Design Of Bedside Monitor Based On Microcontroller

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Abstract — A Bedside monitor is the equipment used to monitor patient condition through some parameters that need sustainable monitoring so that the patient condition is always monitored. This research is monitored by five parameters namely heart signal, heart rate, temperature, respiration and SPO2. This research applies quasi experimental design. The free variable is an ECG phantom or human, and the dependent variable is a bedside monitor. The research instruments are a calibration equipment of ECG signal, temperature, and respiration. The result of the heart signal lead 2 is not different from the standard and the result of the heart rate lead has uncertainty (probability) 0 for Lead 2; which is still under the tolerance number (0.5). The results of the temperature measurement of five samples with five measurements show that there are three samples which have standard deviation and 0 (zero) uncertainty, whereas two samples have 0.76 (higher than 0.5) uncertainty. This condition is influenced by the patient movements, so the sensor attached on the patient-body does not fit with the standard installation. The respiration measurement results have an accuracy of 98%, while the SPO2 results have a standard deviation and uncertainty below 5% after being compared with the standard calculations. Here are the details: standard deviation 0.894427; 0.547723; 0.44; Probability 0.4; 0.244949; 0.2 and 0.2. Overall, it can be concluded that The Design of Bedside Monitor Based on Microcontroller is feasible and the measurement result of heart signal Lead 2, heart rate, temperature, respiration, SPO2 can be presented on a PC.

Keywords — Heart signal, temperature, respiration, SPO2, bedside monitor

I. INTRODUCTION

A bedside monitor is a machine used to monitor the patient's condition that requires continuous monitoring. In general, bedside monitor has several parameters, including heart signals, BPM, respiration [1], body temperature, and SPO2.

There have been many studies which discuss the monitoring of heart signals carried out by previous researchers such as "Monitoring temperature" [2], [3], [1], "Monitoring SPO2" [4][5], and "Heart rate monitoring and PQRST detection" [6], [7], [8], [9]. However, those studies only measured heart signals and heart rates. Another study entitled "Design of Electro Cardiograph Machine" [10], [11], [[13], [14], [15], [16] still has disadvantages including recording speed and sensitivity. Therefore, it is then developed into a bedside monitor device equipped with cardiac, temperature, SPO2, and respiration signal parameters.

These tools are not only used for checking 12-channel heart signals but also function as a bedside monitor. Meanwhile, there is still noise in the existing temperature and respiration research.

Based on the problems mentioned above, the researcher tried to develop the previous research finding, namely 12-channel ECG equipped with the temperature, respiration, and SPO2 monitor. It can also be used to measure 12-channel heart signals by designing microcontrollers. The specific objectives are designing a 12-channel ECG, designing a temperature monitoring circuit, designing a circuit for monitoring SPO2, designing a series of respiration monitors, and creating a program for ECG signal data acquisition. The contribution of this study is that the program can have multi-dual functions (monitors and ECG 12-channels).

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II. RESEARCH METHOD

Experimental setup: This study used five normal subjects with the criteria of age ranged between 21 and 27 years old.

A. Materials

This study used disposable ECG electrodes, temperature sensor, and SPO2 sensor. The electrodes and sensor were attached on the chests, right and left hands, right and left feet of a person. An instrumentation amplifier was built based on the microcontroller AT-mega.

The AT-mega microcontroller was used for ECG, temperature, SPO2, and respiration data acquisition and communication to the computer unit. A digital storage oscilloscope (textronic, DPO2012, Taiwan) was used to test the analogue circuit. An ECG phantom (Fluke, PS320, USA) was used to calibrate the analogue circuit.

B. Methods

a) Experiment

The research design was a pure experimental study, namely experimental series design. The independent variable is ECG phantom or human, and the dependent variables are the bedside monitor devices. Meanwhile, the design of bedside monitor devices applies the following three stages: circuit design, circuit testing, and calibration. This research was conducted at the Electromedical Engineering Department for eight months.

b) Block Diagram

The bedside monitor in this research is equipped with a 12-channel ECG and measurements of body temperature, SPO2, and respiration, as shown in Fig. 1. The bedside monitor's ways of working are as follows: the electrical signals from the heart will be taken through 12 electrodes which are tapped into two measurement fields, namely the forklift that consists of Lead 1, 2, and 3 and AVR, AVL, AVF, while for the transverse fields are V1, V2, V3,V 4,V 5, and V6.

The results of the leads from the phantom/patient will enter each ECG device, which then records the ECG signal through a series of microcontrollers from each of the ECG device that will be sent to the PC. The results of 3 lead ECG devices are monitored and stored on a PC, which then functions as the central monitor. In this research, the bedside monitor consists of object, ECG, and heart rate module, temperature module, SPO2 module, and respiration module.

c) Flowchart

The Delphi program was built based on the flowchart as shown in Fig. 2. The software used for the ECG signal data acquisition process is Codevision AVR which utilizes the C language programming base. Before the data acquisition process, LCD graphic and ADC initialization are needed. The ECG signal acquisition via PORT C is functioned as an ADC. To obtain the desired form of ECG signal, a digital filter process is needed. After going through the digital filter process, the ECG signal data can be displayed to the PC screen, as well as monitoring temperature, respiration, SPO2, and heart rate.
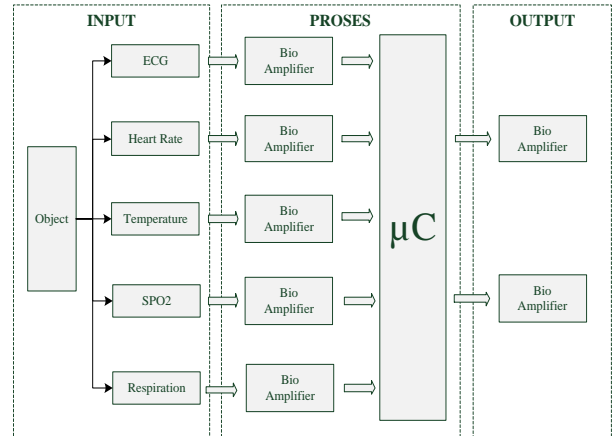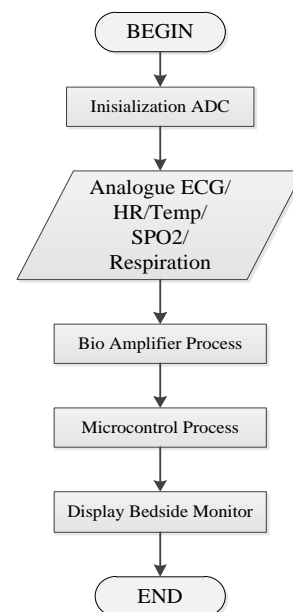

Fig. 1.The Block Diagram of Bedside Monitor

Fig. 2. The Flowchart of The Bedside

d) Analog Circuit

The important part of this development is the analogue circuit which is described in Fig. 3, Fig. 4, and Fig. 5.

1) Pre amplifier Heart Signal and Filter SPO2

An instrumentation of the input and output amplifier and filter SPO2 circuit are shown in Fig. 3. It is the amplifier for the ECG amplifier and SPO2 which takes important part for analog processing. This Circuit is composed of OP-AMP for buffering the signal. The 12 leads of electrodes are connected to the body and is shown in Fig. 3.

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2) Temperature and Respiration

The temperature circuit will take the temperature from the body through the LM35 temperature sensor into the amplifier which then will be processed through a microcontroller so it can be displayed on the PC (Fig. 4). The similar way is done to measure the respiration (Fig. 5).
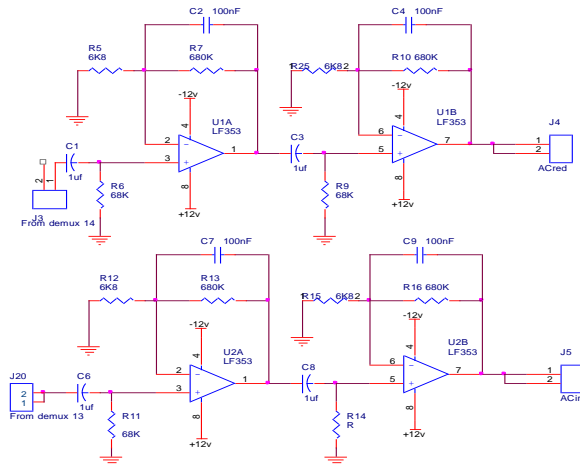

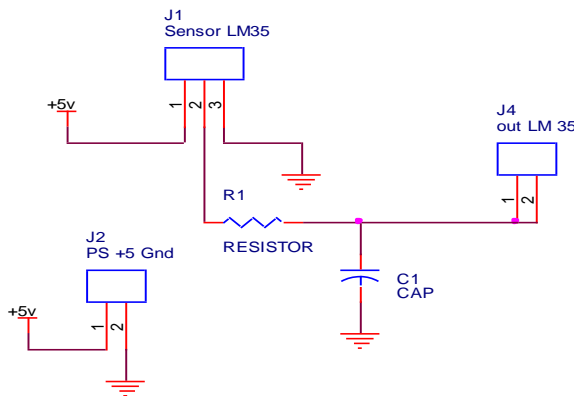Fig. 3. Output Amplifier and Filter SPO2
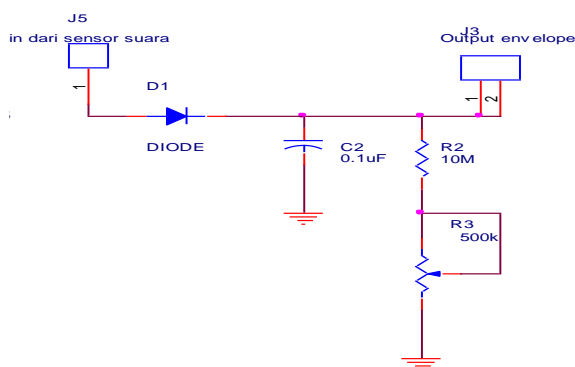

Fig. 4. Temperature Sensor Circuit

Fig. 5. Respiration Sensor Series

III. RESULTS

A. The Bedside Monitor Design

The design of this bedside monitor consists of several parts of the module that can measure 12 channel heart signals, heart rate, SPO2, body temperature and respiration. The ECG Signal was shown in Fig. 6.
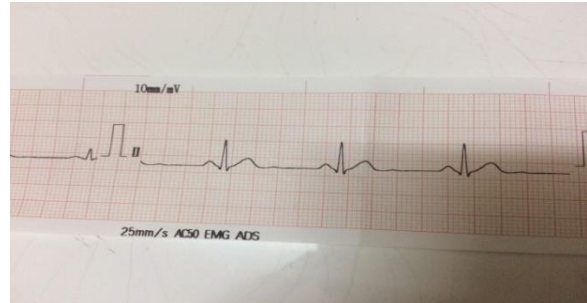

Fig. 6. Result of ECG Signal and Heart Rate from Lead 2.

In this study, the bedside monitor has been tested using ECG phantom (fluke, SP2002, USA) and ECG from the human body. The result shows that the recording is feasible to record the 12-channel ECG signal from the human body, for example signal ECG and heart signal lead 2 as shown in Fig. 6.

B. Results of Heart Rate Measurement (BPM)

Table 1. Result of The Heart Rate (BPM) Measurement with 60 Standard BPM Phantom

Set media	% Error	Standard Deviation	Probability
Lead 1,3, AVL,V1,V2,V5 and V6	0	0	0
Lead 2,AVR,AVF, V3, and V4	0	0.447214	0.2

C. Result of Temperature Measurement

Table 2. Results of Temperature Measurement Comparisons Between Modules and Standard 5 Times.

No	Machine	% Error	Standard Deviation	Probability (p)
1,2,3 and 4	Module	-0.3937	0	0
	Standard	0	0	0
5	Module	0.5807	1.699412	0.76
	Standard	0	0	0

D. Result of Respiration Measurement

Table 3. Comparison Results of Respiration Measurements Between Modules and Standard Devices

No	Machine	% Error	Standard Deviation	Probability (p)
1	Module	0	0	0
	Standard	0	0	0
2	Module	0	0.707107	0.316228

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No	Machine	% Error	Standard Deviation	Probability (p)
	Standard	0	0	0
3	Module	-0.90909	1.643168	0.734847
	Standard	0	0	0
4	Module	0	0.447214	0.2
	Standard	0	0	0
5	Module	0	0.83666	0.374166
	Standard	0	0	0

E. Result of SPO2

Table 4. Comparison Results of SpO2 Measurements between Modules and Standard Devices

No	Machine	% Error	Standard Deviation	Probability (p)
1	Module	0.207039	0.894427	0.4
	Standard	0	0	0
2	Module	0.207039	0.547723	0.244949
	Standard	0	0	0
3	Module	0.824742	0.447214	0.2
	Standard	0	0	0
4	Module	0	0.447214	0.2
	Standard	0	0	0
5	Module	0	0.447214	0.2
	Standard	0	0	0

IV. DISCUSSION

A. Heart Signal and Heart Rate

There is no difference between ECG signals in the module and the standard devices. The sensitivity is different because the standard ECG uses 1 mV sensitivity as much as 2 boxes of amplitude, while the ECG module 1 mV uses 1 box of amplitude, so the ECG module looks smaller in terms of its sensitivity. Meanwhile, the heart rate also has an uncertainty value of 0 for Lead 1.2, AVL, V1, V2, V5 and V6, while Ua = 0.2 for Lead 3, AVR, AVF, V3 and V4 are still below the tolerance value of 0.5. In addition, the results of the measurement show that the heart beat is still in a good condition.

B. Temperature

Measurements are made by placing the LM 35 sensor and digital thermometer in the arm together. From the results of measuring the LM 35, the output is the same as the temperature shown on the PC, for example if the voltage coming out of the circuit temperature is 0.36 mV, then the display on the PC will show 36 degrees. Thus, the accuracy of the LM35 turns out to be very accurate. This temperature measurement has a standard deviation and Uncertainty from 5 samples with 5 measurements. It turns out that the results of the 3 samples have standard deviation and zero uncertainty, while the two measurement results have a value of uncertainty 0.76 (higher than 0.5). The program can be seen in the program listed below:

Listing program of temperature

```
//Pengolahan Data SUHU
procedure TForm1.terimadatasuhu(Sender: TObject;
constStr: String);
Var
//E ,dataAdc : Integer;
E : Integer;
Suhu,dataAdc : Real;
begin
Val (Str,dataAdc,E);
if E = 0 then begin
chart3.series[0].addy((dataADC)*440/1023);
if chart3.series[0].MaxXValue> 5 then begin
Suhu:=chart3.Series[0].MaxYValue;
label1.Caption:=floattostr (Suhu);
label1.Caption:=formatfloat('0.#',Suhu);
chart3.series[0].clear;
//Suhu := dataAdc;
//Suhu := Round(Suhu*470/1023);
//Label1.Caption:=Floattostr(Suhu);
//label1.Caption:=formatfloat('0.##',Suhu);
ifSuhu> 36   then begin
label2.caption:='Normal';
end
else if suhu<37.5 then begin
label2.Caption:='Normal';
end;
ifsuhu< 36 then begin
label2.caption:='Hipotermia';
end;
```

C. Respiration

Respiration measurements are carried out by installing a mouthpiece equipped with an FC-04 sensor. Since there is no accurate comparison tool, the comparison is calculated simultaneously. The picture above is the output of the FC-04 Sensor which is processed by Envelope series. The picture above shows that there is a voltage difference between the inspiration and expiration process. When the inspiration process produces a voltage of 0 V, the expiration will produce an increased voltage. It should be noted that the environmental condition will have an effect such as room noise, because the sensor will capture the sound of the surrounding environment which will affect the sensor output. In addition, laying the sensor on the moutpiece must be precise in order to get the sensitivity in the measurement. The program can be seen in the program list below. From the results of 5 samples and the 5 measurements, 4 samples were stated below 5% and there is only 1 above 5%. Therefore, this tool is considered suitable to use.

Listing Program of Respiration

```
//Pengolahanrespirasi
procedure TForm1.terimaRR(Sender: TObject;
constStr: String);
Var
E,dataADC:Integer;
tegangan1:Double;
begin
Val(Str,dataADC,E);
if E=0 then begin
tegangan1:=(((dataADC/1023)*5)+1);
if tegangan1 < teganganRefrensi1 then begin
    logika1:=false;
end
else begin
if logika1 = False then begin
if RR1jalan= true then begin
Inc(RR1);
end;
    Label5.Caption:=Inttostr(RR1);
    Timer2.Enabled:=true;
end;
```

D. SPO2

The SPO2 circuit's way of working starts from the respiration sensor circuit (connector sensor) that will enter the demultiplexer circuit. J 18 will enter the low filter circuit when the filter 0.8 Hz enters the amplifier and filter 1 will enter the amplifier circuit, then the second filter will enter the microcontroller and the output of the microcontrol is connected by serial to PC. The results of SPO2 measurements turned out to have a standard deviation and uncertainty below 5% compared to the standard calculation: STD 0.894427, 0.547723.0.44, Ua 0.4, 0.244949,0.2 and 0.2, so the tools are considered worth using.

Listing Program SPO2

```
//Program Pengolahan data ACred
procedure TForm1.terimaSPO1ACred(Sender:
TObject; constStr: String);
Var
E,dataADC:Integer;
begin
Val(Str,dataADC,E);
if E = 0 then begin
chart5.series[0].addy(((dataADC)/1023)*5);
if chart5.series[0].MaxXValue> 75 then begin
data1:=chart5.Series[0].MaxYValue;
label17.Caption:=floattostr (data1);
label17.Caption:=formatfloat('0.##',data1);
chart5.series[0].clear;
end;
end;
end;
```

V. CONCLUSION

In this study, a bedside monitor device was combined with a 12-channel ECG device, so it can be used to monitor cardiac signal activity, heart rate, body temperature, respiration and the SPO2 of the patients. It can also be used to measure a 12-channel ECG. In the future, this study can be fabricated and used in the small clinic in the villages at a low cost.

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