

Low Cost Multi-Lead ECG Signal Acquisition in Real Time with Telemetric Capability

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Abstract—This paper presents system design aiming to provide LOW COST solutions to the problems encountered in acquiring Electrocardiograph(ECG) signals in monitoring mode (ECG bandwidth--0.5-35Hz) from the body, as well as providing remote transmission of ECG data through Telemetry. Two separate devices have been constructed to achieve the overall goal. Overall hardware design includes three parts namely front end analog section (acquisition), processing section, and transmission section (telemetry). The software part is implemented using visual basic to get real time data display which is required for continuous monitoring of the patient. This paper aims on achieving minimum possible cost for acquiring ECG signal. The system implemented also allows advance warning operations of heart abnormalities.

Keywords- ECG, Telemetry, AD620.

I. INTRODUCTION

The contraction and relaxation of heart muscles produce electrical signals (biopotentials). These signals are low in amplitude, voltage ranging from 0.01 to 5mV. To acquire low power signals we use electrode sensors connected to the patient. Basically 10 electrodes are used. Four of them are connected to the patient's limb and others to the chest. There are three types of leads:-The unipolar limb leads (AVR, AVL, AVF), the bipolar limb leads (I, II & III) and the unipolar chest leads (V1, V2, V3, V4, V5, and v6). The ECG machine compares the detected electrical signals in various electrodes, and produce graphical pictures called leads. Depending on the direction of the leads from the heart, ECG waveform differs. Thus each lead possesses unique information. Attempts have been made to eliminate various disturbances due to power supply and muscle contraction are likely to provide a favorable alternative to existing methods for recording long-term electrical activity from heart, ECG waveform differs. Thus each lead possess unique information. Attempts have been made to eliminate various disturbances due to surrounding and body. The data thus obtained is digitized and send to personal computer and displayed hence forth. The main advantage of our project is real time display and transmission of signals using telemetry which is low cost and reduces the work load of the physician.

II. HARDWARE DESIGN AND IMPLEMENTATION

The ECG system design arrangement is given which consists of three parts: Front-end Analog part, Processing

part (Digital part) and Transmission part (Telemetry) as follows:-

A. Front end acquisition part

This part includes the transducer and signal - conditioning unit that consists of Cup based suction electrodes, Wilson resistor network, and lead selection unit (Multiplexer), instrumentation amplifier (AD620), and filters. The first unit is used to acquire the biopotential and convert them into electrical signal. The signal conditioning unit provides differential inputs, filtering & linear amplification to obtain desired signal.

1) Cup based suction electrodes

The electrode provides good contact and low noise and can be connected to any Amplifier using single core shielded cable. It is cold sterilized only. ECG GEL is used to make a conducting path between smooth skin and the electrodes. Prior to electrode attachment suction electrode is used in our setup. In summary, our data suggest that suction electrodes are likely to provide a favorable alternative to existing methods for recording long-term electrical activity from heart.

2) Wilson resistor network[7]

A number of equal resistors are used to configure unipolar leads. The electrocardiogram is recorded between a single electrode and the central terminal called Wilson terminal. This central terminal is obtained by connecting the three active limb electrodes together through resistors of equal size. For the unipolar chest leads (V1 to V6), all three active limb electrodes are used to obtain the central terminal, while a separate chest electrode is used as an exploratory electrode. In the unipolar limb leads (AVR, AVL, and AVF) one of the limb electrodes is used as an exploratory electrode while the other two limbs are used to obtain the central terminal.

3) Lead selection unit[7]

This unit is used to select one lead from 12-lead at a time to enter instrumentation amplifier. As illustrated previously, the lead potential is measured with respect to a reference (Wilson terminal) therefore, two analog multiplexers (CD4067BMS) are used. One of them is used to select one from twelve exploratory electrodes while the other selects one from twelve- lead references.

4) Instrumentation Amplifier

The AD620 instrumentation amplifier that we have used is Low cost, low power Amplifier. The other feature

includes Gain Set with One External Resistor. (Gain Range 1 to 1000). Wide Power Supply Range (± 2.3 V to ± 18 V), Higher Performance than Three Op Amp IA Designs, CMRR -100db for (gain=10) is very helpful in dealing with ECG signal. The first Front-end acquisition part consisting of Wilson resistor network, lead selection unit (LSU), and Instrumentation Amplifier is shown in Fig.1. We have kept the gain of instrumentation amplifier at 7.

Calculations of Gain Control register (R_g):

$$R_g = 49.4 / (G - 1). \quad (1)$$

where G is gain of amplifier.

5) Optocoupler

We have used MCT2E which has High Direct-Current Transfer Ratio. It has Base Lead Provided for Conventional Transistor Biasing and also provides High-Voltage Electrical Isolation 1.5-kV or 3.55-kV Rating.

6) Filters

The use of filters is essential especially when dealing with naturally very weak of the ECG signal (0.1-0.5mV) which is affected by many types of noise such as 50Hz power line interference, EMG signal interference, and 35Hz when patient suffers from somatic tremor.

a) High pass filter

A high pass filter (HPF) with cutoff frequency (f_c) equal to (0.5Hz) was used to remove the base line wander. Most informative wave of the ECG lies between 0.5-35 Hz, therefore, the passive filters are used. This filter removes low frequency noise signals.

$$f_c = 1 / (2\pi RC). \quad (2)$$

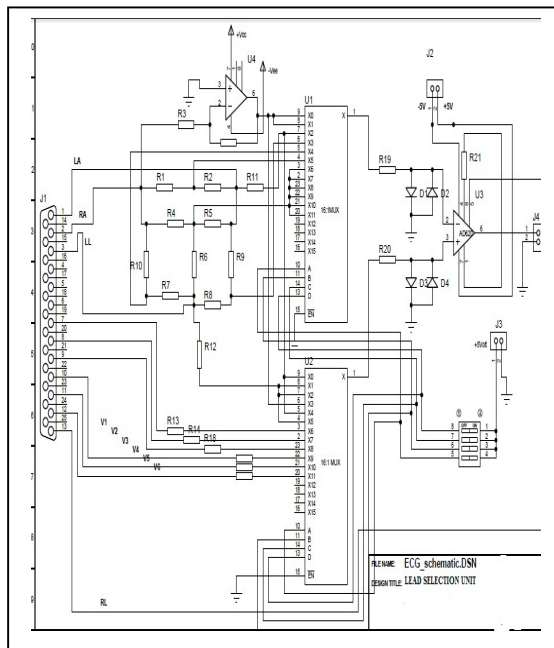


Figure 1 Circuit diagram of lead selection unit

b) Low pass filter

The next type of filters is a low pass filter with a cutoff frequency equal to (35Hz) to minimize the high frequency distortion that is generated by muscle activity that falls in a range of (35-2000Hz). Here we use feedback capacitors to limit the Frequency response of the filter.

$$f_c = 1 / (2\pi R(C1 || C2)). \quad (3)$$

The gain of this filter is kept 143 As to achieve 1000 gain to meet American heart association (AHA) standards.

c) 50 Hz Notch filter

We are not using this filter for 35 Hz notch filter used will remove this noise too.

d) 35 Hz Notch filter

The 35Hz notch filter [8] is used to remove the interference signals from muscles when patients suffer from somatic tremor, therefore this filter is connected through a switch to the rest of the system. The switch is closed only when patients infected with this disease. The 35Hz notch filter is designed to have bandwidth equal (34.5hz) and quality factor equal to 0.121.

$$f_0 = \sqrt{f_1 \times f_2} \quad (4)$$

$$BW = f_2 - f_1 \quad (5)$$

$$Q = f_0 / BW \quad (6)$$

where BW is band width

f_0 is center frequency

Q is quality factor

7) Gain amplifier

Gain amplifier is used as a second stage of amplification (gain equal 1). Since ECG amplitude at body level is ± 2.5 millivolt. So we have used two unity gain amplifiers. The two Amplifiers are connected in cascaded form. First one is an adder to raise voltage level to -5 V and the second one simply inverts the signal to make output 5V.

B. Digital part

It includes two units. The interfacing unit (ADC) takes the samples from an analog signal selected, converts them into a digital output, and transmits to Pc using serial UART port. The processing unit is responsible for data acquisition, analysis, and storage of the input data. The block diagram of the digital part is shown in Fig.2

1) Analog to digital converter (A/D)

IC AD0809 is used as A/D converter for system design. It converts the Analog signal into Digital signal which makes the Processing part easier.

2) Control circuit

The control circuit used in the proposed system consists of 8051 microcontroller. It processes the Digital Data coming out from the ADC.

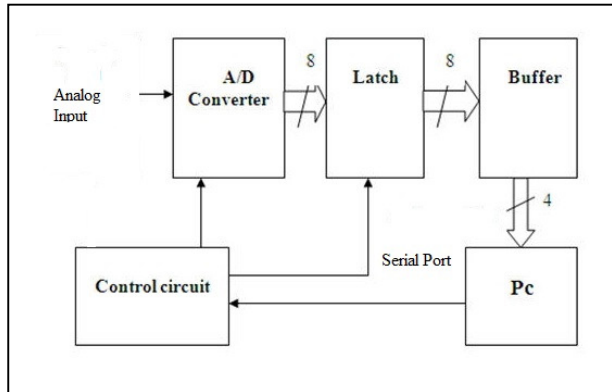


Figure 2 Block diagram of digital part

C. Transmission part

The signal acquired thus is transmitted in real time from Microcontroller to personal computer using ZIGBEE module.

ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios based on an IEEE 802 standard for personal area networks.

Zigbee module which we are using is of zigbee standards of range 100m.

III. SOFTWARE IMPLEMENTATION

The software was implemented using Visual Basic of two parts: The main Program (data acquisition program), which performs the data acquisition of the biomedical signal, and several algorithms and techniques to display multilead ECG signal. The idea behind using Visual Basic is for developing a graphical user interface (GUI) which allows real time data display.

IV. RESULT

The 12-lead ECG signal acquisition with telemetric capability is implemented. The output is displayed on the PC with negligible noise. The output is shown in Fig. 3.

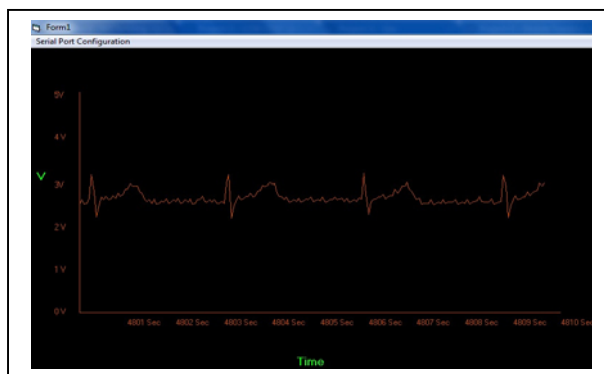


Figure 3 Output ECG signal on PC

V. FUTURE SCOPE

We can transmit the real time Data along with warnings of abnormalities using satellite link to any part of the World.

VI. CONCLUSION

From above we conclude that, these practical results prove the validity of the present work. The interference in the results is Due to movement of patient's body during recording and supplies. The ECG signals are filtered using several types of active and passive filter; the 35Hz notch filter is designed to suppress the power line interference. The acquired ECG signals bandwidth is determined using high and low pass filters, these filters are prevent the high frequency noise (EMG signal) from appearance in the recording ECG signals.

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REFERENCES

- [1] Leslie Cromwell, Fred J. Weibell and Erich A. Pfeiffer, biomedical instrumentation and measurements, 2nd ed, Prentice-Hall Inc., Englewood Cliffs, 1980.
- [2] J. Dong, H.Zhu, "Mobile ECG detector through GPRS/Internet". Proceeding of the 17th IEEE Symposium on Computer-Based Medical System (CBMS'04), 2004.
- [3] J. Rodr.guez, A. Go.i and A. Illarramendi, "Real-Time Classification of ECGs on a PDA," IEEE Trans. On Information Technology in Biomedicine, vol. 9, no. 1, March 2005.
- [4] C. H. Salvador, M. P. Carrasco, M. A. G. de Mingo, A. M. Carrero, J. M. Montes, L. S. Martin, Caverio, I. F. Lozano, J. L. Monteagudo, "Bluetooth Telemedicine Processor for Multichannel Biomedical Signal Transmission Via Mobile Cellular Networks", IEEE Trans. On Information Technology in Biomedicine, vol. 9, n.1, March 2005.
- [5] Robert S. H. Istepanian, Leontios J. Hadjileontiadis, and Stavros M. Panas, "ECG Data Compression Using Wavelets and Higher Order Statistics Methods", IEEE.
- [6] Daniel Lucani, Student Member, IEEE, Giancarlo Cataldo, Student Member, IEEE, Julio Cruz, Guillermo Villegas, and Sara Wong, "A portable ECG monitoring device with Bluetooth and Holter capabilities for telemedicine applications", IEEE.
- [7] R.S. Khandpur, Handbook on biomedical instrumentation, fifth reprint (1992), TMH Publication.
- [8] W.J.Tompkins, Biomedical Digital Signal Processing, Englewood Cliffs, NJ: Prentice Hall, 1993.
- [9] L. Cromwell, F. J.Weibell, E. A. Pfeiffer , Biomedical instrumentation and measurements, 2nd edition, Eastern economy edition publication.
- [10] www.interactive-biology.com