DC Motor Speed Control System In The Rhythm Of Angklung Musical Instrument

Ach. Dafid [1], Mohammad Lutfi Hidayat [2], Firmansyah Adiputra [3]
[1]Department of Informatics Engineering, University of Trunojoyo Madura, Bangkalan, Indonesia
[2]Department of Mechatronics Engineering, University of Trunojoyo Madura, Bangkalan, Indonesia
[3]Department of Information System, University of Trunojoyo Madura, Bangkalan, Indonesia
Corresponding author: Dafid, Ach. Email : ach.dafid@trunojoyo.ac.id

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ABSTRACT

Technological developments to help and facilitate humans are robots. Robots can also be used to introduce or preserve new traditional arts with a modern twist that the younger generation can accept, one of which is the angklung robot. The authors designed an angklung robot control system to introduce and preserve the technology-based angklung musical instrument. The angklung robot combines traditional musical instruments with robot control that works automatically based on the input song and consists of other components. The components used in the angklung robot include the Max4466 sensor, the Arduino Mega2560 microcontroller, the relay module, and the DC motor. The working system of the angklung robot connects a computer to the angklung robot via a USB cable. After that, entering the song is read by the sound sensor, processed by the Arduino Mega2560, controlled by the PID method, and produced output to the DC motor up to the Angklung. Several experiments were taken for the success of the angklung robot tool from the speed of the motor and the investigation of the sound of the song with satisfactory results. The results of proper sensor testing are obtained for each analog value, Tone Do has a frequency of 352 Hz, Tone Re has a frequency of 431 Hz, Tone Mi has a frequency of 565 Hz, Tone Fa has a frequency of 632 Hz, Tone Sol has a frequency of 712 Hz, Tone La has a frequency 792 Hz, the Si tone has a frequency of 853 Hz and the Do' tone has a frequency of 912 Hz. Taken my balloon song experiment five times with a slight difference in analog value but still producing an angklung rhythm that matches my balloon song. There are five of them.

I. INTRODUCTION

The Unitary State of the Republic of Indonesia is a country that has cultural diversity, such as a diversity of languages, food, traditional clothing, musical instruments, and many more. One of the popular varieties in Indonesia is conventional musical instruments with their uniqueness. Along with the swift flow of foreign culture and art, the existence of traditional craft is also under threat. Various conventional skills have started to be marginalized; some have even started to become extinct due to new arts that are not necessarily by our nation's culture. One of the musical instruments that began to shift and began to be replaced by the progress of electronic musical instruments, namely the angklung musical instrument.

Angklung is a traditional musical instrument made from bamboo and comes from West Java; in November 2011, the angklung musical instrument was finally designated as a world cultural heritage by the United Nations Educational, Scientific and Cultural Organization (UNESCO). Angklung is played in groups to produce a musical composition that feels more complicated and expensive compared to other musical instruments(Budi *et al.*, 2013; Budi, 2017; Handayani and Siregar, 2017; Rosydiana, 2017; Eko Cahyono, Arman Prasetya and Puspita Sari, 2018; Tri Herdiyan *et al.*, 2018; Effendi and Hardiyana, 2019; Murpratama, Sunarya and Novianti, 2020). Angklung usually uses a pentatonic scale to produce a note called a chord, but in 1938 musician Daeng Soetigna introduced angklung to the public using a diatonic scale known as Padang angklung, angklung soulmate or modern angklung.

Currently, the development of technology to help and facilitate humans is a robot. Therefore, it is not impossible that robots can also be used to introduce and or preserve traditional arts as the utilization of the role of technology in creating innovations with a modern touch and acceptable to the younger generation, one of which is the angklung robot(Budi *et al.*, 2013; Handayani and Siregar, 2017; Eko Cahyono, Arman Prasetya and Puspita Sari, 2018; Tri Herdiyan *et al.*, 2018; Murpratama, Sunarya and Novianti, 2020). Based on the background of the problems that have been described, the author will design a control system for the angklung robot to introduce and preserve the technology-based angklung musical instrument. Angklung robot is a combination of traditional musical instruments with robot control. The angklung robot will work automatically based on the inputted song and consists of other constituent components. Some of the ingredients used in the angklung robot include the Max4466 sensor as a sound sensor that can convert sound into electrical quantities, the Arduino Mega2560 microcontroller as a system controller, a relay module as a switch, and a DC motor as an actuator and controller using the PID method. The working system of the angklung robot is to connect the computer to the angklung robot via a USB cable. After that, the input of the song is then read by the sound sensor, processed by the Arduino Mega2560 and controlled by the

PID method, and produced output to the DC motor up to the Angklung.

II. METHOD

Most of the research used as supporting theory and guidelines in this study regarding rhythm, on average, discusses how to set melodious rhythm patterns with a microcontroller and monitor rhythms without the use of sensors at all so that it only produces a few rhythm patterns that are less varied and only match desires that are regulated by programs that have been embedded in the microcontroller.

Researchers will create an angklung robot that generates rhythm by adjusting the speed of a DC motor(Suharyanto, 2010; Khubalkar *et al.*, 2016; Pati and Swain, 2017; Qosim and Mujirudin, 2017; Sahputro *et al.*, 2017; Adel, Hamou and Abdellatif, 2018; Kumari and Swain, 2018; Hekimoğlu, 2019; Balamurugan and Umarani, 2020a, 2020b; Guerrero *et al.*, 2020a, 2020b; Dubravic and Serifovic-Trbalic, 2022; Zhao and Hua, 2022; Baidya, Dhopte and Bhattacharjee, 2023). by following the rhythm of music with several components to produce rhythmic sounds that dynamically follow the rhythm of a note or follow the amplitude of a tone received by the max4466 sound sensor as a tone reader as the initial input. The signal received by the sensor has an output analog signal from the range 0 to 1023, which will then be sent to the Arduino Mega2560 microcontroller for processing. The Arduino Mega2560 microcontroller will process the analog signal to be converted into a PWM signal to 4 L298N motor drivers based on calculations from the PID method used to drive the 8 angklung rhythm patterns, which are mirrored into 16 to create beautiful rhythm patterns through the DC motor movement.

A. *Tool Design Design*

The tool design aims to provide detailed and clear information regarding the precise and clear description of the angklung robot, such as the positioning of the supporting components that will be used to manufacture the tool. The angklung robot design is shown in "Fig 1".

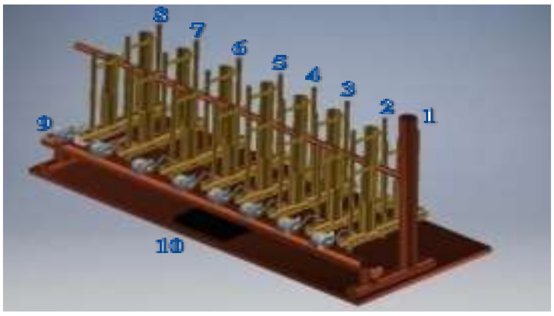

Fig 1. Angklung Robot Design

Information on the numbering and design function of the angklung robot tool in "Fig 1". as in Table I., namely:

TABLE I. TOOL DESIGN NUMBERING DESCRIPTION

Number	**Description**	**Function**
1	Bamboo tube 1	Do rhythm pattern
2	Bamboo tube 2	Rhythm pattern Re
3	Bamboo tube 3	Noodle rhythm patterns
4	Bamboo tube 4	Fa rhythm patterns
5	Bamboo tube 5	Sol rhythm patterns
6	Bamboo tube 6	Rhythm pattern La
7	Bamboo tube 7	Si rhythm patterns
8	Bamboo tube 8	Rhythm pattern Do
9	DC Motor	Drives the bamboo tube of the angklung
10	*Panel box*	Places electronic components such as Max4466 sensors, microcontrollers, power supplies, motor drivers L298N, and a relay module.

The angklung robot has dimensions 95 cm wide and 83 cm high with materials used from bamboo. There are 8 bamboo tubes or eight angklung rhythm patterns, which are mirrored into 16, 8 DC motors as actuators, and other components such as the Max4466 sensor, which functions to read the rhythm patterns of the music being played(Anastasi Seseragi Lapono and Kristian Pingak Jurusan Fisika, 2018; Cahyo, Nugroho and Haj, 2019; Jakaria and Fauzi, 2020). a microcontroller as a controller to control all systems of this tool, power supply as a resource for all the hardware used, the L298N motor driver is a DC motor driver module to control the speed of a DC motor. The relay module functions as a switch to control and distribute electricity.

B. *System Block Diagram*

The block diagram of the control system on the angklung robot consists of input, process, and output blocks using a closed control system (close loop). The following is a diagram of the angklung robot control system, as shown in "Fig 2".

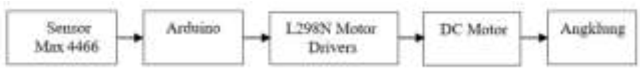

Fig 2. Angklung Robot Control System Block Diagram

Starting from reading the tone by the sound sensor and then processing it by Arduino, the data processing results will be a value in the motor driver. The angklung will sound according to the value given by the motor driver, which is passed on to the dc motor as the driving force.

TABLE II. BLOCK DIAGRAM SYMBOL DESCRIPTION

No	Symbol	Information	Unit
1	x_s	The set point value at each each rhythm pattern	Hz

No	Symbol	Information	Unit
2	x_m	Sound sensor reading results in the form of 8 rhythm patterns	Hz
3	$\bar{x} = x_s - x_m$	The result of the difference from the setpoint value minus the reading result sensors	Hz
4	PWM	The output results from the PID control in the form of motor pwm value	pwm
5	x	The end result of the rhythm pattern	Hz

The block diagram of the control system on the angklung robot can be explained as follows:

a) *Input Block:* The control system input block for the angklung robot is the Max4466 sensor as a sound sensor. Where the music rhythm pattern is detected and recognized by the sound sensor played from the android, the sound reading results will be stored in the xm variable and then compared and calculated the difference from the good setpoint value for each of the 8 rhythm patterns. Data from the sound sensor will be stored and processed to obtain PWM values for each of the eight rhythm patterns.

b) *Process Block:* In the process block, there is an Arduino Mega2560 microcontroller component that functions to control all systems on the angklung robot so that the system can work properly. Apart from that, it also processes song tones from sound sensor readings to obtain PWM values. Then, there is a relay module as a switch to drive the DC motor. Meanwhile, the PID method is also processed in this block, which regulates the speed of the DC motor to play the rhythm according to it so you can play it regularly.

c) *Output Block:* The result of data processing from the process block is in the form of a DC motor movement that plays the angklung robot automatically based on the tone data detected by the previously processed sound sensor. This angklung robot can only play one song. If you want to play a different theme, you need to detect the notes again from the song you want to play.

C. *System Flowcharts*

Figure 3. shows the flowchart of the angklung robot control system, starting with introducing the sensor used in this tool, namely the max4466 sensor, commonly known as the sound sensor. Then the music is played from the android, and the max4466 sensor carries out the sound reading. The detected sound is a tone of 1 octave with eight rhythm patterns, namely Do-Re-Mi-Fa-Sol-La-Si-Do in the form of a frequency value generated, and then a range of values is made to determine the rhythm pattern. After that, the resulting rhythm pattern is stored and processed into a PWM value which will later be controlled by the PID method(Khubalkar *et al.*, 2016; Pati and Swain, 2017; Qosim and Mujirudin, 2017; Sahputro *et al.*, 2017; Adel, Hamou and Abdellatif, 2018; Kumari and Swain, 2018; Hekimoğlu, 2019; Balamurugan and Umarani, 2020b, 2020a; Mahmud *et al.*, 2020; Clitan and Muntean, 2021; Dubravic and Serifovic-Trbalic, 2022; Baidya, Dhopte and Bhattacharjee, 2023). to determine the speed of the DC motor that must be given, namely in the form of movements on the angklung.

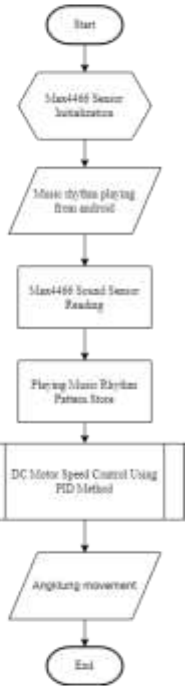

Fig 3. Angklung Robot Control System Flowchart

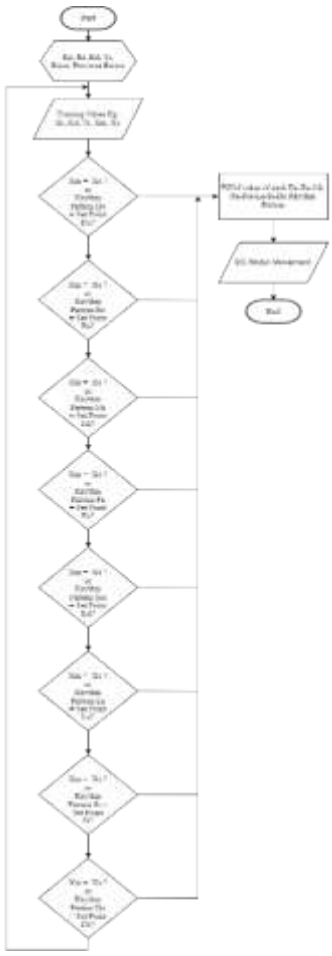

Fig 4. DC Motor Speed Control Flowchart Using the PID Method on Angklung Robots

Flowchart of DC motor speed control using the PID method on the angklung robot, as shown in Figure 3.5 where the PWM values obtained are compared with the sound setpoint values using the PID method. In determining the PID method, the thing that must be done is to determine the values of Kp, Ki, and Kd by tuning, namely by carrying out values randomly until you get the same value or close to the setpoint value. If, in the process, the results are very far from the setpoint value, then the tuning process is carried out again until the values obtained are entirely the same, namely the PWM values for each Do-Re-Mi-Fa-Sol-La-Si-Do rhythm pattern. After that, it was immediately implemented in the DC motor movement to move the angklung.

D. Electronics Network

Electronic circuits are used to run the system as a whole so that it can work. The following is a series of angklung robots as shown in Figure 5.

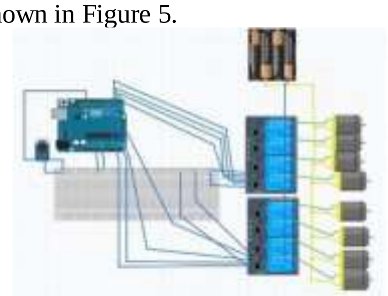

Fig 5. Angklung Robot Electronics Circuit

The power source or power supply used is 12V, the max4466 sensor pin is connected to the microcontroller using two relay modules with each relay consisting of 4 channels with a voltage of 5V, and 8 DC motors, the foot or pin of the DC motor is connected to the relay and the other pin to the power source than from the relay pin is connected to the microcontroller pin.

E. PID Control Implementation

The manual control calculation simulation of the angklung vibration according to the pitch will explain how to create vibrations following the tone frequency read by the sensor. The sensor value reading will be converted to a PWM value of 0 – 255. The lowest PWM value to activate the angklung vibration is 100 PWM and the maximum value is 255 PWM, so the PWM to be used is 100 – 255 PWM. The following is a calculation of the conversion of tone frequency values into PWM values.

$$PWM = \frac{PWM\,\max - PWM\ min}{7\ (basic\ tone)} \quad (1)$$

$$PWM = \frac{255-100}{7}$$

$$PWM = \frac{150}{7}$$

$$PWM = 21{,}3\ pwm$$

Simulation of PID control calculations to adjust the movement of the angklung to produce perfect strains according to the set point between the bamboo angklung tubes, it is necessary to calculate the PID control manually (Khubalkar *et al.*, 2016; Pati and Swain, 2017; Qosim and Mujirudin, 2017; Sahputro *et al.*, 2017; Adel, Hamou and Abdellatif, 2018; Kumari and Swain, 2018; Hekimoğlu, 2019; Balamurugan and Umarani, 2020b, 2020a; Mahmud *et al.*, 2020; Siswanto *et al.*, 2020; Clitan and Muntean, 2021; Dubravic and Serifovic-Trbalic, 2022; Karimi-Ghartemani, 2022; Baidya, Dhopte and Bhattacharjee, 2023). Before calculating the PID it is also necessary to determine the set point before calculating the difference in the speed of the angklung movement from minimum to maximum as follows:
Difference in Voice Rate = min sound speed − Sound Rate *max*
Difference in Voice Rate = 2 − 1.3
Difference in Voice Rate = 0.7 sec/min
The result of the difference in the sound rate of the angklung is divided by the number of fundamental frequency frequencies used, name

$$Setpoint = [\frac{difference\ in\ voice\ rate}{basic\ tone}] \quad (2)$$

$$Setpoint = [\frac{0{,}7}{8}]$$

$$Setpoint = 0{,}09\ Hz$$

So that the resulting setpoint value in Table III is as follows:

TABLE III. MOTOR SPEED SETPOINT VALUE

Rhythm Pattern	Range	Rate
Do	231 – 263 Hz	1,3 PWM
Re	264 – 296 Hz	1,4 PWM
Mi	297 – 329 Hz	1,5 PWM
Fa	330 – 362 Hz	1,6 PWM
Sol	363 – 395 Hz	1,7 PWM
La	396 – 428 Hz	1,8 PWM
Si	429 – 461 Hz	1,9 PWM
Do	462 – 494 Hz	2 PWM

Furthermore, manual calculations are carried out using the PID method to produce the desired PWM as follows:
Is known:

Kp = 1 *Ki* = 0,5

Kd = 0,2 *Ts* = 1

Setpoint = 1,4

Cycle 1

$Error = sound\ rate - setpoint$
$Error = 1.8 - 1.4$
$Error = 0.4\ Hz$

$$PWM = \left(Kp * (error)\right) + (Ki * (error + previous\ errors) * Ts)) + ((\frac{Kd}{Ts}) * (error - previous\ errors)) \quad (3)$$

$$PWM = \left(1 * (0{,}4)\right) + \left(0{,}5 * \left((0{,}4 + 0) * 1\right)\right) + ((\frac{0{,}2}{1}) * (0{,}4 - 0))$$

$PWM = 0{,}4 + 0{,}2 + 0{,}08$
$PWM = 0{,}68\ PWM$

Cycle 2

$Error$ = sound rate $-$ $setpoint$
$Error = 1{,}5 - 1{,}4$
$Error$ = 0,1 Hz

$$PWM = (Kp * (error)) + (Ki * ((error + previous\ error) * Ts)) + ((\frac{Kd}{Ts}) * (error - previous\ error)) \quad (4)$$

$$PWM = (1 * (0{,}1)) + (0{,}5 * ((0{,}1 + 0{,}4) * 1)) + ((\frac{0{,}2}{1}) * (0{,}1 - 0{,}4))$$

PWM = 0.1 + 0.25 - 0.06
PWM = 0.29 PWM

Cycle 3

$Error$ = sound rate $-$ $setpoint$
$Error = 1{,}3 - 1{,}4$
$Error = -0{,}1$ Hz

$$PWM = (Kp * (error)) + (Ki * ((error + previous\ error) * Ts)) + ((\frac{Kd}{Ts}) * (error - previous\ error)) \quad (5)$$

$$PWM = (1 * (-0{,}1)) + (0{,}5 * ((-0{,}1 + 0{,}1) * 1)) + ((\frac{0{,}2}{1}) * (-0{,}1 - 0{,}1))$$

PWM = $-0{,}1 + 0 - 0{,}04$
PWM = $-0{,}14$ PWM (absolute)

Cycle 4

$Error$ = sound rate $-$ $setpoint$
$Error = 1{,}4 - 1{,}4$
$Error$ = 0 Hz

$$\text{PWM} = (\text{Kp} * (\text{error})) + (\text{Ki} * ((\text{error} + \text{previous error}) * \text{Ts})) + ((\frac{Kd}{Ts}) * (\text{error} - \text{previous error})) \quad (6)$$

$$PWM = (1 * (0)) + (0{,}5 * ((0 + 0) * 1)) + ((\frac{0{,}2}{1}) * (0 - 0))$$

PWM = 0 + 0 + 0

PWM =0 PWM

III. RESEARCH RESULTS AND ANALYSIS

A. Tool Results

In making the angklung robot, the design stages include determining the subject matter, reference search, mechanical design, electronics design, and programming. The results of the overall design of the angklung robot can be seen in Fig 6. where in the picture there is a description made by numbered points.

Fig 6. Angklung Robot

Description of the number in Figure 6 is as follows:

a. 1 bamboo tube for the Do pattern

b. Bamboo tube 2 for pattern Re

c. 3 bamboo tubes for the noodle pattern

d. 4 bamboo tubes for the Fa pattern

e. 5 bamboo tubes for the So pattern

f. Bamboo tube 6 for pattern La

g. Bamboo tube 7 for the Si pattern

h. Bamboo tube 8 for the Do pattern

i. 9 DC motors

j. Panel boxes

B. Angklung Robot Testing

a) *Sound Sensor Testing:* In the sound sensor experiment, 10 trials were carried out and the following results were obtained.

TABLE IV. SOUND SENSOR EXPERIMENT

Test	Do	Re	mi	fa	sol	la	si	Do’
1	353	431	566	630	710	790	853	911
2	352	431	567	631	711	794	852	912
3	352	433	568	634	712	792	854	912
4	351	432	566	633	713	791	853	911
5	353	432	565	631	711	792	856	914
6	351	433	564	633	714	793	851	911
7	352	432	560	632	712	791	852	914
8	352	431	567	631	714	794	854	913
9	354	431	567	635	713	792	851	913
10	353	430	565	632	711	791	854	914

1) The Do tone produces an analog signal value of 351 to 354 with an average value of 352.

2) The Re tone produces an analog signal value of 430 to 433 with an average value of 431.

3) The Mi tone produces an analog signal value of 565 to 568 with an average value of 565.

4) The Fa tone produces an analog signal value of 630 to 634 with an average value of 632.

5) The Sol tone produces an analog signal value of 710 to 714 with an average value of 712.

6) The La tone produces an analog signal value of 790 to 794 with an average value of 792.

7) The Si tone produces an analog signal value of 851 to 856 with an average value of 853.

8) The Do' tone produces an analog signal value of 911 to 914 with an average value of 912

The results of the experiment provide a description of the value that is getting higher when the pitch is getting higher. The difference from the tone in the experiment is the level of the result value is not much different from level to level.

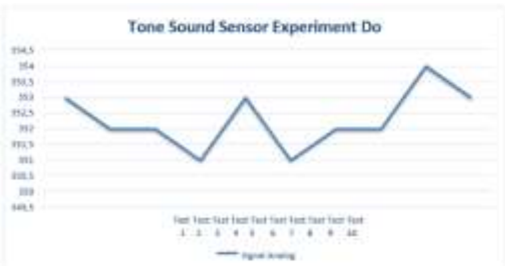

Fig 7. Tone Sound Sensor Experiment Do

In Figure 7. Is the result of a sound sensor test by entering a do tone and producing an analog signal value between 351 Hz to 354 Hz so that an average value of 352 Hz is obtained.

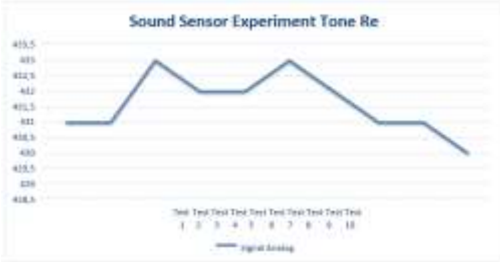

Fig 8. Sound Sensor Experiment Tone Re

In

Figure 8. Is the result of a sound sensor trial by entering a re tone and producing an analog signal value between 430 Hz to 433 Hz so that an average value of 431 Hz is obtained.

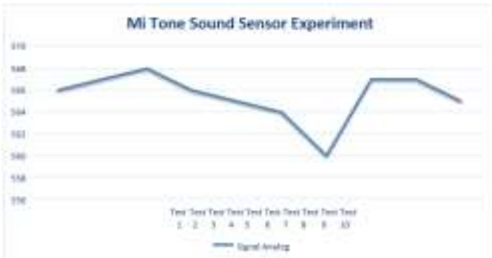

Fig 9. Mi Tone Sound Sensor Experiment

In Figure 9. Is the result of a sound sensor test by entering the mi tone and producing an analog signal value between 565 Hz to 568 Hz so that an average value of 565 Hz is obtained.

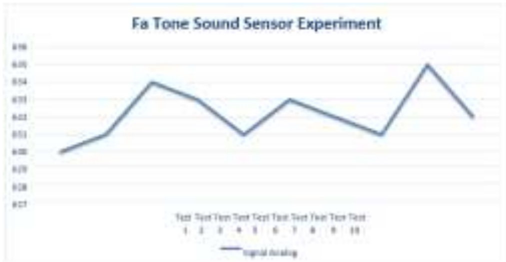

Fig 10. Fa Tone Sound Sensor Experiment

In Figure 10. Is the result of a sound sensor test by entering a fa tone and producing an analog signal value between 630 Hz to 634 Hz so that an average value of 632 Hz is obtained.

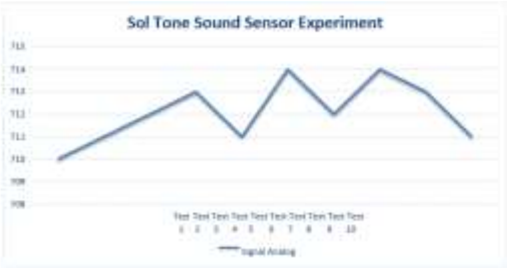

Fig 11. Sol Tone Sound Sensor Experiment

In Figure 11. Is the result of a sound sensor test by entering a sol tone and producing an analog signal value between 710 Hz to 714 Hz so that an average value of 712 Hz is obtained.

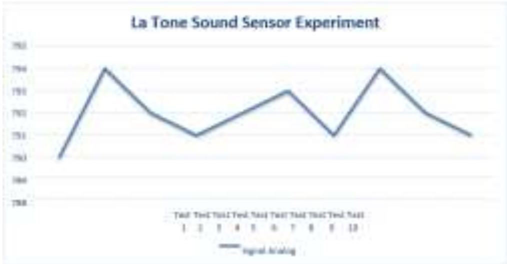

Fig 12. La Tone Sound Sensor Experiment

Figure 12. is the result of a sound sensor test by entering a la tone and producing an analog signal value between 790 Hz to 794 Hz so that an average value of 792 Hz is obtained.

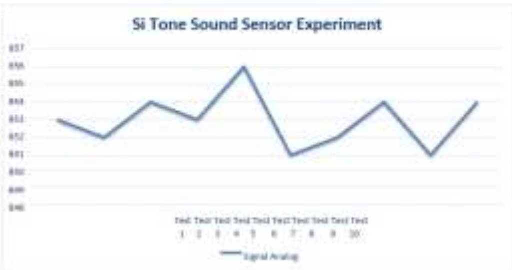

Fig 13. Si Tone Sound Sensor Experiment

In Figure 13. Is the result of a sound sensor test by entering si tones and producing analog signal values between 851 Hz to 856 Hz so that an average value of 853 Hz is obtained.

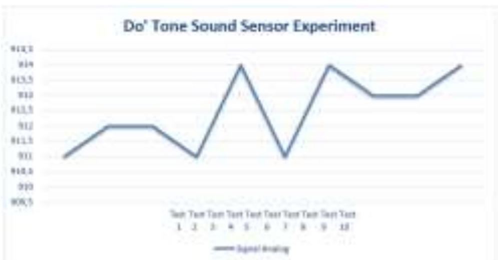

Fig 14. Do' Tone Sound Sensor Experiment

In Figure 14. Is the result of a sound sensor test by entering a do' tone and producing an analog signal value between 911 Hz to 914 Hz so that an average value of 912 Hz is obtained.

b) Experiment with Motor Speed

In Table V, an experimental dc motor speed is entered by entering the motor speed values of 100, 150, 200 and 250 respectively.

TABLE IV. SOUND SENSOR EXPERIMENT

Motor Speed	Do	Re	Mi	Fa	Sol	La	Si	Do
100	NS	NS	NS	NS	NS	NS	NS	NS
150	S	S	S	S	S	S	S	S
200	LF	LF	LF	LF	LF	LF	LF	LF
250	F	F	F	F	F	F	F	F

a) If the input speed of the motor is 100, the results will be obtained from Do, re, mi, fa, so, la, si, do with no sound at all.

b) If the input speed of the motor is 150, you get the results of Do, re, mi, fa, so, la, si, do with all slow beeps.

c) If the input speed of the motor is 200, the results will be obtained from Do, re, mi, fa, so, la, si, do with all the sound descriptions that are not fast enough.

d) If the input speed of the motor is 250, you get the results of Do, re, mi, fa, so, la, si, do with fast beeps. In the input speed experiment on the motor, 10 trials were carried out which obtained the same results in the 10 trials.

c) Angklung Robot Trial on My Balloon Song There are Five

In Figure 15, there are five of the notes for my balloon song which will be the angklung robot experiment.

Fig 15. My Balloon Tones There Are Five

TABLE VI. THERE ARE FIVE RESULTS OF THE ANGKLUNG INSTRUMENT EXPERIMENT ON BALONKU SONGS

No	Description	Song Rhythm						
1	Perverse Tone	Ba	Lon	Ku	A	Da	Li	Ma
	Musical scale	Mi	Fa	Sol	Do	Sol	Mi	Sol
	Signal Analog	566	630	710	353	712	568	70
2	Perverse Tone	Ru	Pa	Ru	Pa	War	Na	Nya
	Musical scale	Re	Mi	Fa	Re	Sol	Mi	mi

	Signal Analog	432	567	635	431	711	560	566
3	Perverse Tone	Hi	Jau	Ku	Ning	Ke	La	Bu
	Musical scale	Do	Do	La	La	Si	Do	sol
	Signal Analog	352	351	792	794	854	354	713
4	Perverse Tone	Me	Rah	Mu	Da	Dan	Bi	Ru
	Musical scale	Mi	Fa	Sol	Fa	Mi	Re	do

In Table VI above, the scales, namely the sounds of the lyrics of the Balonku song, there are five, the tones are processed by the sound sensor which is marked on the analog value, so that the angklung can sound according to the scales in the angklung lyrics. It was found that the results of the first experiment produced an angklung rhythm that matched the five of my balloon songs.

IV. Conclution

A. Conclusion

Based on the experiments conducted on the angklung robot, it can be concluded as follows.

1. The angklung vibrates and makes sound only with the motor speed at 150, 200 and 250.
2. The motor speed that is included is 250 because the sound produced by the angklung is very clear.
3. In the sound sensor experiment, each analog value is obtained as follows.

a) The Do tone produces an analog signal value of 351 Hz to 354 Hz with an average value of 352 Hz.
b) The Re tone produces an analog signal value of 430 Hz to 433 Hz with an average value of 431 Hz.
c) Nada Mi produces an analog signal value of 565 Hz to 568 Hz with an average value of 565 Hz.
d) Tone Fa produces an analog signal value of 630 Hz to 634 Hz with an average value of 632 Hz.
e) The Sol tone produces an analog signal value of 710 Hz to 714 Hz with an average value of 712 Hz.
f) The La tone produces an analog signal value of 790 Hz to 794 Hz with an average value of 792 Hz.
g) The Si tone produces an analog signal value of 851 Hz to 856 Hz with an average value of 853 Hz.
h) The Do' tone produces an analog signal value of 911 Hz to 914 Hz with an average value of 912 Hz.

4. In experiments 1, 2 and 3 of Balonku's songs, there were five very clear responses, namely the scales according to the analog signal that had been tried before.

B. Suggestion

Suggestions for this research to be developed in the future, namely the sensors used, can use newer components so as to produce much better research. Can include several or many songs in the experiment or implementation.

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