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Design and Build ECG Simulator Andjar Pudji1, Ridha Mak'ruf2, Winda Wirasa3 Department of Electromedical Engineering, Health Polytechnic Ministry of Health Surabaya, Indonesia Abstract: ECG Simulator is a tool to simulate ECG signals. This device is useful for testing ECG devices when repairing, for research purposes on ECG signals or for educational purposes. ECG Simulator or often called Phantom ECG in principle is a signal generator in the form of "ECG like" signal or ECG signal that has been recorded. According to the researchers' observations, the ECG Simulator that was made there are still some shortcomings, namely PC-based, only 2 lead signals, limited BPM values and no sensitivity settings. Judging from the importance of using these tools as a standard ECG comparison tool, the researchers intend to design a tool entitled "ECG Simulator Design". This design is based on Arduino and uses 12-bit Digital to Analog Converter to convert Digital data which is the output of Arduino into Analog data in the form of ECG signals. In this study, researchers made the design of the ECG Simulator which is a tool for calibrating ECG equipment. The purpose of this research is to design an ECG Simulator tool. The research design used was a study using a pre-experimental method with after-only design type of research because the final results of measurement tools compared with the control group. While this design through the stages as follows: circuit design and circuit testing. Based on the measurement results obtained an error rate of 0.420% sensitivity of 0.5mV, 0.22% sensitivity of 1.0mV, and 0.22% sensitivity of 2.0mV in the BPM setting 30, obtained an error rate value of 0.342% sensitivity of 0.5mV, 0.460% sensitivity of 1.0mV, and 0.432 % sensitivity of 2.0mV at BPM setting 60, obtained an error rate value of 0.121% sensitivity of 0.5mV, 0.1% sensitivity of 1.0mV, and 0.1% sensitivity of 2.0mV at setting BPM 120, obtained an error rate value of 0.423% sensitivity of 0.5mV,

0.310% 1.0mV sensitivity, and 0.520% 2.0mV sensitivity at 180 BPM settings and 0.246% 0.5mV sensitivity, 0.230% 1.0mV sensitivity and 0.246% 2.0mV sensitivity at 240 BPM settings. Keywords: ECG Simulator, ECG Signal 1. Introduction Electrocardiogram (ECG) is a signal produced by the electrical activity of the heart muscle. This ECG is a recording of heart condition information taken by placing electrodes on the body. This ECG recording is used by a specialist to determine the patient's heart condition. ECG signals are recorded using electrocardiograph devices. ECG signals are one of the objects most often used in studying bioelectric phenomena. This signal is studied in medicine for health applications or in the field of biomedical engineering to study biomedical instrumentation techniques. This signal occurs because the process of depolarization of heart cells that occurs spontaneously is initiated by the Sinoatrial node (SA node). To learn ECG, it needs a tool in the form of an ECG signal generator or an ECG Simulator device to generate ECG signals. ECG Simulator is a tool to simulate ECG signals. This device is useful for testing ECG devices when repairing, for research purposes on ECG signals or for educational purposes. ECG Simulator or often called Phantom ECG in principle is a signal generator in the form of "ECG like" signal or ECG signal that has been recorded Our research is to design a simulator tool better known as the "Design and Build ECG Simulator" that is practical, and easy to operate. Before this ECG Simulator produces a heart pulse with a pulse that can be selected in accordance with personnel and other technicians related to the use of heart electrical activity recording devices. Researchers will make sensitivity settings on the ECG Simulator which will be displayed on ECG paper by analyzing data in the form of Signal Amplitude, sensitivity settings so that the output signal generated in accordance with the calibration standard of 1 mV. ECG simulators or phantom ECG are artificial signals of cardiac activity that are widely used by both medical personnel and other technicians related to the use of heart electrical activity recording devices. Figure 1: Normal Heart Anatomy the test you want to do on an electrocardiograph aircraft, a 1 mV (millivolt) sensitivity test will be carried out so that it The heart is a cone-shaped muscular organ. The heart is can be known whether the aircraft can provide the same located in the chest, behind the sternum in the mediastinal response as that fed. After testing 1 mV BPM selection can (or mediastinal) cavity, between the lungs, and in front of be done with 3 Leads. the spine. The heart is tilted in this area like an inverted ECG simulators or phantom ECG are artificial signals of triangle. The upper part of the heart, or its base, is located cardiac activity that are widely used by both medical just below the second rib; the lower part of the heart, or apex, tilts forward and downward, towards the left side of the body, and rests on the diaphragm. The heart varies in Volume 8 Issue 10, October 2019 www.ijsr.net Licensed Under Creative Commons Attribution CC BY size depending on the size of the person's body, but this organ is about 5 inches (12.5 cm) long and 3.5 inches (9 cm) wide, or about the size of the person's fist. Liver weight, usually 9 to 12 ounces (255 to 340 g), varies depending on size, age, sex, and athletic conditioning. An athlete's heart usually weighs more than the average person, and the parent's heart is lighter. The heart has the main function, which is: collecting blood needed from all parts of the human body, pumping blood into the lungs, collecting filtered blood from the lungs, pumping blood back to all parts of the human body. The heart has 4 chambers, namely 2 atria and 2 ventricles. The atrium is separated from the venous system by the heart valve, so blood flow is only in one direction. The superior veins and inferior veins carry blood to the right atrium of the heart, at the same time the lung channel supplies blood from the left atrium. When the atrium contracts, the atrium pumps blood to the ventricles which are also separated by a valve. The valve only opens blood flow from the atrium to the ventricles and is not the opposite. The valve that separates the atria and ventricles is called the atrioventricular valve. Atrioventricular between the right atrium and right ventricle is called the tricuspid valve because it forms a 3 leaf structure. The left atrium and left ventricle have a bicuspid valve, which separates the 2 chambers. The ventricle expands when filled with pressure produced by blood flow in the atrium. The ventricles contract shortly after the atrium pumps blood as a result of the electrical delay between the atria and the ventricles. The left ventricle pumps blood to the arteries separated by valves to avoid backflow. The aorta supplies blood to all parts of the body. The right ventricle pumps blood to be filtered into the pulmonary artery, and separated by the pulmonary valve, to further enter the pulmonary blood circulation. From the explanation above, it appears that there are 2 circulatory systems in the human body. Circular blood circulation starts from the left ventricle to the aorta and then spread throughout the body to the capillaries and back to the heart through veins into the right atrium. Small blood circulation starts from the right ventricle, the blood goes to the lungs through the pulmonary arteries, then the blood experiences gas exchange in the lungs and then goes back into the left atrium through the pulmonary veins. The endocardium is the deepest layer of tissue that lines the heart space. Myocardium is the thickest tunica of the heart and consists of heart muscle cells arranged in layers that surround the atria and ventricles. The outside of the heart is covered by epithelial layers of flattened (mesotel) supported by a thin layer of connective tissue that forms the epicardium. In the subepicardial loose connective tissue layer there are arteries, veins, nerves, and nerve ganglia. The heart muscle consists of muscle fibers in which there is a continuous cycle of depolarization-repolarization caused by sodium pumping from and into the heart muscle cells which causes the heart beat. The heart muscle cells contract with the aim of pumping blood and are triggered by an action potential and then spread through the muscle cell membrane. The incident was caused because the heart has a mechanism to conduct the electricity that it generates to contract or pump and relax. The mechanism of electric current that causes the action is influenced by several types of electrolytes such as K +, Na +, and Ca2 +, so that if there is interference in the body the electrolyte levels will also cause interference with the electric current mechanism in the heart. The heart conduction system consists of a group of special heart muscle cells in the heart wall that send signals to the heart muscle causing contractions. The main components of the heart conduction system are the SA node, AV node, His bundle, branch bundle, and Purkinje fibers. At the top of the right porch is the sinoatrial (SA) node. This SA node causes stimulation that causes the heart to contract. The atrioventricular (AV) node is located on the wall that borders the right atrium and the right chamber. This knot serves to deliver impulses from the

porch to the cubicle. The impulse from the AV node is then transmitted throughout the chamber through His file. At the end of His file there are many branches. These branches are called Purkinje fibers. Purkinje fibers are in charge of passing impulses from His beam to all the muscles of the chamber. The chambers then contract so that blood is pumped out of the chambers and flows in the circulatory system. Electrocardiogram Electrocardiogram (ECG) is a diagnostic tool that can record the electrical activity of the heart. By analyzing the waveforms produced from the recording of electrical activity of the heart, the following things can be known: a) Knowing the rhythm abnormalities in the heart. b) Knowing the effect of drugs on the heart c) Find out heart muscle abnormalities, d) Estimating enlargement of the heart. e) Assess pacemaker function. Therefore, every recording made with the ECG, the ECG must have a high precision, because if an error occurs in the diagnostic results, resulting in errors in reading the results which will also result in errors in determining the diagnosis of the disease. ECG Signal Normal In the picture below, a normal human heart pulse has a magnitude of 1.1 mV, this can be seen by counting the number of boxes from point Q to point R, where there are 11 boxes. Each box is equal to 0.1 mV, so 11 boxes is 1.1 mV. P wave is a wave that arises due to atrial depolarization from the sinoatrial node to the atrioventricular node where the normal amplitude value is <0.3mV. The Q wave is the first negative deflection after the P wave and which precedes the R deflection, generated by depolarizing the ventricular start where the normal amplitude value of the Q wave is 25% of the R wave. The R wave is the first positive deflection after the P wave and is caused by the main depolarization of the ventricle where the normal amplitude is 1.6 to 3 mV. The S wave is a negative deflection after the R deflection. This whole ventricular depolarization generates a complex QRS wave. The T wave is a wave that arises by ventricular repolarization where the normal amplitude value is 0.1 to 0.5 mV. The P-R interval has a normal duration of 0.12 to 0.20 seconds. The Q-T interval has a normal duration of 0. 35 to 0.44 seconds. The S-T interval has a normal duration of 0.05 to 0.15 seconds. The Q-R-S interval has a normal duration of 0.06 to 0.10 seconds. Figure 2: Normal ECG Signal ECG leads Each ECG signal leads are the result of electrical leads from 2 or more electrodes mounted on the surface of the body. Each ECG signal has a different heart vector orientation. With this 12-lead ECG, all electrical conditions in the heart muscle can be seen so that it will make it easier to make a diagnosis of cardiac abnormalities. In general these leads consist of: Frontal Saddle In the frontal leads, the Einthoven triangle method is used which produces 3 ECG signals which are then called Lead I, Lead II, and Lead III. Lead Lead I, the positive electrode is connected to the left hand and the negative electrode is connected to the right hand. Lead Lead II, the positive electrode is connected to the left foot and the negative electrode is connected to the right hand. Lead Lead III, the positive electrode is connected to the left foot and the negative electrode is connected to the left hand. As a grounding, one electrode is attached to the right foot. More clearly about this frontal leads can be seen in the picture below Figure 3. Frontal Lead ECG Simulator To learn ECG needed a tool in the form of an ECG signal image or an ECG device to display ECG signals. ECG Simulator is a device that can produce heart pulses with a pulse and amplitude that can be adjusted according to the tests conducted on the Electrocardiograph. This device is useful for testing ECG devices during repairs or calibrations, for research purposes on ECG signals or for educational purposes. ECG Simulator or often called Phantom ECG in principle is a signal generator with the form of "ECG like" signal or ECG signal that has been recorded[1]. Conceptual framework This conceptual framework explains how this research process works: Figure 4: ECG Simulator Block Diagram When the appliance is turned on the MCU or microcontroller will wait for commands from the control to select the type of wave and other controls other than that the display will display the type of signal that was immediately issued the first time the device is turned on [2]. While the rotary switch (BPM control) will immediately work according to its rotation and cause the first signal form issued by the MCU even without touching the control to be issued to the Digital to Analog Converter or DAC circuit in Digital form. The choice of signal shape by turning the rotary switch will have a different BPM range and then it will also be displayed on a 2x16 LCD display. While the LA, RA, LL, RL blocks, will receive the form of signals issued by the DAC in the form of analogues which were previously processed in the Resistor Network Circuit block. This Network Circuit Resistor Block serves to provide different impedances for each Lead. 2. Research Methods This research on experiment and designed on Arduino and uses 12-bit Digital to Analog Converter to convert Digital data which is the output of Arduino into Analog data in the form of ECG signals. 3. Result and Discussion ECG Wave Formation In this study, researchers conducted the formation of ECG signals from scanning Figure 5: ECG simulator printout results The ECG printout used is Lead II 30 BPM, 60 BPM, 180 BPM and 240 BPM with a sensitivity of 1.0 mV. After the printout results were scanned, the researchers used the help of the Engauge Digitizer program version 10.1 to convert the signal image into digital data in the form of X and Y coordinates. Measurement Results for Every Increase in BPM Measurements on modules with increasing BPM parameters for each BPM using ECG recorder Comparison is done by adjusting the BPM value of the module and looking at the results of BPM values on the LCD ECG recorder[3]. Table 1: Measurement of BPM values 30-240 with an increase in BPM sensitivity of 0.5 mV BPM Measurement Data Value 1 2 3 4 5 6 30 30 30 30 30 30 30 60 60 60 60 60 60 60 120 120 120 120 120 120 180 180 180 180 180 180 180 180 240 240 240 239 240 239 240 Measurements were made with an ECG recorder by looking at the recorded BPM values. The measurement uses a paper speed setting of 25 mm / s and a sensitivity of 10 mm / mV. Figure 6: Graph of Comparison of Errors at 0.5mV Sensitivity From the graphic image above can be seen error difference between the ECG Simulator module with the ECG Simulator comparison tool The blue line represents the error value of the ECG Simulator module and the red line represents the error value of the ECG Simulator comparison tool Can be seen the error value in the BPM 30 setting has a difference of 0.12% and in the BPM setting 120 there is also a difference of 0.16%. Whereas the other BPM values have the same error value[4][5]. 4. Conclusion Based on the measurement results obtained an error rate of 0.420% sensitivity of 0.5mV, 0.22% sensitivity of 1.0mV, and 0.22% sensitivity of 2.0mV in the BPM setting 30, obtained an error rate value of 0.342% sensitivity of 0.5mV, 0.460% sensitivity of

1.0mV, and 0.432 % sensitivity of 2.0mV at BPM setting 60, obtained an error rate value of 0.121% sensitivity of 0.5mV, 0.1% sensitivity of 1.0mV, and 0.1% sensitivity of 2.0mV at setting BPM 120, obtained an error rate value of 0.423% sensitivity of 0.5mV, 0.310% 1.0mV sensitivity, and 0.520% 2.0mV sensitivity at 180 BPM settings and 0.246% 0.5mV sensitivity, 0.230% 1.0mV sensitivity and 0.246% 2.0mV sensitivity at 240 BPM settings

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