Light Weight, Low Cost, Wearable Ecg Monitoring

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ABSTRACT

This paper describes the proposed signal processing scheme for wearable monitoring Electrocardiogram. This includes the acquisition, amplification and filtering of the on body ECG signal. EC signal is very sensitive in nature and if a small noise get mixed with the original signal, various characteristi of the signal changes. Hence filtering is an important issue. Remote monitoring of ECG and oth Physiological signals is becoming important as it can significantly reduce the cost and risks involved personal healthcare. Digital signal processing and data analysis are very commonly used methods, biomedical engineering research. Microcontroller based ECG monitoring is also described in this pape PIC16F877A microcontroller with inbuilt ADC is used for the purpose of R-peak detection and Heart ra monitoring. Wearable ECG monitoring is the need of ageing society now a days. Our device is low co monitor and easily wearable ECG monitor, so that it can help in home monitoring of ECG data. The basic a behind this project is detection of abnormality or emergency condition, before they prove dangerous.

KEYWORDS: *Electrocardiogram (ECG), Electrodes, Filters, Graphical User Interface, Heart ra monitoring, Noise, Signal Processing*

I. INTRODUCTION

World-wide survey conducted by World Health Organization (WHO) has confirmed that Heart related diseases are on the rise today. Many of these cardiac problems are due to modern lifestyle, food habits, obesity, smoking, lack of physical exercise, etc. Post operative patients can develop complication once they are discharged from the hospital. In some patients[1], cardiac problem may re-occur when they start doing their routine work. Hence ECG of such patients needs to be monitored continuously for some time after operation. The main challenge in the development of wearable device is local ECG signal processing with high accuracy. It is important to acquire the accurate ECG signal and remove the unwanted noise using a proper signal processing scheme with low expenditure. Various experiments are in progress to develop a good signal processing scheme and get a low cost wearable ECG monitoring device. These type of wearable monitoring devices must be run using the small batteries as the power supply for less consumption of power[2].

This reduces the weight and dimensions of the device. Also these must be easy to use unchanging the quality of life of the personal. A high level of integration is required to minimize the size and cost of such a sensor. It is desirable to do most of the signal processing tasks like ECG filtering and QRS detection locally. Once the QRS complex position is found, the other components of ECG signal are not difficult to be detected, such like P and T waves, ST segment. So the QRS complex detection is the key for ECG analysis[3]. This paper presents an ECG signal conditioning circuit. ECG signal is usually influenced by baseline drift, motion artifact, and power line interference.

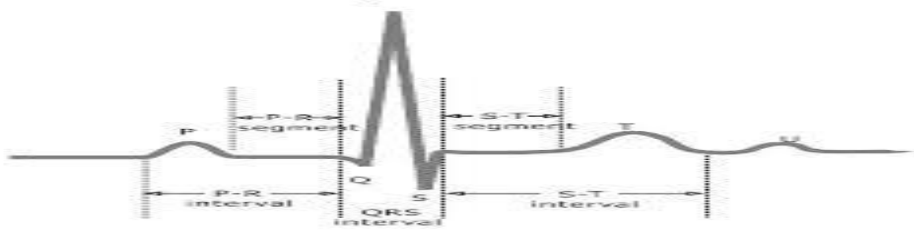


Figure1. Normal ECG wave with noted features

An ECG is a graphical display produced by an electrocardiograph, which records the electrical activity of the heart over time. The electrocardiograph as shown in Figure 1 is obtained by measuring the electrical potential between various points of the body. The ECG waveform consists of several sections, labeled P, Q, R, S, T and U. Each section has its own characteristics and yield important diagnostic information, which an experienced cardiologist can interpret to diagnose a wide range of possible ailments.

The paper is organized as follows. In section II gives the background behind the wearable monitoring. Details of electrodes used are given in section III. Section IV gives the Hardware design of the proposed scheme and simulation results are presented in section V. Concluding remarks are given in section VI.

II. BACKGROUND

From literature study it is found that, Electrocardiograph devices are the most widely employed tool used for cardiac monitoring. Two different classes of ECG devices are in general use today. The “standard” ECG generally involves the connection of between twelve and fifteen conductive leads to a patient’s chest and/or extremities via adhesive pads[1]. The device records a short sampling of the heart’s electrical activity between various pairs of electrodes. Each pair of leads provides a unique depiction of the heart’s electrical impulses as they are conducted through surrounding tissue. An experienced cardiologist can rapidly interpret a standard ECG tracing to diagnose a wide range of possible ailments[2]. However, because standard ECG traces only represent a short sampling of patient data, cardiac conditions which are irregular or intermittent may not be identifiable.

To address this shortcoming, many hospitals employ another class of ECG, called stress or Holter monitoring[1], to monitor patients in intensive care. Medical personnel deploy an ECG device that uses fewer electrodes (usually three or five), which provides a less detailed sampling of cardiac activity over an extended period. The cardiac rhythm is generally shown on a near-by display so that the patient’s general cardiac condition can be monitored continuously. A physician may advise continuous monitoring if it is suspected that a patient has a cardiac problem, such as an irregular heartbeat, that occurs intermittently.

Many ECG machines, both standard and continuous, are marketed as “portable,” but this does not always indicate that they are small and unobtrusive. Many such devices receive power from an electrical outlet and are sufficiently heavy that they must be mounted on a cart and wheeled from one location to the next. Wireless sensor networks have the potential to significantly improve this situation[1].

III. ECG ELECTRODES

Disposable sensor electrodes are used for testing purpose. They are pre-loaded with a low impedance wet Ag/Cl gel which is better than solid gels at reducing skin impedance, that is important for obtaining a clean signal. A tab connector allows for the cable to move around without disturbing the electrode-skin contact, which highly reduces the motion artifacts. Fig. 2 shows the picture of electrodes used for this purpose. We used these electrode for RA, LA and LL position. Three lead ECG signal is acquired for the wearable application.

Figure2. Disposable sensor electrode used for testing

ECG clamp electrodes can also be used for acquiring the ECG signal. Clamp electrodes with suitable universal connection are very suitable for getting ECG signal with better accuracy. The metallic surfaces of these electrodes are silver-silver chloride (Ag-AgCl) plated to provide maximum signal quality. Clamp electrodes are color coded IEC or AHA protocols (IEC color code: Red, Green, Yellow, Black and AHA color code: Red, Green, White, Black). Length of the clamp electrodes are 140 mm for adults.

Clamp electrodes are reusable electrodes and gel is used as the contact medium. ECG gel contains the free charges which guarantee electrical conduction. It is important to apply the electrode gel as it also minimizes the motion artifacts. Recent breakthroughs have been made in the form of insulated bio-electrodes (IBEs) as mentioned in [7]. They can measure the electric potential on the skin without resistive electrical contact and with very low capacitive coupling. This has been made possible by a combination of circuit design and the use of a new, low dielectric material. These IBEs enable through-clothing measurements.

IV. HARDWARE DESIGN

Analog front-end processing is an important part of ECG signal processing, since it needs to distinguish between noise and the desired signal which is of small amplitude. The front-end processing circuitry consists of an instrumentation amplifier which reduces the common mode signal[9].

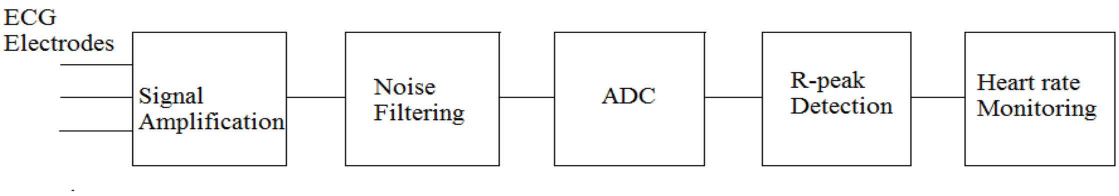


Figure3. Block diagram of wearable Heart-rate monitoring system

Based on information gathered by signal analysis, we can design specific procedures for signal processing. In order to enlarge the R-wave to about 0.5 – 1 V, the signal needs to be amplified by an amplifier (or several amplifiers) with a total gain of about 500. To remove the low-frequency noise, a high-pass filter can be used. The corner frequency of the filter should be between 0.03 to 0.1 Hz. Since the other two kinds of noise have frequency ranges that are overlapping with that of the ECG waveform, they are more difficulty to remove.

A set of buffer amplifiers is used before the instrumentation amplifier to acquire the Two lead ECG signal by grounding the third lead, as shown in the figure 3. This prevents the instrumentation amplifier from loading and faster acquisition of ECG data is possible. LM 324 is used for this purpose. It has wide bandwidth and large voltage gain. Also it works on very low power and hence is best suited for this circuit.

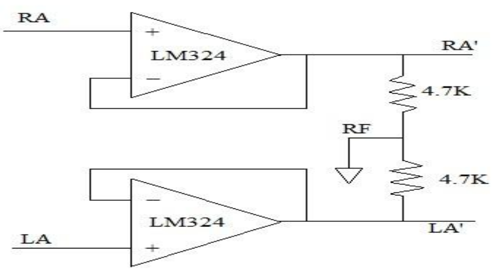


Figure4. Buffer amplifiers for ECG signal

The AD620, with its high accuracy of 10 ppm maximum nonlinearity, low offset voltage of 200µV max and offset drift of 2 µV/°C max, is ideal for use in precision data acquisition systems, such as weigh scales and transducer interfaces, Thermocouple amplifiers, Difference amplifiers, Low power data acquisition. Furthermore, the low noise, low input bias current, and low power of the AD620 make it well suited for medical applications such as ECG and noninvasive blood pressure monitors. Instrumentation amplifiers that operate on +/-6V are commonly used to take advantage of the large input voltage range. The instrumentation amplifiers should have high input impedance since the skin resistance could be very large. The gain of the instrumentation amplifier is kept near about 100. The signal chain for the ECG acquisition system consists of instrumentation amplifiers and filters.

In Fig. 5, different colors are used to help you to identify different stages in the overall signal processing. The circuit around AD620 with blue color corresponds to the block "1st Amplifier" in Fig. 1. The gain of the circuit is determined approximately by the following formula: $G = 50\ K/ R_1$. The circuit with green color (C_1 and R_2) is the high-pass filter. The circuit around 741 with brown color is the 2nd Amplifier and the circuit with purple color (R_5 and C_2) is the low-pass filter.

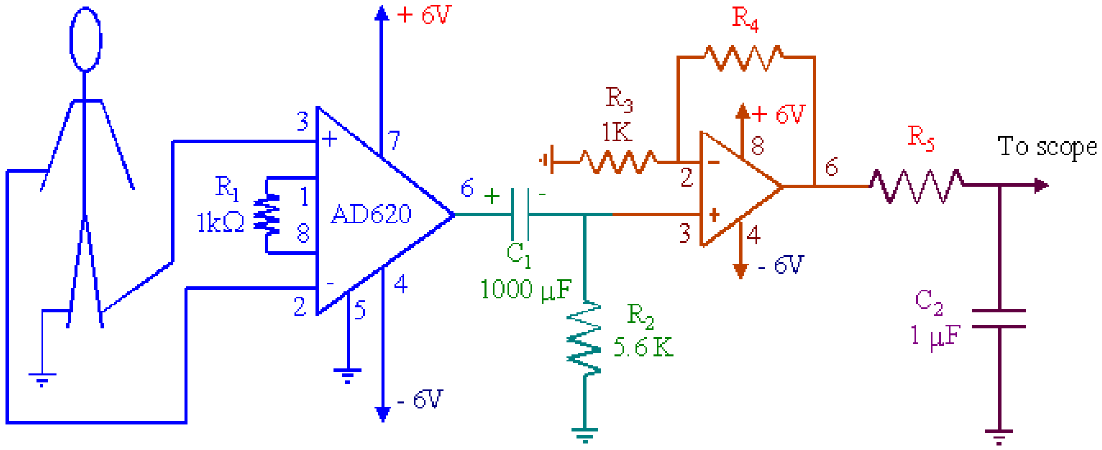


Figure5. Design of ECG signal processing scheme

Signal processing is a huge challenge since the actual signal value will be 0.5mV in an offset environment of 300mV. Other factors like AC power supply interference, RF interference from surgery equipment, and implanted devices like pace makers and physiological monitoring systems can also impact accuracy. The main sources of noise in ECG are[5]:

[1] Baseline wander (low frequency noise)
[2] Power line interference (50Hz or 60Hz noise from power lines)
[3] Muscle noise (This noise is very difficult to remove as it is in the same region as the actual signal. It is usually corrected in software.)
[4] Other interference (i.e., radio frequency noise from other equipment)

Baseline wander is a low frequency component present in the ECG system. This is caused due to offset voltages in the electrodes, respiration, and body movement. This can cause problems in the analysis of the ECG waveform. The offset also limits the maximum value of gain which can be obtained from the instrumentation amplifier. At higher gains, the signal can saturate. This noise can be removed by implementing a high pass filter. The cut-off frequency should be such that the ECG is undistorted while the baseline wander must be removed. A typical value of the cut-off frequency is 0.05Hz.

Most of the high frequency noise can be filtered before it is sampled by the ADC. The device can be shielded to prevent high frequency radiated noise from being coupled. So, a inbuilt low pass filter is used to remove the high frequency noise from the signal. The cut-off frequency for the low pass filter is 150Hz. This removes high frequency noises in the ECG signal.

PIC16F877A micro-controller is used for Heart rate monitoring. It contains 10 bit, 8 channel Analog-to-Digital Convertor (ADC).it consumes very less power and works on high speed FLASH/EEPROM technology. It has wide operating range. Fig. 5 shows the over-all flow-diagram of working of the controller.

The ECG signal is digitized and compared to the standard one. If the signal voltage is greater than the Standard voltage Vg, then the counter is incremented by one. After the given period of time is completed, the counter calculates the Heart beats. The heart beat count is multiplied with the desired multiplication factor and the heart rate is calculated. If the heart rate is beyond or above the standard limit, the alarm is given to the patient. Also there is provision to take serial data out. IN future, this data can be transmitted to the remote or nearest doctor using wired or wireless communication, so the doctor can regenerate the ECG wave whenever he wants to monitor the patient.

A graphical user interface is developed using Visual basic (software design). We can manually adjust the time duration of monitoring the ECG data in seconds. And a click on start button will start the Graphical recording of ECG on our GUI. The snapshot of the GUI is as shown in figure 7.

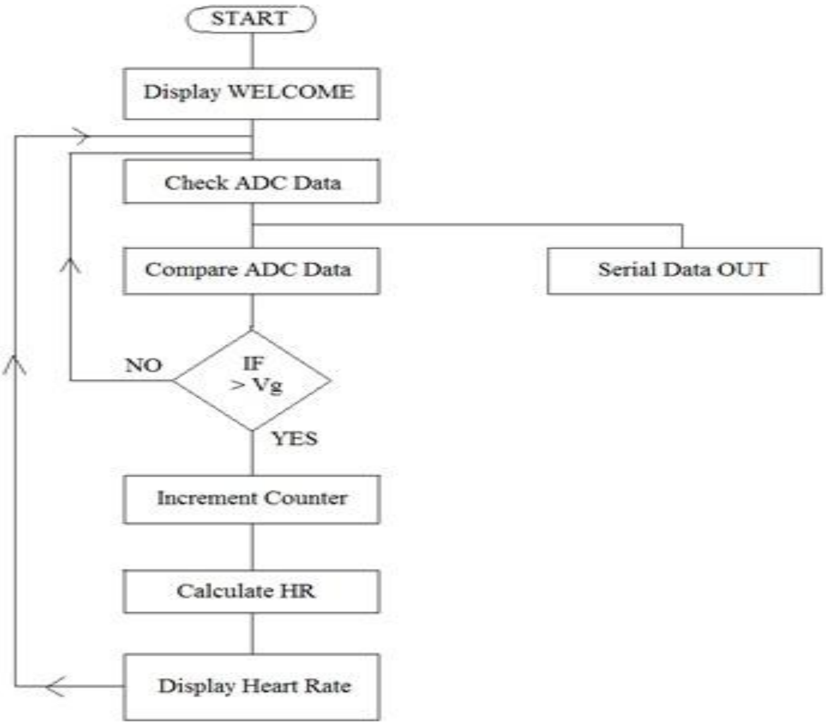


Figure6. Flow chart of working of PIC controller

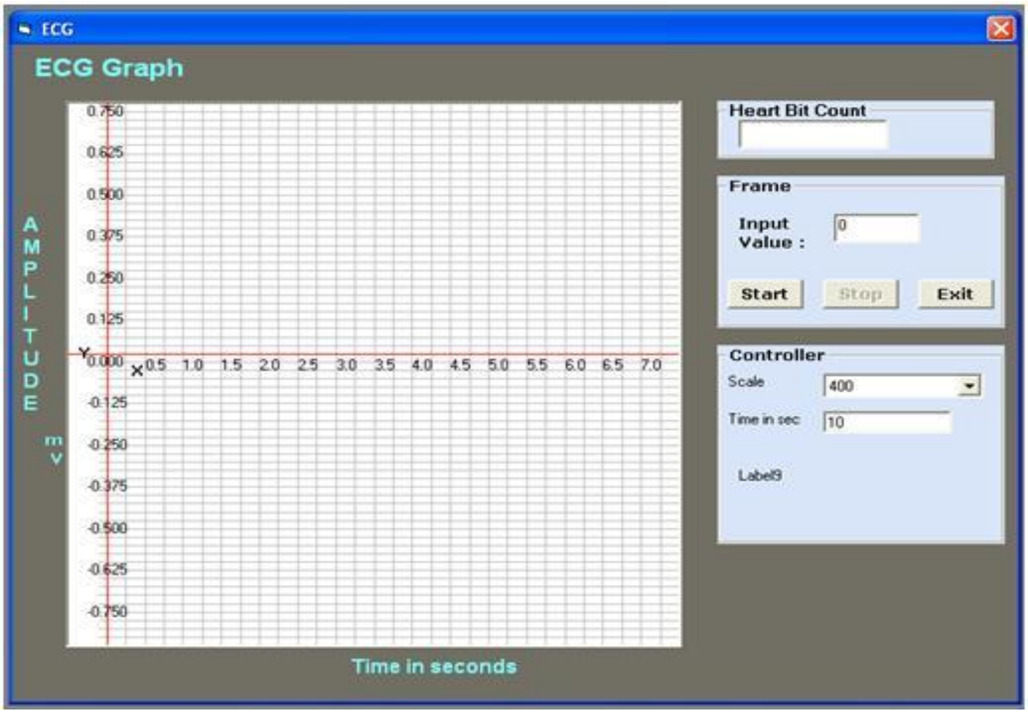
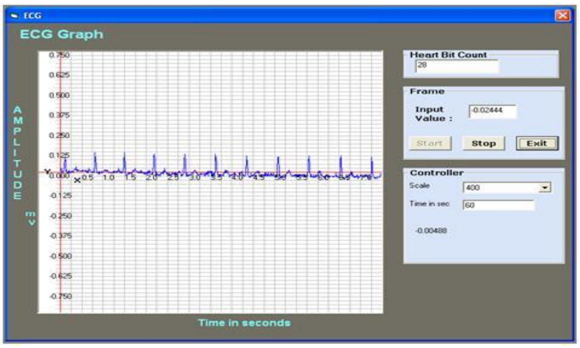


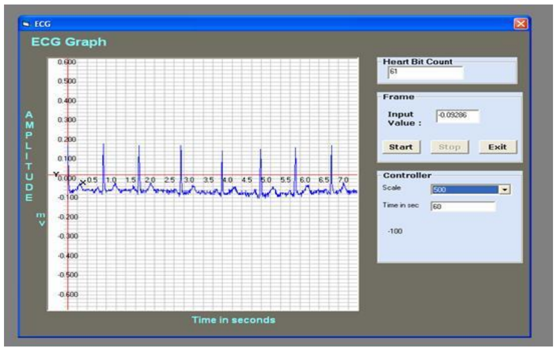
Figure7. Graphical User Interface for Wearable ECG Monitoring

V. RESULT

Figure 8 (a) and (b) are sample of results obtained form different patients. Results match with the doctors opinion as asked for the guidance. The results ware compared with the other techniques of heart rate monitoring. The performance is as better as other heart rate monitors used in hospitals. With this device more number of patients can also be monitored with some changes in the software.



(a)



(b)

Figure8. (a) patient with heart-beat count 78 (normal) and (b) patient with heart-beat count 57 (Normal for post operative patient)

VI. CONCLUSION

In this paper, we have explained the signal processing of ECG signal to remove noise content and to obtain the well amplified signal. Also we discussed the algorithm of working of the microcontroller for heart beat calculation. Alarm is given for abnormal ECG and the patient can concern to the doctor. With the development of this device we have reduce the cost of ECG monitor. Also the device is wearable and can be easily operated by the patient anywhere he wants. Thus our basic aim to detect the emergency conditions before its too late is satisfied.

In Future, we can work on making some provision to transmit the Digital data on Hyper terminals to the doctor through wired or wireless communications, where the data will get stored at any specific location and doctor can regenerate the ECG wave from this data. Thus, the patient will receive good attention and this will reduce critical conditions. This helps in reducing cost and risks involved in personal Healthcare.

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