Design of a Low Cost ECG System

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Abstract: The ECG may be monitored continuously when the patient is in emergency care, in a coronary care unit, an intensive care unit or during stress tests. In these cases only one lead, usually lead II is monitored, on a display. ECG machine is a vital part of hospitals and aid the doctors to keep track of patient's vital sign during emergency. The aim of present work is to develop a Computer based system by means of which we can non-invasively and reliably characterize a normal person and a person with heart disease. The ECG lead-II signal is taken with help of system designed. The basic bandwidth used for the ECG is from 0.05 Hz to 106 Hz. The ECG graph obtained using designed system and standard ECG graph are almost same.

General Terms: PC based medical-Electronics.

Keywords: ECG (Electrocardiogram), Lead, coronary care unit.

1. INTRODUCTION

The aim of present work is to develop a Computer based system by means of which we can non-invasively and reliably characterize a normal person and a person with heart disease. The electrocardiogram is the graphic recording or display of time variant voltage produced by the myocardium during Cardiac cycle. The electrocardiogram is used clinically is diagnosing various diseases and conditions associated with the heart. It also serves as a timing reference for other measurements. Engineers working in the medical profession are encouraged to learn as much as possible about medical and hospital practices and in particular about physiology of human body. It is only by gaining such an understanding that they can communicate intelligently with medical professionals. This interaction between the two fields has led to the development of sophisticated medical equipment and systems.

2. CIRCULATORY SYSTEM AND HEART

2.1. Heart

The heart is made of a special kind of muscle, so that it can beat automatically without having to be told to do so by the brain. The left side of the heart drives oxygen rich blood out of the aortic semi-lunar outlet valve into circulation where it is delivered to all parts of the body. Blood returns to the right side of the heart low in oxygen and high in carbon dioxide and is then pumped through the pulmonary semi-lunar pulmonic valve to the lungs to have its oxygen supply replenished before returning to the left side of the heart to begin the cycle again as shown in Figure 1.
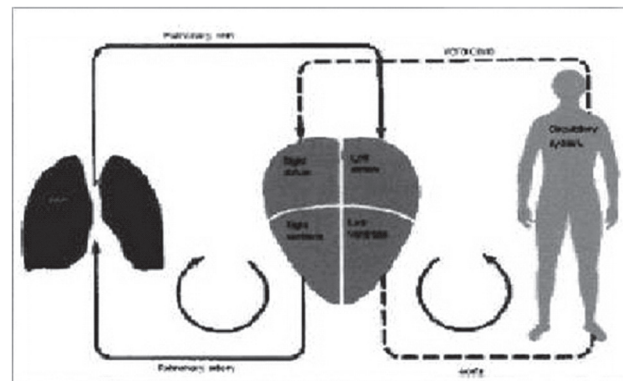

Figure 1: The Basic Cardiopulmonary

2.2. Electrocardiogram

Thefirst wave, known as the P wave, represents atrial depolarization, and is a result of the depolarization wave from the Sino atrial node (SA node) through the atria. This action precedes and is the cause of atrial contraction. The QRS complex is the result of ventricular depolarization. It is caused by the electrical activity spreading from the Atrioventricular node (AV node), through the ventricles via the Purkinje fibers, and precedes ventricle contraction. During this time, atrial repolarization is also occurring however its occurrence is usually masked by the large QRS complex being detected. Finally, the T wave occurs when the ventricles repolarize. Repolarization, is slower than depolarization, hence the T wave is usually wider than the P wave and the QRS complex as shown in Figure 2.
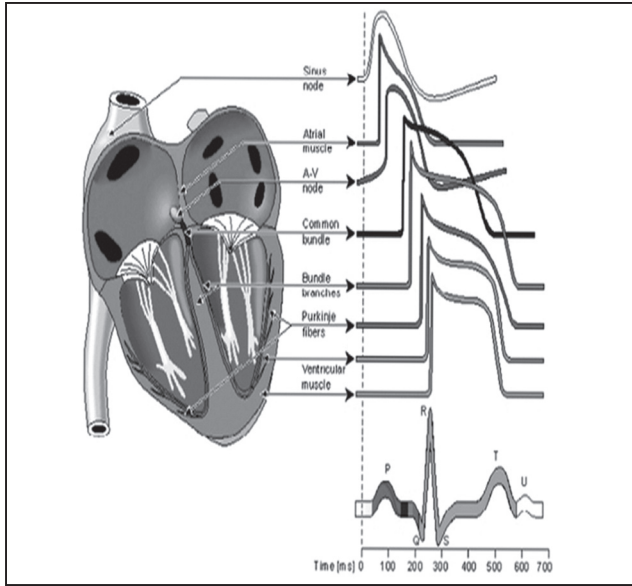
Figure 2: Electrocardiogram Signal

3. OVERVIEW OF SYSTEM

3.1. Block Diagram

Basically, this system divided into two main parts, hardware design and software design as shown in Figure 5. There are three electrodes are placed on human body in lead II configuration to capture small electrical voltage produced by contracting muscle due to each heartbeat. Two electrodes are placed each on the right wrist and left leg , while the third electrodes is placed on the ankle of the right leg as ground. The output from ECG is fed into the next stage for signal amplification and filtering purposes. Then, analog output from this stage is fed into the next stage for analog to digital conversion. Finally the digital output from ADC is sent to PC via serial port interface as shown in Figure 3.
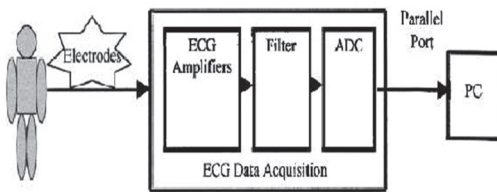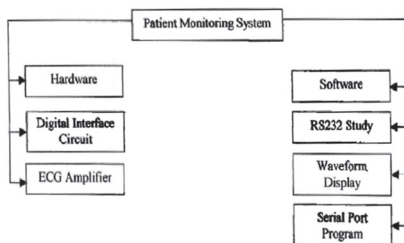

Figure 3: Block Diagram of PC Based ECG Display

Figure 4: The Structure of PC Based ECG Display

3.2. Major Component of System

The major concentration in this system is the development of the PC interface programming and waveform display program. Generally the system has two main functions that are allowing user to monitor ECG signal waveform and also have function to save the patient's information include heartbeat rate.
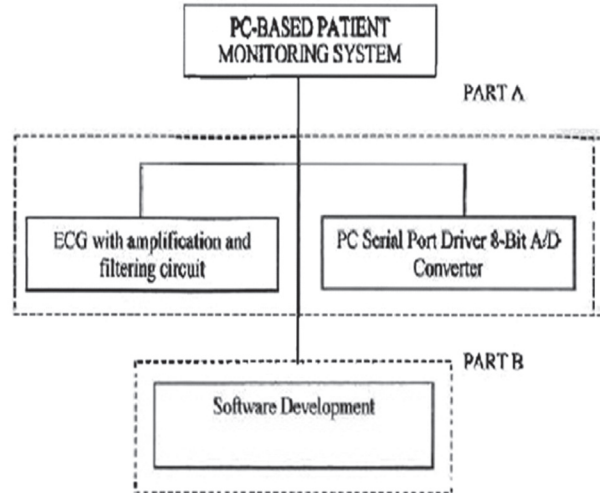

Figure 5: Major Component of PC based ECG Display

4. ECG ACQUISITION

4.1. ECG Buffer and Amplifier

ECG signal is acquired from the surface of the body using disc type floating electrodes. For ECG data acquisition AD713 is used AD713 is quad-opamp consisting of four high speed BIFET opamp having 14 pins. First two opamp are used as buffer. The input from right arm is connected to non-inverting pin of first buffer and the input from left leg is connected to non-inverting pin of second buffer for lead II configuration. The output of first buffer is connected to non-inverting pin of instrumentation amplifier AD620 and the output of the second buffer inverting pin and output of the second buffer is connected to inverting pin of instrumentation amplifier AD620 as shown in Figure 7.
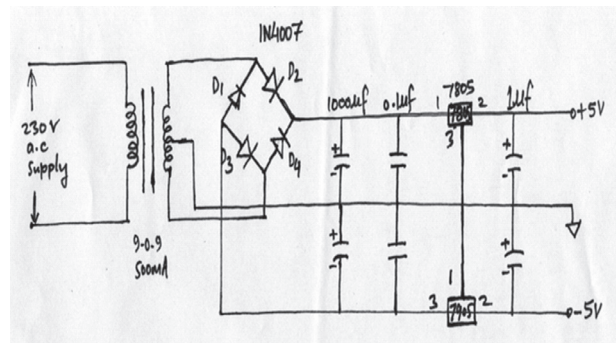

Figure 6: 5 Volt Power Supply

The gain of instrumentation amplifier can be set by resistor RG connected between pin 1 and 8 G = 49.41/1.2 + 1 = 42. RG = 1.2 k.The output of instrumentation amplifier is connected to band pass filter (opamp of AD713) for frequency band of .05 hz to 106 hz. The noise signal produced due to patient movement is by passed to ground through right leg before amplification through instrumentation amplifier. This accomplished through 4th opamp of AD 713.
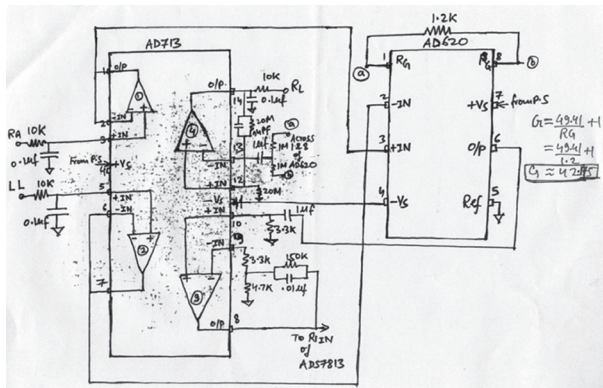

Figure 7: ECG Acquisition

4.2. Computer Interface

The out put of band pass filter is connected to pin No. 1 of ADS7813 (16 pins) as shown in Figure 8. The ADS 7813 is a low power signal +5v supply, 16 bit, sampling analog to digital converter. It contains a complete 16 bit capacitor based SAR A/D with sample hold, clock reference and serial data interface. The converter can be configured for a variety of input ranges including + 10v, +5v, 0v to 10v and 5v to 4.5. A high impendence 3v to 2.8v input range is also available (input impedance> 10 Meg Ohm.) for most input ranges, the input voltage can swing to +16.5v or -16.5v without damage to the converter.

A flexible SPI compatible serial interface allow data to be synchronized to an internal or external clock. The ADS 7813 is Specified at 40 KHz sampling rate over the 40 C to 85 C. There are four signals ADS 7813 which are required for data acquisition these are:

DATA (OUTPUT)

DCLK (INPUT)

BUSY(OUTPUT)

CONV(INPUT)

The DATA and BUSY can be connected to two transmitter pins of MAX 232 C whereas DCLK and CONV can be connected to two receiver pins of MAX 232 C. MAX 232 C is a level converter having 16 pins. The transmitter convert CMOS or TTL level to EIA 232 C level and receiver converts EIA 232 C level to CMOS or TTL level These four signals can be accessed through RS 232 C connector into the serial port of the computer.
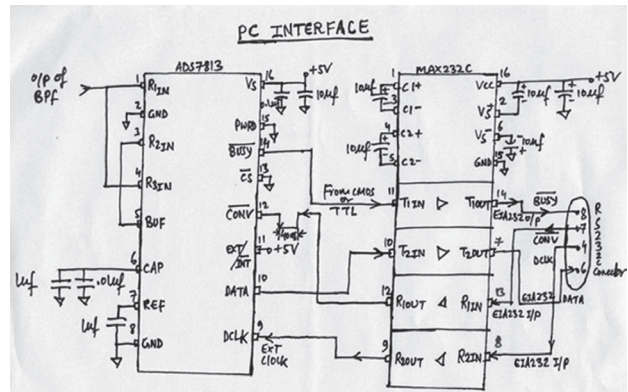

Figure 8: ADC and PC Interface

4.3. Real Time Data Acquisition

The data acquisition was done with the sound card which takes analog signals as input. Initially the data is sampled at 22 KHz. Since this much sampling is sufficient to capture the analog signal it is re-sampled so that the code does not become slow when processing the data. Real-time data acquisition supports tactical decision-making. It also supports operational reporting by allowing you to send data to the delta queue or PSA table in real-time. You then use a daemon to transfer Data Store objects to the operational Data Store layer at frequent regular intervals. The data is stored persistently in BI.The Data Source has to support real-time data acquisition. The above given components are arranged in an timely fashion. Therefore, the complete circuit diagram is shown as follows to display the standard ECG graph as shown below with the standard intervals and amplitudes.

4.4. Data Processing

The RS 232 standard describes a communication method where information is sent bit by bit on a physical channel. The information must be broken up in data words. The length of a data word is variable. On PC's a length between 5 and 8 bits can be selected. This length is the information length of each word. For proper transfer additional bits are added for synchronization and error checking purposes. It is important, that the transmitter and receiver use the same number of bits. Otherwise, the data word may be misinterpreted, or not recognized at all.

With synchronous communication, a clock or trigger signal must be present which indicates the beginning of each transfer. The absence of a clock signal makes an asynchronous communication channel cheaper to operate. A disadvantage is that the receiver can start at the wrong moment receiving the information. All data received in the resynchronization period is lost. Another disadvantage is that extra bits are needed in the data stream to indicate the start and end of useful information. These extra bits take up bandwidth which leads to reduction in useful bandwidth. Data bits are sent with a predefined frequency, the baud rate. Both the

transmitter and receiver must be programmed to use the same bit frequency. After the first bit is received, the receiver calculates at which moments the other data bits will be received. It will check the line voltage levels at those moments. With RS 232, the line voltage level can have two states. The on state is also known as mark, the off state as space. No other line states are possible. When the line is idle, it is kept in the mark state. The Figure 9 shows the specifications of RS 232 serial port and actual RS 232 serial port used in major applications for interfacing of the hardware with the system.
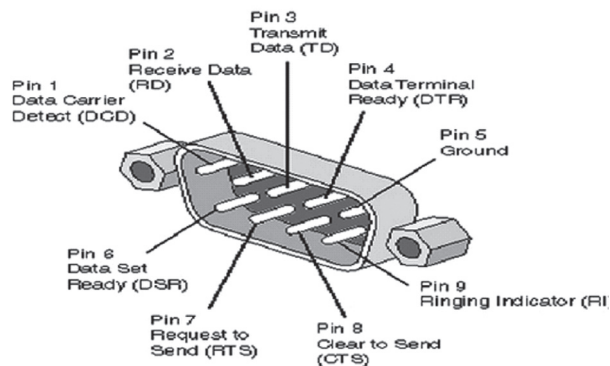

Figure 9: Specifications of RS 232 Serial Port

1. ADS7813 is initialized
   a. Data cloak is external so EXT/INT pin is connected to +5 V.
   b. Analog input range is + 3.33 volts and input impedance is 21.3 K ohms
   c. The reference is internal therefore REF is bypassed to ground via 1 mircofarad tantalum capacitor.
   d. Voltage on BUF pin is the output of internal reference buffer i.e. 2.5 V.
   e. Power down pin is grounded for normal operation.
   f. CS is connected to ground to enable all outputs i.e DATA, BUSY and DCLK analog input.
   g. + 3.33 is the digital out put
1. Make CONV = 1 for 2 micro seconds make CONV low for at least 50 ns.
2. Poll BUSY for logic 1.
3. After conversion time of 20 micro seconds, 5 micro seconds is for acquiring the DATA. External DCLK Square Wave form having time period of 100ns should be given immediately after conversion time of 20 micro seconds total data bits that can be serially acquired are 60 and total time required will be 16,00 ns. DATA is valid serially on negative edge of DCLK. DATA will be available MSB first and in 2's complements form.
   LSB is 100.653 micro volts.
4. Accept data and store it again repeat the same process i.e. trigger ADC

4.5. Interfacing with Visual Basic 5

A simple intuitive GUI is implemented for the display of the ECG data. The GUI is implemented using visual basic 5.0 Enterprise Edition.

5. DESIGN OF THE SYSTEM

5.1. Amplifier and Filter

AD 713 is quad opamp consisting of 4 high speed BIFET opamp having 14 pins. First two op-amps are used as buffer the third one used as band pass filter with frequency band of .05 hz to 106 hz. Fourth opamp is used for base line adjustment due to patient movement the noise signal is by passed to ground through right leg. AD 620 is low drift, Low power instrumentation amplifier which set gain of 1 to 1000.

A1 = Gain 49.41 / RG + 1(RG = 1.2 k), A 2 = 1 + Rf / R1 (RF = 150k and R1 = 4.7k)

Therefore A1= 42.175, A 2 = 32 Total Gain i.e. A = A1.A2 = 42.175. 32.914 =1388

Fl = ½ pie RC = .05 Hz, R = 3.3M C = 1 microfarad, Fl = 0.05 Hz

FH = ½ PIE RC = 106 Hz , R = 150K C = .01 microfarad, FH = 106 Hz

6. RESULT

ECG graph obtain

Standard ECG graph
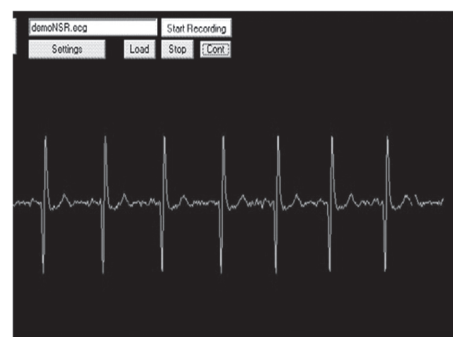
7. CONCLUSION

We have developed a system which is capable to capture the ECG of a patient on a PC. With technology advances being seen all around us in our everyday life, it is extremely important to use such technology for the benefit of the community at large. Monitoring of a patients heart condition is presently being achieved by a system using several cables wired to specific points on the patients body to produce an ECG signal. We observe that the ECG graph obtained and standard ECG graph are almost same. Power line interference of 50 Hz can be seen on the ECG graph obtained. ECG graph obtained is lead-II ECG signal having bandwidth of 0.05 Hz to 106 Hz. 50 Hz Power line interference can be removed using notch filter.

REFERENCES

[1] K. Krishna bai, S. C. Prasanna Kumar, *Canadian Journal on Biomedical Engineering & Technology,* Vol. 3, No. 2, February 2012, Design of a Low Cost ECG System: Review.

[2] K. Siddique-e Rabbani, A Raihan Abir, A K M Bodiuzzaman, BJMP, Vol. 4, Issue 1, 2011, Design and Development of Low Cost Personal Computer Based ECG Monitor.

[3] Rabbani K S, Local Development of Biomedical Technology- A Must for the Third World, Proceedings, Regional Conference of IEEE-EMBS and 14th BMES- India, Delhi, p. 1.31-1.32, 1995.

[4] Rabbani K S, How to Deliver the Benefits of Modern Biomedical Engineering to the Common People in the Economically Developing Countries, Invited Lecture, 9th Medical Engineering Conference, Yamagata, Japan, October 26-27, 1995.

[5] IEC 60601-2-51, Medical Electrical Equipment - Part 2-51: Particular Requirements for Safety, Including Essential Performance, of Recording and Analyzing Single Channel and Multichannel Electrocardiographs, 2003.

[6] G. Pagnacco, E. Oggero, D.R. Morr and N. Berme, Oversampling Data Acquisition to Improve Resolution of Digitized Signals, *Biomed Sci., Instrum*. 34 (1997), p. 137.

[7] IEC 60601-1, Medical Electrical Equipment—Part 1: General Requirements for Safety and Essential Performance, International Electro technical Commission, Geneva, Clause 8.7, 1995.

[8] J. G. Webster, Medical Instrumentation, Application and Design (2nd ed.), Houghton Mifflin, Boston (1992).

[9] W.J. Tompkins, Biomedical Digital Signal Processing, Prentice Hall, Upper Saddle River, NJ (1992).

[10] J.J. Bailey, A.S. Berson and A. Garson *et al.*, Recommendation for the Standardization and Specification in Automated Electrocardiography: Bandwidth and Signal Processing, *Circulation*, 81 (1990), p. 730.

[11] A.V. Oppenheim and R.W. Schafer, Discrete-time Signal Processing, Prentice Hall, Englewood Cliffs, NJ (1989).

[12] E. O. Brigham, The Fast Fourier Transform and its Applications, Prentice Hall, Englewood Cliffs, NJ (1988).

[13] J.S. Bendat and A.G. Piersol, Random data (2nd ed.), Wiley, New York (1986).

[14] J.C. Huhta and J.G. Webster, 60-Hz Interference in Electrocardiography, *IEEE Trans* BME-22 (1973), p. 252.