Computers in Biology and Medicine 39 (2009) 361 – 367

Contents lists available at ScienceDirect

Computers in Biology and Medicine

journal homepage: www.elsevier.com/locate/cbm

A computer based wireless system for online acquisition, monitoring and digital processing of ECG waveforms

Dipali Bansal[a,*], Munna Khan[b], Ashok K. Salhan[c]

[a]Electronics & Communication Engineering Department, Apeejay College of Engineering, Sohna, Gurgaon, Haryana, India
[b]Electrical Engineering Department, Jamia Millia Islamia (A Central University), New Delhi, India
[c]Biomedical Instrumentation Division, Defence Institute of Physiology and Allied Sciences, DRDO, Delhi, India

ARTICLE INFO

Article history:
Received 17 September 2008
Accepted 22 January 2009

Keywords:
Digital filters
ECG system
MATLAB
Signal processing
Wireless data acquisition

ABSTRACT

Various ECG instruments have addressed a wide variety of clinical and technical issues. However, there is still scope for improvement in them particularly in the area of their susceptibility to noise, lack of universal connectivity and off-line processing. A prototype system has been developed that caters to these limitations. It includes an analog system and a FM transceiver pair interfaced through sound port of the computer. The real time acquired data is viewed and filtered using MATLAB software. The ECG system described captures the bio-signal faithfully in real time wireless mode with minimum noise and has universal connectivity.

1. Introduction

ECG system is an ideal instrument for patient monitoring and supervision. An extensive range of human physiological conditions can be inferred from the PQRST waves obtained from an ECG instrument. Although ECG instruments were quite bulky, miniaturization in recent years has enabled development of wearable versions that collect and process ECG data. Subtle changes in the physiological signals of an individual are easily monitored using wearable health checking systems. Telemetry in combination with such systems prepares physicians to take clinical decisions when considerable changes are noticed in the physiological parameters [1,2]. Looking at the recent trends in bio-medical applications, a major advancement can be noted in health monitoring devices. This ranges from simple and portable Holter instruments to sophisticate and costly implantable gadgets. The Holter monitors have been used only to collect data in ambulatory patients. Processing and analysis are then performed offline on recorded data [3]. Systems with multiple sensors have too many wires between the sensors and the monitoring device, which limit the patient's activity and comfort level. Available systems also lack universal connectivity of interfacing to any output display device through common communication ports. There is a requirement of data acquisition (DAQ) circuits with analog to digital converters as the interface between the Instrument and the Computer. The hospitals generally use Wilson Central Terminal arrangement having three electrodes placed at the limbs and connected at the inverting input of the ECG amplifier. The Wilson reference can however degrade the overall amplifier specifications [4]. Implantable Cardioverter Defibrillator (ICD) is other system, which is very expensive and invasive method to record physiological data. The ICD is used only on high-risk cardiac patients [5]. MOLEC monitor is an embedded real time system that captures, processes, detects, analyzes and notifies abnormalities in ECG [6]. However, the cost of MOLEC monitor is high. Further, EPI-MEDIC is a twelve-lead ECG system that allows continuous monitoring, but has a large array of electrodes, which makes the system cumbersome [7]. Normal ECG done in clinical setting allows monitoring and recording but gives no analytical results. Available data analysis algorithms are complicated, as they do not implement transparent decision procedure. Table 1 shows a literature survey on existing ECG systems with their features and limitations.

The growing health concerns, especially for cardiac disorders reflect on the need of developing a simple and portable ECG system for use at homes. In a commonly available system, sensors pick health details and transfer them to a computer using the DAQ card. The DAQ card and the use of ADC modules make the system bulky and expensive. An alternate data transfer method using simple interface i.e. the sound card proves out to be very convenient and effective. In the present work, a single channel ECG monitor has been developed that successfully extracts faithful ECG wave in a simple, wireless and cost effective manner. The developed hardware consists of a cascaded amplifier, an active band pass filter and the right leg drive circuits. The amplified and filtered output is then fed to a

* Corresponding author. Tel.: +91 9910122000; fax: +91 129 2296772.
E-mail addresses: dipali.bansal@yahoo.co.in (D. Bansal), mkhan.el@jmi.ac.in, khanmunna@yahoo.com (M. Khan), ashoksalhan@yahoo.com (A.K. Salhan).

0010-4825/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.compbiomed.2009.01.013

Table 1
Literature survey.

Systems	Features	Limitations
Holter monitors	Non-invasive method Most commonly used ECG device Can be used in ambulatory subjects	Data acquisition card required Lacks universal connectivity Data analysis done off-line No online monitoring
R-TEST	Non-invasive method Continuous monitoring possible up to eight days Single lead arrangement	Data acquisition card required Easily corrupted by interferences like motion artefact
MOLEC monitor	PDA (Personal digital assistant) based Wireless system Bluetooth technology Embedded real time system	Performs local real time ECG classification using ready made tools Analog to Digital Converter (ADC) required
Implantable Cardioverter Defibrillator (ICD)	Used on high risk patients	Invasive Very expensive
EPI-MEDICS	Twelve lead ECG system Makes on-line continuous monitoring User friendly intelligent ECG monitor Uses RS-232 port for Computer Interface	Data acquisition card required Uses large array of electrodes Expensive
HP-Agilent telemetry system	Wireless system High performance ECG Device	Expensive system

commercially available cost effective FM Transmitter. The receiver unit receives the signal in wireless mode and is interfaced in a simple manner to the Laptop through the sound port. The real time acquired ECG signal is viewed and analyzed using software developed in MATLAB. The noise present in the output of the ECG system is further removed using online software digital filters. The developed ECG system is also interfaced to the computer using the DAQ card (National Instruments (NI)). The ECG wave is recorded and analyzed using LabVIEW software. Various ECG recordings have been made and compared using both the arrangements of acquisition i.e. DAQ card and direct acquisition through sound port.

2. Materials and methods

A prototype ECG system has been developed that consists of front-end amplifier, wireless transceiver, interface with output display device and digital filters for noise removal.

2.1. Front-end amplifier section

Front-end amplifier section consists of electrodes, buffer and unity gain amplifiers, DC restoration circuit, right leg drive circuit, active filter circuit and the power supply unit. ECG signal is picked from the body using non-invasive Ag–Ag–Cl electrodes. The Ag–Ag–Cl sensor used is made of silver and is coated with chloride ions that help in transducing the bio-potential into a measurable voltage signal. The transducer can sense low amplitude signals in the range of 0.05–10 mV and senses the ECG signal. Sensor exhibits a flat frequency response in the range 0.05–150 Hz and is suitable for picking up ECG signals [8]. An electrolytic gel (Ag–Ag–Cl) is used on the skin to reduce skin impedance for better current flow. An operational amplifier (OP-AMP) chip TL084C is used to amplify the ECG signal picked. The OP-AMP has large common mode rejection ratio (CMRR) of 86 dB and adjustable gain up to 500. This IC chip has been used in the present work to design buffer amplifier, unity gain follower and DC restoration circuit. Apart from the amplifier, a right leg drive is also used to improve the CMRR. The right leg drive is feedback body reference circuit and is also made using TL084C. Further, an active analog filter is designed to eliminate the noise picked up in the process. Input voltage is fed into the system from 9 V batteries and avoids the use of 230 V supply.

2.2. Wireless FM transceiver

Output of the front-end ECG Amplifier section is fed into a commercially available low range FM Transmitter. The transmitter consists of a sub carrier oscillator, UHF transmitter and an inbuilt antenna. The FM Receiver consists of a high frequency unit, a demodulator and an inbuilt antenna. The receiver unit is interfaced to the sound port of the computer using a compatible jack. The FM transmitter and receiver are powered using 1.5-V battery each. Wireless FM transmitter and receiver are made to operate in the frequency range of 88–108 MHz.

2.3. Output display devices

Output of developed hardware is viewed on a Tektronix make TDS1002 dual channel 60 MHz Mono Digital Storage Cathode Ray Oscilloscope (CRO) in a laboratory. Alternatively, the ECG wave is also viewed and stored on a virtual CRO on the Laptop. The CRO and Laptop were also used as the output display devices during wireless transmission. The ECG waves were observed and recorded in the simulated CRO on the screen of laptop using following:

(a) *DAQ system*. A DAQ system converts a PC into a measurement and monitoring system. The acquired analog signal is digitized using analog to digital converters to enable interface with the computer. For this, a terminal block and a DAQ device NI PCI-6052 E developed by NI are used. Before installing the DAQ board, LabVIEW and NI-DAQ are installed. LabVIEW is also developed by NI that allows graphical user interfaces (GUIs) to be easily programmed on a computer to view and process the acquired data. NI-DAQ is driver software that communicates with a NI's