DESIGN OF A TRANSTELEPHONIC ECG AND THERMOMETER DEVICE USING THE MOBILE PHONE

by

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ABSTRACT

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The need of effective and low cost personal and emergency monitoring telemedicine solutions are the main concern of this project. The patients who have heart diseases, ambulances are common examples of possible emergency cases, while critical care telemetry and telemedicine personal follow-ups are important issues of telemonitoring. In order to support the above different growing application fields we created a combined store and forward(nearly real-time) facility that consists of a base unit and a telemedicine(mobile) unit using a commercial mobile phone and an external little capture card. Essentially this will allow the transmission of two vital biosignals (3 lead ECG, Body Temperature). This system can also be portable to other sensor applications.

This design consist of a two part, the hardware which is compose of three lead ECG and its peripheral circuits, power units and digital part which consists of PIC Microcontorller, TCP/IP chip and 512Kb EEPROM. Beside the ECG circuit a thermometer IC is used in 0.5°C resolution to measure body temperature.Transmission is performed through GPRS service network and the data is sent to certain IP address on internet using the commercial mobile phone. The software side which is provided by a PC assigned to Access server and Web Server. The data which are sent by patient remotely are stored in Access server and Web Page was designed to demonstrate and make it accessible from everywhere. This part of the project probably would be launched in patient observation center (hospital, specialized clinics etc).

Keywords: Telemedicine, transtelephonic ECG, GPRS, GSM.

ÖZET

CEP TELEFONU KULLANARAK TRANSTELEFONİK EKG VE SICAKLIK ÖLÇÜMÜ YAPABİLEN BİR CİHAZ TASARIMI

Bu projenin temel amacı kişisel sağlık ve acil durumlar için gerekli gözetleme ihtiyacına düşük maliyetli etkin ve verimli çözüm sunabilecek ortak bir teletıp platformu gerçekleştirmektir.Kalp hastalarının her an bulundukları yerden gözlenmeleri ve ambulans servisleri gibi kritik uzaktan algılama (servis öncesi) ihtiyaçlarınıkarşılayabilecek ürünlerdir. Yukarında sözü geçen ve gelişme potasiyeli olan bu uygulama alanlarına çözüm sunabilecek GPRS destekli cep telefonlar ile uyumlu çalışabilen taşınabilir bir data toplama aygıtından oluşan yükle/gönder (gercek zamanda) şeklinde çalışan bir mobil unite ve edinilen bilginin alınıp saklanabileceği ve daha sonrada sergilenebileceği bir merkez istasyon sistemi tasarlanmıştır.Sistem başlangıçta iki temel biyolojik sinyalin (1 kanallı EKG ve Vücut Sıcaklığı) iletilebilmesi üzerine kurulmuştur ve diğer biyolojik algılayıcılar ile de uyumlu calışabilme özelliğine sahiptir.

Tasarım iki bölümden oluşmaktadır. Tek kanallı EKG ve evresel devreler, güç birimi, PIC Mikrodenetleyici, TCP/IP yongası ve 512kbit EEPROM'un bulunduğu dijital kısım ve ek olarak 0.5°C çözünürlüklü vucut sıcaklığını algılayacak olan entegrenin bulunduğu donanım kısmıdır. İletim, GPRS servis ağı üzerinden datanın internette belli bir IP adresine gönde-rilmesi şeklinde olmaktadır. Yazlm kısmında ise Access sunucu ve Web sunucusunun bulundugu özel olarak tahsis edilmiş bir PC bulunmaktadır. Hasta bilgilerinin saklandi MS Access sunucu ve bu bilgilerin sergilenip her yerden ulaşımını sağlayacak bir Web Sitesi hazırlanmıştır.

Anahtar Sözcükler: Teletıp, teleiletimli EKG, GPRS, GSM.

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LIST OF ABBREVIATIONS

AEP	Auditory Evoked Potential
ASCII	Standard Code for Information Interchange
bps	Bits per second
CMIS	The CSIRO Mathematical and Information Sciences Division
CPU	Central Processing Unit
CSIRO	The Commonwealth Scientific and Industrial Research Organisation
DB-25	25 pin communications connector used for serial and parallel protocols
DB-9	A 9 pin serial communications connector
DTD	Document Type Definitions
EEPROM	Electrically Erasable Programmable Read Only Memory
FTP	File Transfer Protocol
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication
HTML	Hyper Text Markup Language the language used to describe web pages
IO	Input and Output
IP	Internet Protocol
ISDN	Integrated Services Digital Network
ISP	Internet Service Provider
ISR	Interrupt Service Routine
K or k	multiple of 1024
KB	Kilo Bytes (1024 bytes)
LAN	Local Area Network
LED	Light Emitting Diode
NAT	Network Address Translator

PABX	A telephone exchange for switching calls
PAP	Password authentication protocol
PPP	Point to Point Protocol
PSTN	Public Switched Telephone Network
RAM	Random Access Memory
RS-232	A common serial communication protocol
SIM	Security Identity Module
SMS	Short Message Service
SQL	Structured Query Language
TCP	Transmission Control Protocol
XML	eXtensible Markup Language
VEP	Visual Evoked Potential

1. INTRODUCTION

Telemedicine literally means 'medicine at a distance' and the term telemedicine is defined as the delivery of health care and sharing of medical knowledge over a distance utilizing telecommunication technology. The aim of Telemedicine is to provide expert-based health care to understaffed remote sites and to provide advanced emergency care through modern telecommunication and information technologies. The concept of Telemedicine was introduced about 30 years ago through the use of nowadays common technologies like PSTN and GSM networks. Today, Telemedicine systems are supported by State of the Art Technologies like Interactive video, high resolution monitors, high speed computer networks and switching systems, and telecommunications super highways including fiber optics, satellites and cellular telephony [1]. Mobile service for medical applications, such as those encountered in ambulance operations, is critical. Pre-hospital management in emergency care can be essential for patient survival. A portable medical device that transfers patient diagnostic information to physicians at a distant location while in the ambulance has been developed generation digital cellular network will have faster and larger transmission capabilities, more complex medical services can be delivered reliably and without degradation o quality [2].

1.1 Motivation

Cardiac emergency services are designed to provide immediate analysis and response for patients with heart complaints or other subscribers who require assistance. Once a real cardiac event is diagnosed, rapid intervention is performed aimed to minimize irreversible damage to the heart, reduce anxiety, and possibly restore life. Telemedicine performs monitoring functions, but these are likely to be focused on the vital signs of someone in a high risk category and may be useful to anyone who requires some level of medical attention, not just the elderly, though they would probably constitute the largest group with this need. It is obvious that such telemedicine systems are caused dramatic decrease in total patient cost. Recent studies have revealed that the number of patients being managed at home is increasing, in an effort to cut part of the high hospitalization's cost, while trying to increase patient's comfort [3]. GSM network providers are expanding the level while reducing the frequency of visits to healthcare institutions [4]. Furthermore, a variety of diagnostic devices can be attached to the system giving to the physician the ability to see and interact directly with the patient. For example, pulse oximetry and respiratory flow data can be electronically transmitted (for patients with chronic obstructive pulmonary disease). Diabetes patients can have their blood glucose and insulin syringe monitored prior to injection for correct insulin dosage. Furthermore, obstetric patients can have their blood pressure and fetal heart pulses monitored remotely and stay at home rather than prematurely admitted to a hospital.

1.2 Objectives

The overall objective of this project is to design and implement an inexpensive, yet adaptable and easy to use telemedicine system based on ECG and body thermometer measurement which replaces wired connections between sensor points and a central node with General Packet Radio Service (GPRS) link using a commercial mobile phone. Successful implementation of the final system would be of benefit to all involved in the use of electrocardiography and temperature as access to, and movement of, the patient would not be impeded by the physical constraints imposed by the conventional wired telephone.

In case of elderly and chronic patient arriving data give valuable information about patient and make the doctor knowlagefull about situation of the illness and in case of emergency before arriving patient to the hospital gives crucial information to the emergency service. This integrated system can be used regularly by chronic patients and when handling emergency cases in ambulances, a mobile telemedicine unit at the emergency site and a base unit at the hospital expert's site.

1.3 Simplicity

Not only such devices need to be relatively simple to create given the limited time and resources, but it is very important for it to be simple to use. The system was aimed at end users, hospitals and even companies with varying levels of technical ability not just those with dedicated health or electronics experts. This meant that the device would need to be relatively simple to use and maintain. A level of abstraction could be introduced to ensure that users(patients) of the device would not need to be familiar with the microprocessor or other pieces of hardware used on the board. Similarly, the sending of control signals and data should be handled by the device in a seamless manner such that the end user does not need to be concerned with, for example, how to ensure that control signals are received in the same order they are sent. As less user interaction as possible would be done via the web. By having users interact with a service, rather than managing devices themselves, much complexity of operations can be hidden, allowing the users to concentrate on the regular application and not the technology. This had to be done in such a way that although the device would be simple to use, no compromises would be made on functionality.

1.4 Cost

An important goal of this project was to make the use of Telemedicine more wide spread, and more easily available to end user and hospitals institutions that previously found the cost too prohibitive.This means being able to manufacture a device at a cost much lower than existing sophisticated Telemedicine systems or devices. A reasonable price for such a device is relative to the company purchasing it and application for which it is being used. Creating a substantially cheaper Telemedicine system or device, would make the technology less restrictive cost wise for many more patients, hospitals and companies. The initial price goal was to create a device which would cost less than $500, and we succeded in realizing this price. This is extremely low relative to existing sophisticated Telemedicine devices. Although potentially a lot less specialized and sophisticated than such devices, this device could be applied to many situations where it was previously too expensive to use Telemedicine Systems.

1.5 Adaptibility

By creating a single device that can be used in many different purposes, we aimed to design a common preprocessing and bearing platform for many other telemedicine application. In spite of needing for each individual user to create their own device from the bottom up according to their diseases we created a generic device that can be adapted to a particular need very easily. In other words, something that can be adapted to a given situation by a person who is not necessarily an expert in the telemedicine or electronics fields. The device should have only the bare essentials, allowing each user to modify it for their particular use. Modifying the device consists of attaching any peripherals to the device (Non-Invasive Blood Pressure (NIBP), Invasive blood Pressure (IP), Temperature (Temp), Respiration (Resp), Oxygen Saturation (SpO2), Blood Glucose Meter) and writing a small application to define what the device is to do (mostly how the sensors are applicable or needs to be implemented certain point on patient body). This system initially designed in one way communication fashion in order to make the use of device easy. This feature is most strong way of system in one aspect because users based faults will be eliminated by this way.

2. BACKGROUND

2.1 GENERAL PACKET RADIO SERVICE (GPRS)

In this thesis, continuous transfer of data from the device to the center is required. This operation is desired to be not too costly and providing as much freedom of mobility as possible. Hence GPRS over mobile communication network was chosen.

GPRS builds on the existing technology but improves it in such a way, that a bigger bandwidth is available for data transmissions. It has several improvements, like that the dial-up connect time will be very short, bandwidth up to 100 Kilobit per second could be available and that the user will have to pay for the transmitted data only but not for the connection-time. GPRS is a digital telephony standard, which is based on packets, like TCP/IP does in the Internet [5].

GPRS is similar to SMS in that it is a communication method relying on the GSM network and utilises bandwidth (and costs) based on data, not time. GPRS provides users with reliable connections, and a continuous online presence in the same way as a PC connected to a LAN has continuous access to the other computers on the network, but only utilises bandwidth when it is transmitting or receiving data.

In GSM the user gets a channel (similar as when using normal telephone lines) and a certain bandwidth, regardless if he will use it the whole time. In GPRS the user “produces” only packets, which use all available bandwidth and are transmitted to the destination and which have to find their way to the recipient on their own through the network, similar to TCP/IP.

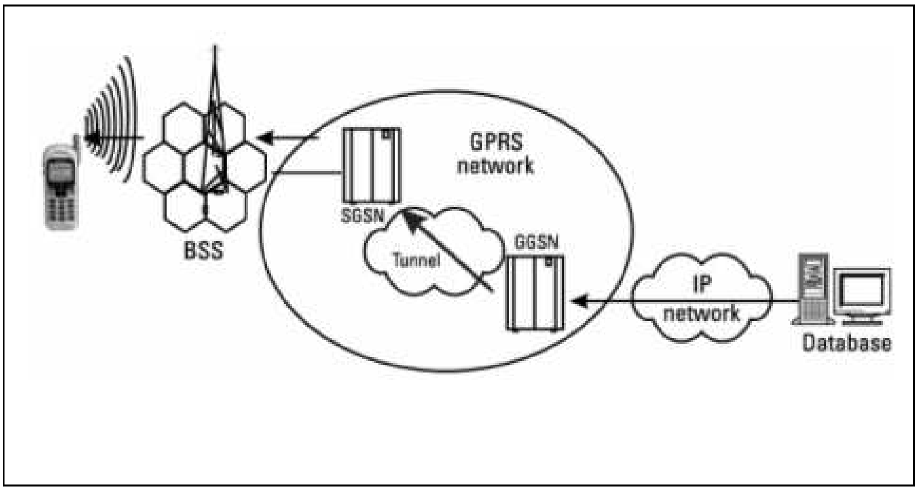

Figure 2.1 GPRS architecture

2.1.1 GPRS IP Backbone Elements

The most important two new network elements are the Serving GPRS Support Node (SGSN) and Gateway GPRS Support Node (GGSN). Although the functionality of these devices can be combined in one physical node called simply GPRS Support Node (GSN), there are several benefits in using a distributed structure where nodes are interconnected using an IP Backbone network. The distributed architecture both

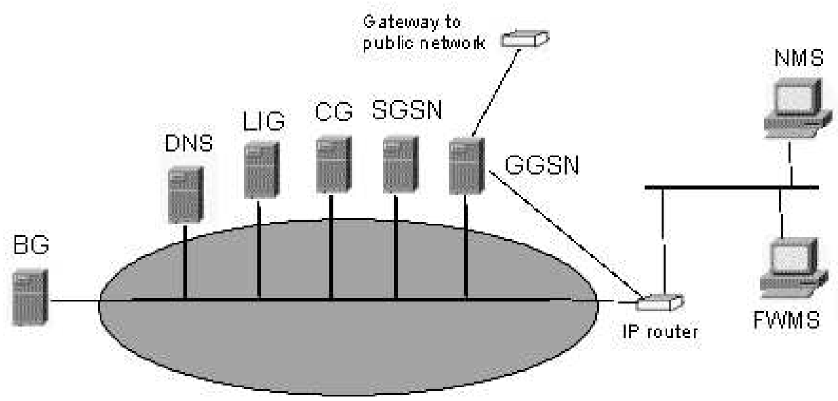

Figure 2.2 Structure of the GPRS Backbone

enables flexible implementation and offers more reliability, for the nodes are not co-located. The capacity of a distributed system is also easier to scale up or down and the same backbone can be used as a part of future third generation networks [6].

The devices interconnected in the GPRS IP Backbone are described shortly below.

2.1.1.1 Serving GPRS Support Node (SGSN). Serving GRPS Support Node services all mobile stations located on its service area. It forwards all IP packets that are either to or from the mobile stations in its routing area. The mobile terminated packets are routed from the SGSN straight to the BSS. SGSN takes care of the necessary protocol coversion between the IP backbone and the BSS/MS. The SGSN takes care of the ciphering and authentication of the MS packet switched data, session management, mobility management and charging information collection for the radio network usage. It also handles the interaction with the MSC/VLR and HLR. If packets are destinated to an external network, SGSN forwards the traffic to an appropriate GGSN.

2.1.1.2 Gateway GPRS Support Node (GGSN). Gateway GPRS Support Node acts as the gateway from GPRS network to external packet data networks such as public Internet or the operator's own network. From the external networks point of view the GGSN is only a router to the IP subnetwork containing the MS:s. GGSN performes the routing funcionality for networks IP addresses to reach the subscribers of the GPRS network from the outside. GGSN handles the IP address allocation to mobile stations. Again, GGSN forwards packets destined to a mobile station to an appropriate SGSN. GGSN collects also charging data related to the external IP network usage.

2.1.1.3 Charging Gateway (CG). **CG** collects charging data from the GPRS network and directs it to the billing system. The charging information of the packet switched data or the tickets are generated by the SGSNs and GGSNs in the network.

2.1.1.4 Border Gateway (BG). Border Gateway connects the IP backbone to different operators networks, forwarding mainly GTP to between operator's networks in an efficient and secure way. The main purpose of BG is to make roaming from different operators networks possible. The network between BG:s could in theory be any packet data network providing the most efficient and secure passage, even a VPN connection over the Internet. It's up to the operators to decide this.

2.1.1.5 Domain Name Server (DNS). A standard name server, that converts logical names to IP addresses and vice versa. The main tasks of the DNS servers are to convert APN and host names to IP addresses. The reverse DNS is needed basically for operational and maintenance purposes. The DNS handles only .gprs address queries.

2.1.1.6 Lawful Interception Gateway (LIG). Lawful Interception Gateway is an functionality that allows authorities to intercept or 'wiretap' GPRS mobile data traffic. Operators in most countries have to provide this functionality in the network before the commercial rollout. GPRS interception is rather different from regular GSM interception, for the implementation in GPRS is done by archiving binary data created by the specific MS.

2.1.1.7 IP routers and switches. Provide the connectivity between the different segments of the GPRS network. These use standard application level protocols such as SNMP, HTTP and Telnet.

2.1.1.8 Firewall and Network Management stations. To protect the GPRS network from several external attacks and enforce different security policies firewalls are needed. For example the GGSN firewall might block all MT traffic not initiated by the terminal. These firewalls should be managed from one station, attached to a different network than the GPRS subnetwork.

2.1.2 GPRS, A Packet Switched Network

The introduction of the GPRS represents an important step in the evolution of the GSM network. Significantly, GPRS is a packet-switched system, unlike GSM and HSCSD, which are circuit-switched. The aim of GPRS is to provide Internet-type services to the mobile user, bringing closer the convergence of IP and mobility. Indeed, apart from addressing a significant market in its own right, clearly GPRS can be considered to be an important stepping stone between GSM and UMTS.

In packet-switched networks the user is continuously connected but may only be charged for the data that is transported over the network. This is quite different from circuit-switched networks, such as GSM, where a connection is established at call set-up and the user is billed for the duration of the call, irrespective of whether any information is transported. In this respect, packet-switched technology can be considered to be more spectrally efficient and economically attractive. Essentially, channel resources are made available to all users of the network. A users information is divided into packets and transmitted when required. Other users are also able to access the channels when necessary.

2.1.3 Data Rate and Data Transmission

GPRS offers non-real time services at data rates from 9 up to 171 kbit/s, with most networks offering about half the maximum data rate. The available bit rate is dependent upon the number of users of the network and the type of channel coding employed. GPRS specifies four types of coding (CS-1, CS-2, CS-3 and CS-4), the choice of which depends on the operating environment. The theoretical maximum data rate is achieved by employing CS-4, whereby no coding is employed, and only a single user is gaining access to channel resources. The data rates offered allow a full range of services to be accessed, from simple messaging to efficient file transfer and web browsing. Inter-working with TCP/IP and X.25 bearer services will be available. Once connected to the network, a call can be established in less than 1 s, which is significantly faster than

GSM. GPRS, in addition to providing point-to-point services, has the capability to deliver point-to-multipoint calls, where the receiving parties can be either closed-group or users within a particular broadcast area.

GPRS makes use of the same radio interface as GSM. To achieve a variable data rate, aMS can be allocated from one to eight time-slots within a particular TDMA frame. Moreover, the time-slot allocation can be different in the forward and reverse directions. Hence, the MS can transmit and receive data at different rates, thus enabling asymmetric service delivery. This approach is the key to the efficient provision of Internet-type services. Channels are dynamically allocated to MSs on a per-demand basis from a common pool of resources available to the network. Upon completing a communication, the channels are released by the MS and returned to the pool, thus enabling multi-users to share the same channel resources. Packets are transmitted on unidirectional packet data TCHs (PDTCH), which are similar to the fullrate TCHs used by GSM for speech. These channels are temporarily allocated to a particular MS when data transfer occurs. TCHs are transmitted over a 52-multiframe physical channel, which is made up of two GSM 26 multiframes. A 52-multiframe comprises of 12 blocks of four TDMA frames plus two frames for the packet broadcast control channel (PBCCH) and two spare. Hence, a 52-multiframe lasts for 240 ms. A 51-multiframe is also defined for the exclusive transmission of the packet call control channel (PCCCH) and PBCCHs. In addition, GPRS provides a number of logical channels for control and signalling purposes, grouped under PBCCCH, packet dedicated control channel (PDCCH) and PCCCH [7].

The way the packets take can be different (and depends on the load of the network-nodes). At the end the cell station of the recipient simply sends out all packets on all available channels and the recipients mobile device has to pick them up. As the network simply has to deliver these packets without interpreting them any kind ECG and enhanced. Studies demonstrated that ECGs transmitted of data can be transmitted, as long as the recipient can interpret and use them. GPRS supports both important protocols IP and X.25. It reaches the high rates by the following method: It uses the same voice-transmission-channels, which are sent by voice telephony now.

These channels are split in 8 sub channels, which have a bandwidth of 34 Kilobit per second each. GPRS can combine these channels in a similar way like ISDN does with its both B-Channels. The GPRS standard has a mechanism, which allows any mobile cell-station to combine these channels in such a way, that the highest possible bandwidth is available for the user, who is sending data through this cell at this specific time [8, 9].

2.1.3.1 Possible Limitation of GPRS. As the users are only using these channels when transmitting data (and not blocking a channel like with GMS all the time) it is possible to serve several users and to provide them with the highest possible bandwidth. This could be a handicap of the new technology too: experts predict that only up to 50 kbps should be possible, because the cell-stations are already now overloaded and with a lot of users at the same time couldn't provide a high bandwidth [12]. Nevertheless GPRS will be a big step forward for the mobile telecardiological devices, as it will be possible to transmit more precise ECG data in much shorter time. Thus the interaction between the patient and the cardiologist will have fewer delays.

2.1.4 Pricing

As specified in the GSM phase 2 standard [10], GPRS provides packet switched access to the Internet using the GSM mobile infrastructure. A voice or data call placed on a GSM network occupies one slot for the duration of the call. GPRS on the other hand only takes up bandwidth when data is being transmitted or received such that a slot not being used for a voice call may be shared by tens of GPRS users simultaneously using time division multiplexing. During a voice call, when both parties are silent, the slot is still being used, even though no useful information is being transmitted. Using a GPRS connection to browse the web for example, would only utilise bandwidth while actually loading pages, not while the user reads a loaded web page. **Telecommunication providers charge GPRS users based on the amount of data transmitted, not the amount of time online.**

2.2 Electrocardiogram

2.2.1 The Heart

The heart is the muscular organ of the circulatory system that constantly pumps blood throughout the body. Approximately the size of a clenched fist, the heart is composed of cardiac muscle tissue that is very strong and able to contract and relax rhythmically throughout a person's lifetime [11, 12, 13, 14].

The heart has four separate compartments or chambers. The upper chamber on each side of the heart, which is called an atrium, receives and collects the blood coming to the heart. The atrium then delivers blood to the powerful lower chamber, called a ventricle, which pumps blood away from the heart through powerful, rhythmic contractions. The human heart is actually two pumps in one. The right side receives oxygen-poor blood from the various regions of the body and delivers it to the lungs. In the lungs, oxygen is absorbed in the blood. The left side of the heart receives the oxygen-rich blood from the lungs and delivers it to the rest of the body.

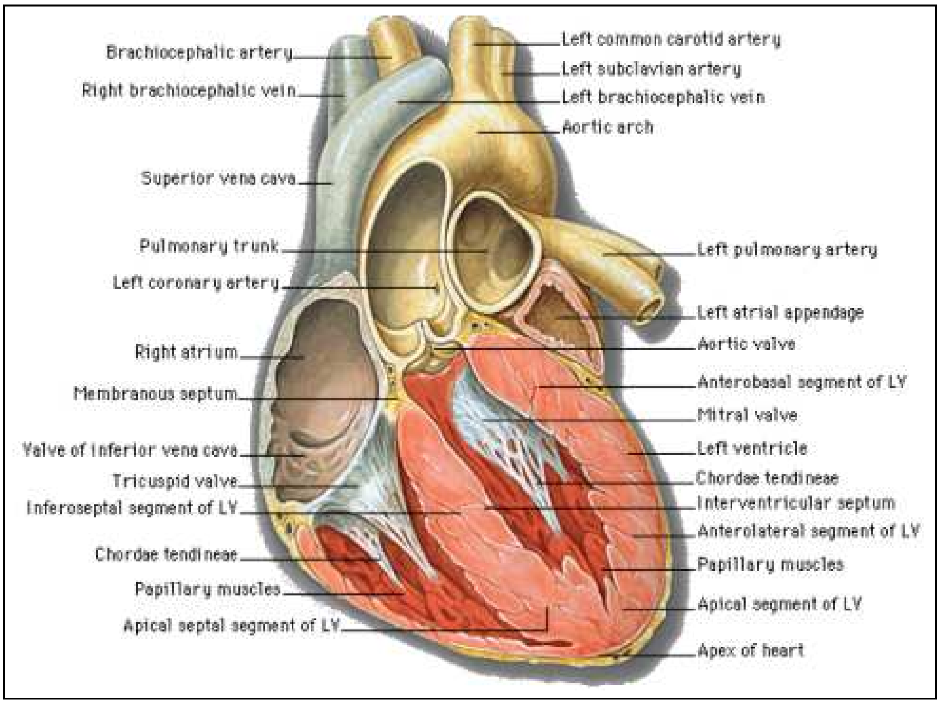

Figure 2.3 The anatomy of the heart [15]

2.2.1.1 Systole. The contraction of the cardiac muscle tissue in the ventricles is called systole. When the ventricles contract, they force the blood from their chambers into the arteries leaving the heart. The left ventricle empties into the aorta and the right ventricle into the pulmonary artery. The increased pressure due to the contraction of the ventricles is called systolic pressure.

2.2.1.2 Diastole. The relaxation of the cardiac muscle tissue in the ventricles is called diastole. When the ventricles relax, they make room to accept the blood from the atria. The decreased pressure due to the relaxation of the ventricles is called diastolic pressure.

2.2.1.3 Electrical Conduction System. The heart is composed primarily of muscle tissue. A network of nerve fibers coordinates the contraction and relaxation of the cardiac muscle tissue to obtain an efficient, wave-like pumping action of the heart.

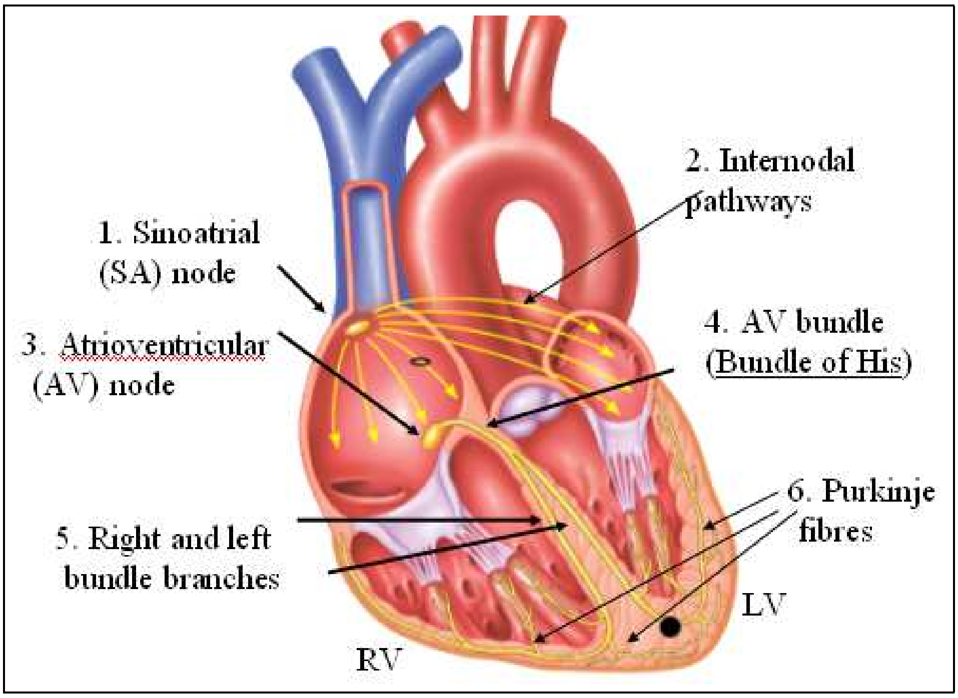

Figure 2.4 The Conduction System of the Heart [16]

The **Sinoatrial Node** (often called the SA node or sinus node) serves as the natural pacemaker for the heart. Nestled in the upper area of the right atrium, it sends the electrical impulse that triggers each heartbeat. The impulse spreads through the atria, prompting the cardiac muscle tissue to contract in a coordinated wave-like manner. The impulse that originates from the sinoatrial node strikes the **Atrioventricular node** (or AV node) which is situated in the lower portion of the right atrium. The atrioventricular node in turn sends an impulse through the nerve network to the ventricles, initiating the same wave-like contraction of the ventricles. The electrical network serving the ventricles leaves the atrioventricular node through the Right and Left Bundle Branches. These nerve fibers send impulses that cause the cardiac muscle tissue to contract

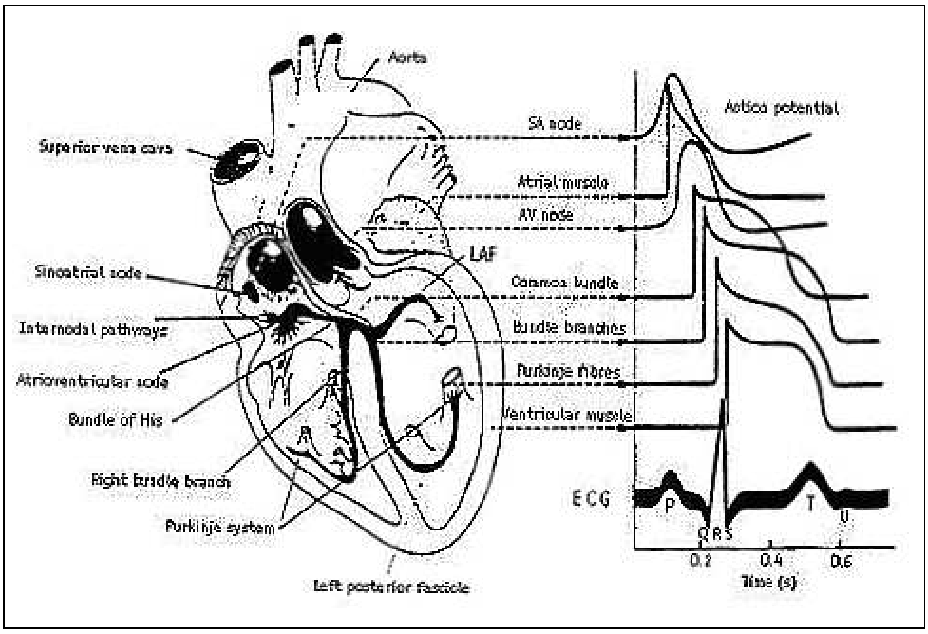

Figure 2.5 ECG components

2.2.1.4 Action potentials and cardiac contraction. Cardiac contractions are the result of a well orchestrated electrical phenomenon called depolarization. Cell membranes move from their negative resting potential to a more positive threshold which ultimately stimulates them to contract. In the myocardium there are specialized fibers that are very conductive and allow the rapid transmission of electrical impulses across the muscle, telling them to contract. In order to maximize the force of the contraction there is uniformity in the sequence. That is, the atria contract, then the ventricles contract. This allows both sets to fill properly before ejecting the blood to its next destination. These two sections are independent, yet linked to a single impulse, (in a healthy heart,) initiated by the sinoatrial, (or sinus) node. The tissue around the valves helps to channel the impulse from the sinus node through another collection of specialized tissue, the atrioventricular node, that is situated between the two sets of chambers. This area allows slightly slower transmission of the impulse to the ventricles, allowing the atria to empty into the ventricles before they contract and force the blood to the lungs or body. This area, the A/V Node, slows the impulse down to about 1/25th of the original signal then passes it through to the atrioventricular bundle, or the bundle of His. This bundle divides itself into two distinct tracts through the ventricles, the bundle branches, and on to the Purkinje fibers, where the muscle of the ventricle is stimulated to contract from the bottom up, maximizing the force of ejection.

2.2.2 Theoretical Basis of the Electrocardiogram (ECG)

An electrocardiogram is a measurement of the electrical activity of the heart (cardiac) muscle as obtained from the surface of the skin. As the heart performs its function of pumping blood through the circulatory system, a result of the action potentials responsible for the mechanical events within the heart is a certain sequence of electrical events. In the resting state, cardiac muscle cells are 'polarized', with the inside of cell negatively charged with respect to its surroundings. The charge is created by different concentrations of ions such as potassium and sodium on either side of the cell membrane. In response to certain stimuli, movement of these ions occurs, particularly a rapid inward movement of sodium. In this process, known as 'depolarization', rapid loss of internal negative potential results in an electrical signal. The mechanism of cell depolarization and repolarization is used by used by nerve cells to carry impulses and by muscle cells for triggering mechanical contractions.

An electrical current in the direction towards the positive end of a bipolar electrode causes a positive deflection of the stylus of the ECG. If the number of myocardial cells (dipoles) in this direction increases, the current will increase as well. The greater the current, the more positive the voltage. An electrical current in the direction away from the positive end of a bipolar electrode causes a negative deflection of the stylus of the ECG. If the number of myocardial cells (dipoles) in this direction increases, the current will increase as well. The greater the current, the more negative the voltage.

2.2.2.1 ECG Leads. An electrocardiographic lead is a recording electrode or a pair of recording electrodes at a specified location. In clinical practice, twelve leads are usually used in the diagnostic ECG, although there is no limitation to the number of leads one may select for special purposes. The leads are usually placed on the elbows and stifles. A right leg electrode is used as the ground.

2.2.2.2 ECG Standard Leads and Placements. Electron leads are placed on the body as shown in the Figures 2.6 or 2.7. Before placing the electrodes, skin should be cleaned at contact electrode site.

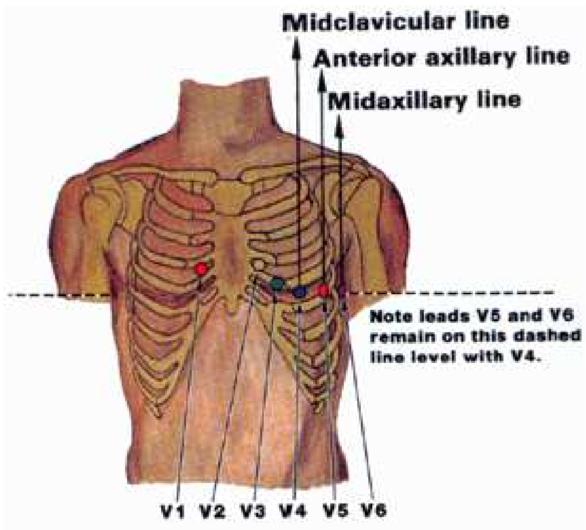

Figure 2.6 The V6 electrode placement for ECG

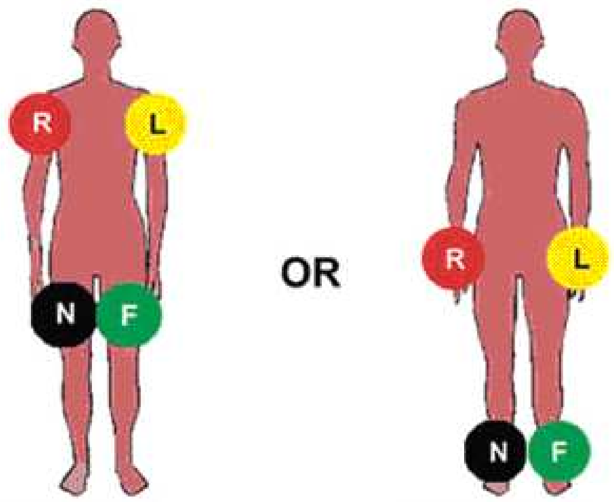

Figure 2.7 Four electrode placement for ECG

2.2.2.3 Explanation of the ECG parameters. A typical ECG signal pattern is shown in the below Figure 2.8. Each little square is 1mm1mm in length. X-axis is represents time and Y-axis represents voltage. In the X-axis, 1mm corresponds to 0.04 seconds and in the Y-axis 1mm corresponds to 0.1 mV.

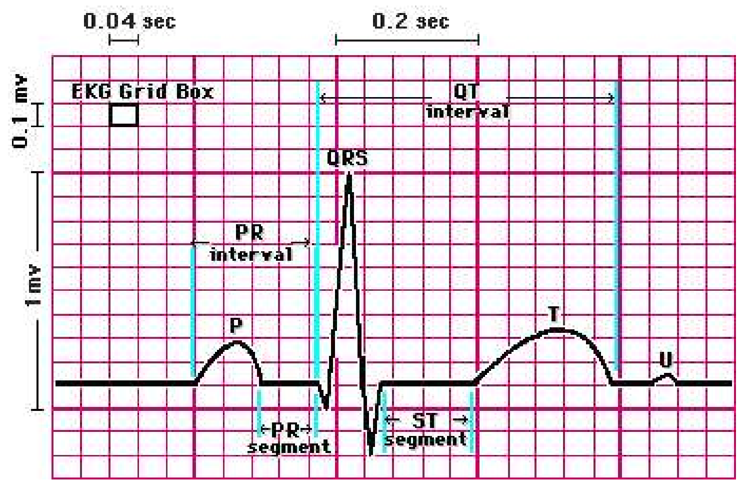

Figure 2.8 A typical periodic signal pattern in ECG (also called EKG) records

For **Heart Rate** The distance between QRS complexes are examined. If the distances are regular, we count the number of "little boxes" from the beginning of one QRS to the beginning of the next QRS complex. Then the number of "little boxes" (which each represent 0.04 seconds) is divided into 1500 to obtain the heart rate in beats per minute. If the distances are irregular, the number of QRS complexes is counted, beginning at one QRS complex to the beginning of the last QRS complex within 30 large boxes (which each represent 0.2 seconds) and multiplied by 10 to obtain the heart rate in beats/minute.

The PR interval is the time in seconds from the beginning of the P wave to the beginning of the QRS complex. It corresponds to the time lag from the onset of atrial depolarization to the onset of ventricular depolarization. This time lag allows atrial systole to occur, filling the ventricles before ventricular systole. Most of the delay occurs in the AV node. The PR interval is longer with high vagal tone. A prolonged PR interval corresponds to impaired AV conduction.

The QRS interval represents the time it takes for depolarization of the ventricles. Normal depolarization requires normal function of the right and left bundle branches. The QRS duration may vary with the size of the heart and is longer in the base-apex lead. A block in either the right or left bundle branch delays depolarization of the ventricle supplied by the blocked bundle, resulting in a prolonged QRS duration.

The QT interval begins at the onset of the QRS complex and terminates at the end of the T wave. It represents the time of ventricular depolarization and repolarization. It is useful as a measure of repolarization and is influenced by electrolyte balance, drugs, and ischemia. The QT interval is inversely related to heart rate. A QT interval corrected for heart rate can be calculated.

2.3 Body Temperature Measurement

Body temperature is a measure of the body's ability to generate and get rid of heat. The body is very good at keeping its temperature within a narrow, safe range in spite of large variations in temperatures outside the body. However, regulation of our body temperature is not absolutely precise. For example, our body temperature varies slightly during the course of the day, tending to be highest in the evening and lowest in the middle of the night. The French physiologist Claude Bernard noticed that the bodys internal environment generally remains almost constant in spite of large changes in the external environment. This observation led to much work into the phenomenon of homeostasis, which is the tendency for an individuals internal environment to remain fairly constant. The word "homeostasis" comes from two Greek words: "homos" meaning "same" and "therme" meaning "heat". Keeping body temperature in a narrow band of temperature range is important for the homeostasis of the body.

Deep or core body temperature refers to that of the tissues deep within the skull or the thoracic and abdominal cavities, whereas surface or shell temperature refers to the outer body tissues, essentially the skin. Core body temperature is regulated mainly by the hypothalumus in the brain, which responds to input from thermoreceptors located centrally in the body core and peripherally in the skin. The pulmonary artery is considered to be the gold standard measurement site for core body temperature. However, the use of this site is rarely an option in normal clinical practice, and other methods of temperature measurement are generally employed. There has been much debate about the most reliable site from which to monitor body temperature in children. The majority of the studies conclude that axillary temperature measurement (from the armpit), whilst safe and easy to perform, is not sensitive enough to detect fever in infants, and hence rectal temperature measurement should be used. Rectal temperature has most commonly been monitored by conventional mercury-glass thermometers [17].

2.3.1 Importance of Measuring Body Temperature

In adults, an oral temperature above 37.8°C or a rectal or ear temperature above 38.3°C is sometimes considered a mild fever. A child has a fever when his or her rectal temperature is 38°C or higher. A fever may occur as a reaction to:

- Infection. This is a common cause of a fever. Infections may affect the whole body or a specific body part (localized infection).

- Medications such as antibiotics, narcotics, barbiturates, antihistamines, and many others. These are called drug fevers. Some medications, such as antibiotics, raise the body temperature directly; others, including nonsteroidal anti-inflammatory drugs (NSAIDS) and phenothiazines (such as Compazine, Mellaril, or Thorazine), interfere with the body's ability to adjust its temperature when other factors cause the temperature to rise.
- Severe trauma or injury, such as a heart attack, stroke, heat exhaustion or heat-stroke, or burns.
- Other medical conditions, such as arthritis, hyperthyroidism, and even some cancers (such as leukemia, Hodgkin's lymphoma, and liver and lung cancer).

An abnormally low body temperature (hypothermia) can be serious, even life-threatening. Low body temperature may occur from cold exposure, shock, alcohol or drug use, or certain metabolic disorders, such as diabetes or hypothyroidism. Oddly, a low body temperature may also occur in certain infections, particularly in newborns, older adults, or people who are frail. Certain overwhelming infections, such as Gram-negative sepsis, may also cause an abnormally low body temperature.

Hence measurement of body temperature has a very big importance not only for patients but also for everybody for checking the health status.

3. HARDWARE Of The SYSTEM

To design the aimed system, architecture shown in the Figure 3.1 is used. The system measures ECG, body temperature and then *nearly* in real time sends these data over GPRS network to the base center. Parts of the system are explained in the following sections.

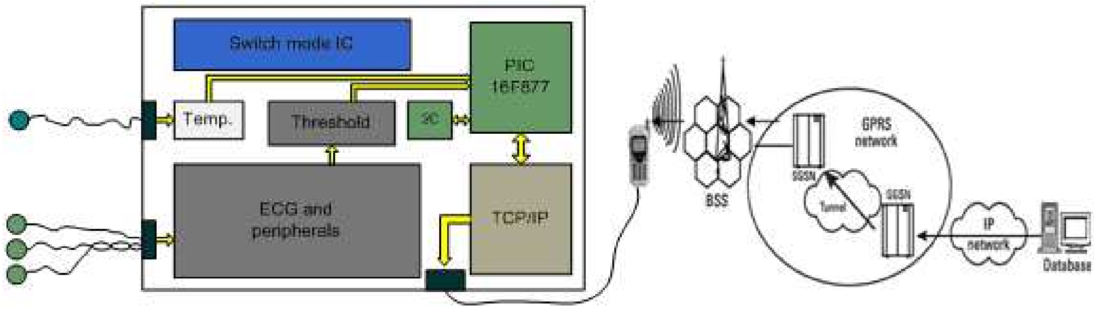

Figure 3.1 Complete system architecture of the designed system

3.1 Analog Part

3.1.1 Instrumentation

The key component of the hardware design is ECG circuit and its peripherals. The analog front end uses the typical approach with an instrumentation amplifier (IA). In the center of single channel ECG circuit an Analog Device's micropower, high performance (90db CMRR at G=1), programmable DS8221 IC instrumentation amplifier (Fig. 3.2) is used to obtain reliable ecg signal from body. Low voltage offset, low offset drift, low gain drift, high gain accuracy, and high CMRR make this part an excellent choice in applications that demand the best DC performance possible. Nearly it has 50mV max offset voltage, low input bias current (0.5 nA max), and low input voltage noise (70V). Design which uses tiny surface-mount components in order to minimize noise and current draw SOIC packet form was chosen.

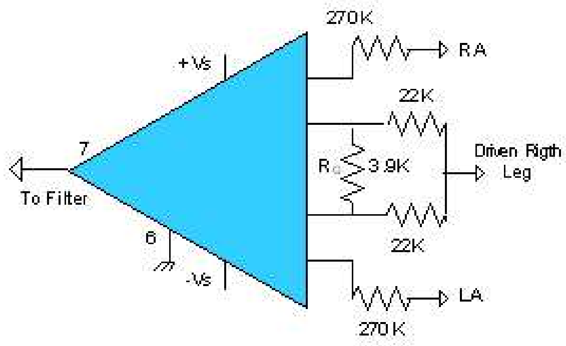

Figure 3.2 DS8221 configuration

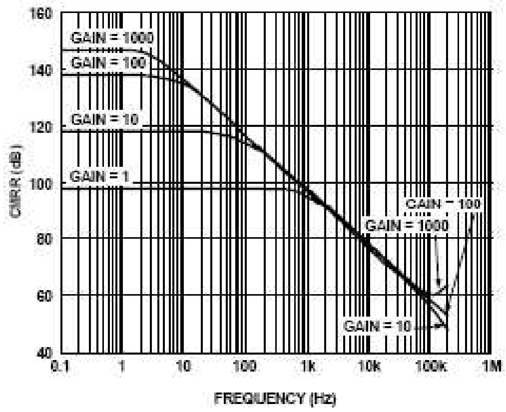

Figure 3.3 CMRR v.s. frequency of DS8221

The DS8221 requires only a single external gain-setting resistor,RG, for a gain of [Gain = 1 + 49.4k/RG]. To avoid output saturation, the usable gain is limited by the output swing and the maximum input voltage to the IA. According to the output voltage swing(V) versus supply voltage(V) graphic the amplification of the IA is limited with 13.77 [Gain = 1 + 49.4k/3.9k]. With a ±5V power supply, the output swing of the DS8221 is about ±4.2V; and the maximum input is ±5 mV plus a variable DC offset of up to ±300 mV, allowing a maximum gain of 13.77. Here, the gain is conservatively set to 13.66 (±1%), using RG = 3.9K ohms. In spite of the swing voltage, value of RG is chosen 510ohm and total amplification is set to about 98. Because, DC component of amplified signal is removed by HPF. Another important parameter is power consumption. Since the design is mobile and battery powered circuit we had to consider power consumption. DS8221 is well performanced IC in that way too because it is just sank 1mA. After receiving very low amplitude (1-5mV) ECG signals via

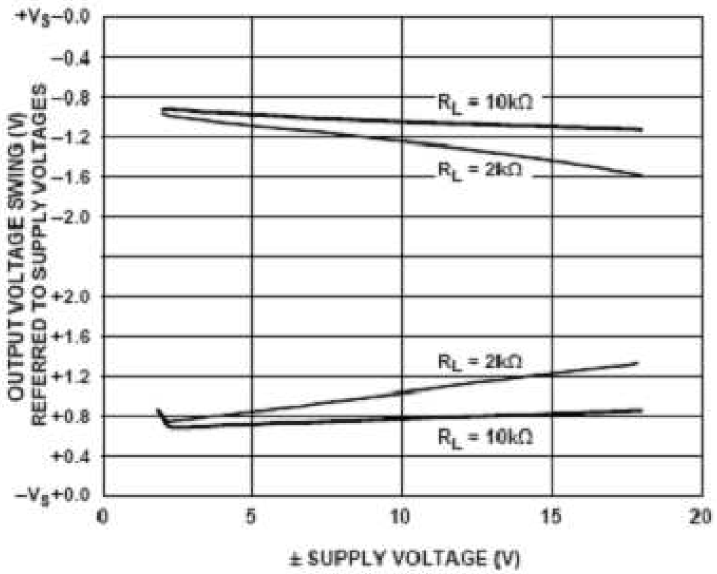

Figure 3.4 Swing rate of DS8221

shielded and twisted pair cable, these signals are sent to instrumentation amplifier.

3.1.2 Driven Right Leg and Guarding Circuit

The op amp used in the right-leg common-mode feedback circuit and guarding circuit is an Analog Device's dual opamp OP297. It is a low-power, high-precision operational amplifier with extremely high common-mode rejection (120 dB minimum).

This circuit applies an inverted version of the common-mode interference to the subject's right leg, with the aim of canceling the interference. The op amp has a voltage gain of 45.5, [R_1/22k = 1Mohm/22 k ohm], with a low-pass cutoff at about 130 Hz for stability [f = 1/(2 π x 12 k ohms x 100nF)]. This frequency is chosen higher that the acquisition frequency which is 100Hz.

Since guarded signal path will be a key contributor to successful in low current measurements desing there has been desined a guarding circuit. The driven guard output on a typical low current measurement designs provides a buffered output voltage that follows the source output. Since the voltage difference between the signal path

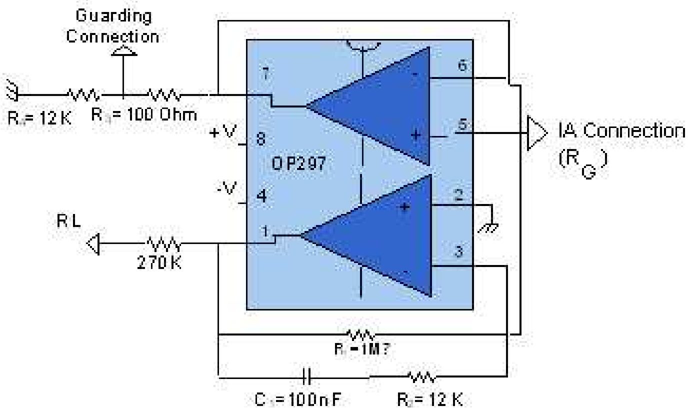

Figure 3.5 Driven right leg and guarding configuration

and guard shield will be nearly zero, the leakage current through the isolation will be maintained at very low levels. Charging delay (settling time) of the signal line will be substantially reduced for the same reason.

Shielding minimizes the amount of interference induced into a measurement circuit as the result of electromagnetic fields. In simplest terms a shield consists of an enclosure around the component being measured and this enclosure is usually connected to ground. Because of that theoretical background shielded and twisted cables are used to connect to body electrodes.

Measurements referenced to ground are subject to influence by what is generally called common-mode sources (potential differences between the measured device and the measuring reference). Guarding techniques help minimize the effects of these common-mode sources.

3.1.3 Filters

Because of the tolerance and the physical constrains of the components that have been used in this thesis are measured one by one before implementing them into circuit. Especially in filters tolerances are very important because little change in value may cause severe shift in frequency response of filter.

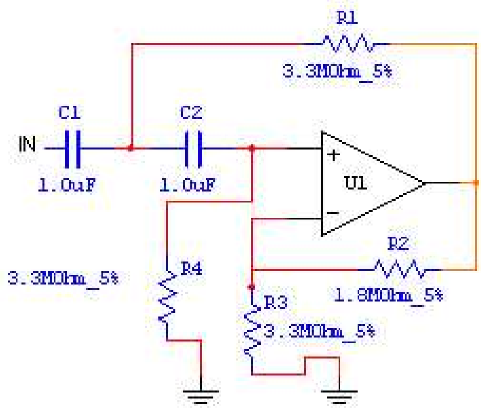

Figure 3.6 High pass filter configuration

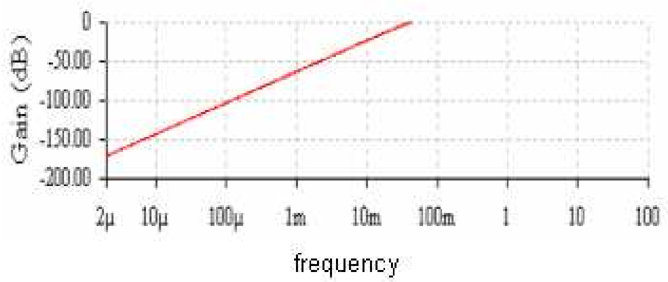

Figure 3.7 Frequency response of the used high pass filter (MultiSIM)

3.1.3.1 High Pass Filters. HP filters are essential especially for get rid of unwanted dc component of the ECG signals. Here it is used 3th order butterworth active filter. Designed filter's cut-off frequency is 0.05Hz and its frequency response is as illustrated in Figure 3.7.

3.1.3.2 Low Pass Filters. It is seen the used active filter configuration and its frequency response of active filter. Since the ECG signal is contained in the relatively narrow frequency spectrum below 100Hz, a low pass filter can remove a large amount of ambient noise. With microprocessors and an RF transmitter in close proximity to the analogue circuitry, the low pass filter is responsible for ensuring these do not detrimentally affect the ECG obtained. The low pass filter implemented is shown in Figure 3.8. It is a 3th order active Butterworth filter. The corner frequency is calculated to be 105Hz. It is chosen as unit gain. Figure 3.9 shows the frequency response of the filter as generated by MultiSIM.

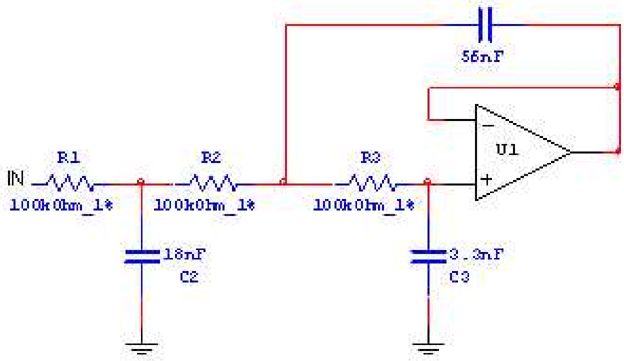

Figure 3.8 Low pass filter configuration

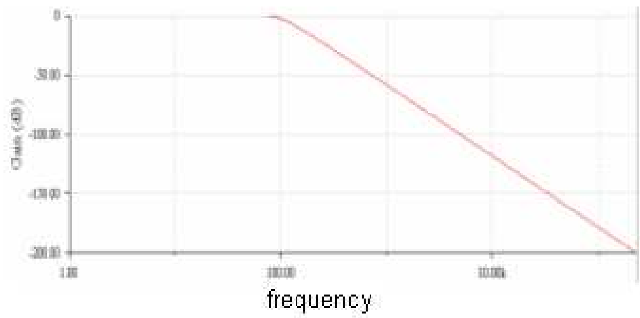

Figure 3.9 Frequency response of the used low pass filter (MultiSIM)

3.1.3.3 Notch Filter. As is it know mains power noise is the biggest problem for normal ECG measurement, and especially so in this system due to the unsuitability of right leg driver circuitry. In order to combat this, a notch filter is implemented ($F_c = (1/(2\pi R_4 \times 9.4nF))$. The depth of the notch depends greatly on accurate components and much effort is required to identify capacitors which give good attenuation at the correct frequency.

Capacitors C4, C2 provide 9.4nf and provides the value of band pass frequency which is 50Hz. In simulation and in practice capacitor couple of C4 and C2 when adjusted 9.3nF gives better suppression for 50Hz. The rejection quality could be easily improved by decreasing R3, but is not easy to implement because a narrower filtering bandwidth requires more accurate components determining the bandwidth. Adjusting R1 and R3 resistor can give better suppression result but on the other hand limits of suppression is enlarged and caused extra rejection neighbor frequencies. Quality factor

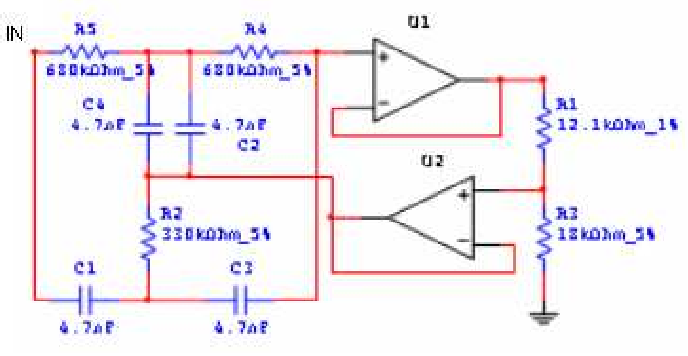

Figure 3.10 Notch filter

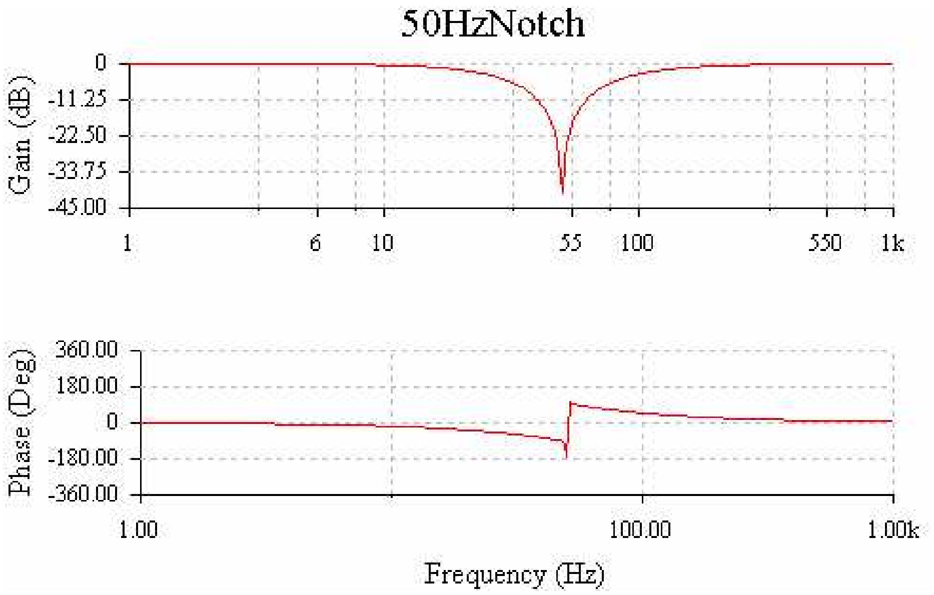

Figure 3.11 Frequency response of notch filter (MultiSIM)

is define $Q = 1/2(1 - R1/R3)$ and $Q = 1.5$.

3.1.4 Summing Amplifier

Before sending the filtered data to the PIC's ADC module a summing amplifier designed to shift the ECG signal between 0V to 5V. After this shifting, the data is ready to be digitized by the ADC. The ADC requires the signal it is sampling to be contained completely in the positive voltage domain. The summing amplifier is used to achieve this and its topology is shown in Figure 3.12. The DC voltage that the

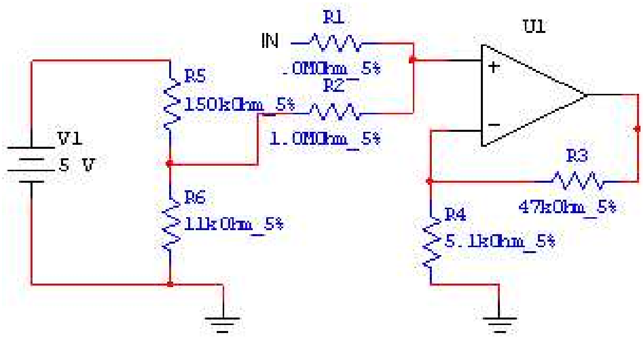

Figure 3.12 Summing amplifier

signal will be added to is supplied by the voltage divider formed with two 150k and 11k resistors. The other resistors set the gain of the amplifier to be about 11K, and the other resistors are chosen very larger so they don't influence the voltage division. R1 receive the ECG signal which is coming from filter circuits.

3.1.5 R wave detection

In order to display whether electrodes are well plugged or to give operation sense to user there is placed a flash circuit which determines the R waves of ECG. Designed circuit works in comparator mode and compares the define value which is set by voltage (3V) divider as illustrated below. The output of the summing amplifier is connected to

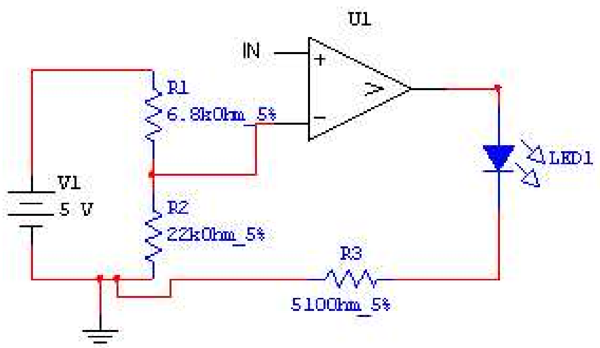

Figure 3.13 R wave detection circuit

both comparator's positive lead and PIC's ADC inputs. Since the comparator negative input's impedance is very high there can not be voltage drop or signal lost.

3.1.6 Supply Units

In this part of the project an Analog Device's SOIC packet Switch Mode Power Supply IC is used for acquiring -5V regulated voltage for the analog circuit. ADP3605 is a 120 mA regulated output switched capacitor voltage inverter. It provides a regulated output voltage with minimum voltage loss and requires a minimum number of external components. In addition, the ADP3605 does not require the use of an inductor. For

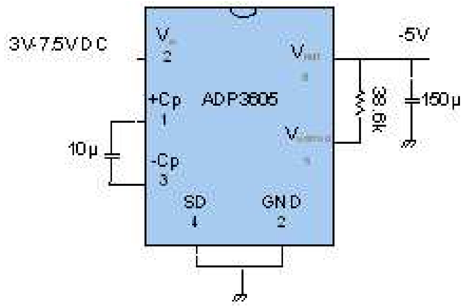

Figure 3.14 -5 V power supply circuit

the adjustable version of the ADP3605, the regulated output voltage is programmed by a resistor which is calculated inserted between the VSENSE and VOUT pins, as illustrated in Figure 3.14. The inherent limit of the output voltage of a single inverting charge pump stage is -1 times the input voltage. The value of output voltage is calculated by this formula Vout = (1.5/9.5K)R. Positive power requirement is supported by

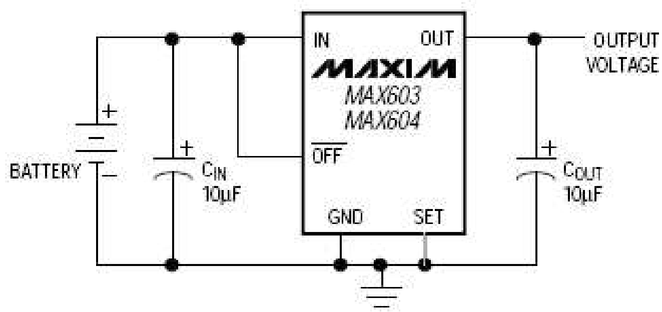

Figure 3.15 +5 V power supply circuit

Maxim's 5V adjustable, low dropout, 500mA linear regulator. Its input voltage range is 2.7-11.5 volt.

Generally in mobile solution minimum power consumption is important because it allows small sized batteries to be used as power supply in our case 9V, 250mAh standard battery. This is of course essential if the amplifier module is used in ambulant recordings but can present some important advantages in stationary measurement systems as well. In a system which is powered by the mains supply by the use of an isolation transformer which means extra space and weight, most of the capacitance across the isolation barrier is usually caused by the power supply. A small battery-powered amplifier to have very small capacitance to the environment, resulting in a low common mode voltage.

Another advantage is the greatly improved safety because there are no high voltages present in the amplifier cabinet. Finally, batteries deliver a very “clean” supply voltage which is essential for low-noise operation. Mains supply voltages are often polluted with a lot of high-frequency interference (spikes).

3.1.7 A Sample ECG Data

A snapshot of the ECG data viewed on oscilloscope screen is given in Figure 3.16.

3.2 Digital Part

3.2.1 PIC16F877

Whole digital processes such as communication(RS232), storage(I2C), ADC and 1-Wired Bus protocols are carried out by PIC microcontroller. Microchip’s 16F877 is a 8 bit 20Mhz microcontroller. It posses 8KByte Rom, HW RS232, 8 channel 10 bit ADC and HW I2C port. These properties are very essential for this study. During the development and TTL/RS232 converter(MAX232) IC was used.

Figure 3.16 A snapshot of the ECG data viewed on oscilloscope screen

3.2.2 ADC

ADC is configured 10 bit resolution and 2ms sampling rate which is very enough to digitizy the ECG data. Sampling rate is limited with 20KHz which means vey high from our sampling rate. Port selection is configured in assembly program using related register(A/D Control Register0 (ADCON0) and A/D Control Register1 (ADCON1) sets the function of the port pins. The upper eight bits of the sample are stored in the A/D Result High Register (ADRESH)). Since the ADC is 10bit, acquired digital data is written to ADRESH in Bank0 at 1Eh and ADRESl in Bank1 at 9Eh. Before use ADC realted port(RA) must be chosen as adc and then a suitable mask value multiplied with ADCON0. then just by set GO value to 1, conversion begin. after each conversion LSB and MSB byte of 10 bit of ADC is read from its address by taking care of bank adsress. ADC are in TRISA port for example TRISA = 00000001 sets portA pin 0 as input, all others output. Speed of acqusition is justify by timer.

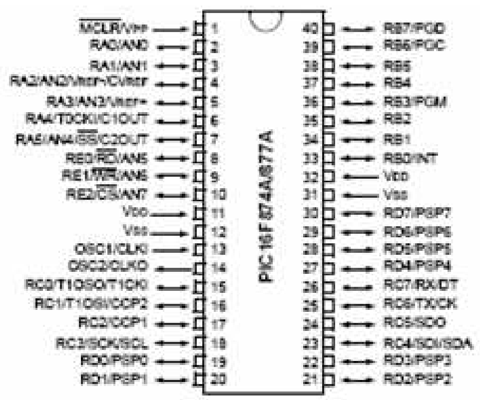

Figure 3.17 PIC16F877 pin diagram

3.2.3 RS232

RS232 port is used to communicate with TCP/IP chip. The speed of RS232 is set 19200 because of TCP/IP chip. Required setting are set via TRISC register because the RS232 port is in C port. To make that port anable it must be set to that a mask value is multiplied by suitable mask.In C port RC6 is transmit and RC7 is receive port because of that before using these ports they must be enabled. Just by writing TRISC=11000000 we make the RS232 enable, after that there is no need to deal with protokol of RS232.

3.2.4 I2C port

Although 16F877 has its own EEPROM it is not enough large for writing more than 256 byte. There fore an external 512kbit EEPROM is chosen and driven. By using this module it could be possible to store more than 60seconds ECG data before sending them to center node.

This port is used to communicate with a EEPROM. It is also a HW por there fore it is easy to use and it is controlled by SSPSTAT, SSPCON1 and SSPCON2 registers. Generally microcontrollers are set as master and other peripherals are set as slave before beginning to data transfer.

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	U-0	R/W-0
ADCS1	ADCS0	CHS2	CHS1	CHS0	GO/$\overline{DONE}$	—	ADON
bit 7							bit 0

bit 7-6 **ADCS1:ADCS0**: A/D Conversion Clock Select bits (ADCON0 bits in **bold**)

ADCON1 <ADCS2>	ADCON0 <ADCS1:ADCS0>	Clock Conversion
0	**00**	Fosc/2
0	**01**	Fosc/8
0	**10**	Fosc/32
0	**11**	FRC (clock derived from the internal A/D RC oscillator)
1	**00**	Fosc/4
1	**01**	Fosc/16
1	**10**	Fosc/64
1	**11**	FRC (clock derived from the internal A/D RC oscillator)

bit 5-3 **CHS2:CHS0**: Analog Channel Select bits
000 = Channel 0 (AN0)
001 = Channel 1 (AN1)
010 = Channel 2 (AN2)
011 = Channel 3 (AN3)
100 = Channel 4 (AN4)
101 = Channel 5 (AN5)
110 = Channel 6 (AN6)
111 = Channel 7 (AN7)

Note: The PIC16F873A/876A devices only implement A/D channels 0 through 4; the unimplemented selections are reserved. Do not select any unimplemented channels with these devices.

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

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

bit 0 **ADON**: A/D On bit
1 = A/D converter module is powered up
0 = A/D converter module is shut-off and consumes no operating current

Figure 3.18 ADC register configuration

The Master Synchronous Serial Port (MSSP) module is a serial interface, useful for communicating with otherperipheral or microcontroller devices. These peripheral devices may be serial EEPROMs which is our case, shift registers, display drivers, A/D converters, etc. The MSSP module can operate in one of two modes: o Seria Peripheral Interface (SPI) o Inter-Integrated Circuit (I2C) - Full Master mode - Slave mode (with general address call) The I2C interface supports the following modes in hardware: o Master mode o Multi-Master mode o Slave mode

3.2.5 1-Wire Bus

As it seen it is know it is a one wire signaling protocol and has time intervals to communicate devices. DS1820 is the device that we to communicate in order to make it possible 1-wire protocol must be functioned perfect. This temprature senser not only a sensor but also it is an IC,it means it calculates the value of temprature for you and send it to you. It has 0.5C0 resolution which is enough for outdoor measurement.Since our aim is to design a mobile general telemedicine device this value gives us filtered value inherently.

3.2.6 TCP/IP Chip

It is mostly esed in to communication and its control is perfprmed by AT command which are used by computer to communicate with modem. In that desing modem is embedded into mobile phone before sending data modem must be ready. This chip justfy the settings of modem for example data transfer rate, connection IP, user name and password check. It consist of 1kbyte buffer before sending data it waits until buffer is full of then send them to related IP.

3.2.7 I2C port

GPRS connection is carried out by this chip and management of session controlled by that chip. PIC controller controls that chip and make the data ready for it and set it to TCP/IP chip.

3.3 SOFTWARE OF THE SYSTEM

In the center a pc assigned for that project and installed on that MS Advance Server together with Internet Information Server(IIS). Since the pc located in campus and its IP had to be open to connection of http in order to do that number 80 port has been made enable in campus firewall software.

In next step a data base table designed in Access which consist of two parameter ECG and body temperature. According to our design after data acquisition and session procedures are complete data is sent 1kbyte by 1 kbyte and 512kbit of data will be sent in 64 times. First ECG data will be sent then temperature.

When ECG data arrives it will bear a data type information by knowing that, data will be written into related data base. In the same manner sequential temperature data are written into related data base.

After writing process complete the program which has been coded in ASP environment will display them as in their own nature.

This system aimed to design more that one user therefore it is possible to used by multiple users by taking care of their user name and password.

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R-0	R-0	R-x
SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D
bit 7							bit 0

bit 7 **SPEN:** Serial Port Enable bit
1 = Serial port enabled (configures RC7/RX/DT and RC6/TX/CK pins as serial port pins)
0 = Serial port disabled

bit 6 **RX9**: 9-bit Receive Enable bit
1 = Selects 9-bit reception
0 = Selects 8-bit reception

bit 5 **SREN**: Single Receive Enable bit
Asynchronous mode:
Don't care.
Synchronous mode – Master:
1 = Enables single receive
0 = Disables single receive
This bit is cleared after reception is complete.
Synchronous mode – Slave:
Don't care.

bit 4 **CREN**: Continuous Receive Enable bit
Asynchronous mode:
1 = Enables continuous receive
0 = Disables continuous receive
Synchronous mode:
1 = Enables continuous receive until enable bit CREN is cleared (CREN overrides SREN)
0 = Disables continuous receive

bit 3 **ADDEN:** Address Detect Enable bit
Asynchronous mode 9-bit (RX9 = 1):
1 = Enables address detection, enables interrupt and load of the receive buffer when RSR<8> is set
0 = Disables address detection, all bytes are received and ninth bit can be used as parity bit

bit 2 **FERR**: Framing Error bit
1 = Framing error (can be updated by reading RCREG register and receive next valid byte)
0 = No framing error

bit 1 **OERR**: Overrun Error bit
1 = Overrun error (can be cleared by clearing bit CREN)
0 = No overrun error

bit 0 **RX9D:** 9th bit of Received Data (can be parity bit but must be calculated by user firmware)

Figure 3.19 RS232 register configuration

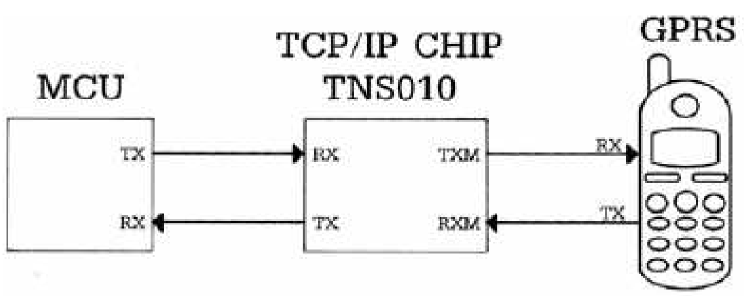

Figure 3.20 General TCP/IP usage concept

4. RESULTS AND FUTURE CONSIDERATIONS

4.1 Hardware

One channel 3 leads ECG signal acquisition system was successful implemented and acquired and stored signals were successfully sent to the target node as it was intended. The design of ECG circuit meets the reliability and linearity requirements of a accurate ECG design. Figures 4.1 shows typical result of ECG circuit composed of filtered and shifted signal into 0-5V domain and 3 seconds pulse response of the design.

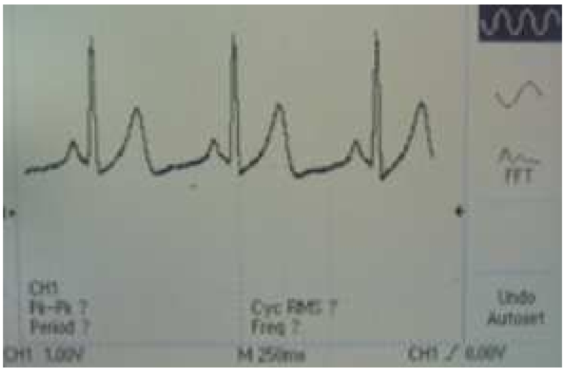

Figure 4.1 Result of ECG and summing circuit output

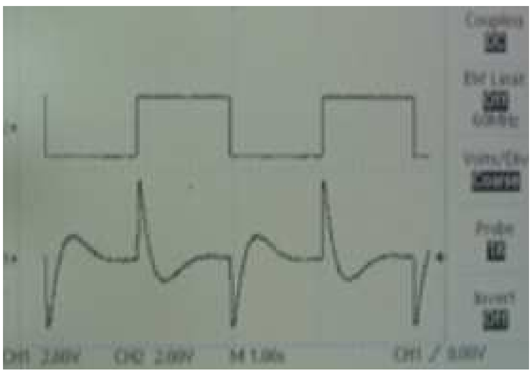

Figure 4.2 Pulse response of filter circuit

To do that whole components of the design were measured one by one to obtain best performance and frequency response. This consideration especially implemented in the filter circuits. Through careful trial and selection of capacitors and resistors, 50Hz notch filters were created that closely match the performance obtained in MultiSIM simulations. Figures 4.3 and 4.4 demonstrate the performance of the notch filters with a 50Hz signal shown greatly attenuated on an oscilloscope and signal source and its set value for notch filter.

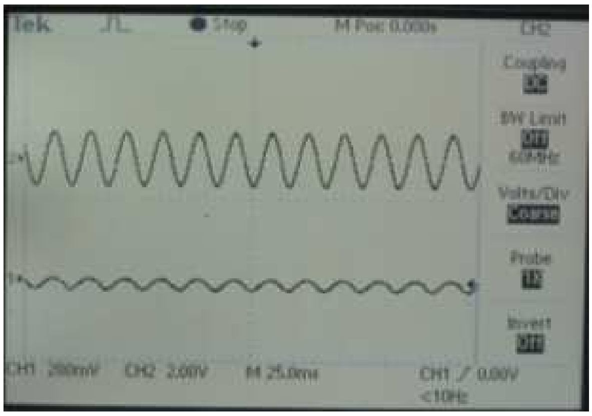

Figure 4.3 Notch filter response

Figure 4.4 Notch filter input frequency

Sampled frequency response of analog blok of the system is very close in pattern and similar to MultiSIM Bode Diagram. Figures 4.5 and 4.6 show the correlation between frequency and attenuation characteristic of the HPF, Notch and LPF.

Since the intended design is mobile, size and power consumption were ones of main concern in design period. Because of that active and passive circuit components were selected in SMD form. ICs were selected according to their technical specifications. The size of the PCB restricted in 5x9cm and total power consumtion is less than 120mA.

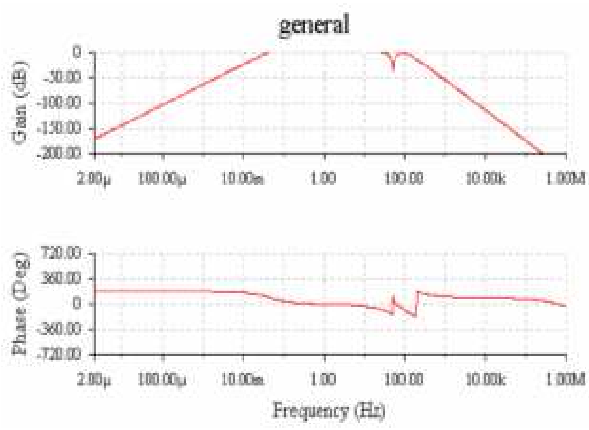

Figure 4.5 General frequency response of filter circuits (MultiSIM)

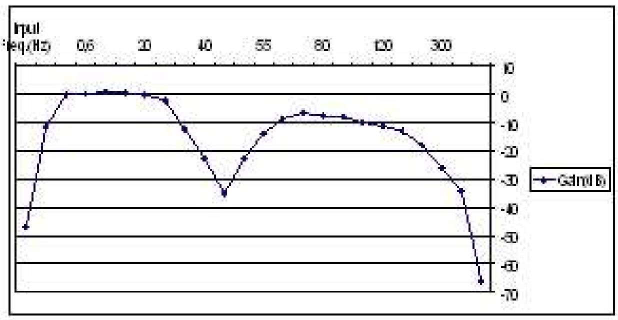

Figure 4.6 Real response of filter circuits

4.2 Software

All facets of the PIC and PC based software and database configuration were operated correctly. Timing and order of the process of data bearing and initiating of GPRS services were performed correctly. Sampling rate and resolution used in design 500Hz(2ms ps) and 10bit respectively. According to these parameter it is produced 5kbps data but the this data covers 8kbit in EEPROM because 10bit corresponds to 2byte in EEPROM. Thus total data storage lates more than 60s.

The acquired and stored data is sent in packet form 256byte once a time and sent 12 second periodically.

Successful A/D conversion and communication with the other components in

Figure 4.7 Picture of hardware

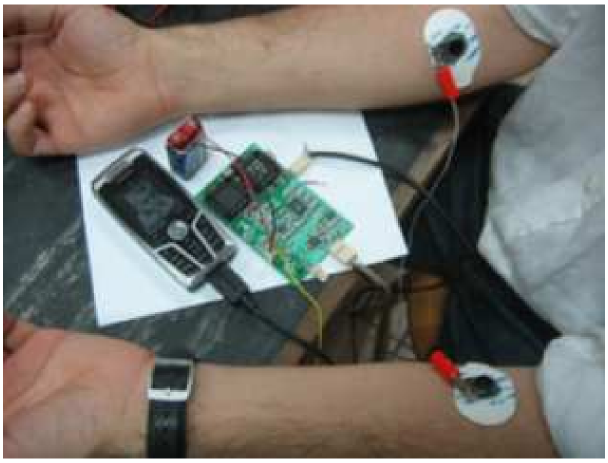

Figure 4.8 Typical application of the designed hardware

the design is evidenced through the eventual signal display on the PC (Figures 4.7 and 4.8). Below we see same of 10Hz Square Wave and Sin Wave and three different ECG signal samples which were acquired three different person. It was proven that GPRS based data transmission is possible in terms of biological signals and again we succeeded in integrating acquisition of a bio-signal system and bering system using personal mobile phone's GPRS modem for a telemedicine application. It is clear that using a mobile phone's GPRS modem makes this system efficient for patient to be used in comfort.

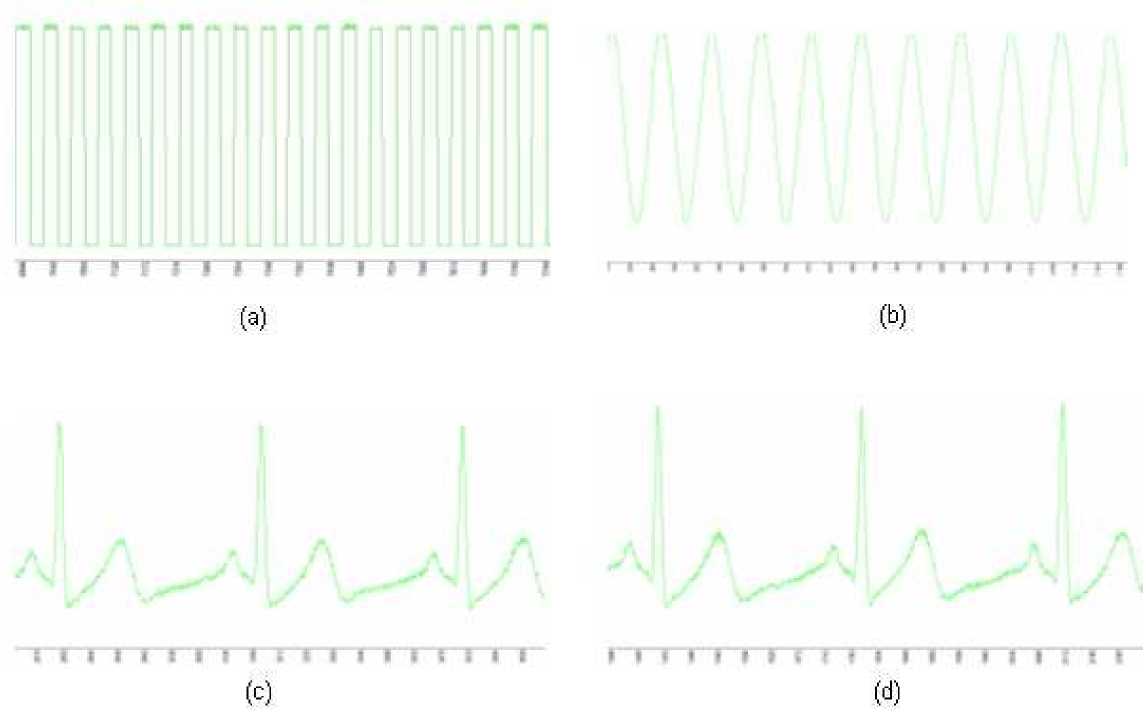

Figure 4.9 a) Sinus sample at 10 Hz, b) Square wave sample at 10 Hz, c) Typical ECG 1, d) Typical ECG 2

4.3 Future Considerations

It is evident that a lot of work and improvements in all part of the system are required before the ultimate goal of a miniature completely GPRS based ECG system can be reached. This section seeks to detail some of the more important required improvements and recommend ways to go about implementing them.

Investigating the implementation of metal based stainless electrodes in that application. Thus either cable's destructive effects or complicates are gotten rid of.

Since the system is mobile power consumption gains importance, in that respect choosing less consume PIC will be next step towards more efficient system. Another point is to choose 16bit microcontroller to add digital signal processing property to the system. Signal averaging, digital filters and some data compression algorithms would be more efficient with 16bit microcontroler.

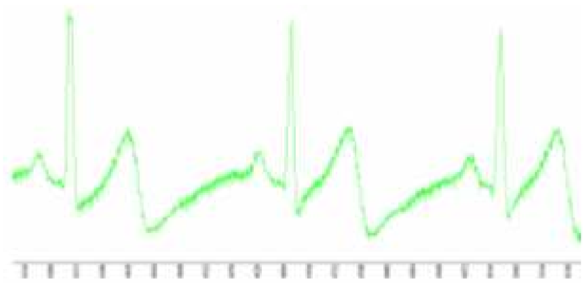

Figure 4.10 Another typical ECG

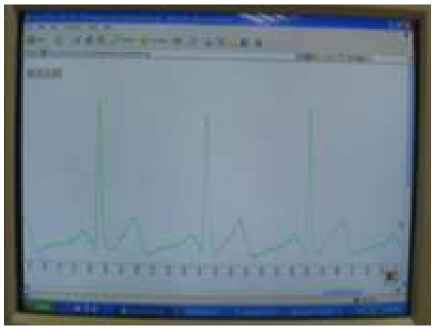

Figure 4.11 Sketch from internet server view

Reducing the size of PCB makes the design more usable and bering together with patient. Adding efficient high resolution LCD display would be better for giving a sense to patient about the current situation of bio-signals.

In the server side, the chart graphic and code works behind the graphic can be developed multifunctionaly. In base side data base can be configured in SQL by doing this very vast and multi user data quering or processing would be more efficient and more dynamic. QRS complex parameter can be automatically visualized on graphic just by pointing the related region.

5. CONCLUSION

The result of this project is showed that GPRS based telemedicine systems are possible and has big potential especially with the 3G GSM or UMTS, because with these technologies, real time data transfer or even video data will be possible to transfer via user mobile phone.

Another important result is, without spending to much money it is possible to implement personal monitoring device and system for patients without interrupting their life of quality. A little biological signal capture device which will not be restrict the user movement and connection to personal mobile phone is enough.

This study failed in developing noise independent mobile ECG. But has been taken some steps toward inventing a methodology that will prove the feasibility of mobile ECG. Future researchers into the problem should be done to make more stable and better ECG accusation system.

It is shown that in contrast to ECG holter devices there is no need to a PSTN line. Due to this fact it is a big step towards development to life of quality of patience.

APPENDIX A. PIC CODE

```
    list p=16f877
    __FUSES _CP_OFF&_WDT_OFF&_XT_OSC&_PWRTE_OFF&_LVP_OFF&_BODEN_OFF
; __CONFIG _CP_OFF & _DEBUG_OFF & _WRT_ENABLE_OFF & _CPD_OFF &
_LVP_OFF & _BODEN_OFF & _PWRTE_ON & _WDT_OFF & _XT_OSC


#define CTRLIN  H'A0'           ;I2C value for CONTROL BYTE when
INputin data to the EEPROM #define CTRLOUT H'A1'      ;I2C value
for CONTROL BYTE when requesting OUTput from the EEPROM

#define BAUD        D'100'      ;Desired Baud Rate in kbps #define
FOSC        D'10000'    ;Osciallator Clock in KHz

#define ADC_RA0         B'10000001' ;AN0

#define _C      STATUS,C #define _Z      STATUS,Z

#define Bank0   bcf STATUS,RP0 #define Bank1   bsf STATUS,RP0

#define DQ      4   ; 1-Wire Data Bus    -> PORTB<4>

#include <p16f877.inc>      ;Processor Include file, for standart
names

    CBLOCK 0x20

    Adres_H, Adres_L, DATA8, temp, PageCounter, Counter256, SAYI,
    Num counter3s
```

```
    ADC_H, ADC_L
    counter256
    CounterA
    CounterB

        counter750ms
        DS_TRMT
        DS_RECV
        DS_BITNO

        COUNT
        TEMP_L
        TEMP_H

    ENDC

    CBLOCK  0x70
        DS_COUNT
    ENDC

SEND    MACRO   SAYI
        movlw   SAYI
        call    Send
        ENDM


ORG 0                       ; Start of code (location 0)

;****   Setup I/O   ****

    clrf        PORTB       ;PROTB pins set to drive low when enabled
    Bank1
```

```
;   MOVLW   B'00000010' ;   MOVWF   OPTION_REG  ; PORTB pull-up
enabled, RB0 int disabled, TMR0 clock source is internal, ykselen
kenar , Prescalar is assigned to TMR0 1:4

    movlw       0xFF        ; ADC iin INPUT
    movwf       TRISA       ;
    movlw       B'10011000' ; RC3, RC4 are inputs for PORTC
    movwf       TRISC       ; RC7<-- RX,  RC6--> TX
    clrf        TRISB       ; all PORTB pins conf. for output mode
    clrf    TRISD           ;

    movlw   B'00100100'     ; Asenkron hab., High sp., Enable trans.
    movwf   TXSTA
    movlw   .31
    movwf   SPBRG       ; 19200 baud ( 10 Mhz iin 19200 baud )
    movlw   B'11000000' ; Right justify,1 analog channel
    movwf   ADCON1      ; VDD and VSS references

    Bank0
    movlw   B'10010000' ; Seri port en., 9 bit disab., Receive en.
    movwf   RCSTA
    clrf    INTCON      ; interrupt enable bitleri ve bayraklar sfr.
    bsf     INTCON,GIE      ; 7 1 Enable all un-masked interrupts
    bsf INTCON, PEIE    ; Enable PERIPHERAL interrupts.

    movlw   ADC_RA0
    movwf   ADCON0      ; Kanal 0 seiliyor.


    call Delay3s

    #include "InitGPRS.asm"
```

```
main ;********************************
    #include "I2Cwrite.asm"
I2CwriteOK

    clrf    CounterA    ; 128 kere dnecek
Dongu256
    clrf    CounterB

    #include "GPRS.asm"

Dongu256_paket
    movf    CounterA,w  ;
    movwf   Adres_H
    movf    CounterB,w  ; Adres = CounterA : CounterB
    movwf   Adres_L

    movlw   HIGH    ASCIITablo
    movwf   PCLATH

    #include "I2Cread.asm"
    movwf   SAYI
    swapf   SAYI,w
    andlw   0x0F
    call    ASCIITablo
    movwf   TXREG       ; 8 bitlik bir sayi-->ACCII yapan
    call    Delay1ms

    movf    SAYI,w
    andlw   0x0F
```

```
    call    ASCIITablo
    movwf   TXREG       ; 8 bitlik bir sayi-->ACCII yapan
    call    Delay1ms

    incf    CounterB,f
    btfss   STATUS,Z
    goto    Dongu256_paket
    movlw   .13
    movwf   TXREG

    call    Delay3s
    call    Delay3s
    call    Delay3s
    call    Delay3s
    call    Delay3s
    call    Delay3s
    call    Delay3s



    incf    CounterA,f
    btfss   STATUS,Z
    goto    Dongu256

Tamam256
    call    ReadT
    goto    $-1

    call    ReadT
    goto    $-1

    call    ReadT
    goto    $-1
```

```
    goto    SON


;****SUBROUTINES & ERROR HANDLERS**** I2CFail
    bsf     SSPCON2,PEN ;Send STOP condition
    call        WaitMSSP    ;Wait for I2C operation to complete
    movlw       B'10101010'
    movwf       PORTB       ;
    goto        $


WaitMSSP
    Bank0

WaitMSSP1
    bsf PORTB,7
    bcf PORTB,7
    btfss   PIR1,SSPIF      ;Check if done with I2C operation
    goto    WaitMSSP1

    bcf PIR1,SSPIF      ;I2C module is ready, clear flag
    Retlw   0           ;Done, Return 0


Send ;******************************************************
    movwf   TXREG
    call    Delay1ms
    return


Delay1ms    clrf    temp
```

```
        NOP
        NOP
        NOP
        NOP
        NOP
        NOP
        NOP
        NOP
        NOP
        DECFSZ  temp,f
        GOTO    $-9
        return

Delay2ms    call    Delay1ms
        call    Delay1ms
        return

Delay4ms    call    Delay1ms
        call    Delay1ms
        call    Delay1ms
        call    Delay1ms
        return


Delay3s     clrf    counter3s Delay3sTekrar   call    Delay1ms
        call    Delay1ms
        call    Delay1ms
        call    Delay1ms
        call    Delay1ms
        call    Delay1ms
        call    Delay1ms
        call    Delay1ms
```

```
        call    Delay1ms
        call    Delay1ms
        call    Delay1ms
        call    Delay1ms
        decfsz  counter3s,f
        GOTO    Delay3sTekrar
        return

Delay1s     clrf    Num Delay1sTekrar   call    Delay1ms
        call    Delay1ms
        call    Delay1ms
        call    Delay1ms
        decfsz  Num,f
        GOTO    Delay1sTekrar
        return



    #include "OneWire.asm"

ASCIITablo
    addwf   PCL,f
    retlw   '0'
    retlw   '1'
    retlw   '2'
    retlw   '3'
    retlw   '4'
    retlw   '5'
    retlw   '6'
    retlw   '7'
    retlw   '8'
    retlw   '9'
```

```
    retlw   'A'
    retlw   'B'
    retlw   'C'
    retlw   'D'
    retlw   'E'
    retlw   'F

SON

    end
```

APPENDIX B. ASP CODE

```
<html> <head> <title> Result of Database Query</title> </head>
<body> <h1>Connection Succeeded</h1>

<%
set myconn = server.createobject("adodb.connection") set
rs=server.createobject("adodb.recordset")

connection="Data Source="
connection="Provider=Microsoft.Jet.OLEDB.4.0;Data Source="  &
server.mappath("yuksel.mdb")  & ";Persist Security Info=False"

'connection="dsn=yuksel;uid=guest;password=atf"

call myconn.open (connection) 'rs.open "tbl_ecgdata",connection,
adopenstatic,adlockoptimistic


' line 15 ;uid=guest;password=atf set result =
server.createobject("adodb.recordset") a=Request.QueryString.Item(1)


'sql1="SELECT int_timeindex  FROM tbl_ecgdata"
'rs=myconn.Execute(sql1)


'Response.Write rs(0)

'Response.Write a 'line 20 'on error resume next
```

```
for i=1 to len(a) step 4
    response.write mid(a,i,4)


sql1="SELECT MAX(int_timeindex) as sayac1 FROM tbl_ecgdata"
 rs=myconn.execute(sql1)



'   ilksayi=0


    ilksayi=rs("sayac1")
ilksayi=ilksayi+1

'   temp=temp+cint( mid(a,i,2))

'if mid(a,i,2)="40" then 'response.write "Control char" 'else
temp1=0

if mid(a,i+1,1)="1" then temp1=16*16 elseif mid(a,i+1,1)="0" then
temp1=0 elseif mid(a,i+1,1)="2" then temp1=2*16*16 elseif
mid(a,i+1,1)="3" then temp1=3*16*16 end if

if mid(a,i+2,1)="1" then temp1=16+temp1 elseif mid(a,i+2,1)="2" then
temp1=2*16+temp1 elseif mid(a,i+2,1)="0" then temp1=temp1

elseif mid(a,i+2,1)="3" then temp1=3*16+temp1 elseif
mid(a,i+2,1)="4" then temp1=4*16+temp1 elseif mid(a,i+2,1)="5" then
temp1=5*16+temp1 elseif mid(a,i+2,1)="6" then temp1=6*16+temp1
elseif mid(a,i+2,1)="7" then temp1=7*16+temp1 elseif
mid(a,i+2,1)="8" then temp1=8*16+temp1 elseif mid(a,i+2,1)="9" then
```

```
temp1=9*16+temp1 elseif mid(a,i+2,1)="A" or mid(a,i,1)="a" then
temp1=10*16+temp1 elseif mid(a,i+2,1)="B" or mid(a,i,1)="b" then
temp1=11*16+temp1 elseif mid(a,i+2,1)="C" or mid(a,i,1)="c" then
temp1=12*16+temp1 elseif mid(a,i+2,1)="D" or mid(a,i,1)="d" then
temp1=13*16+temp1 elseif mid(a,i+2,1)="E" or mid(a,i,1)="e" then
temp1=14*16+temp1 elseif mid(a,i+2,1)="F" or mid(a,i,1)="f" then
temp1=15*16+temp1 end if


if mid(a,i+3,1)="1" then temp1=temp1+1 elseif mid(a,i+3,1)="2" then
temp1=temp1+2 elseif mid(a,i+3,1)="0" then temp1=temp1

elseif mid(a,i+3,1)="3" then temp1=temp1+3 elseif mid(a,i+3,1)="4"
then temp1=temp1+4 elseif mid(a,i+3,1)="5" then temp1=temp1+5 elseif
mid(a,i+3,1)="6" then temp1=temp1+6 elseif mid(a,i+3,1)="7" then
temp1=temp1+7 elseif mid(a,i+3,1)="8" then temp1=temp1+8 elseif
mid(a,i+3,1)="9" then temp1=temp1+9 elseif mid(a,i+3,1)="A" or
mid(a,i+1,1)="a" then temp1=temp1+10 elseif mid(a,i+3,1)="B" or
mid(a,i+1,1)="b" then temp1=temp1+11 elseif mid(a,i+3,1)="C" or
mid(a,i+1,1)="c" then temp1=temp1+12 elseif mid(a,i+3,1)="D" or
mid(a,i+1,1)="d" then temp1=temp1+13 elseif mid(a,i+3,1)="E" or
mid(a,i+1,1)="e" then temp1=temp1+14 elseif mid(a,i+3,1)="F" or
mid(a,i+1,1)="f" then temp1=temp1+15 end if



sql1="INSERT INTO tbl_ecgdata VALUES(" & ilksayi & "," & temp1 & ")"
'Response.Write sql1 'Response.end
'rs("int_ecgdata")=cint(mid(a,i,2)) 'rs.update call
myconn.Execute(sql1) 'Response.Write Response.Write "--"
Response.Write temp1
    Response.Write "--"
```

```
next



'rs.close 'set rs=nothing

%>
</p> </body>

</html>
```

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