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Design and Build a Distance and Heart Rate Monitoring System on a Dynamic Bike Integrated with Power Generating System

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ABSTRACT The rapid development of the field of health sciences, this can affect not only aspects of medicine, but also other supporting fields of science such as chemistry, biology, pharmacy, and other scientific fields. With the development of medical science, people are always active in improving their physical fitness to remain optimal in the current new normal era. After the Covid-19 pandemic, many things change to adapt to the environment around us. One of the implications of the adjustment in the new normal era is the use of transportation for social distancing. Many people use environmentally friendly and healthy modes of transportation, such as bicycles, to travel. In 2016, Deshmukh and colleagues conducted a study entitled 'Design of a Walking Bike', one of several developments in the title of research that discusses the design of a treadmill bicycle [5]. In this study, a mechanical test and design of a treadmill bicycle was carried out in the form of 3D modeling which had been integrated with a power generating system in the form of adding a BLDC motor to the rear wheel. By following the rapid development of technology. The authors investigated the effect of treadmill cycling on heart rate monitoring using the MAX30102 sensor. The two initial values can easily be derived from the results of the conducted studies. The first test has an error rate of 12.64% and the second test has an error rate of 22.09%. From the results of these tests, the author is in further investigation by adding the Kalman filtering method to the MAX30102 sensor. Then, the output generated from this power generating system can charge the battery up to 12.95 volts with a period of 25 minutes of testing.

INDEX TERMS Treadmill Bicycle, Heart Detector, BLDC Motor, Treadmill Bicycle Power Generating

I. INTRODUCTION

Health is a state of mental, physical and social well-being that enables a person to live economically and socially. Health is the most important asset in human life. Because providing good health allows us to do various activities and think better [1]. One of the healthy organs that must be protected is the heart. The heart is one of the organs of the human body that has the necessary functions to sustain life. Maintaining health is a top priority and requires careful attention, so that small abnormalities in the heart can have a big impact on body performance [2]. In addition to the rapid development of the health sciences, this can affect not only the medical side, but also other supporting fields of science such as chemistry, biology, pharmacology and other scientific fields[16]. The informatics plays an important role in maintaining, monitoring, diagnosing, and managing health, especially heart health. Heart rate is one measure of human health and can be observed with an increase in resting pulse rate [3].

With the development of medical science, people are always eager to improve physical fitness and adapt to post-pandemic environmental conditions caused by the Covid-19 virus to remain optimal in the current new normal era[17]. Adjusting the effect of adapting to the new age Normality is to use transportation and keep a distance from each other. Many people use environmentally friendly and healthy modes of transportation, such as bicycles, to travel. A bicycle is a vehicle with two or three wheels, a seat, handlebars, and a pair of pedals for foot movement [4]. At the beginning of the 18th century, a new bicycle was introduced to society as a means of two-wheeled transportation called a velocipede. Later, with the development of mechanical technology, bicycles began to be known as two-wheeled vehicles[22]. The most important component is the frame, as it supports the rider's load and plays an important role in connecting the various components. This created the shape of the bicycle as we know it today.

In 2016, Deshmukh and colleagues conducted a study entitled 'Design of a Walking Bike', one of several developments in the title of research that discusses the design of a treadmill bicycle [5]. In this study, mechanical testing and design of a treadmill bicycle was carried out in the form of 3D modeling. Then, along with the development of technology, currently being faced with the problem of air pollution due to motor vehicle pollution[24]. So that in this study developing the recent study, which there is no implemented of power generating system in treadmill bicycle. Therefore, in this research the treadmill bicycle was integrated with a power generating system by adding a BLDC type electric motor as a rear wheel drive. This BLDC motor converts static energy from wheel rotation into electrical energy[6]. So as to be able to create innovative and environmentally friendly vehicles.

So the problem is that many cyclists neglect their health because they are forced to cycle and the lack of adequate water intake causes lack of oxygen and dehydration among riders[18]. This can cause the driver to lose concentration, suddenly lose consciousness and, in the worst case, lead to a heart attack. Based on the problems above, in this study it is hoped that these problems can be solved by measuring the concentration of oxygen in the body with a treadmill bicycle equipped with a heart rate monitor[7]. And, can create alternative energy solutions to support green energy and as a first step for environmental development.

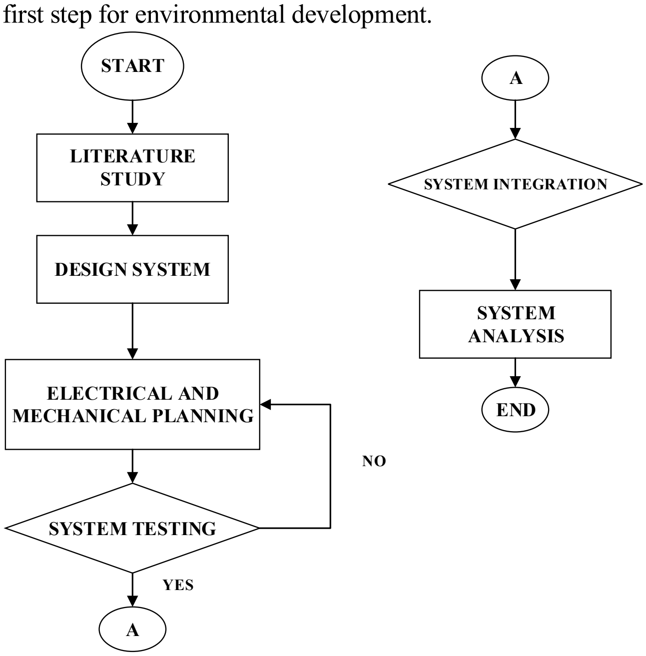

Figure 1. Flowchart Research

II. MATERIALS & METHODS

A. FLOWCHART OF THE RESEARCH

The studies is beginning form the literature have a look at. in this step researcher is searching out linier literature to support the studies. Then, through a few literature the layout device be build. It along with electrical layout and mechanical design. After that, the layout is constructed into prototype. Then, the prototype can be examined to recognize the result and by means of the test it can be regarded the machine construct within the studies. Then, by using the checking out the facts can be collected, through it the facts may be evaluation by using take a look at the result checking out. so that, it could be regarded the machine is labored and the energy might be generated.

B. LITERATURE AND METHODS

1. BICYCLE TREADMILL

An electric bicycle is a type of vehicle that is driven by an electric motor whose power uses electrical energy stored in batteries or other energy storage areas. An electric motor is an electromagnetic device that can convert electrical energy into mechanical energy. E-bikes use mechanical energy to drive electric motors [5].

Electric bicycle development begins with a study entitled "Designing and Building a Treadmill Bike". In addition, there are several studies, one of which was carried out by Devashish Tiwari and his colleagues in a study entitled The Effect of Modifying a Treadmill Bike with Chain Drive[23]. The argument illustrated by the two studies is to modify the mechanical design of the treadmill bicycle so that it can be moved manually or manually[15]. In this condition, the exertion experienced by treadmill bicycle users is very high, which in turn affects the distance that can be covered during exercise. The working mechanism of a treadmill bicycle is very simple and uses two power sources[19]. The initial power source comes from the battery, which can power the motor to run the treadmill. The second power source is then provided by the user's power while walking on the treadmill which is transmitted the rotational motion of the belt[8]. The torque converter that drives the rear wheels of a motorcycle.

2. SENSOR MAX30102

The MAX30102 sensor module is a type of sensor that can detect human heart rate and body temperature. The sensor has infrared and red LEDs, next to which is a photodetector which blocks out light around the sensor to make it low noise enough. Generally, these sensors are used in fitness aids, embedded in smartphones, tablets, or devices capable of supporting sensors to allow regular monitoring of physical condition during the training process [2].

This sensor operates from a single 1.8V supply and a separate 3.3V supply for the internal LEDs. This sensor module features I2C as a standards-compliant interface, enabling mobile devices to communicate with the microcontroller[10]. The module can be turned off by software without standby power and can be left on all the time. Sensor readings depend on hemoglobin, with oxygen-enriched hemoglobin absorbing more infrared light and deoxygenated hemoglobin absorbing red light[14]. The probe microprocessor calculates the difference in oxygen content and converts this information into a digital value. This value is estimated to determine the amount of oxygen carried by the blood. Relative optical absorption measurements are performed several times per second [7].

3. HEART RATE STANDARD

Heart rate can be said to be normal if it is calculated at rest or without physical activity. The pulse is determined by calculating the sudden change in pressure that propagates as a wave across the walls of the blood vessels [11]. To manually calculate the heart rate, you can use a stethoscope as a measuring device to manually determine the heart rate status. Similarly, heart rate is one of the factors that measure a person's health and can be observed with an increase in resting pulse rate[20]. Heart rate is also a factor in measuring a person's health and can be observed with an increase in resting heart rate. Measurement of heart rate is very useful to know the current physical condition in relation to gender and age [3]. When measuring your heart rate, you can find out your physical condition according to your age and gender, as shown in the table below. Heart rate is your heart rate per minute expressed in beats per minute (bpm) [25]. Heart rate is lower during periods of inactivity or rest and higher during periods of high activity, such as walking. For example, sports [6]. The resting heart rate is 70-100 bpm for children ages 6-15 and 60-100 bpm for adults over 18 years.

The average heart rate is determined primarily by the balance between the levels of sympathetic and parasympathetic activity in the heart [13]. Decreased nerve activity can be affected simultaneously by decreased sympathetic nerve activity, both of which are autonomic. In principle, the combination of several levels of sympathetic and parasympathetic activity should produce the same average heart rate [21].

TABLE 1
Men's Resting Heart Rate [11]

Condition	Ages					
	18-25	26-35	36-45	46-55	56-65	65+
	Heart Rate (BPM)					
Very-Very Good	49-55	49-54	50-56	50-57	51-56	50-55
Very Good	56-61	55-61	57-62	58-63	57-61	56-61
good	62-65	62-65	63-66	64-67	62-67	62-65
More Than Enough	66-69	66-70	67-70	68-71	68-71	66-69
Enough	70-73	71-74	71-75	72-76	72-75	70-73
Less	74-81	75-81	76-82	77-83	76-81	74-79
Bad	82+	82+	83+	84+	82+	80+

4. BLDC SYSTEM

Basically, the use of this BLDC motor has the same concept as other generators. However, the efficiency level of the BLDC motor is higher than the induction motor or other conventional direct current motors [9]. Then for the electrical system on the BLDC motor, it is a combination of electronic and electromechanical circuits, sensor systems and centralized algorithms [10]. Thus, the use of this BLDC motor produces a responsive and energy efficient output. In this BLDC motor, it does not use its commutation brushes and has a synchronous speed[12]. The use of permanent magnets in BLDC motors makes this motor not require an amplifier coil and there is no load current flowing through it.

TABLE 2
Heart Rate Rest Conditions WOMEN [11]

Condition	Ages					
	18-25	26-35	36-45	46-55	56-65	65+
	Heart Rate (BPM)					
Very-Very Good	54-60	54-59	54-59	54-60	54-59	54-59
Very Good	61-65	60-64	60-64	61-65	60-64	60-64
good	66-69	66-68	65-69	66-69	65-68	65-68
More Than Enough	70-73	69-72	70-73	70-73	69-73	69-72
Enough	74-78	73-76	74-78	74-77	74-77	73-76
Not Enough	79-84	77-82	79-84	78-83	78-83	77-84
Bad	85+	83+	85+	84+	84+	84+

5. SYSTEM DESIGN

Figure 4 shows a system diagram design which is divided into two types of systems. Figure (a) shows a power generation system implemented on a bicycle treadmill. Where the mechanical energy generated by the user with a belt treadmill will rotate the rear wheels which will also drive the BLDC motor. In this BLDC motor, static energy is converted into electrical energy which will be stored in the accumulator or battery. Before being stored later the voltage will also be stabilized on the buck converter.

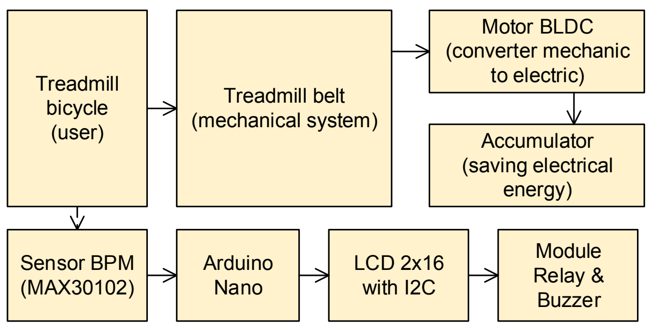

Figure 3. **(a) Power Generating System Diagram (b) Heart sensor System**

Then, the heart rate detector system consists of three main parts. Namely input, controller and output. The input is a sensor to detect heart rate, the controller uses an Arduino uno, and the output is an I2C module that combines a 16x2 LCD and a relay module to drive the buzzer. The reading of the MAX30102 sensor depends on the position of the finger attached to the sensor. The sensor then sends digital data to the microcontroller to process sensor readings. Then the LCD display output value is changed to 16x2 LCD. If the sensor exceeds the specified limit, the minimum is 93 beats/minute and the maximum is 157 beats/minute.

6. Treadmill Bike Mechanical Design
Figure 5 is a 3D modeling design of a treadmill bicycle. The blueprint is meant to be the first drawing before building the actual mechanism. This was used not only as an initial drawing, but also to reduce errors in the manufacture of the bicycle frame. Figure 5(a) is the overall design of a treadmill bicycle and Figure 5(b) is a grid arrangement for placing circuits such as LCD and controller (Arduino). The results of the 3D design are shown in Figure 6.

Figure 5. Results of Treadmill Bike Design

III. RESULT

In this test, the authors compare the MAX30102 sensor output readings with the fingertip pulse oximeter validator. The test was carried out experimentally. The test is divided into two parts: normal walking on a treadmill, cycling, and brisk walking on a treadmill. The data collection method for this test was cycling on a treadmill. The compiler places the thumb on the MAX30102 sensor and the finger-trip pulse oximeter on the index finger. Below is a description of the validator used and how comparative data is collected between the MAX0102 sensor and the validator while riding a bicycle. Figure 8 is a test of the MAX30102 sensor with a comparison using a validator, namely a fingertrip pulse oximeter. The test is divided into two parts, namely taking MAX30102 sensor readings by walking normally on a treadmill and walking fast on a treadmill.

Figure 6. Fingertip Pulse Oximeter as Validator

Figure 7. Testing the MAX30102 Sensor and Validator by Riding a Treadmill Bike

A. SENSOR TESTING DURING NORMAL RUNNING

In this test, the rider rides a treadmill bicycle with normal running conditions. The test was carried out by riding a treadmill bicycle for approximately 500 meters 10 times. The results of the comparison between the MAX30102 sensor and the validator are in Table 5.

TABLE 3
Testing the MAX30102 Sensor and Validator with Normal Running Conditions.

No.	Oximeter (BPM) Calibrator	MAX30102 (BPM) Sensor	Error (%)
1	113	118	3.6
2	114	119	4.39
3	115	116	0.87
4	116	117	1.76
5	118	117	1.69
6	119	115	4.15
7	120	118	2.48
8	121	115	4.95
9	113	116	2.65
10	112	-	100
Average Error (%)			12,65

Based on the data in Table 5, we can see that the average error rate generated by the 10 tests is 12.64%. On the 10th test, the sensor failed to read my finger reading caused by the vibration from riding the treadmill bike.

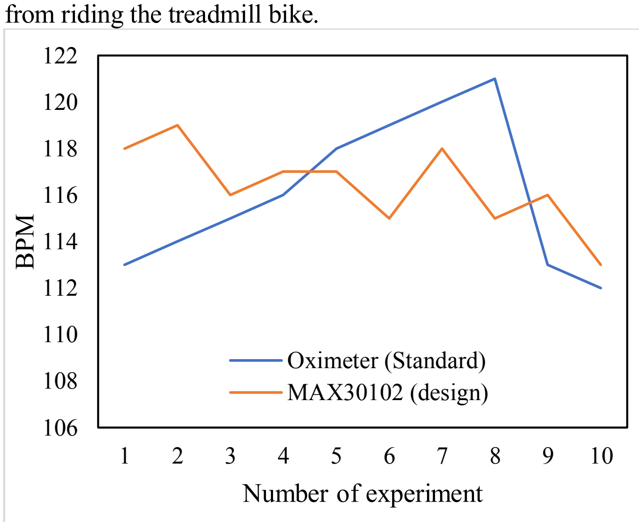

Figure 8. Graph of MAX30102 Sensor Testing and Validator with Normal Running Conditions.

B. SENSOR TEST ON FAST WALKING

In this test, the rider rides a treadmill bicycle under normal walking conditions. The test was carried out by cycling 10 times on a treadmill bicycle with approximately 500 meters. Table 6 shows the results of the comparison of the MAX30102 sensor and the validator.

TABLE 4
Testing the MAX30102 Sensor and Validator with Fast Running Conditions.

No	Oximeter (BPM) (standard)	MAX30102 (BPM) (Sensor)	Error (%)
1	120	120	0
2	119	124	5.083
3	118	123	5.084
4	124	122	2.3
5	125	122	2.4
6	122	122	0
7	124	123	1.6
8	123	-	100
9	124	-	100
10	115	120	4,357
Average Error (%)			22,18

Based on the data in Table 6, we can see that the average error rate generated by the 10 tests is 22.09%. In the eighth and ninth tests, the sensor failed to read thumb values. This is caused by vibrations from riding the treadmill bike too fast. The design of the bicycle frame design and suspension settings greatly affect the reduction of bicycle vibration when passing through bad roads [8].

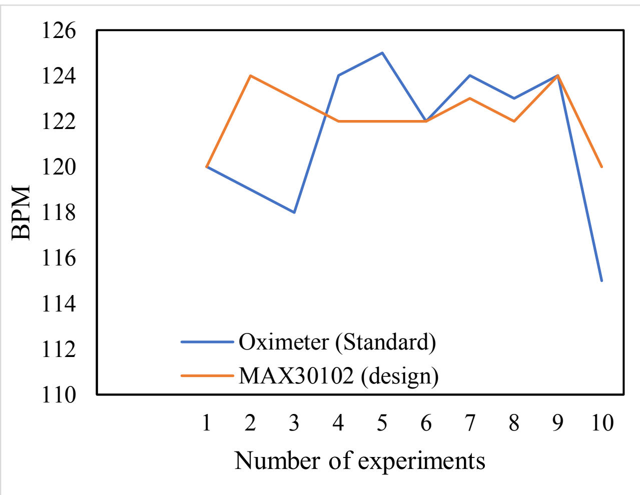

Figure 9. Graph of MAX30102 Sensor Testing and Validator with Fast Running Conditions.

C. BIYCYCLE POWER GENERATING TREADMILL TEST

Based on the test results of the conversion of static energy to electrical energy produced by the rotation of the belt from the biycycle treadmill, it shows that during the 30 minute test the bicycle is able to produce an output for charging the battery up to 12.95 volts. The output obtained is stabilized in a buck converter. The resulting output also depends on road conditions and also the speed of the bicycle, so that it affects the RPM produced by the biycycle treadmill.

TABLE 5
Testing Power Generating System Treadmill Bicycle

No	Min.	RPM	Bicycle Speed (m/s)	Generator Output Voltage (vdc)	Buck Converter Output Voltage (vdc)	Current (A)	Accu Output Voltage (Vdc)
1	-	-	-	-	-	-	12,12
2	5	62.31	16,988	14.87	12.98	0.079	12.69
3	10	75.89	21,293	16.19	13.78	0.099	12.81
4	15	57.23	15,967	16.21	13.89	0.082	12.92
5	20	70,12	19,632	15.05	13.98	0.091	12.84
6	25	82.46	22,956	16,16	13.76	0.088	12.96
7	30	78.92	22.198	15.82	13.81	0.058	12.95

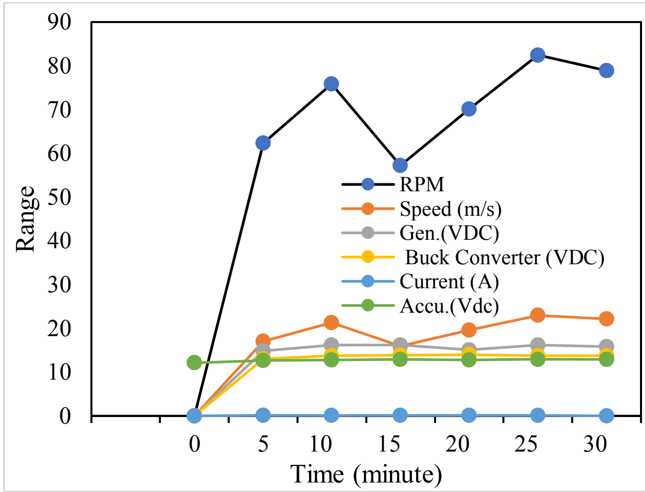

Figure 10. Power Generating Treadmill Bicycle Testing Chart

IV. DISCUSSION

In this study, the prototype treadmill bicycle was designed to be able to measure the oxygen concentration in the user's body using a treadmill bicycle equipped with a heart rate monitor. This is to minimize uncontrolled heart rate when too much in cycling. The test results for the MAX30102 sensor show an error rate of 12.64% in normal operation. The percent error value is obtained by comparing the sensor output with the validator. In the tenth test, the vibration from riding the treadmill caused the loss of the sensor value package. The test results show that the MAX30102 sensor has an error rate of 22.09% at high speed. The percentage error value is obtained by comparing the sensor output and the fingertip pulse oximeter validator.

Then, the bicycle treadmill is integrated with the power generating system. So that the static motion generated by the rotation of the wheel is converted into electrical energy which is stored in a 12volt battery. Based on the test results, it takes about 25 minutes to fully charge the battery until the battery output reaches 12.96 volts. The voltage generated in this experiment is directly proportional to the rotation of the bicycle wheel which affects the speed of the bicycle to rotate the generator. Thus, the role of the user in operating the bicycle also affects the stability of the bicycle output.

V. CONCLUSION

The conclusion from the research treadmill bicycle integrated with power generating system below. The readings from the MAX30102 sensor show a high error rate, with an error rate of 12.64% on a normal treadmill test. This exceeds the specified limit for the sensor to read accurately. The sensor accuracy percentage error limit is a maximum of 5%. Then, The output of the power generating system of the bicycle treadmill is very dependent on the speed of the user in operating the bicycle. Where the voltage generated is directly proportional to the rotational speed of the bicycle wheel in driving the generator. In this research trial, it takes 25 minutes to reach the maximum voltage (charging process) of the battery with an output that has been stabilized by the buck converter.

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