

Simulation of ECG signal using Advanced Virtual Instrumentation system Based on LAB VIEW

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Abstract: ECG signal can be acquired using various software's. This paper introduces the concept and advantages of Virtual instruments. National Instruments Lab VIEW-II is used to design the ECG acquisition experimental system and then briefly outlines its salient characteristics. The aim is to provide a new approach to fully understand signal acquisition, and data-saving process in biomedical research. It is a flexible experimental platform for exploring new ECG acquisition methods.

Keywords: Virtual instrument, Lab VIEW, ECG, ECG parameters

1. Introduction

ECG has proved out to be very useful in the analysis of human heart beat and subsequently diagnosis of various human cardiovascular diseases. The design of real time ECG acquisition system is difficult since real time environment is not always available for the performance analysis of these systems. The existing ECG analyser systems are more expensive. The use of advanced virtual instrumentation system based on National Instruments LabView software makes the system cost efficient and can be utilized as a test bench for the study of ECG signals at the laboratory level.

1.1 THEORY OF ECG:

Electrocardiography is a method of monitoring and recording the electric currents generated during the alternating contractions of the atria and ventricles of the heart. The device used to monitor and record these signals is an electrocardiogram, more commonly referred to as an ECG.

The ECG records the electrical activity of the heart, where each heart beat is displayed as a series of electrical waves characterized by peaks and valleys. Any ECG gives two kinds of information.

- 1) The duration of the electrical wave crossing the heart which in turn decides whether the electrical activity is normal or slow or irregular
- 2) The amount of electrical activity passing through the heart muscle which enables to find whether the parts of the heart are too large or overworked

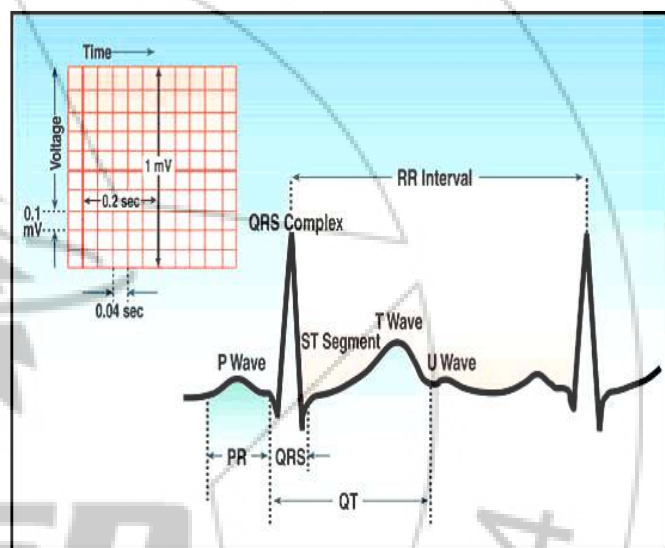


Figure 1: ECG waves and intervals [15]

Normally the frequency range of an ECG signal is 0.05–100 Hz and its dynamic range – of 1–10 mV. The ECG signal is characterized by five peaks and valleys labelled by the letters P, Q, R, S, T. In some cases we also use another peak called U. The performance of ECG analyzing system depends mainly on the accurate and reliable detection of the QRS complex, as well as T and P-waves. The P-wave represents the activation of the upper chambers of the heart, the atria, while the QRS complex and T-wave represent the excitation of the ventricles or the lower chamber of the heart. The detection of the QRS complex is the most important task in automatic ECG signal analysis. Once the QRS complex has been identified a more detailed examination of ECG signal including the heart rate, the ST segment *etc.* can be performed [1]. Normal ECG with standard values is shown in Fig-1 & 2.

Normal Values for Amplitudes and Durations of ECG Parameters:			
Amplitude:	P wave	0.25 mV	Atrial Depolarization
	R wave	1.60 mV	
	Q wave	25% of R wave	
	T wave	0.1 to 0.5 mV	Ventricular Repolarization
Duration:	P-R interval	0.12 to 0.20 sec	
	Q-T interval	0.35 to 0.44 sec	
	S-T segment	0.05 to 0.15 sec	
	P wave interval	0.11 sec	
	QRS interval	0.09 sec	Ventricular Depolarization

Figure 2: Normal ECG Waveform [16]

So, from the recorded shape of the ECG, we can say whether the heart activity is normal or abnormal. The electrocardiogram is a graphic recording or display of the time variant voltages produced by the myocardium during the cardiac cycle. The P-, QRS- and T-waves reflect the rhythmic electrical depolarization and repolarization of the myocardium associated with the contractions of the atria and ventricles. This ECG is used clinically in diagnosing various abnormalities and conditions associated with the heart

The normal value of heart beat lies in the range of 60 to 100 beats/minute. A slower rate than this is called bradycardia (Slow heart) and a higher rate is called tachycardia (Fast heart). If the cycles are not evenly spaced, an arrhythmia may be indicated. If the P-R interval is greater than 0.2 seconds, it may suggest blockage of the AV node.

- Each action potential in the heart originates near the top of the right atrium at a point called the pacemaker or sinoatrial (SA) node.
- The wave generated by action potential, terminates at a point near the center of the heart, called the atrioventricular (AV) node.

The horizontal segment of this waveform preceding the P-wave is designated as the baseline or the isopotential line. The P-wave represents depolarization of the atrial musculature. The QRS complex is the combined result of the repolarization of the atria and depolarization of the ventricles, which occur almost simultaneously. The T-wave is the wave of ventricular repolarization, whereas the U-wave, if present is generally believed to be the result of after potentials in the ventricular muscle.

So, the duration amplitude and morphology of the QRS complex is useful in diagnosing cardiac arrhythmias, conduction abnormalities, ventricular hypertrophy, myocardial infection and other disease states [2].

1.2 Types of ECG Recorders

There are numerous types of ECG recorders. Many of these are portable units, while others are part of permanent installations. 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 sophisticated and costly implantable gadgets. The Holter monitors have been used only to collect data in ambulatory patients. Processing and analysis are then performed off-line 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 [8].

The growing health concerns, especially for cardiac disorders reflect on the need of developing a simple inexpensive and portable ECG system. In the present work, a simple ECG simulator module has been developed using LabVIEW-11 that displays ECG wave. The ECG wave is recorded and analyzed using LabVIEW software.

1.3 CHALLENGES IN ECG ACQUISITION

ECG signal is a very small signal and it is difficult to capture. The noise will be interfered and distort the signal. The notch filter is used to filter the noise. Any noise from 50Hz power line present the input signal will be attenuated by 80dB. This means that the 50Hz noise at the output will be 10000 times smaller than at the input. The notch filter rejects just 50Hz. It passes frequencies below and above the 50Hz centre. But while tried to reduce the 50Hz noise, the entire small signal also been rejected include the ECG signal [9].

2. Materials and Methods

A simple virtual ECG simulator experimental system has been developed that consists of front-panel and block diagram using National Instrument's LabVIEW -11 software. Virtual system displays ECG signal for different parameters on user interface i. e. block diagram.

2.1. Virtual Instrumentation

Virtual instrumentation is the foundation for the modern laboratory. A virtual instrument consists of a computer,

software, and modulator hardware; all combined and configured to emulate the function of traditional hardware instrumentation. It is also called as LabVIEW program. Because their functionality is software-defined by the user, virtual instruments are extremely flexible, powerful and cost-effective.

Virtual instruments, by virtue of being PC-based, inherently take advantage of the benefits from the latest technology incorporated. These advances in technology and performance, which are quickly closing the gap between stand-alone instruments and PCs, include powerful processors such as the Pentium 4 and operating systems and technologies such as Microsoft Windows XP, .NET, and Apple Mac OS X. In addition to incorporating powerful features, these platforms also offer easy access to powerful tools such as the internet. Stand-alone traditional instruments such as oscilloscopes and waveform generators are very powerful, expensive, and designed to perform one or more specific tasks defined by the vendor. However, the user generally cannot extend or customize them. The knobs and buttons on the instrument, the built-in circuitry, and the functions available to the user, are all specific to the nature of the instrument. In addition, special technology and costly components must be developed to build these instruments, making them very expensive and slow to adapt.

A typical system of Virtual Instrumentation (VI) is constituted by a set of devices capable of communicating between them and for a program that controls the mentioned communication. The device that controls the system of virtual instrumentation is a computer, whereas other devices are measurement devices (multimeters, oscilloscopes, sensors...) and other equipments (generators of sign, power sources, and speed controls of motors...). From the information loaded by the different devices we can change the conditions of the test, modifying parameters of the measurement instruments. In an environment as the described one, the current trend is that specialized software controls the system, coordinating the functioning of the different elements. One of these programs software is LabView of National Instruments. Labview allows to load, to analyze and to monitor the information inside a graphical programming environment in which there are assembled objects called virtual instruments to form the program of application with which the user will interact. In addition LabView allows the information representation in interactive panels that work as if it was a real instrumentation, and it allows multiple options of information treatment, as his storage on disc and to share them in network or with other applications. The interaction with other applications will be able to be carried out by means of calls to bookshops of dynamic link (DLL: Dynamic Link Library) and dynamic exchange of information (DDE: Dynamic Data Exchange) in local way or by means of TCP/IP in remote connections. Always looking for independence of the platform in which we have carried out our application. A measurement instrument that we can have in any laboratory remains perfectly defined by a few controls and a few elements of representation. However, a virtual instrument will be related to the concept of software. This software will execute in a computer that will have a few elements lodged hardware concrete,

information acquisition cards (analogical and digital), cards of interface with the buses of instrumentation and a few channels of control also analogical and digital. Virtual instrumentation will allow to operating with this hardware by means of a user's graphical interface that will be the controls panel of the habitual devices (Oscilloscope, multimeter, etc.). By means of its representation on screen of the graphical elements of visualization and control that will use as interface with the user, this one will observe the conditions of the input selected in the screen and will interact directly or by means of the execution of the routines that finds programmed [10]. LabView is a graphical programming environment which provides high-level network capabilities. This software platform has provided us with the ability to perform remote handling of equipment in a highly interactive manner, but with enough simplicity.

2.2. Introduction to LabVIEW - A Graphical Programming

The software package LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a commercial product from National Instruments and runs on several host machines (PC, Macintosh, or Sun workstations). LabVIEW is a powerful graphical development environment for signal acquisition, measurement analysis, and data presentation, giving the flexibility of a programming language without the complexity of traditional development tools. Since 1986, when National Instruments introduced LabVIEW for the Macintosh, it has quickly and consistently attracted engineers and scientists looking for a productive powerful programming language to use in test, control and design applications. Today, LabVIEW is the preferred graphical development environment for thousands of engineers and scientists. With the right software tool, engineers and scientists can efficiently create their own applications, by designing and integrating the routines that a particular process requires. They can also create an appropriate user interface that best suits the purpose of the application and those who will interact with it. They can define how and when the application acquires data from the device, how it processes, manipulates and stores the data, and how the results are presented to the user. With powerful software, we can build intelligence and decision-making capabilities into the instrument so that it adapts when measured signals change inadvertently or when more or less processing power is required. An important advantage that software provides is modularity.

LabVIEW has been developed as an environment for the design of virtual instruments (VI). LabVIEW is a software package developed to build programs with symbols (icons) rather than writing out lines and lines of programming text. It is a graphical programming. It uses symbols, terminology and formats that are familiar to technicians, scientists, and engineers. LabVIEW is programmed to act as an interface, helping pieces of hardware "communicate" with each other. Moreover, LabVIEW offers built-in libraries that allow the user to work over the internet and use different programming formats and systems.

Every VI comprises a control panel and an interconnection diagram i.e. block diagram. On the panel, the user can

interactively specify graphical devices for input (e.g., sliding cursors, buttons, text controls) and for output (e.g., gauges, images, graphs). In the diagram, the user graphically enters the functionality of the VI. A library of standard functionalities is available to perform this task: icons performing numerical functions, string treatment, matrix computations, etc. can be linked together to design an algorithm. An icon can be associated with a complete VI and used hierarchically in the diagram of another instrument, thus allowing a modular approach. Moreover, modules can be written in standard programming languages, such as C or Pascal [11].

2.3. LabVIEW Applications

The applications to LabVIEW are endless. In the past, multiple instruments were necessary to obtain the data a researcher wanted. In the case of the ECG, several oscilloscopes would be needed to view more than one heart beat from an individual simultaneously. Instead, LabVIEW has virtual instruments (VIs). These are programs that are built into LabVIEW and perform the same function as another piece of equipment such as an oscilloscope, so that user can view as many heart beats from many individuals as he wants. User just needs to specify how many channels he will need rather than use multiple oscilloscopes. LabVIEW' virtual instruments may be modified for each specific application. This means that the user can manually add functions to their VI at any time. Furthermore, Lab VIEW can be "plugged" into the internet, so progress can be controlled from remote locations [12].

3. Simulation of Virtual ECG using LabVIEW

For viewing the ECG signal, software must be used to convert the electrical impulse into a visual representation that we can see and understand. Lab VIEW is a unique software package that provides just that.

Virtual cardiograph has been designed using LabVIEW -11 software of National Instruments. The cardiograph is used for monitoring of the ECG signal [13, 14]. In this case the signal was taken from ECG simulator. Figure (3) shows front panel diagram. ECG signal was displayed for various parameters such as P-wave magnitude, T-wave magnitude, QRS-magnitude, Noise amplitude, Baseline fluctuation frequency, No. of iterations and others as shown in block diagram. The acquired signal from ECG simulator has been shown in Figure (4) for the case of 30 beats/min which indicates the abnormality of bradycardia. Similarly Figure (5) shows the same for the 60 beats/min Figure (6) shows the virtual cardiograph for 140 beats/min which shows the problem of tachycardia. Figure (7) shows block diagram of ECG for BMP = 60, with noise amplitude= 4mv, P-wave Mag.= 0.3v, T-wave Mag.= 0.5v. Thus by adjusting the various parameter values different types of virtual cardiographs can be generated and studied. Data logger can also be made that provides the numeric values of acquired waveforms in terms of Virtual voltage and x-values. The corresponding data can be read in terms of graph on LabVIEW. Cardiograph has provision to start acquisition and save data that gives more flexibility to the cardiologist.

3.1 Data Logging Module

It is often necessary to permanently store ECG-data acquired. LabVIEW includes the ability to create a LabVIEW measurement file, an ASCII text file that can be read by a spreadsheet, or a text editor. The LabVIEW measurement file is easy to create. When we place the Write LabVIEW Measurement File Express VI on the block diagram, a configuration dialog box appears where we can specify how to store the file. For example, we can specify the format of the file, and how often we want the file to be saved to the hard drive.

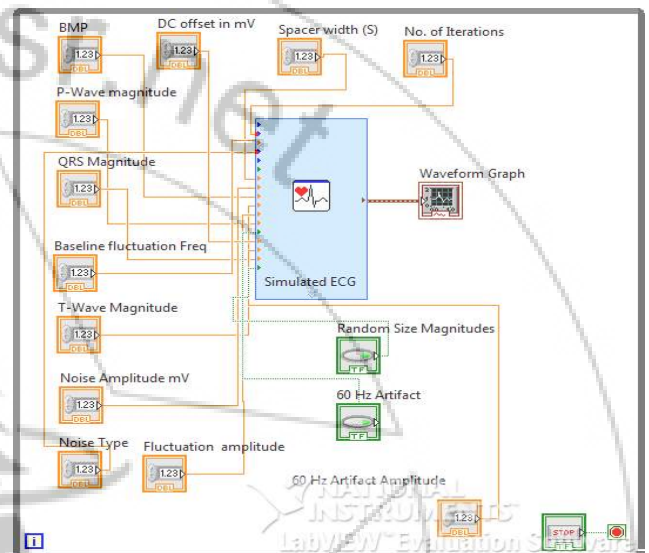


Figure 3: Front panel of ECG Simulator

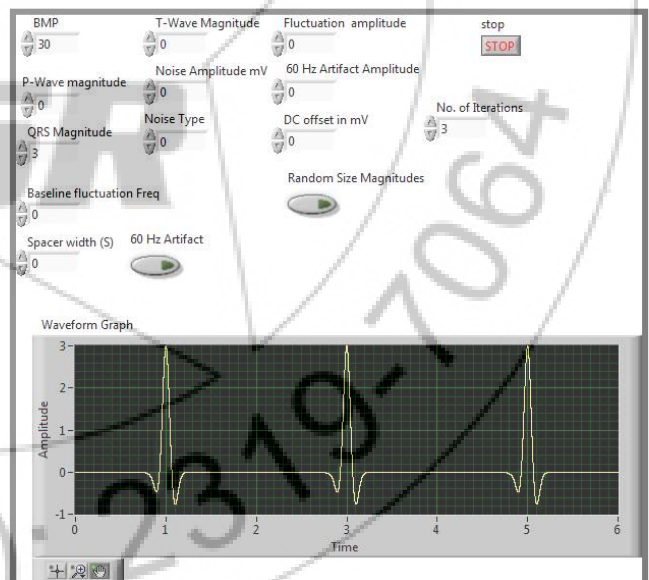


Figure 4: Block Diagram of ECG for BMP = 30

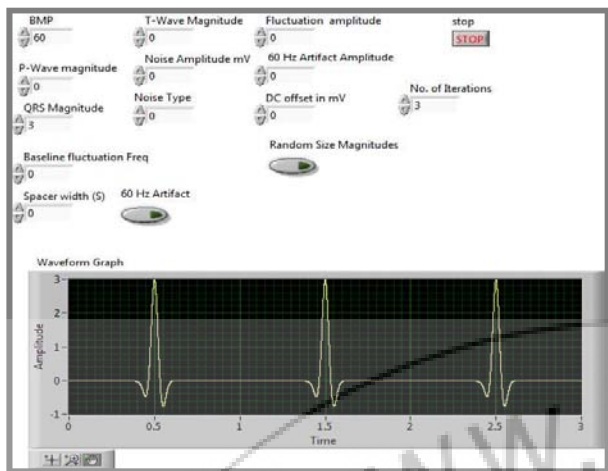


Figure 5: Block Diagram of ECG for BMP = 60

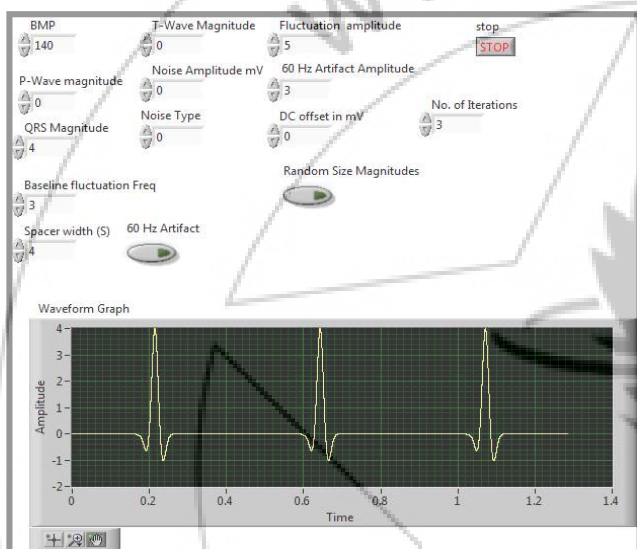


Figure 6: Block Diagram of ECG for BMP = 140

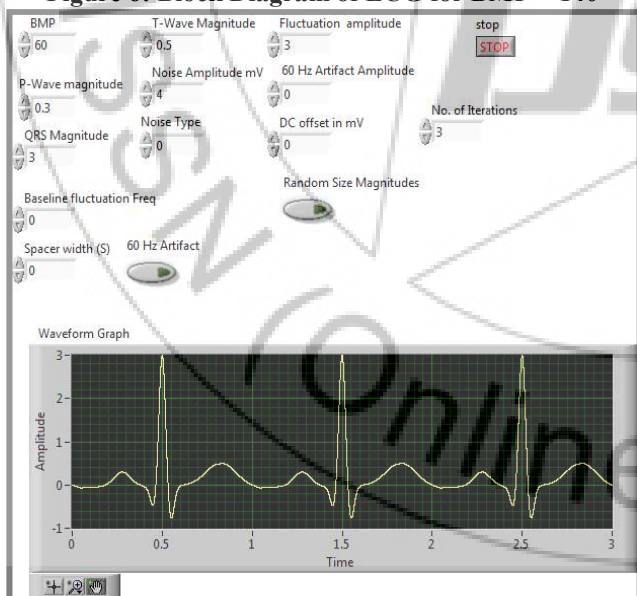


Figure 7: Block Diagram of ECG for BMP = 60, with noise amplitude= 4mv, P-wave Mag.= 0.3, T-waveMag.= 0.5

4. Conclusion

The use of advanced virtual instrumentation system based on National Instruments LabView-11 software is much

more helpful for the acquisition and study of different types of virtual electrocardiogram. Thus software makes the system cost efficient and can be utilized as a test bench for the study of ECG signals at the laboratory level with more interactive and simplicity.

The virtual instrumentation provides the flexibility for biomedical researchers. It can rapidly create applications using intuitive graphical language, it is easy to customize the instruments and add new functionality by modifying the LabVIEW code. This ECG-Analyzing experimental system based on virtual instrument is helpful to improve initiative study and enhance the understanding of theoretical knowledge.

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