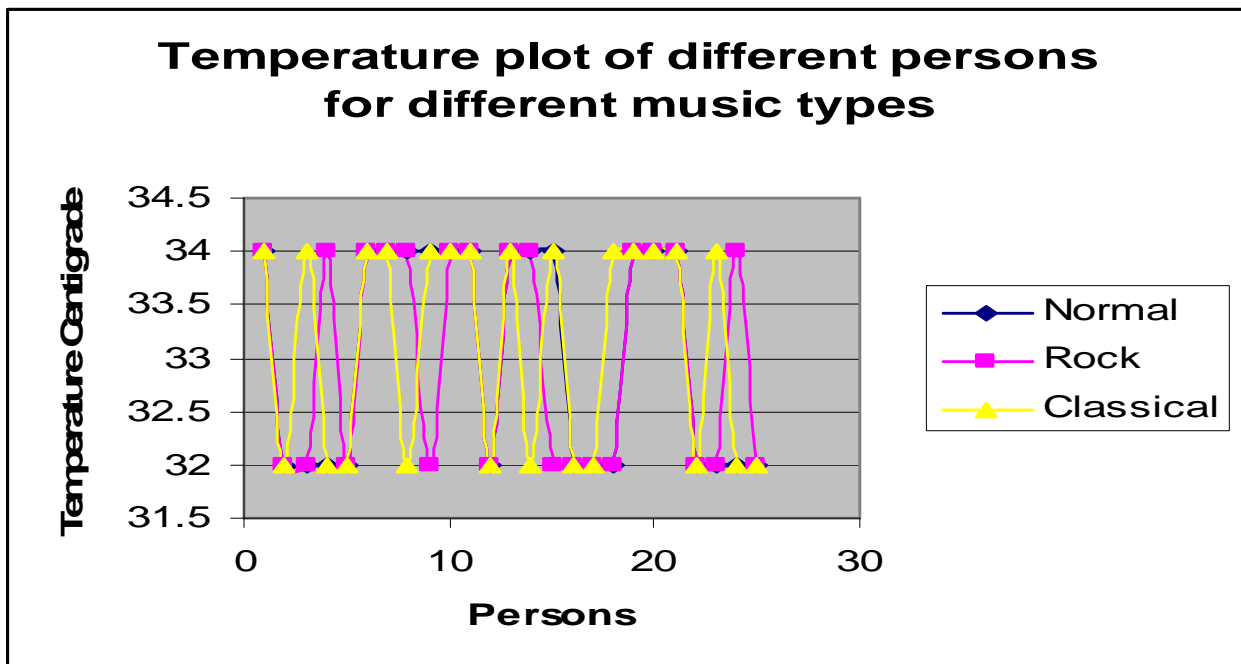
S.No.	Person	Normal	Rock Music	Classical
1.	x1	70	74	68
2.	x2	67	72	71
3.	x3	69	73	72
4.	x4	66	71	69
5.	x5	70	70	68
6.	x6	72	73	70
7.	x7	66	68	66
8.	x8	70	72	67
9.	x9	68	70	70
10.	x10	70	68	66
11.	x11	69	67	69
12.	x12	69	69	66
13.	x13	67	71	69
14.	x14	74	70	70
15.	x15	68	71	68
16.	x16	73	74	70
17.	x17	74	75	73
18.	x18	68	71	67
19.	x19	70	72	66
20.	x20	67	68	68
21.	x21	69	71	69
22.	x22	71	71	70
23.	x23	70	69	68
24.	x24	69	70	67
25.	x25	73	71	71



**Fig.6.2 Pulse rate plot**

**Table-4 Values of Temperature of different people**

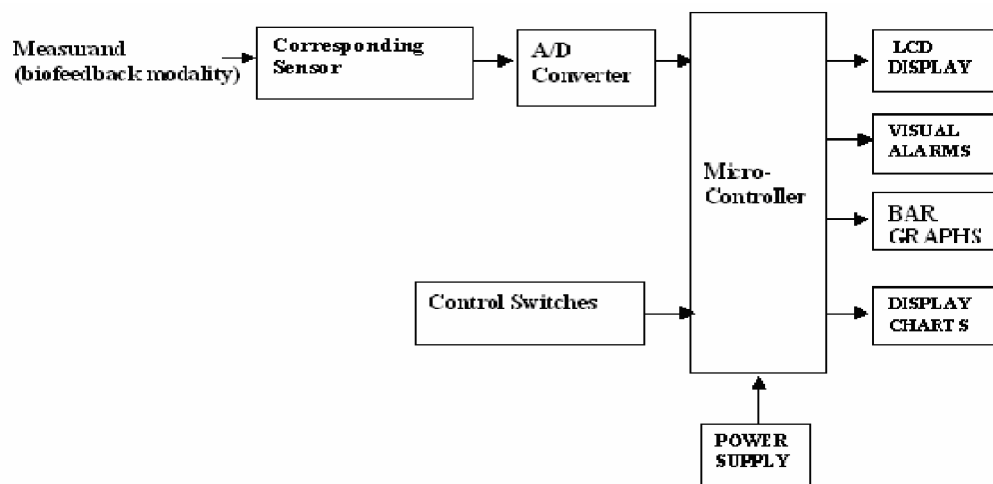
S. No.	Persons	Normal	Rock	Classical
1.	x1	34	34	34
2.	x2	32	32	32
3.	x3	32	32	34
4.	x4	32	34	32
5.	x5	32	32	32
6.	x6	34	34	34
7.	x7	34	34	34
8.	x8	34	34	32
9.	x9	34	32	34
10.	x10	34	34	34
11.	x11	34	34	34
12.	x12	32	32	32
13.	x13	34	34	34
14.	x14	34	34	32
15.	x15	34	32	34
16.	x16	32	32	32
17.	x17	32	32	32
18.	x18	32	32	34
19.	x19	34	34	34
20.	x20	34	34	34
21.	x21	34	34	34
22.	x22	32	32	32
23.	x23	32	32	34
24.	x24	32	34	32
25.	x25	32	32	32



**Fig.6.3 Temperature plot**

## 6.2 Conclusion

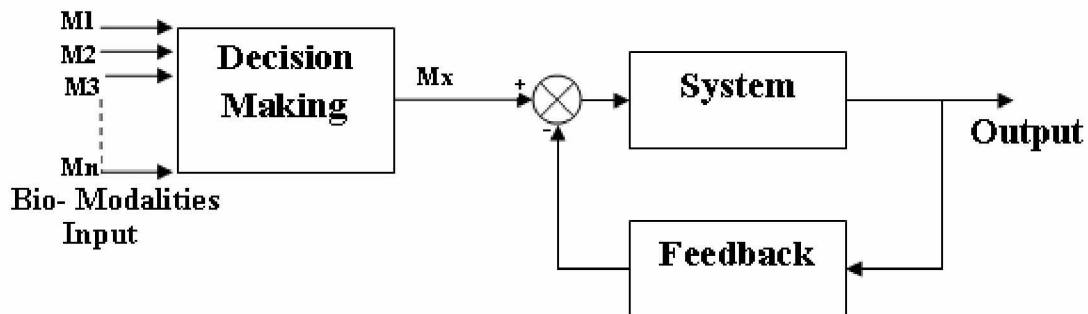
In general engineering terms, feedback is used to control a process. If this concept is applied to biological processes within the body, it is known as biological feedback or biofeedback.[20] A variable produced by the process is measured and compared with the reference value and based on the differences, action is taken to bring the variable to the reference value. The body functions that are controlled by the autonomic nervous system are not normally subject to voluntary control. In fact, most of these body functions are not consciously perceived. However, it has been found that if these functions are measured by some suitable methods, and, if information pertaining to their magnitude can be conveyed to the subject, a certain degree of voluntary control can be exercised over some of the body functions. Biofeedback is not completely understood but it is being presently used in clinical treatments. Many different physiological processes have been evaluated for possible control by biofeedback methods including EEG, EMG, heart rate, blood pressure, GSR, BSR, and temperature. Heart rate can be measured fairly easily. Blood pressure on the other hand is a fairly elusive variable. While both of these variables can be controlled to a certain degree by biofeedback methods, clinical applications for the treatment of hypertension have had disappointing results. There have been a number of experiments in the use of biofeedback for secondary effects.



**Fig.6.4 Basic Biofeedback System**

Biofeedback instrumentation includes a transducer and amplifiers measure the body variable that is to be controlled by the bio feedback process. The magnitudes of the measured variable are converted into suitable visual or auditory cue that is presented to the subject. Sometimes, it is necessary to provide additional signal processing between the measurement and feedback part of the instrumentation. This is especially true when the variable to be controlled is subject to substantial fluctuations and only a statistical characteristic is to be controlled.

In the system deigned here the changes in the different bio-modalities due to change in external conditions are recorded and among them the most sensitive bio-modality is selected and the biofeedback system designed on that particular modality. In this thesis pulse rate is taken as the suitable modality for designing the biofeedback system. Some applications of biofeedback that have been demonstrated successfully include a group of students who were able to slow their heart rate by an average of nine beats/minute, a group who were able to equate their own EEGs to their relaxation habits



**Fig.6.4 Concluded Biofeedback System**

and some patients who have been able to control migraine headaches. Biofeedback has been represented by some to be the purest form of “self-control”. The success of biofeedback depends on interpretation of data and training of the subjects so that the can use the results effectively.

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# Appendix