A DESIGN OF PORTABLE HEART-RATE MONITORING SYSTEM

Mehmet ENGİN[1], Tayfun DALBASTI[2], Saygın BILDIK[1], Turan KARIPÇIN[1], Erkan Zeki ENGIN[1], Candan CANER[1]

[1]Ege University, Faculty of Engineering, Electrical & Electronics Eng. Department
[2]Ege University, Medical Faculty, Neurosurgery Department
mehmet.engin@ege.edu.tr, tayfun.dalbasti@ege.edu.tr; sayginbildik@yahoo.com; turan_13@hotmail.com; erkan.zeki.engin@ege.edu.tr, candancaner@yahoo.com

Abstract: *Telemedicine is producing a great impact in the monitoring of patients located in remote non-clinical environments such as homes, elder communities, gymnasiums, schools, remote military bases, ships, and rural area. A number of applications, ranging from data collection to chronic patient surveillance, and even to the control of therapeutic procedures, are being implemented in many parts of the world. As part of this growing trend, this paper explains the design of a portable heart-rate monitoring system. A prototype system consists of analog data acquisition and pre-processing module which has an EEPROM memory for recording heart-rate values and corresponding time sequences. This module connected to computer via serial data communication protocol. At the computer side, we use interface software which is enable to graphically display the recorded heart-rate values.*
Keywords: *ECG monitoring, heart-rate, microcontroller, telemedicine.*

1. Introduction

Real-time continuous monitoring of human's heart-rate could allow not only for emerging detection of the patient health condition but also for long-term assessment to establish the right dose and timing of medication [1]. The design of compact, continuous monitoring devices has been very important [2]. For this aim, many research studies have been carried out over many years. Applied technologies improve efficiency and effectiveness, lowering costs, saving time, and increasing direct attention to patients. It might be necessary to collect medical data for patients in hospital environment, in home for homebound patients or for outpatients [3].

There are several clinical situations in which continuous observation of the ECG and heart-rate is important to the care of the patient. Continuous observation of the ECG during the administration of anesthesia helps doctors monitor the patient's condition while he or she is on the operating table and during recovery from anesthesia [4]. Constant monitoring of the ECG and heart-rate of the myocardial-infarction patient during the danger period of several days following the initial incident has made possible the early detection of life-threatening cardiac arrythmias. Also, continuous monitoring of the fetal heart-rate during labor may help in early detection of fetal distress. Conventional methods of monitoring and diagnosing arrhythmia rely on detecting the presence of particular signal features by a human observer. Due to the large number of patients in intensive care units and the need for continuous observation of such conditions, several techniques for automated arryhtmia detection have been developed to attempt to solve this problem [5].

Recently, the availability of quite sophisticated telecommunication systems is making the global aim of providing all individual with access to advanced communication, information, and control systems that improve their life conditions a reality [6]. In the case of remote monitoring in non-clinical environments, a new model of health delivery that begins with the user is being experimented. There is a shift from episodic intra-hospital medical care, which creates new relationships between users and service providers, and new challenges in the deployment of machine intelligence and the design of low-cost and at the same time versatile and reliable remote units [6].

In the case of diagnosing variation in the fetal heart-rate (FHR) such as caused by fetal hypoxia, continuous FHR monitoring is recommended [7]. However, the FHR is normal (120-150 beat per minute (BPM)) most of the time even for pregnant women with high risk of prematurely and miscarriage. Studies have shown that a home monitor combined with more patient awareness and more intensive nursing contact will reduce the incidence of prematurely and miscarriage [7]. These women can maintain normal daily activities at home as well as work, avoiding unnecessary hospital stay, with the use of 24h

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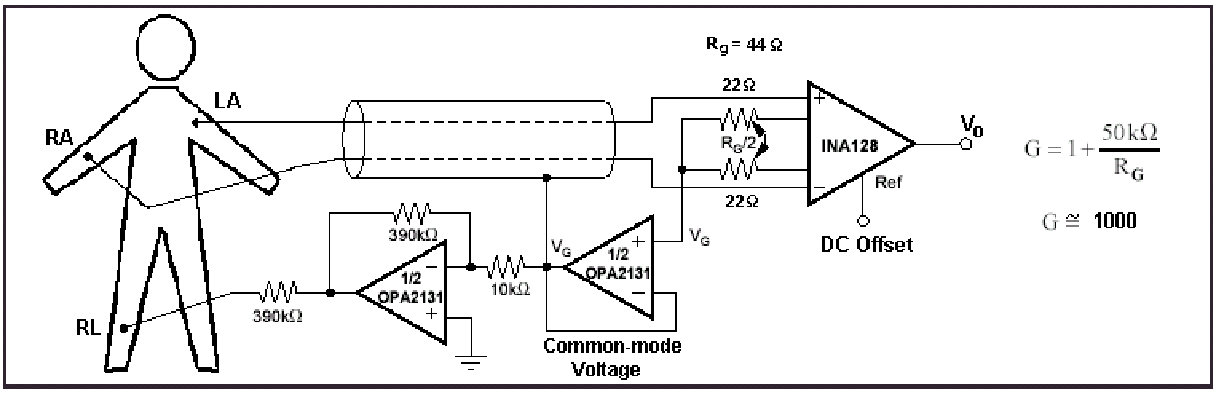

Figure 1. Instrumentation amplifier circuit

monitoring of FHR. Many methods have also been proposed for extracting the fetal QRS complexes from the abdominal ECG to measure FHR.

This paper presents a design of microcontroller based heart-rate monitoring system has capable of real-time heart-rate monitoring of a subject. The use of programmed intelligence and serial transmission with a personal computer, allows the acquisition, collection, and plotting of continuous heart-rate data. The designed system consists of the following stages. The first stage consists of acquisition of ECG signal via one ECG derivation (i.e.; the one electrode is located on the right arm, the left arm, and the right leg). After amplifying and filtering of ECG signal, QRS collection and pulse generation are implemented according to QRS complexes. At the second stage, the simultaneous generated pulses are counted by a microcontroller and the heart-rate values of patient are stored on the external memory with the real-time values of the measurement. Here, we also check the reliability of the measurement data, whether if any abnormal heart-rate value exists, the microcontroller warns the remote third circuit via RF communication. The third stage of the system is a connection unit which communicates with the personal computer. The stored heart-rate values of all the measurements are sent with their measuring time through this unit. For this aim, we used a serial port with RS232 protocol. At the computer side, the designed software lists and graphically plots the heart-rate data with related measuring time.

2. Considerations in the Heart-rate Monitoring

ECG's heart-rate monitoring can be of great interest in the follow-up out-of hospital patients receiving drugs in order to assess efficacy of therapy and potential harmful conditions to the heart. Data collection protocols at home or care institutions can also be carried out for data logging purposes, particularly to provide low-cost heart-rate monitoring for the subjects. Such continuous monitoring system can provide unique and useful information for preventing diagnosis in which long-term trends and signal patterns are more important. Especially, fetal heart-rate variations observed over 20 minute during pregnancy and labor have commonly been used as direct indications of the fetal condition [8]. The ability to perform long-term (e.g., 24 h) monitoring of the FHR would, thus, provide more information on the fetal condition.

3. Hardware and Software Developments

The data acquisition stage was designed taking into consideration the requirements of non-clinical conditions. Namely, this module has some technical specifications, including low noisy signal acquisition hardware, user friendly, and lower power supply cost. A common front-end in bio-potential measurements is a dc-coupled fully differential amplifier followed by a difference amplifier, as in the classical three op-amp instrumentation amplifier [9]. The front-end amplifier was built by using the Burr-Brown INA128 instrumentation amplifier, driven right leg, and guard driving circuits, simple controlled gain. The overall gain is set to 1000 and for DC power supply, we use 9V batteries. Figure 1 shows the instrumentation amplifier circuit [10].

In order to enhance the QRS complex, we built a bandpass filter (f_o=17 Hz, Q=3, and BW=6 Hz) around OPA213P amplifier. After amplifying and filtering of ECG signal, a Schmitt trigger circuit is used to generate related pulse wave which represents coming ECG intervals. The output of the bandpass filter and the Schmitt trigger is shown in Figure 2. The digital section of this stage comprises the following subsections; the control unit (PIC 16F877A microcontroller), the real time clock (RTC DS 1307), and the memory chip (24C16 EEPROM). In order to start heart-rate counting and recording, microcontroller's PB.4 bit is set to logic one. The recording time is set according to user's demand (maximum 36 hours). After making connection between the terminal stage and the microcontroller, the recorded heart-rate values and corresponding recording time sequences are sent to terminal stage. The recording time interval can be extended to 36 hours.

In the case of existing of abnormal heart-rate values (out of range of 24-132 beat per minute), the microcontroller warns the remote circuit via a RF communication. The warning RF signal triggers the

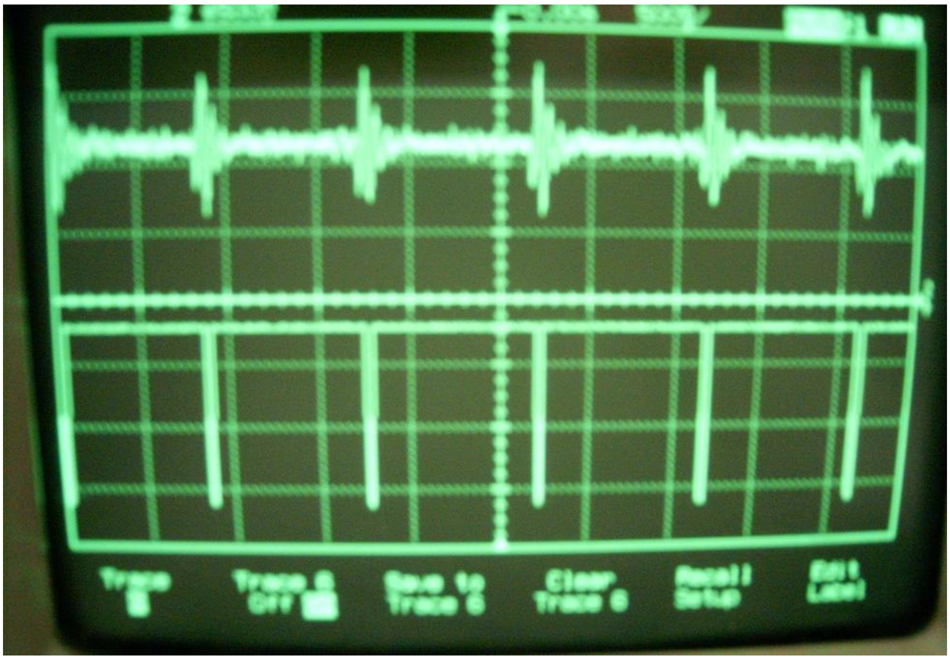

Figure 2. Filtered ECG and corresponding pulse waves

buzzer of this circuit and the medical staff at the terminal side realizes that some unexpected situation had occurred during the measurement process. For this aim, a RF transmitter is built by MPSH10 RF transistor and PT2262 encoder chip. Above mentioned control and recording stage is shown in Figure 3.

In order to analyze the recorded heart-rate values, a graphically plotting program is needed. For this aim, the recorded heart-rate values are sent to personal computer via serial communication protocol. Data frame consists of 10 bits (the first bit was start bit and the last bit was stop bit). The baud-rate was set to 1600 and the parity bit was not used.

For indexing and plotting of receiving data coming from the serial port, interface software is developed. A typical user interface's window is shown in Figure 4.

4. Conclusions

The designed complete real-time continuous ECG

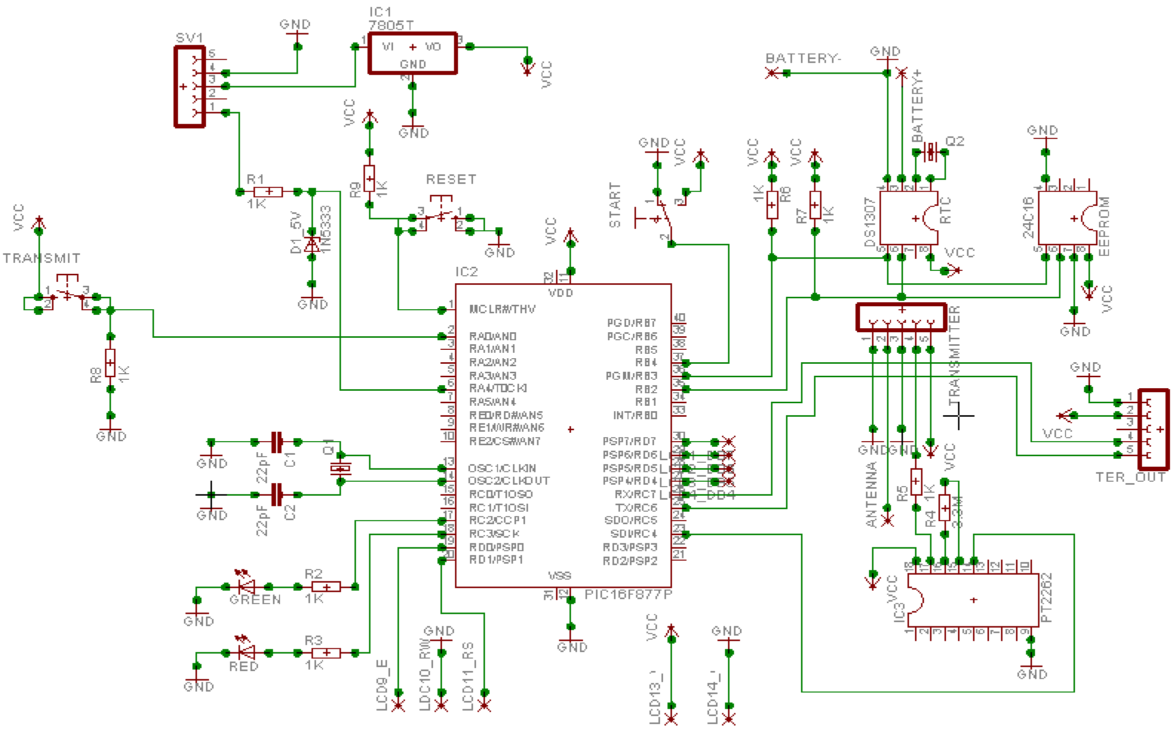

Figure 3. Control and recording circuit

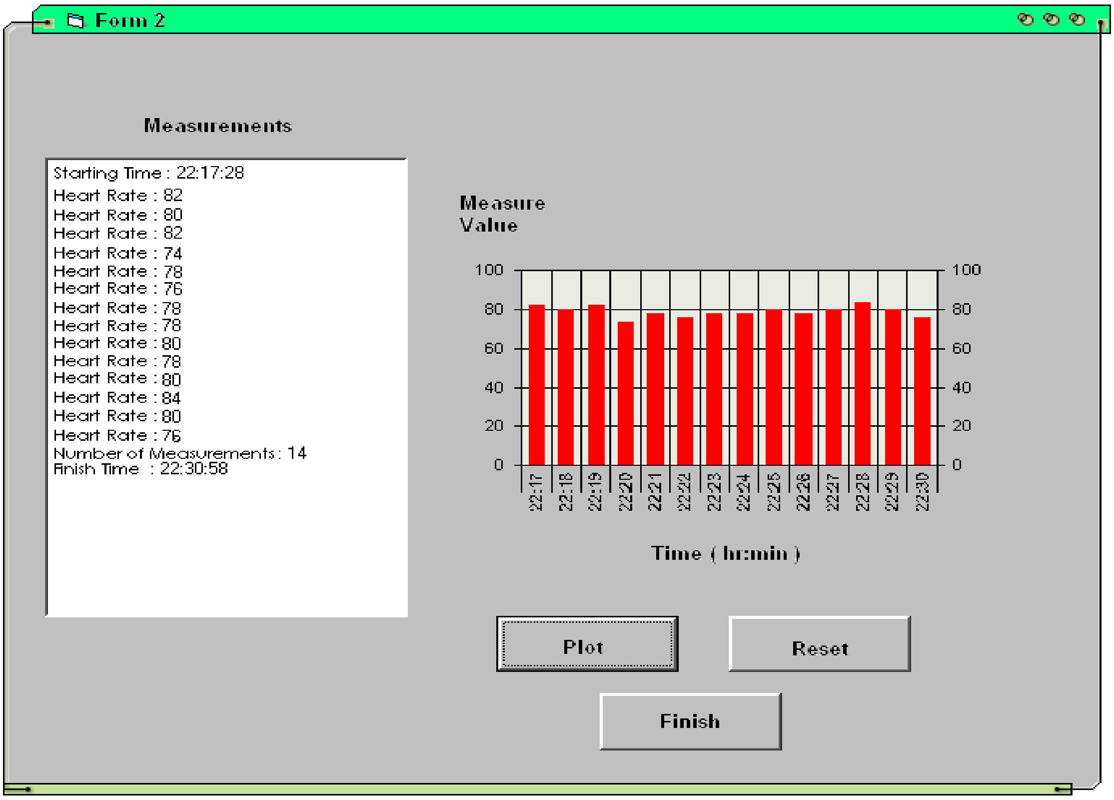

Figure 4. The window of user interface program

heart-rate recording and monitoring system has the following properties; the analog acquisition, real-time recording and storing, serial communication, and graphically visualization.

This system is capable of easy to use and dedicated for no clinical applications. This system does not require any tuning and maintenance from the user and it has low-power consumption. Because of using batteries for DC supply, any electrical isolation was not needed. The connection between system and personal computer is easily accomplished. In order to obtain reliable heart-rate measuring, used ECG derivation could be sufficient. In the future, receiver applications could include more sophisticated signal processing techniques and interpretative software. And also, the physical dimensions of the system should be decreased for easily carrying as a pocket device.

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Note:

Mehmet ENGIN received M.Sc degree from Marmara University and Ph.D. degree from Kocaeli University, 1988 and 1996, respectively. From 1996 to 1999, he was Assistant Professor at Electronic and Computer Education Department of Kocaeli University. He is currently Assistant Professor at Electrical & Electronics Engineering Department of Ege University. His research interests include biomedical signal processing and biomedical instrumentation, wavelet transform.

Tayfun DALBASTİ graduated from University of Ege, School of Medicine, Izmir, Turkey in 1984. He came to the USA after graduation with an award from Rotary International. Here he worked at the Applied Neural Control Laboratory of the Case Western Reserve University, Cleveland, OH where he studied effects of magnetic stimulation on ex vivo hippo campalslices. In 1989, he returned back to Turkey, University of Ege to become a Neurosurgeon. He established a Biosensor Laboratory for electrochemical detection of some analytes and DNA. He is currently working as a Vascular Neurosurgeon at the Department of Neurosurgery. Besides his clinical activities, he works as an Adjunct Faculty Member of School of Engineering, Electric/Electronics Department of the University of Ege where he joined several research projects on photonics, nonlinear time series analysis, signal and image processing and RF network communication.

Saygın BİLDİK

Turan KARİPCİN

Erkan Zeki ENGIN received B.Sc., M.Sc. and Ph.D degree in Electrical and Electronics Engineering from Ege University, 2000, 2003 and 2010, respectively. Currently, he is assistant at Ege University. His research interests include biomedical signal processing, biomedical instrumentation, voice processing and cochlear implant.

Candan CANER