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IOP Conference Series: Materials Science and Engineering PAPER • OPEN ACCESS [A low-cost Holter monitor design equipped with external memory and Bluetooth connection To cite this article: D Nofitasari et al 2020 IOP Conf. Ser.: Mater. Sci. Eng. 850 012020 View the article online for updates and enhancements. This content was downloaded from IP address 182. 1.125.55 on 10/04/2021 at 06:02 A low-cost Holter monitor design equipped with external memory and Bluetooth connection D Nofitasari\\*, I D G H Wisana, T Triwiyanto, E D Setioningsih, M R Mak'ruf and P C Nugraha Department of Electromedical Engineering, Poltekkes Kemenkes, Jl. Pucang Jajar Timur No. 10, Surabaya, 60245. \\*dewinofita51@gmail.com Abstract. Monitoring the heart activity is critical for a patient with heart disease. Twenty-hour detecting of the ECG signal will help the clinician to diagnose the hearth. This device is usually called a Holter monitor. However, the price of this device is very expensive, therefore the development of a Holter is required. The purpose of this study is to develop a portable and low- cost Holter system to record the ECG signal in twenty-four hours. The mainboard is composed of a pre-amplifier, bandpass filter, notch filter, summing amplifier, Arduino microcontroller, SD Card Memory, and a Bluetooth transmitter. ECG signal is collected from the body based on the standard measurement of LEAD II. The ECG signal is sampled with a frequency sampling of 200 Hz. To record the raw data of the ECG signal, the SD Card Memory was used to save the data for further data analysis. Calibration was conducted by using an ECG phantom. The calibration was performed in order to make this design to be a standard ECG machine. The design was also equipped with a Bluetooth transmitter to transmit the data to the computer. The total price to develop this device is 460,000 IDR. After the evaluation, the BPM error of this Holter is  \$\pm 0.0273\%\$  and the Holter able to operate in 24 hours. The developed ECG Holter is portable in dimension and low cost to be fabricated for mass production to help people with heart disease. 1. Introduction Holter Monitor, or sometimes also referred to as an ambulatory electrocardiographic \(ECG\) device, is a portable device used to monitor various activities on the cardiovascular system continuously for 24 hours \[1\]. The principal work of this device is by attaching electrodes to the patient's chest while an instrument records the ECG \[2\]. This device usually works with the battery. This Holter can be used as an ECG recorder that can be bagged or carried everywhere with a belt or straps on the shoulder \[3\]. Holter monitor works by tapping the ECG's electrical signal on the heart and is reinforced so that the signal can be read and diagnosed by the medical doctor. Holter monitor function is to analyze and monitor a person's heart activity caused by abnormalities or abnormal changes in the heart \[4\]. However, the use of this device is only limited to the area in the hospital or medical institution, while the need for this Holter is also essential for monitoring ECG signals at home or in areas that far from the hospital. The function of this device is as early prevention of heart problems in a person, and it is critical to always monitor the heart health regularly by examining the heart signal recordings independently \[5\].](#)

Therefore, this is very much needed a portable and practical Holter (easy to carry and easy to use) for a patient with heart disease. By adding a wireless monitoring system and utilizing a computer as a visualization of the ECG signal, the Holter can be used effectively to monitor ECG signals wherever they are without having [Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author\(s\) and the title of the work, journal citation and DOI. Published under licence by IOP Publishing Ltd 1](#) to look at [the ECG record in the treatment room \[5\]](#). Holter monitors are vital for checking the heart abnormalities. In cases of arrhythmia, the use of the Holter monitor is very emphasized because this device can record ECG signal activity for 24 hours and is portable [6]. Tai et al. [7] proposed an ECG recorder with an adaptive sampling algorithm and has been evaluated using the MIT / BIH database, but from this study, it can use a simpler method so that it can improve signal reconstruction better. Related research was also developed by Luciani et al. [8]; they made [a portable ECG monitoring device with Bluetooth and the Holter](#) that has the capability for telemedicine applications for remote monitoring. In this study, the data obtained [can be stored on a flash memory card \(FAT16\)](#) or sent [via Bluetooth or USB to a local station or](#) Access Point. The research can operate [in two modes: Holter and on-line transmission](#). Jin and Miao [9] developed ECG Holter using the MSP430 microcontroller and USB flash. ECG signals are recorded and sent to the monitoring center via a USB flash disk using the SL811HS USB controller, but in this study monitoring still uses serial USB. Further research was developed by Carrasco et al. [10] with the title of design and development of Holter Prototype with Bluetooth Transmission, in this study using Bluetooth technology as wireless communication, using data storage and user interfaces with Lab View Software but the signal obtained still has noise. Lee et al. [11] develop Holter with noise artifact reduction using the Empirical Decomposition Mode and Statistical Approach. In this study, it has also been designed with a real-time method for detecting artifact and noise (MN) that often disrupts the rhythm of specific ECG signals. But from this research, there is still noise from the signal and PPG signal. Furthermore, the development of the Holter monitor was also has been developed by Putra et al. who modified the EKG into a Holter with a display on the computer, however, in those studies, the data could not be sent directly to the Computer. Furthermore, the Holter was also developed by Ananta Faxia, the Holter Monitor, which can be used as an Electrocardiograph (ECG) monitoring device that can be monitored the ECG signal via a computer screen using wireless system, but the weakness of those study is that the noise still exists and unstable when there is a movement of the subject [11,12]. Based on those problems, [the objective of this study is to develop a Holter monitoring based on Arduino microcontroller equipped with SD card memory and Bluetooth connection \[13\]](#). The salient feature of this design is that the recorded ECG data can be sent wireless through the Bluetooth connection to the computer host. Furthermore, the Holter can be used as a standard electrocardiograph (ECG) monitoring device and portable ECG recorder. As a conventional ECG device, this proposed design can monitor the ECG signal wirelessly to display on the computer using Bluetooth communication [14]. The second option, the proposed model can be used to record the ECG signal for 24 hours, and the ECG data was saved to the SD card memory. In this study, a marker, in which to assign when a heart attack happens, was also equipped. Hence the system can measure the number of abnormalities [1]. This study implies that the design can be used personally at home for further diagnosed by a doctor and can be built at a low cost.

2. Materials and methods

2.1. [Experimental setup This study used ten normal subjects with the criteria the ages ranged between 22 and 27 years old and the weight is between 45 to 50 kg. The subjects were randomly sampled and the data collection is repeated 5 times.](#)

2.1.1. [Materials and tool. This study is used a disposable electrodes ECG \(OneMed, Jayamas Medical Industr, Indonesia\). The electrodes were attached to the right and left a hand on the human. The instrumentation amplifier was built based on TL084 OP-AMP \[15\]. The Arduino Nano microcontroller was used for ECG data acquisition and communication to the computer unit using Bluetooth module HC-05. SD Card Memory with a 16 Mbyte was used to save the ECG data in real-time. A digital storage Oscilloscope \(Textronic, DPO2012, Taiwan\) was used to test the analog circuit. An ECG phantom \(Fluke, PS320, USA\) was used to calibrate the analog circuit.](#)

2.1.2. Experiment. In this study, after the design was completed then the frequency response of this device was tested using a function generator [according to the specification of the ECG signal. In the calibration stage, the Holter ECG was tested using an ECG simulator \(phantom\) with all ranges \(30, 60, 120, 180, and 240 BPM\). Each setting, the output of the Holter was calculated to validate the result of this study. Then the Holter was tested on the human body \[3\].](#)

3. [The diagram blocks In this research, the ECG recording was performed based on the placement of the three electrodes for LEAD II combination as shown in Figure 1. The ECG signal was then amplified using instrumentation amplifier, filtered using a bandpass filter, notch filter, non-inverting amplifier, and summing amplifier or adder for offset adjustment. A built-in analog to digital converter \(A/D\) in Arduino Nano was used to convert the analog ECG signal into digital \[16\]. The ECG recording was saved to the SD card memory for further data analysis. The ECG data was also can be delivered to the computer unit via the Bluetooth module. Figure 1. The diagram block of the Holter monitor.](#)

3.1. [The flowchart The Arduino program was built based on the flowchart as shown in Figure 2. After the initialization of the Arduino, the program asks the Bluetooth whether the connection is active or not. If the Bluetooth is active, then the data was ready to send to the computer. The other option is the data can be directly saved to the SD card memory. The computer program was built based on the flowchart as shown in Figure 3. The menu divided into 2 namely readings from Bluetooth serial and from SD card memory \[17\]. The data from Bluetooth connection active, the data is ready to send to the computer and then read ECG Signals from the Delphi program. While reading the data from SD Card Memory is initialization and then received data, Conversion data from SD card memory and final reading of the ECG signal. Figure 2. The Flowchart of the Arduino program. Figure 3. The flowchart of for the Delphi programming.](#)

3.2. [The analog circuit The important part of this development is the analog circuit which describes in Figure 4 \(instrumentation amplifier\), Figure 5 \(bandpass filter\), Figure 6 \(notch filter\), and Figure 7 \(summing amplifier\). The circuit is used to process the ECG signal. Hence it will ready for digital processing using Arduino microcontroller.](#)

3.2.1. [Preamplifier. An Instrumentation amplifier circuit as shown in Figure 4 was the pre-amplifier for the ECG amplifier which takes an important part for analog processing. This circuit is composed of three OP-AMP and one additional OP-AMP for buffering the signal. The overall gain was adjusted by R1 \(560 Ohms\). The two leads of electrodes were connected to J16 and J17 as shown in Figure 4. 4 U9D TL084 12 - + 14 13 - R32 22k 11 U9A 11 R26 2 - TL084 22k J16 1 1 3 + R20 2 22k 11 U9C TL084 9 - CON2 4 R1 8 560 10 + + R22 22k 4 R25 R27 22k 22k 11 U9B TL084 J17 6 - 1 7 2 5 + CON2 4 Figure 4. Instrumentation amplifier.](#)

3.2.2. [Bandpass filter. The bandpass filter is to limit the frequency of the signal; hence the processed ECG signal is only by characteristics of the ECG signal. The bandpass filter was designed for the cut off frequency of 0.05 to 100 Hz. The gain and the cut off value were calculated based on equation \(1\) and equation 2, respectively. In this study, the gain of the bandpass filter was 101 times. R7 100k R6 R8 1k 1k - 11 U11A TL084 J7 1 2 3 R30 - + 1 R18 47K TP1 C7 10uF 330K 4 + C3 U11B 33n 11 TL084 R19 6 - 7 5 + 47K C8 33n 4 Figure 5. Bandpass filter. Gain = 1+\(Rf/R6\) \(1\) where Rf is the feedback gain, R6 is the divider resistance and the Gain is the amplification of the circuit  \$fc = 1/\(2\pi RC\)\$  \(2\) where R is the resistance value, C is the capacitance value, and fc indicated the cut off frequency.](#)

3.2.3. [Notch filter. The notch filter was designed to eliminate the line power interference from the environment in which the frequency of the bandstop filter is 50 Hz. This interference could dominate the main signal \(ECG\) due to the small amplitude of the ECG signal. The input of this circuit was connected to the output of the bandpass filter. The notch filter was designed as shown in Figure 6. U11C R28 C10 C14 R31 4 TL084 J2 68k 47n 47n 68k TP4 10 + 8 1 C15 9 - J1 47n 1 11 R33 R35 TP3 C16 68k 68k 47n U11D TL084 1 4 R34 + 12 2 100k 14 - 13 11 3 Figure 6. Notch filter 50 Hz.](#)

3.2.4. [Summing amplifier. The summing amplifier was composed of two operational amplifiers \(Buffer and Inverting Amplifier\). This circuit is to offset the level of the ECG signal so that the signal is fit to the digital part of Arduino Microcontroller which is the A/D converter. The ECG signal was added with a setpoint voltage from a variable resistor \(R4\) as shown in Figure 7. According to Figure 7, the buffer circuit is used to maintain the signal voltage. + U12A 4 TL084 1 + 3 J4 - 2 1 R2 + 1k R11 11 TP6 U12B 1k J6 11 TL084 2 1 - 6 R10 R4 - 2 7 1k 100k + 5 D1 2 3 1 Output C1 3.1V 4 100nF 1 R15 R23 100k 1k Figure 7. Summing amplifier.](#)

3.2.5. [Bluetooth module. The Bluetooth \(BT\) module used in this design was HC-05. This Bluetooth module was used to transmit the ECG signal from Holter monitor to the computer unit. For the communication between the Arduino board and the Bluetooth module, it needs two pins which are Tx \(to transmit the ECG Data, and The Rx is to receive the information between the microcontroller and computer unit\). The connection between the BT and Arduino module was shown in Figure 8. Arduino Tx Nano Rx Tx Rx BT HC-05 GND GND Figure 8. Bluetooth Connection.](#)

4. Results [In this](#)



