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RESEARCH ARTICLE

Efficient Implementation of Heart rate monitoring system using PPG and NI-MyDAQ

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Abstract

Portable health monitoring systems support early detection of health problems and help in preventing their consequences. A traditional approach of heart monitoring has always meant that people will go to a hospital where a cardiologist or medical officer will examine the patient for any heart diseases. A standard Electrocardiogram (ECG) machine normally found in big hospitals is not economical due to its high cost and requires a specialist to handle the machine. A Low Cost Portable Heart beat monitor using Infrared sensor is a Bio-medical project built to measure the heart beat in real-time. In this project, Infrared LED and a photodiode has been used as a sensor to measure the heart rate and NI-myDAQ to convert the Analog output signal to Digital signal. Our proposed Heart rate measuring device is user friendly and uses optical technology to detect the flow of blood through the body. The phases used in monitoring heart beat include pulse detection, pulse amplification and Pulse measurement. The proposed model has got an improved accuracy in the detection of heart beat by using a 2-stage amplifier design along with post processing of the digital signal.

Introduction:-

Optical health monitoring sensors integrated into the medical field which can be operated by mobile systems to represent a novelbiophotonic technology to detect early heart abnormalities to overcome some frequent problems. Recently there is some improvement in the medical fields which gave rise to a new method to overcome our problems using wireless communications and physiological sensing open the way for miniature, lightweight, low power and intelligent cardio-vascular monitoring devices. Heart rate measurement could show the condition of the heart. Heart rate will vary according to age, person's physical and mental condition. Human heart rate for adult who is healthy is around [60 -100] beats per minute (Bpm). While for an athlete, it is slower than an active adult because as they do a lot of exercises which maintains good blood flow, their heart doesn't need to pump blood with much effort. For a baby on the other hand, the heart rate is higher which is around [120 – 160] Bpm and for their children's heart rate is around [75 – 110] Bpm. Abnormal heart rate such as lower heart rate than the normal rate is called 'Bradycardia' whereas for a higher heart rate which is higher than the normal is called 'Tachycardia'. The traditional way of heart rate counting is by putting our finger above the pulse artery and count the pulse rate within 30 second and then the heart rate (Bpm) can be found by multiplying with '2'. This way is easy but inaccurate especially when the artery pulse state is high. The most accurate method to measure heart rate is by using an electrocardiogram (ECG), but this equipment is expensive and could not be afforded by common people.

Why "PPG"?

Photoplethysmography (PPG) helps in detection of blood volume by a time-resolved analysis of the reflected or absorbed optical IR light. Earlier methods of heart rate detection used Electrocardiogram (ECG) signal acquired from different parts of the body and then studied. This process of detection requires a medical officer to identify the heart rate and also the system is of high cost such that it could not be afforded by normal people. Moreover it needs a patient to visit the hospital for checking. This proposed method of PPG makes use of optical technology which made it a user friendly, efficient and portable device.

Sensor working:-

A Sensor is mostly defined as a convertor which can detect and measure a physical quantity and then converts it into an electrical signal such that it could be analyzed by any instrument. Infrared sensor is a particular type of a sensor which detects the intensity difference between different colors. IR reflective sensors have an emitter (IR LED-TX) and a receiver (Photo diode). If a reflective surface (typically white) is present beneath the IR LED, IR rays are reflected and are detected by the receiver (refer fig1). While in the case of a black surface, the light gets absorbed and hence receiver does not get any IR rays (refer fig2). In our project this reflective nature of the IR rays has been used to detect the flow of blood through our body. The heartbeat is measured by placing our fingertip over the IR-sensor part (refer fig3). This sensor piece comprises of an IR- LED (Tx) and a Photodiode, mounted side by side as shown in the figure below. The IR diode sends an infrared light of certain wavelength onto the fingertip (which is put over the sensor unit), and the Rx wits the portion of the light that is reflected from the blood vessels.

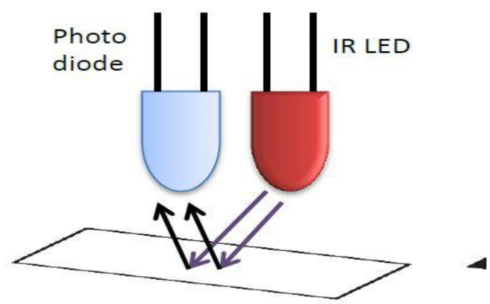

Fig.1. Light Reflected off white surface

The force of reflected light relies on the blood volume streaming inside the fingertip. In this way, every heart beat marginally changes the measure of reflected infrared (IR) light that can be distinguished by the photodiode.

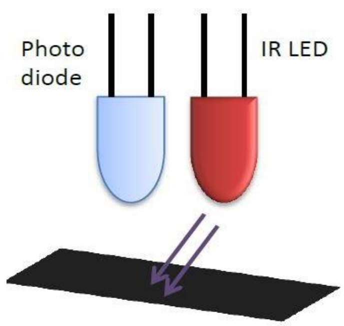

Fig2. Light absorbed by the black surface

With the utilization of a legitimate signal modeling, this little change in the sufficiency of the reflected light could be changed over into a throbbing wave.

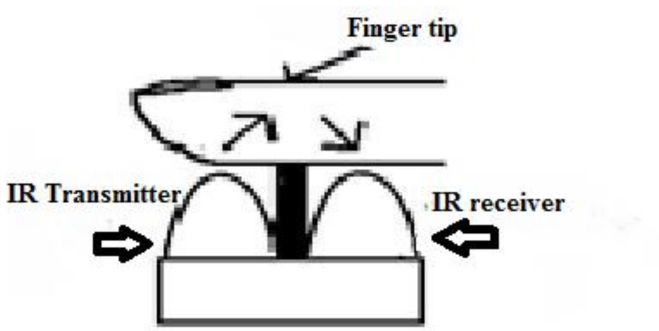

Fig3: PPG sensor

The sensor is made to identify the small change in the amount of blood through the finger. For this a potentiometer has been used in order to adjust the sensitivity of the receiver. The sensed signal consists of a DC component as well as an AC variation. Our interest is to extract the AC component for which the signal has been passed through an essential signal conditioning stage. In this stage the DC component will be removed by the use of a High pass filter.

Signal conditioning stage:-

The hemoglobin molecules (red color) in the blood absorb the IR light; because every color absorbs the light of a specific wavelength say (600nm in this case). Each time heart pumps the blood, the volume of oxygen loaded blood increases in the finger and in some other parts of the body. As a result, the amount of ox hemoglobin molecules will also increase in our blood. Absorption of this infrared light is also very high and, reflection of infrared light is low. Then, each heart beat slightly varies the amount of reflected infrared light which can be detected by the IR Rx. The more IR light it receives the less the voltage of the input point from the sensor part is generated. The IR Rx selects an AC signal with some DC components. The DC parts come up from non-throbbing blood tissues. Direct cross-talking between the IR transmitter and the receiver diode has been avoided. On the other hand, they are put eagerly by isolating them perfectly. A Resistor is joined with the Infrared gatherer (IR Rx) to diminish the current increased out of the identifier. If the power, of IR light is too high, then the reflected infrared light from the tissue will be sufficient, such that the photo distinguishing diode leads always, and no signal will exist. So the value of the resistance or POT connected in series with the Infrared light transmitter (IR Tx) is chosen to regulate the amount of current and hence reduces the intensity of the transmitted infrared light. The change in the blood quantity with respect to the heartbeat causes a pulse train at the output of the photo diode, the amplitude of which is too little to be detected directly by any device, hence the use of a 2-stage dynamic high gain, active low pass channel filter design educing two Operational Amplifiers (OPAMPs) for filtering and for strengthening of the signal to appropriate voltage level so that the pulses can be counted by the my-DAQ.

LM324 IC (Quad OpAmp):

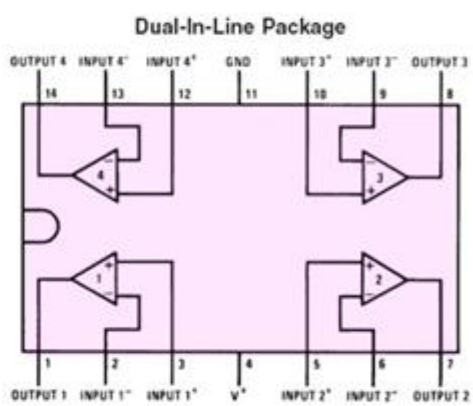

Fig4: LM324 IC

The LM324 IC– is a highly popular chip that is used in many circuits for various applications. It is a package of four operational amplifiers (Quad OP-AMP) that can be powered up by a battery which can be either single supply or dual supply. The single-polarity supply (positive and negative only) is used over a very wide voltage range. The four op-amps are embedded in a single 14-pin package. We can use one or more of these op-amps for our purpose. The current consumption is not affected by the power supply /voltage.

Technical specifications of LM324 IC:
1. The input power supply voltage ranges between +3V and +30V.
2. The input power supply current (min) that is used: 0.8 mA.
3. The typical output current of each op-amp (at o/p to ground) is: 20 mA typical (min 10 mA).
4. The normal output current that flows from the +ve supply to the o/p -pin): 8 mA typical (min 5 mA).
5. The max voltage gain is 100,000. This gain is set by the feedback resistors between o/p -pin and the inverting (-ve) i/p of the opamp.

The signal modeling circuit has two indistinguishable dynamic low pass channels with a combined gain of 121 and with a cut-off frequency of around 2.34 Hz, which is corresponding to the variety of the beats. The mathematical formula for increase of every phase of the LPF is given beneath:
Each Stage Gain = $1 + (R_f * C_f)$
In the outlined circuit, aggregate increase is 121. Estimations of Rf and Ri are chosen as 680 Kohm and 68 Kohm. The 1uF capacitors, which are associated in arrangement to the i/ps of every channel, hinder the undesired DC segments of the sign. The two 1µF capacitors ought to have the capacity to withstand some reverse biased condition, so they ought to be non-polarized. This implies the most extreme quantifiable heart rate is around 140 Bpm. These channels obstruct any higher frequency distortions present in the signal. The 2-stage channel and amplifier circuit changes over powerless signal originating from the photodiode sensor unit into a heartbeat. The DC segment of the distinguished signal ought to be wiped out keeping in mind the end goal to just acquire the alternating varieties of the heart. A light emitting diode joined at the output flickers each time showing a heart beat is recognized. The beat created from the signal conditioner and amplifier is nourished to the Computerized or Simple I/O pin of My-DAQ in light of the necessity.

NI-myDAQ:-
NI-myDAQ (Data Acquisition system) is a portable device which bridges the gap between hardware and software. It has mainly '8' commonly features which makes it to use as a portable computer-based lab instruments based on NI- LabVIEW software environment including several analyzing devices such as a digital multimeter (DMM), oscilloscope (CRO), and a function generator (F-Gen). We can access all the runtime software tool kits to perform variety of experiments with a Bode analyzer (Gain& frequency Measurements), an arbitrary signal generator, dynamic signal analyzer (FFT), digital i/p, and digital o/p. This platform comprises of a data acquisition machine that we can use to measure two differential Analog i/p and Analog o/p channels (200 kS/s, 16 bits, ±15 V). The '8' Digital i/p and Digital o/p lines (3.5 V TTL-compatible) helps us to interface both low voltage TTL (LVTTL) and 3.5 - 5 V TTL digital circuits. An NI- myDAQ supplies enough required power for simple circuits and sensors with ±5 V, -15 V, and +15 V power supply o/ps (up to 500 mW of power). The isolated 60 V Multimeter can measure both AC and DC voltage (V) and current (I) as well as resistance (Ohms), Diode voltage, and continuity.

Fig5: NI-myDAQ

System overview:-

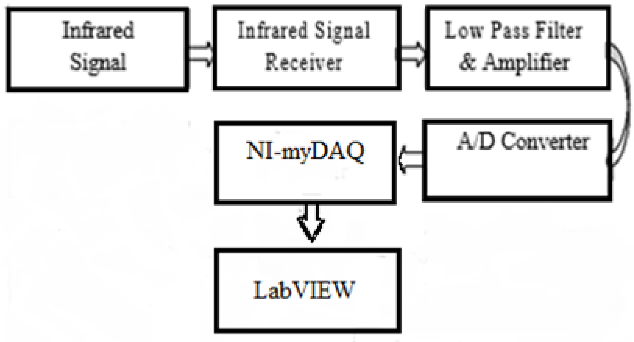

Fig6: Block diagram of operation

Parameters Considered:-

Supply:-

The gadget works on a 5V battery source in view of its little bundling being used by our circuit. Max power utilization of the gadget is upto 0.7W.

Robustness:-

The outlined gadget works in an extensive variety of temperature environment [00C to 7000C]. The gadget bundling has been intended to withstand under ordinary utilization. The bundling is stun yet not water-safe.

Operating speed:-

Our circuit is built upon an embedded environment where a real time signal is acquired and then interfaced with a digital computer for post processing. This makes the speed of rate monitoring increase and gives efficient output to the end user.

Fidelity:-

The circuit we have used can be operated at various temperatures and can last on a long run. It has also got variable sensitivity by which we can adjust the output signal based on our requirement.

Post processing:-

The post processing of the signal is essential in order to make sure the error in detection is reduced to the maximum extent. The National Instruments' Data Acquisition System (DAQ) has been used for acquiring the signal from real world and then a software package named National instruments' LabVIEW has been used to process the signal in a virtual environment by creating some Virtual Instruments (VI).

LabVIEW Environment:-

LabVIEW is a virtual instruments workbench and a system-development stand and design environment for real time programming and processing of analog or digital signals from National Instruments. It includes mainly two types of programming: 1.) Data flow programming and 2.) Graphical programming. Data flow includes applying the numerical inputs as data and then performing some arithmetic and logical operations on the data. Graphical programming includes processing of real time signals by making use of signal processing tool box. LabVIEW helps in creating user required blocks by general programming. This makes it user friendly and flexible in usage.

Things we can do with LabVIEW:

1. Acquire and then process the signal
2. Testing and validation of system
3. Embedded monitoring and control applications
4. Wireless system prototype building
5. Parallel processing and programming

The DAQ is used to estimate the number of heart beats per minute. The DAQ drives a display on the LabVIEW software which shows the calculated values. So any external LCD or LCD driver is not required. A loop continuously inputs the analog signal of heart condition and transfers the values to the computer. If the signal voltage is more than the set threshold voltage, then it's considered as a detection of heart beat and counts up to 30 beats. A timer block counts the time for 30 beats and calculates the heart rate by multiplying by 2. This post processing involves mainly three phases which are: 1.) Threshold detection, 2.) Beats per minute counting and 3.) Data representation.

1. Threshold detection VI:-

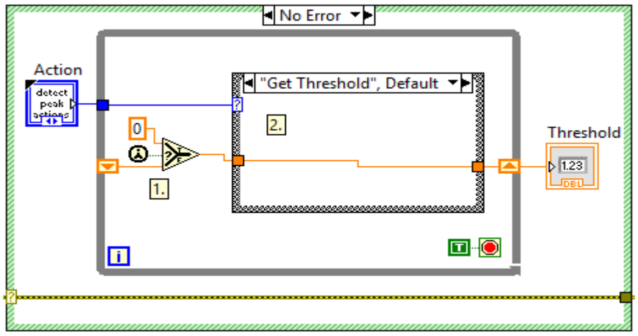

Fig7: First stage VI

This block measures the amplitude of the acquired signal and compares it with a previous set threshold value and gives the corresponding output out of it. The Output signal from the circuit has been acquired from the Analog input pin of the DAQ. A predefined value of voltage has been set in the VI block in order to compare with input and give the output. A continuous while loop has been created to acquire the signal continuously. A structured palette is put to verify the condition whether any input is being acquired or not. Based on the condition the while loop executes. A wait time of around 10millisecond is been applied in order to control the performance of the CPU which may be affected by the continuous while loop. The output is then given to the next block where the beats per minute are calculated.

2. BPM Count Block:-

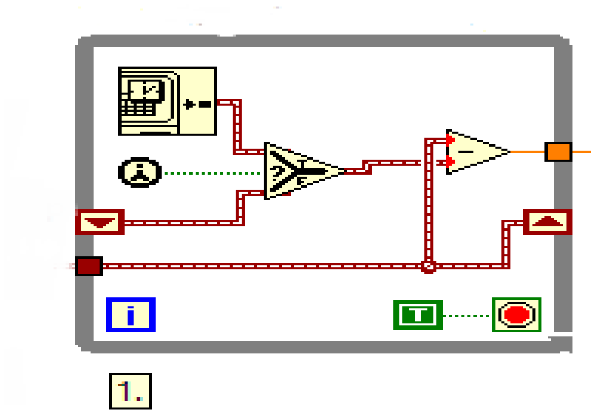

Fig8: Second stage VI

In this stage a counter has been created in order to count the beats based on the condition of whether the signal amplitude is greater or less than the threshold. This VI block is used here in order to count the number of pulses obtained out of the threshold block. The number is counted for 30 sec and then multiplied by 2 in order to get the result for 60sec or 1min. For accurate results counting for 60sec is preferable.

3. Data representation:-

This is the last stage in the post processing of the signal. Here the acquired signal will be displayed by making use of a graphical palette and a signal simulator. The digital count of the BPM is also displayed on the numeric palette of the LabVIEW project.

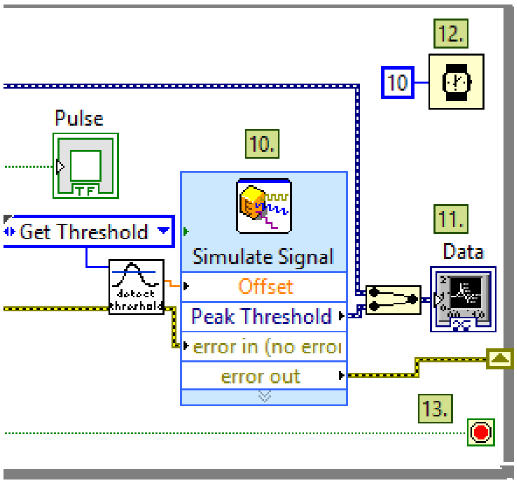

Fig9: Third stage VI

Results:-

The circuit has been tested on various platforms. An initial simulation is done using NI-Multisim software package.

1. Simulation results (NI-Multisim):

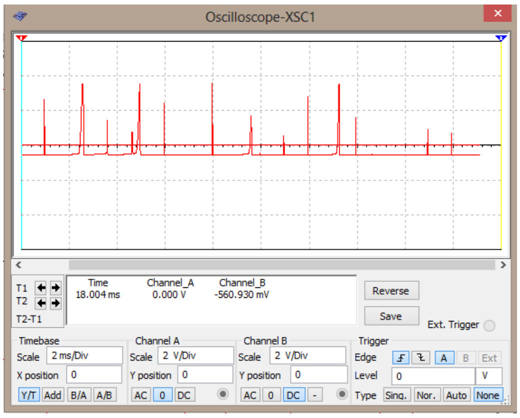

Fig10: Simulated sensor output

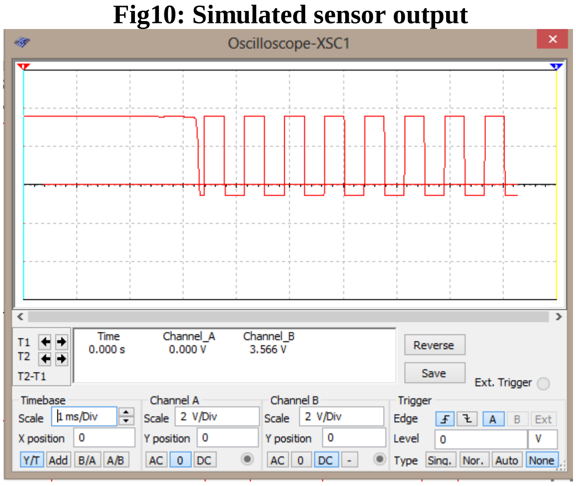

Fig11: Output of signal conditioning circuit (simulated)

2. Output graphs seen on virtual CRO:

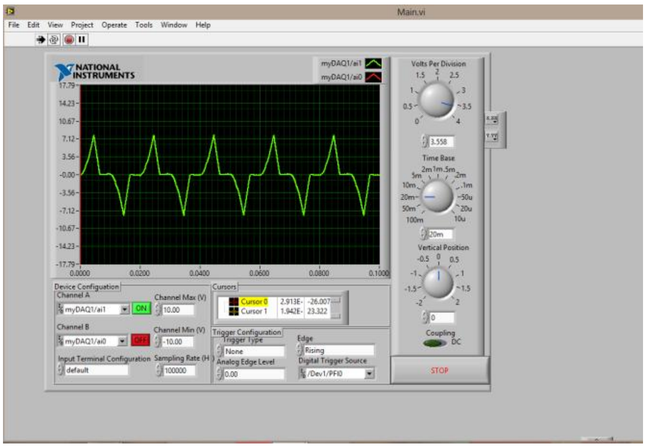

Fig12: DAQ Output waveform (Pre Processed)

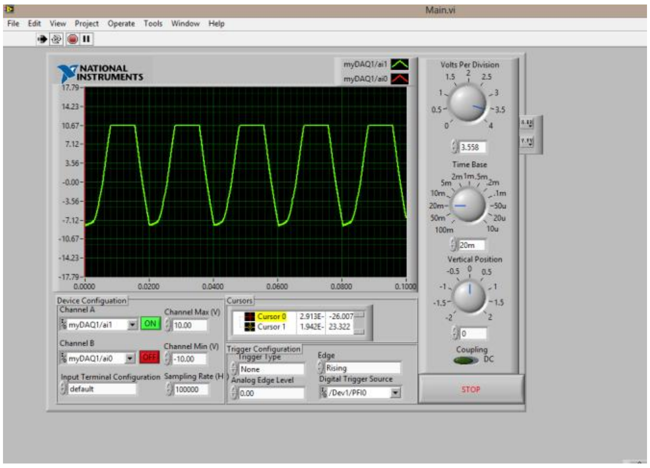

Fig13: DAQ Output waveform (Post Processed)

The last stage results were observed on the graphical interface and numeric indicator of the LabVIEW environment.

3. Output seen after post processing through LabVIEW:

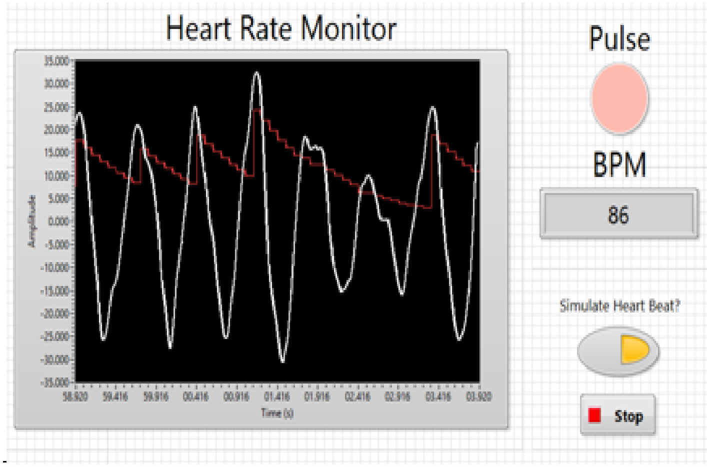

Fig14: Detected waveform and pulse rate after post processing

Conclusion:-

An efficient system which can monitor the heart rate of a person has been successfully implemented. The present status of the project desires to be enhanced such that it makes possible to handle a large amount of data from wide range of people and transmit the data to a nearby hospital for remote patient monitoring. This may inlcude the usage of GSM /WIFI technology for the transmission of data. We are looking forward to advance our project to make it reach a lot of people in the society and help them in the best way possible. The ending concept of the system by ourselves was positive and also have endlessly encouraged this development and got implemented in a sensible way and continuity as a project. It is notable that the idea of this work is to show the opportunity of having a useful solution, low cost, utilizing the existing systems in telecommunications technologies at the place of interest and the use of efficient software tools for the application development. Also the use of LabVIEW enabled us to reduce the cost a lot and it also helps in application building. This concept of app building can be utilized to make an Android app which can monitor and transmit the heart beat over a long distance using either GSM or WIFI.

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