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Study on AFE Chip Based ECG Data Acquisition

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Abstract— In this paper, we have suggested the development of ECG (electrocardiogram) monitors based on AFE (Analog Front End) chips. The project aims to make a switch from traditional analog circuitry to chip based circuitry that is programmable and whose parameter values are not vulnerable to changes of temperature or other environmental conditions on account of being packaged inside the chip ,hence giving us accurate results. We have even formulated a portable, compact, and low power monitor that is capable of performing real time ECG signal processing in which an AFE chip has been interfaced with a MSP430 microcontroller to acquire an ECG signal.

Keywords— ECG, measurement, detection, AFE, chip

I. INTRODUCTION

A. Evolution of ECG

Sedentary lifestyle and unhealthy habits have made inroads for variety of diseases in our lives. Heart diseases are widely prevalent in and around the world and have become a common phenomenon nowadays. These are dangerous because lack of proper medical aid, in time can lead to death of the individual too. This has invoked the need for proper and timely diagnosis of the heart disease subsequently followed by required treatment and medication. Initially, it was seen that heart rate could be measured in a raw manner by feeling the arterial pulse on the wrist and counting the number of pulses in a minute. Later, it was discovered that, electrical currents exist inside the body. The sinus node or the sino-atrial node is the source in the heart from which the electrical pulse of the heart starts. The heart has a rhythmic activity of 72 beats/ minute, which means for every beat, a new electrical wave starts. In this single beat, deoxygenated blood flows from the upper and the lower ends of the body and is carried to the lungs to get it purified or oxygenated.

A method of measuring this pulse called 'electrocardiography' was discovered. The heart signal could be captured by electrodes, carried through cables to processing circuitry and seen on a display unit. The waveforms obtained could be analysed to confirm the presence or absence of the disease and were known as electrocardiograms or ECG. For analysing the diseases, ECG waveform gradually got segmented into 5 portions: P, Q, R, S and T according to the sequential steps involved in the heart's activity. Electrodes are placed on the body and electrolytic gel applied helps in better conductivity and transmission of signal through the ECG cables. Electrode placement has a large role in the type of waveform that we obtain. The term 'lead' denotes the potential difference between 2 electrodes or two points where they are applied. For every lead there is a corresponding ECG waveform that differs from the other only in the amplitudes of the wavelets P, Q, R, S and T. All of these waveforms help in detection of variety of heart diseases.

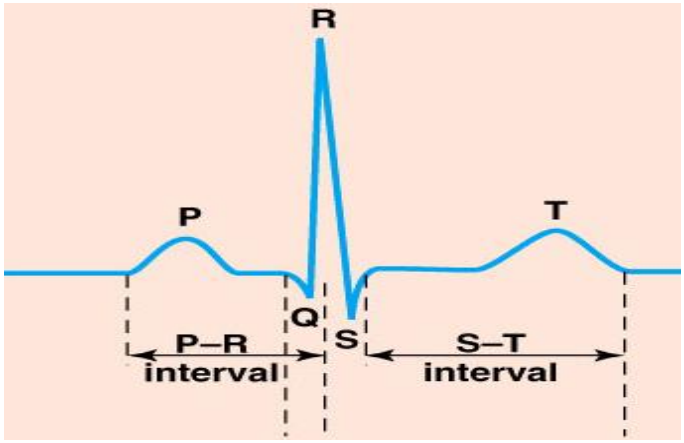

Figure1. ECG waveform

ECG signals are very low amplitude signals of the order of 0.5-5mV that exist in the bandwidth of 0.05Hz to 100 Hz [3]. They get distorted when they are affected by various kinds of noises such as:

- Power line interference exists in the range of 50-60Hz resulting from the ac mains.
- Baseline drift: Caused by electrode contact noise and respiration it exists below 0.01Hz.
- EMG signals developing from muscle contraction interfere with ECG signals.
- Electromagnetic interference from electrode wires playing as antennas.
- High frequency noise above 150 Hz coming from other working electronic devices around the monitor.
- Common mode noise resulting from the potential between body and the ground.

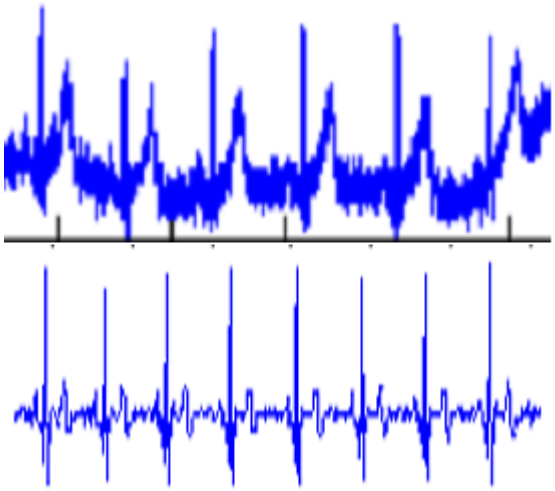

Figure2. Noisy (above) and noise free (below) ECG signal

B. Development of ECG Detection

Electrocardiography was done conventionally using large sized ECG machines in hospitals. These systems are tape based [1] that obtained the ECG waveform on a graph paper which was later studied for determination of the abnormality.

There were many flaws with the system, for instance they were restricted to hospitals and not singularly dedicated to ECG. They were power consuming and prevented real time analysis. Besides, reading the graph being a manual activity was prone to error and the method was inconvenient for a reliable diagnosis and conclusion. Also the patient's detection of disease could not be done while running, walking etc as patient was confined to the place of measurement sparking the need for something more flexible. This made the researchers go deeper to find out something that could bring ECG measurement out of the hospitals and into the hands of the layman bringing into effect the introduction of small sized portable ECG monitors [1] based on microcontrollers that could process the signal in no time and give parallel results.

This brought about a revolution in the mechanism of the methodology involved in ECG measurement i.e. ECG machines shifted from being electromechanical devices producing one time results to being microprocessor based which processed as well as stored in real time.

Subsequently, betterment was done with the reduction in size, cost and power by involving microcontrollers. They swept over traditional systems because they combined mechanical systems with user interaction making the systems more flexible. Criteria governing the systems could be changed at will, as and when required. They have succeeded even over digital signal processors (DSP) or field programmable gate array (FPGA) based embedded systems as far as portability and cost effectiveness of the circuit is concerned because DSPs are good enough only for numerical capabilities and FPGAs lack the user-friendliness of a microcontroller.

All these efforts have shown excellent results as emergency cases have been found to be dealt better, faster and easier as compared to the previous methods of hospitalization of the patient. These efforts have now been shifted to the treatment not being a localized phenomenon, with the involvement of wireless transmission. This concept has undergone a lot evolution with the heart rate being measured by finger tip [8] and ear leads [4] to the ECG waveform being not just displayed but also emailed, messaged and sent via Bluetooth [5]. It has helped reduce the delay and effort involved in not just transporting the patient to the hospital but also the long wait in the queues outside the hospital. In combining the concept of measurement with immediate transmission of the ECG waveform by the common man, the doctor also gets the option of sending his review or the next course of action for the patient back via email or message [3]. This method is also used by athletes for monitoring their heart activity [6].

Electrocardiographs are very useful as they not only help in treatment of heart disease but are also used for knowing a person's response to drug therapy and reveal the changes that have occurred in the functioning of the heart. In course of betterment, the systems that are coming up are substituting the usage of passive components by chips which are produced on a large scale making the systems more digitized or automated and accurate.

C. Previous Work Done

A few previously done researches are listed below:

Christopher M. Tenedero [7] has suggested the general ECG circuit design used traditionally. It is composed of 2 electrodes making a single channel lead I ECG transmit the signal to the conditioning and processing circuitry started by an instrumentation amplifier which magnifies the minute signals and make them bigger with respect to the noise they are coming with. This is followed by an isolation amplifier which helps in rejecting common mode noise and protects the patient from cardiac shocks etc. This is followed by a band pass filter made up of resistors, capacitor and/or op-amps which helps in passing the ECG signal only and rejecting the noise coming with it. The right leg drive amplifier too is used for suppressing common mode interference. Then processing is done a second time using digital filters after digitizing the signal through a data acquisition board and finally concluded by a display unit that shows the ECG waveform.

Sharief F. Babiker [8] has presented a Heart Rate Monitor based on Microcontroller using fingertip sensors which does not involve the use of electrodes. This device uses optical technology involving standard infrared Light Emitting Diode (LED) placed above the finger for transmitting light and photo sensor placed below the finger to detect the same IR light to determine the difference in the volume of blood in it. These reflections are processed in order to measure the heart rate.

Hailong Jin [2] has suggested the design of Holter ECG System based on MSP430 and USB Technology that is compact and low power run by a battery having large amount of memory.. In this project he has assembled together a preamplifier module, 50 Hz notch filter, secondary amplifier filter module and MSP430F149 microcontroller whose program is burnt on16 bit Flash chip used separately. The communication between these components is made possible by a USB controller. The most significant aspect of the project is the use of filter chips that could be programmed to act as any filter and he has made a 50Hz notch filter in it.

YANG Xue [3] has made an EGG wireless monitoring instrument based on GPRS in which ECG signals collected by electrodes pass through an amplifying and filter circuit before passing through MSP430 microcontroller. The ECG signals are analog to digital conversed by the microcontroller before being displayed on an LCD. The instrument then calculates the heart rate every 3s and sounds an alarm if the result is abnormal and send a message to the physician.

II. THE PROPOSED MODEL

A single channel ECG has been suggested using the AFE chip and MSP430 microcontroller performing signal processing to see a noise free signal on the display unit.

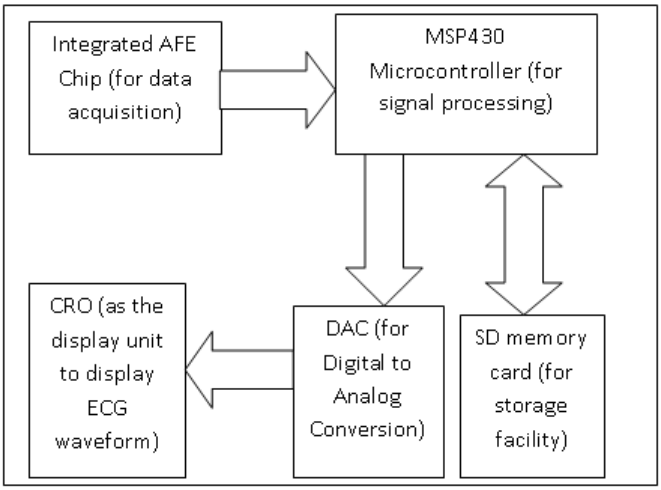

Figure3. Block Diagram of the ECG circuit

A. Analog Front End (AFE) Chip

The integrated AFE (Analog Front End) comes inbuilt with multiple components including programmable gain amplifiers, filters, ADC to sample and digitize the signal. It is employed as a multipurpose board to acquire the signal and filter out noise to send a noise free signal to the microcontroller.

B. MSP430 microcontroller

MSP430 are a chosen because of their ultra low power consumption. This microcontroller configures the AFE as well as operates and receives the data from it and processes it further to display it on an oscilloscope. It is programmed by USB Debugging interface using Code Composer Studio (CCS) as the development environment using JTAG as an interface. It connects with the DAC that during signal acquisition to display an ECG signal on an oscilloscope. The ECG waveform can be stored in the SD card for later reference.

III. CONCLUSIONS AND FUTURE SCOPE

Chip based systems are advantageous over analog form of systems because they are less exposed to environmental conditions and hence less prone to error because individual components are packaged inside the chip. Thus, they are

reliable and efficient. Being programmable they are flexible and can make good low power, low cost, low weight and portable ECG monitors. Semiconductor technology has revolutionized in the last few years with mass production of chips having a very low unit cost. It is thus a potential field for such excellent ECG monitors as mentioned above.

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