

Modification of Holter ECG Monitoring Based on Arduino Uno with Data Storage



Nur Hudha Wijaya, Rahmat Jalaluddin, Susilo Ari Wibowo

Abstract: Heart monitoring is needed in order to know the patient's heart condition. In monitoring, storage media of heart monitor result is needed in order to help doctors and paramedics examine the patients. Therefore, a research to plan and create logger data system of heart signal as a modification of electrocardiograph was conducted. This research used amplifier, active High Pass Filter, active Low Pass Filter, Noch Filter, summing adder, and Microcontroller, and Delphi 7 Software to make interface program on personal computer. Heart Rate score (BPM) on 2x16 LCD indicated final error of 2,8%. Meanwhile, the final error of Software module was 1,4%. The measurement of lead II R signal amplitude resulted the final error of -4,5% and the final error on the distance length from R to R was -1,1%. Heart Rate score (BPM) with two human samples indicated error on sample one on sitting position of -3,8% and on sample two -6,3%, Sample one on Standing Position 2,9% and sample two -4,1%, Sample one on Roll Call -1,7% and sample one -8,4% and sample one on running in place -4,6% and sample two 4,1%. The result reading on Delphi 7 Software the errors were -0,3% on sample one and -6,5% on sample two. On standing position, sample one was -0,6% and sample two -2,2%, roll call position for sample one 1,7% and sample two -8,4%, and running in place for sample one 4,1% and sample two 3,3%. The score of R signal amplitude and the distance length from R of R on human sample indicated error for amplitude in sitting position -9,6%, standing -1,3%, roll call -3,0%, running in place -5,9%. The error on distance from R to R on sitting position was -5,9%, standing -17,3%, roll call 6,7%, and running in place 13,8%.

Keywords : Heart, Electrocardiograph, Data Logger, Microcontroller, ATmega 328P, Delphi7.

I. INTRODUCTION

Data from the World Health Organization (WHO) in 2012 showed that 17.5 million people worldwide died from cardiovascular disease or 31% of 56.5 million deaths worldwide. More than 3/4 of deaths from cardiovascular

disease occur in developing countries with low to moderate income [1]. Cardiovascular disease can be known from the performance of the heart, which is from the rhythm of the heartbeat. The rhythm of the heartbeat can be seen through the electrical signal activity of the heart. To be able to obtain an ECG signal requires a precise analog signal amplifier system

[2]. The heart's electrical signal activity can be seen with the help of a heart's electrical activity monitoring tool. One of the monitoring tools for the heart's electrical activity is the electrocardiograph (ECG) which utilizes electrophysiology in the heart [3] [4]. Many methods are used, among others, in enhancing the ECG delineation approach based on wavelet transforms in a continuous way, a significant increase in the accuracy of P and T waves is obtained [5], with some of these methods an ECG monitoring system is needed by portable means [6].

Electrocardiograph technology can facilitate the work of medical personnel to detect cardiovascular disease early, so that deaths caused by cardiovascular disease can be suppressed. However, the current use of electrocardiograph devices in hospitals, in their use must be procedural in accordance with the operational rules applied, so far recording the condition of heart signals with electrocardiograph devices can only be done in hospitals, whereas cardiovascular disease can occur suddenly when the patient is active for a day -day. The problem here is that the examination can only be done in a hospital [7], the electrocardiograph cannot store the patient's heart signal data in digital form, so if you want to do further tests, you have to do a re-examination.

From these problems, it is necessary to modify and develop electrocardiograph technology, namely holter monitor. Holter Monitor or often also called Ambulatory. Electrocardiographic Devices is a portable technology that can be used to continuously monitor various electrical activities of the cardiovascular system for at least 24 hours [8]. With a holter monitor tool can facilitate medical personnel and patients in operating the tool. In addition to being easy, the device can be carried when the patient's daily activities with a fixed position to record the heart signal, so that the patient's heart condition is always monitored continuously because it is accompanied by a heart signal data logger. By adding a heart signal data logger to the SD CARD storage media, it can be used as a medical record of the patient's heart and also make it easier for the patient to check the patient's heart condition while undergoing outpatient care by only carrying the SD CARD, then the results recorded on the SD Card will be analyzed by the doctor heart by using a personal computer.

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II. RESEARCH METHOD

2.1 Hardware Designing

At the hardware design stage, it is carried out by making circuit blocks [9] – [14], which consist of a series of instrument amplifiers, filter circuits namely active high pass and low pass filters, and also notch filters, then summing adder circuit blocks and ATmega 328P microcontroller circuit blocks [15] – [23]. Design block diagram as shown in Figure 1.

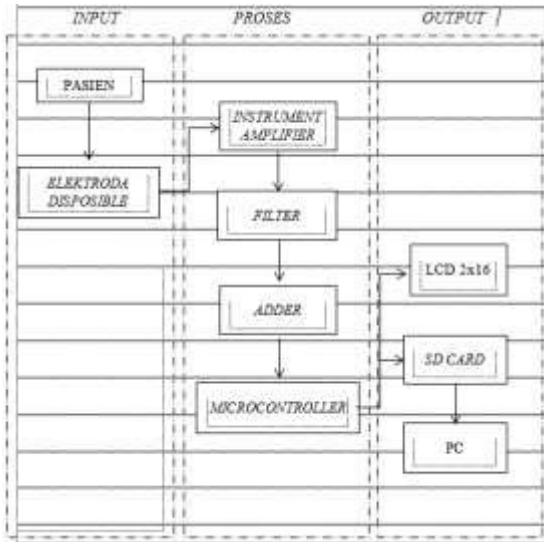


Figure 1. System Block Diagram

Disposable electrodes mounted on the patient's body at the base of the right hand and the base of the left leg, as well as the base of the right foot as grounding, because what is used is Lead II leads, the heart's electrical signals originating from these leads will be received by the Instrument Amplifier for signal processing, wherein the signal will be buffered then amplified. Heart signals originating from leads will produce noise which can affect the shape of the heart signal. To eliminate this noise the output of the Instrument Amplifier circuit will be included in the filter circuit to eliminate noise in addition to eliminating noise the filter chain is used to pick up the heart signal at the desired frequency, research This uses an active High pass filter to pass a signal above the cutoff frequency and uses an active Low Pass filter circuit to pass a signal below the cutoff frequency, because it uses the HPF and LPF circuits, the desired signal is obtained, combining the HPF and LPF circuits into a Band Pass filter circuit [24] – [27]. From the LPF circuit the signal will be processed in the notch filter circuit, this circuit serves to attenuate the signal that is at a certain frequency, this circuit is to reduce noise coming from PLN electrical interference which has a frequency of 50/60 Hz. After getting a signal with the desired frequency and the signal is clean from noise, then the signal will be entered into an adder circuit because of the sinusoidal heart signal shape, where the sine signal has two polarities, positive and negative, if there are signals in positive and negative polarity it is not can be read by a microcontroller [28] – [31], so a sequence of adder is needed to shift the polarity or phase of the heart signal. The output of the signal adder will be input right into the microcontroller in the ADC pin to be processed and stored in the SD CARD to be displayed on the monitor.

2.2 Software Design

The program used in this study which is used to process analog signals from ECG signals into ADC values is used Arduino Uno software. In this program analog values that have been converted into ADC values will be processed so that ADC values can be changed to BPM values and can be stored in SD CARD. Flow chart for processing analog values into ADC values to BPM values and stored in SD CARD as shown in Figure 2.

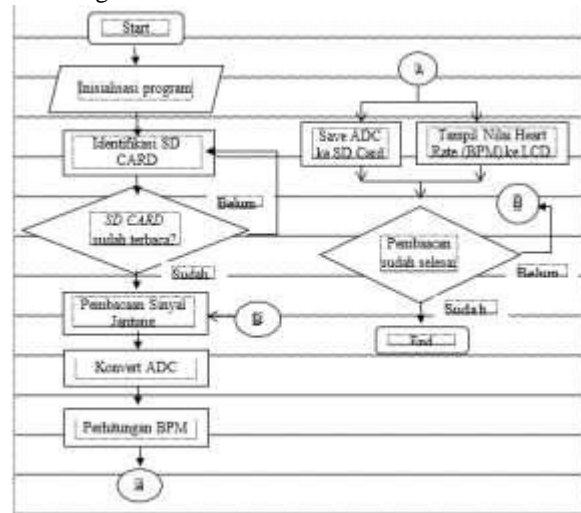


Figure 2. Process Flow Diagram.

III. RESEARCH RESULTS AND DISCUSSION

In this study module testing is done by measuring the BPM value, the amplitude value of the signal R and the length of the signal R to R with a phantom comparison.

3.1 Results of Heart Rate Values Measurement (BPM)

To measure BPM values carried out by reading the heart rate values from phantom with a scale setting of 60, 80, 100, 120, and 140, then the data was collected 6 times for each scale setting.

Table 1. BPM Value Measurement Results

Setting HR Phantom	Level	Pembacaan Heart Rate (BPM)	Hasil Pembacaan						Maksud	Kesalahan Maksimal Yang diizinkan
			1	2	3	4	5	6		
60	LCD 2x16	58	57	61	58	59	59	58,7	2,2	
	Software Delphi 7	58	57	59	59	58	59	58,3	2,8	
	LCD 2x16	82	82	79	83	81	82	81,3	-2,5	
80	Software Delphi 7	83	81	80	81	80	83	81,5	-2,2	
	LCD 2x16	101	104	100	100	102	103	101,7	-2,8	
	Software Delphi 7	101	100	100	102	101	101	100,8	-1,4	
100	LCD 2x16	120	119	119	117	118	122	119,2	1,4	
	Software Delphi 7	121	118	118	118	117	121	118,8	1,9	
	LCD 2x16	143	142	142	143	140	141	142,8	-3,1	
140	Software Delphi 7	146	143	148	144	141	140	143,7	-6,1	

Table 1 shows the retrieval of heart rate (BPM) data 6 times, obtained different values, the values read on the reading of the Heart Rate (BPM) are relatively the same, so we get an error at setting 60, has an error of 2.2%, setting 80 has an error of -2.5%, setting 100 has an error of -2.8%, setting 120 has an error of 1.4%, and setting 140 has an error of -3.1%. On reading Delphi 7 software, the value of the Heart Rate (BPM) is relatively different, so that the error value in the setting of 60 is 2.8%, in the 80 setting there is an error of -2.2%, setting 100 there is an error of -1.4%, the setting 120 there is an error of 1.9%, and setting 140 there is an error of -6.1%.

3.2 Measurement of Amplitude and Distance of Signal R

For the measurement of the pulse amplitude R and the length of the distance R to R, signal retrieval is done by connecting the phantom device to the device prepared to the PC that will not be displayed on the monitor screen with a phantom scale heart rate value (BPM) 60 and an amplitude of 1mV, resulting in the image below this,

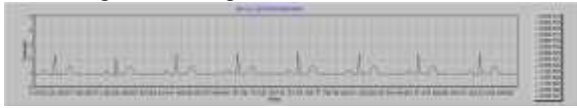


Figure 3 Signal Display Graph 1 Lead II Tool Module



Figure 4 Graph Display of Signal 2 Lead II Tool Module

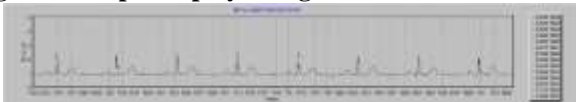


Figure 5 Display Signal Chart 3 Lead II Tool Module

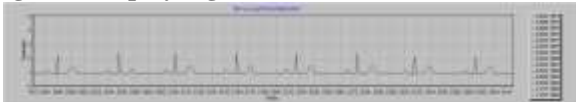


Figure 6 Signal Display Graph 4 Lead II Tool Module

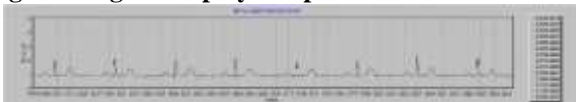


Figure 7 Graph Display of Signal 5 Lead II Tool Module

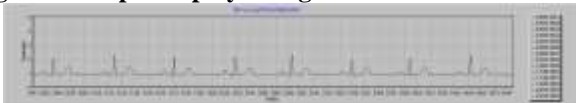


Figure 8 Graph Display of Signal 6 Lead II Tool Module

Table 2 Measurement of Signal Amplitude R

Tinggi Amplitudo Sinyal R pada Lead II Pada Modul EKG Tugas Akhir (mm)												
No	Nama	Phantom	Sinyal 1	Sinyal 2	Sinyal 3	Sinyal 4	Sinyal 5	Sinyal 6	Sinyal 7	Sinyal 8	Mean	Error (%)
1	Lead II	10	10,4	9,1	10,3	10,5	10,1	10,2	9,8	10,2	10,1	-0,7
2		10	8,3	9,1	9,8	10,1	10,1	10,6	10,1	10,5	9,8	1,8
3		10	10,1	10,5	10,2	10,4	10,5	9,2	9,1	10,1	10,0	0,1
4		10	10,2	10,4	10,1	9,4	10,1	10,2	8,5	8,8	9,7	2,9
5		10	9,7	9,9	8,6	9,6	9,3	9,4	10,1	10,2	9,6	4,0
6		10	9,7	10,2	10,3	9,6	10,4	8,1	8,7	10,4	9,7	3,1
Final Error (%)											1,9	

In taking the amplitude measurement data for each R wave in Lead II, there are 10 signals with a setting of Heart Rate (BPM) of 60, with an amplitude of 1mV. From taking the 8 signals, measurements were made using calipers, the results of which can be seen in Table 2. The results of the data are compared with the results of measurements of the original ECG readings, a final error value of 1.9% was obtained. From the error value is still below the error value that is equal to ± 5%.

Table 3 Measurement of R to R Signal Length

Panjang Sinyal R ke R pada Lead II Pada Modul EKG Tugas Akhir (mm)												
No	Nama	Phantom	Sinyal 1	Sinyal 2	Sinyal 3	Sinyal 4	Sinyal 5	Sinyal 6	Sinyal 7	Mean	Error (%)	
1	Lead II	25,7	25,8	25,9	27,3	26,4	26,6	25,2	25,6	26,7	-4,9	
2		25,7	25,8	25,9	25,1	26,2	25,6	25,2	25,6	25,8	-3,1	
3		25,7	25,8	25,9	26,1	26,2	25,8	26,6	25,9	26,1	-4,5	
4		25,7	25,8	25,9	26,1	26,1	26,4	25,7	27,1	26,2	-4,3	
5		25,7	25,8	25,9	25,8	26,7	26,5	25,7	25,5	26,1	-3,4	
6		25,7	25,8	25,9	25,5	26,1	25,8	25,9	25,8	25,8	-4,2	
Final Error (%)											-4,2	

Retrieval of data measuring the distance between peak R to

peak R from the results of the instrument module with the setting of the Heart Rate (BPM) 60 and Amplitude 1 mV on the Phantom calibrator obtained results as in table 3. The results are obtained from the measurement of the distance between the R signal to the next R signal as much as 7 distances between peak R to peak R. Measurements were made using calipers. From the data table 4.14 obtained the final error value of -4.2%, with the final error value, meaning the reading is still below the maximum error limit of ± 5%.

3.3 Discussion

3.3.1 Instrument Amplifier circuit

1. Using instrumentation IC, namely AD 620 AN.
2. The IC requires a working input voltage of +5 VDC, -5 VDC, and GND.
3. There is a 74x gain

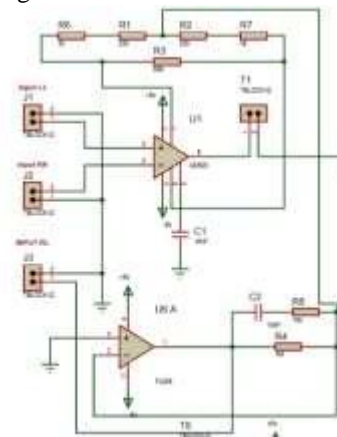


Figure 9 Instrument Amplifier Circuit

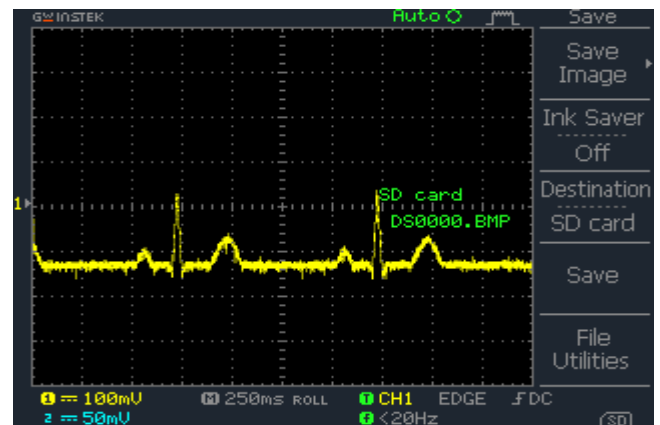


Figure 10 Instrument Amplifier Output

The instrumentation circuit is used to process the heart signal for the first time. IC AD 620 has the characteristics of low noise, only requires a small current, and also has a high gain. In the instrumentation circuit that is used for the heart signal processing device module the first time has a gain of 74 times after calculation. This series of instrumentations is used to tap heart signals at the base of the right hand and the base of the left leg. At the base of the right leg connected to the Common Mode Rejection Ratio CMRR circuit, this CMRR circuit is used to reduce the noise generated from the body.



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The CMRR circuit consists of an LPF circuit which is grounded using an opamp. The waveforms of the instrumentation circuit with the Phantom Input and read on the oscilloscope are shown in the figure

3.3.2 Filter Circuits

Component specifications used in the filter circuit are:

1. The filter circuit consists of a series of High Pass Active Filters, Low Pass Active Filters, Noch Filters.
2. In the filter circuit using TL 074 IC.
3. TL 074 IC requires a working voltage of + 5 VDC, - 5VDC, and GND.
4. TP 2 is used to check the output of the Active High Filter Filter series, the cut off frequency is 0.04 Hz.
5. TP3 is used to check the Active Low Pass Filter Output, the cut off frequency is 102.66 Hz.
6. TP 4 Used to check Output Noch Filter, cut off frequency 49.8 Hz.

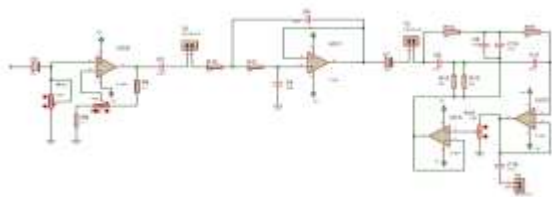


Figure 11 Filter Circuit

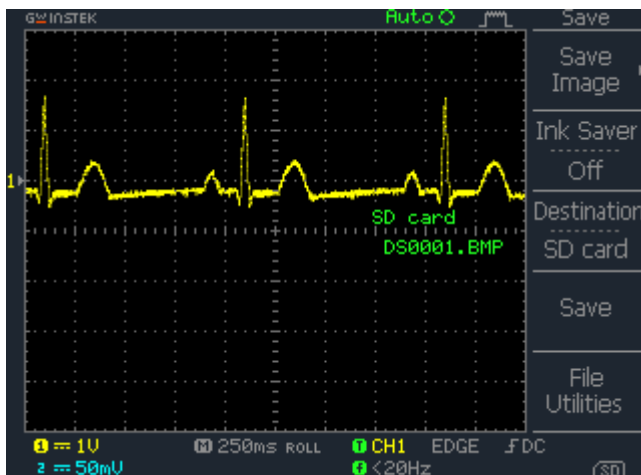


Figure 12 Active High Pass Filter

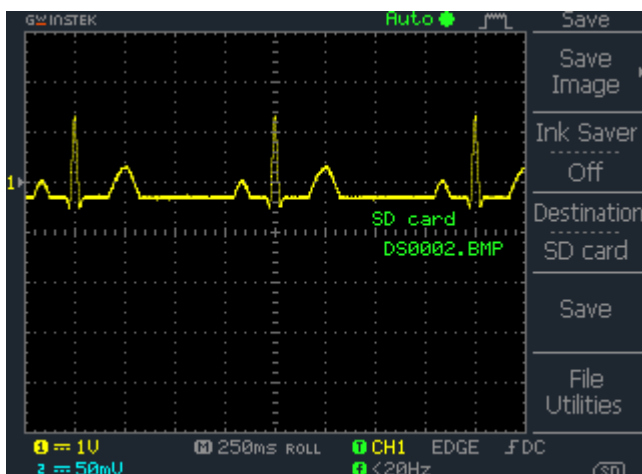


Figure 13 Active Low Pass Filter

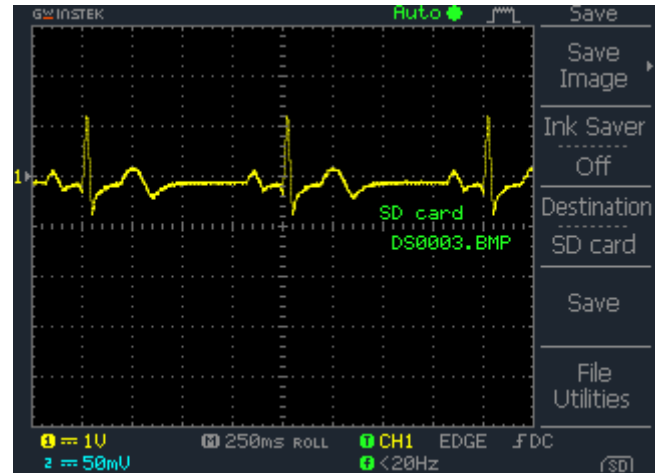


Figure 14 Noch Filter

The filter circuit in this thesis uses a series of filters High Pass Active Filter, Low Pass Active Filter, Noch Filter. In the active HPF circuit shown in Figure 11 on TP2, after the calculation has a cut-off frequency of 0.04 Hz, meaning that the signal below the cut-off frequency will be pressed or filtered, then the frequency above the cut-off value will be passed. This HPF filter aims to retrieve all tapped signals that have been processed by the instrumentation circuit. The results of the HPF filter contained in Figure 14 still get high noise, because the noise enters in a high frequency it requires a series of Active Low Pass Filter (Active LPF) shown in Figure 11 on TP3. From the calculation done the active LPF circuit has a cut-off frequency of 102 Hz, so frequencies above that frequency will be suppressed. The results of the Low Pass Filter circuit are found in Figure 13 for the Noch Filter circuit which has a cut-off frequency of 49.8 Hz. The Noch Filter circuit is used to filter out 50 Hz noise interference generated from a PLN power source. The results of the wave from the Noch Filter series are shown in Figure 14

3.3.3 Summing Adder Series

Component specifications used in the filter circuit are:

1. Using IC TL071.
2. Requires a working voltage of + 5 VDC, - 5VDC, and GND.
3. Using Variable Resistors used to set the reference voltage.
4. TP 8 is used to determine the output of the summing adder circuit, as below:

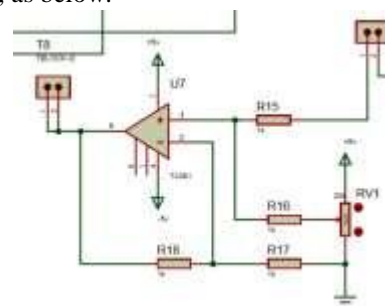


Figure 15 Summing Adder Series

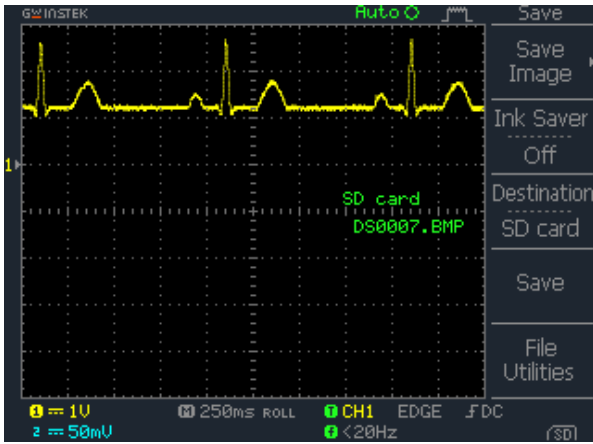


Figure 16 Output Summing Adder

The summing adder circuit in figure 15 is used to shift the phase or increase the signal which is in negative polarity, so that all signals are in positive polarity or above the reference voltage. After all the signals are in positive polarity, the new signal can

read by ADC. The results of the summing adder circuit as shown in Figure 16 are the image signals that are read on the oscilloscope.

3.3.4 ATmega 328P Minimum System Series

ATmega 328P AVR microcontroller already has quite complete feature features. ATmega 328P AVR microcontroller is equipped with internal ADC, internal EEPROM, Timer / Counter, PWM, Analog comparator, etc. According to the ATmega 328P data sheet with a 28 Pin DIP (Dual In-Line Package) configuration and added to the SD CARD module circuit The ATmega 328P Microcontroller minimum system circuit has a feature selection, which is as follows: 1. Has 23 I / O channels, consisting from PortB, PortC, and PortD. 2. Has 6 ADC internal channels. 3. Has a timer counter as much as 3 pieces. 4. CPU capacity with 32 registers. 5. Has an internal oscillator. 6. Has SRAM memory of 1Kb. 7. Has 8KB of flash memory with a self-programable flash system. 8. Has external and internal interruptions. 9. Has an EEPROM memory of 512 bytes. 10. Has a USART (Universal Synchronous and Asynchronous Saerial Receiver and Transmitter) port that is used for serial communication. All these facilities form a series as follows:

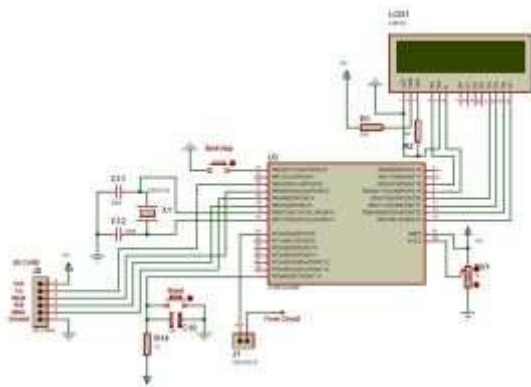


Figure 17 Summing Adder Series

3.3.5 Discussion of the Overall Series

Disposable electrodes that are attached to the base of the right hand, the base of the left and right legs will tap or pick up a potential difference between the base of the right hand and

the base of the left leg. Where at the base of the right hand (RA) take or tap the negative charge, while at the base of the left foot tapping the positive charge, and as a reference point or grounding used the base of the right foot. The results of taking a positive charge and a negative charge will be compared to the Amplifier instrumentation circuit. In the instrumentation circuit the signal amplifiers will be compared and processed using the AD620AN IC which has a reinforcement value of 74 times.

The output of the signal processing in the Amplifier instrumentation circuit has a signal that is still in the order of 100 mV and there is still a lot of noise, so the Output from the Amplifier instrumentation circuit enters the HPF circuit which has a Cutt off frequency value of 0.04 Hz which will filter out the resulting noise from the body, and will suppress the body signal below the cutt off frequency. The results of the HPF filter enter the non-inverting amplifier circuit to amplify the heart signal that is still in order mV to become the order of 1 V. Because the heart signal is strengthened then the noise that still passes from the HPF filter will also be strengthened, then the LPF filter which has a Cutt off frequency of 102 Hz. This filter will block or suppress a signal whose value is above the cutt off value. For additional filters used to block noise generated from PLN electrical interference whose frequency is 50/60 Hz, the Noch Filter circuit is used with a Cutt off value of 48.9 Hz. This filtered and amplified signal has an amplitude that is at a positive potential and a negative potential, because tinsel at 2 potentials the signal cannot be processed in the microcontroller, so before the signal enters the microcontroller circuit the signal enters the summing edder circuit, which functions to increase signals that are at negative potential become positive potential.

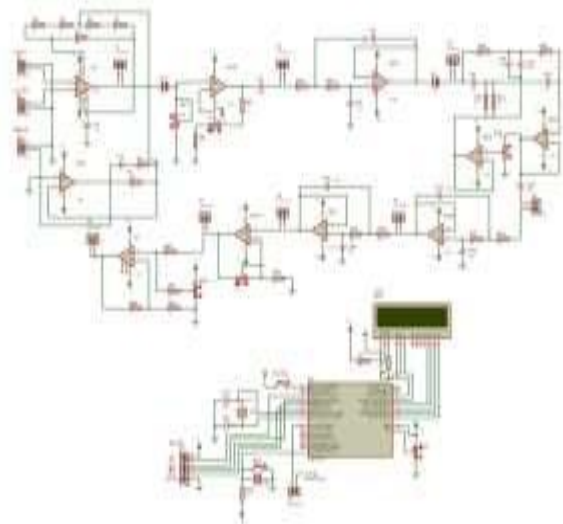


Figure 18 Overall Series.

The output of the summing edder circuit will go into the microcontroller circuit for processing. Heart signal goes to ADC pin 0, ADC pin will change the heart signal which is still in analog quantity to digital amount. The ADC reading results, the heart signal is processed to find the BPM value, the results of processing the Heart Rate (BPM) value will be displayed on the LCD, and the ADC value of the heart signal will be saved to the SD CARD module to read the heart signal on the personal computer.



IV. CONCLUSION

Modification of ECG Holter Monitoring for Cardiovascular Disease Patients Outpatient period can run well, with an error of 2.3% in the measurement of the Heart Rate (BPM) Hardware, 1.4% for the measurement of the Heart Rate (BPM) Software. The measurement value of the R signal amplitude that the modification reading is compared with the original Electrocardiograph with the ECG Phantom Input setting, obtained a final error of 4.5%. The measurement value of the wavelength of the R to R signal which is the result of the reading of the Final Task Module compared to the original Electrocardiograph with the Input Phantom EKG setting, obtained a final error of 1.1%.

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