DESIGN OF SYNCHRONOUS SERIAL COMMUNICATION TO CONTROL PITCHES OF ANGKLUNG

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Report submitted in partial fulfilment of the requirements
for the award of Bachelor of Mechatronics Engineering

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BORANG PENGESAHAN STATUS TESIS◆

JUDUL: DESIGN OF SYNCHRONOUS SERIAL COMMUNICATION TO CONTROL PITCHES OF ANGKLUNG

SESI PENGAJIAN: 2012/2013

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We certify that the thesis entitled "Design of Synchronous Serial Communication to Control Pitches of Angklung" by Anas Muzamil bin Hamiddin. We have examined the final copy of this thesis and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of "Bachelor of Mechatronics Engineering". We herewith recommend that it be accepted in fulfilment of the requirements for the degree of Bachelor of Mechatronics Engineering.

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SUPERVISOR'S DECLARATION

I hereby declare that we have checked this project report and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechatronic Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this report entitled "Design of Synchronous Serial Communication to Control Pitches of Angklung" is the results of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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Dedicated to my beloved father, Hamiddin bin Abdul Aziz,
mother, Hazirah binti Ismail, brothers and sisters,
and my supervisor, Prof. Ir. Dr. Ahmad Faizal Mohd. Zain.

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ABSTRACT

This thesis describes the control device angklung (traditional musical instrument) with a 3 octave by using microcontroller. Each angklung pitch should be shaken to produce intonation. The electric motor is used as a vibrator mechanism and installed on every pitch angklung. Parameters such as the time duration and the motor speed to needs to be controlled and this require a Motor Drivers. Angklung pitch usually arranged in a Diatonic Scale. In a frame of angklung, there is 7 pitch intonation compiled in one octave, then there are 21 motors needs to be controlled by a microcontroller to control the angklung that has 3 different octaves. If each motor requires 12 volt and 100 mA to move, then 2.1 A is required for all motor to operate simultaneously without problems. This requires Power Supply which provide 12 volt and 3 A. By using the Serial Parallel Interface (SPI), 21 connections from microcontroller to control each motor can be reduced. Because all motor drivers connected in serial connection, then the latency in motor drivers should be measure. Latency is the amount of time it takes for a system after the system receives the signal till the system is producing other signal out. If the motor drivers produce high latency, the delay produced by the angklung can be heard. The normal human ear can notice latency more than 3 ms.

ABSTRAK

Tesis ini menerangkan alat pengawalan angklung (alat muzik tradisional) yang mempunyai 3 oktaf dengan menggunakan microcontroller. Setiap pitch angklung perlu digoncang untuk menghasilkan intonasi. Motor elektrik digunakan sebagai mekanisme penggetar dan dipasang pada setiap pitch angklung. Parameter seperti tempoh masa dan halaju motor perlu dikawal dan ini memerlukan Motor Driver. Pitch angklung kebiasaannya disusun mengikut sekala diatonic. Dalam satu bingkai angklung tersusunnya 7 pitch intonasi dalam satu oktaf, maka terdapat 21 biji motor perlu dikawal oleh microcontroller untuk mengawal angklung yang mempunyai 3 oktaf yang berbeza. Jika setiap motor memerlukan 12 volt dan 100 mA untuk bergerak, maka 2.1 A diperlukan untuk kesemua motor beroperasi serentak tanpa masalah. Ini memerlukan Power Supply yang mampu mengeluar 12 volt dan 3 A. Dengan menggunakan Serial Parallel Interface bus (SPI), 21 sambungan kawalan dari microcontroller kepada setiap motor dapat dikurangkan. Oleh kerana kesemua motor driver disambung secara serial communication, maka Latency di dalam motor driver perlu diambil kira. Latency adalah jumlah masa yang diambil bagi sesebuah sistem selepas sistem itu menerima isyarat hinga sistem itu mengeluarkan isyarat keluar. Jika motor driver menghasilkan latency yang tinggi, maka delay intonasi yang dihasilkan oleh angklung dapat didengar. Latency yang dapat didengar oleh telinga manusia biasa adalah melebihi 3 ms.

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LIST OF ABBREVIATIONS

DC	Direct Current
MOSFETs	Metal-Oxide Semiconductor Field-Effect Transistors
BJT	Bipolar Junction Transistors
CMOS	complementary MOS
MOS	Metal-Oxide Semiconductor
TTL	Transistor-Transistor Logic
IC	Integrated Circuit
SPI	Serial Peripheral Interface Bus

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter will describe background of proposed study, problem statement, objectives, scope of research and significant of research. Those information are important as we will further discuss it in the analysis and study case later.

1.2 Project Background

Many traditional musical instruments have been modified according to the latest trends form an instrument which automatically controlled. For this project, Angklung will be implemented to play by device that being control by microcontroller.

Angklung is music instrument that have being made by joining pieces of bamboo. It consists of two to four bamboo tubes suspended within a bamboo frame and produce certain notes when the bamboo frame is shaken or tapped. Each angklung produces a single note or chord, so several players must collaborate in order to play melodies.

This project is to develop device that can control Angklung with 3 octaves at minimum. In one octave of Angklung, there have about 12 of frame angklung. That frame will be taped by DC motor to produce a sound. Duration and velocity of the DC motor need to be control. Because we have about 3 octave of angklung, 36 DC motor needs to control by microcontroller. In this project, serial communication technology being applied to control all of that DC motor.

1.3 Project Problem Statement

The idea of electrically playing a angklung is not new. Many student from Indonesia have already produced a angklung-playing system under the names "Klungbot" and "Klungto Mobi". The usual angklung-playing system is just being preinstalled to the angklung and the system being control using parallel communication. This system is not easy to be maintained or troubleshoot by a normal guy. The new system could be installed into any existing angklung and allowing it to play music stored on computers that can send out MIDI signal. The device connected to the angklung by serial communication, capable to operate to add expression to the music by varying the voltages applied to the motors and can play angklung that have many octave.

1.4 Project Objective

The objectives of this study are:

(i) Develop the mechanical system that can be used to play an angklung.
(ii) Develop the electronic circuit to control all mechanical system.
(iii) Develop the electronic circuit using Synchronous Serial Communication concept.

1.5 Project Scope

The scope of the project is limited to the below parameter:

(i) Using Synchronous Serial Communication concept to control the angklung.
(ii) Controlling minimum 3 octave of the angklung.

1.6 Thesis Outline

This thesis contains 5 chapter which is every chapter have its own purpose. After viewing the entire chapter in this thesis hopefully viewer can understand the whole system design for this project.

Chapter 1 describe background of proposed study, problem statement, objectives, scope of research and significant of research. Those information are important as we will further discuss it in the analysis and study case later.

Chapter 2 describes about relation of Angklung Control and Serial Communications. The sources are taking from the journals, and articles and books. Literature review is helping in order to provide important information regarding previous research which related to this project. Those information are important to know before can proceed further to analysis and study later.

Chapter 3 describes about the procedures analysis on the serial data that being sending to motor driver to control the motor. Research methodology is a set of procedures or methods used to conduct research. Methodology is needed for a guideline in order to ensure the result is accurate based on objective. There are several steps need to be followed to ensure the objective of the research can be achieve starting from finding literatures until submitting the final report.

Chapter 4 will discuss every experiment on the methodology or the flow of work is come out with the result and analysis. The result of this project will include the signals that have being handled by motor drive to drive the motor. This chapter will discuss mainly about the problems encountered during the whole project was been carried out.

Chapter 5 represents about conclusion and recommendation for the project. In this chapter will discuss mainly about the conclusion of the project, concluding all the process that involved. Besides that this chapter also contains recommendation about the project. So for this recommendation it can make further improvement for future reference.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will explain about relation of Angklung Control and Serial Communications. The sources are taking from the journals, and articles and books. Literature review is helping in order to provide important information regarding previous research which related to this project. Those information are important to know before can proceed further to analysis and study later.

2.2 Principle of Angklung

Angklung is a music instrument made from joint pieces of bamboo. It consists of two to four bamboo tubes mounted together within a bamboo frame, bound with rattan cords. The angklung produce certain notes when the bamboo frame is shaken or tapped. Each angklung produces a single note or chord, so several players must collaborate in order to play melodies. The instrument has been known since ancient times in some parts of Indonesia, especially in West Java, Central Java, East Java, and Bali. Figure 2.1 shows example single pitch of the Angklung. (Professor Kuo-Huang Han)

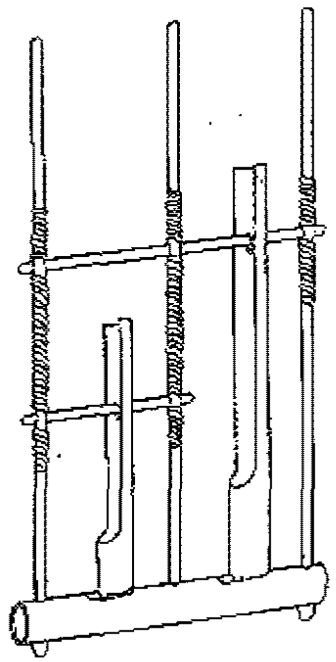


Figure 2.1: Example single pitch of the Angklung

The interval between the differently-sized bamboo tubes on each Angklung is one octave. Most Angklung sets today are tuned to the western chromatic and diatonic scales. (Professor Kuo-Huang Han)

2.3 Basic of the Angklung Scale

In music, an octave or perfect octave is the interval between one musical pitch and another with half or double its frequency. The octave relationship is a natural phenomenon that has been referred to as the "basic miracle of music", the use of which is "common in most musical systems". It may be derived from the harmonic series as the interval between the first and second harmonics.

2.3.1 The Diatonic Scale

In music theory, a diatonic scale is commonly defined as a seven-note, octave-repeating musical scale comprising five whole steps and two half steps for each octave, in which the two half steps are separated from each other by either two or three whole steps. This pattern ensures that, in a diatonic scale spanning more than one octave, all the half steps are maximally separated from each other. (Adam Koss)

Any sequence of seven successive natural notes, such as C-D-E-F-G-A-B, and any transposition thereof, is a diatonic scale. Table 2.1 shows diatonic scale in degrees in solfege. Piano keyboards are designed to play natural notes, and hence diatonic scales, with their white keys. It is made up of seven distinct notes, plus an eighth which duplicates the first an octave higher Insolfege, the syllables used to name each degree of the scale are "Do–Re–Mi–Fa–Sol–La–Ti–Do". Figure 2.2 below shows example diatonic scale on the angklung. (Adam Koss)

Table 2.1: Example Diatonic Scale

Notes in C major	C	D	E	F	G	A	B	C
Degrees in solfege	Do	Re	Mi	Fa	Sol	La	Ti	Do

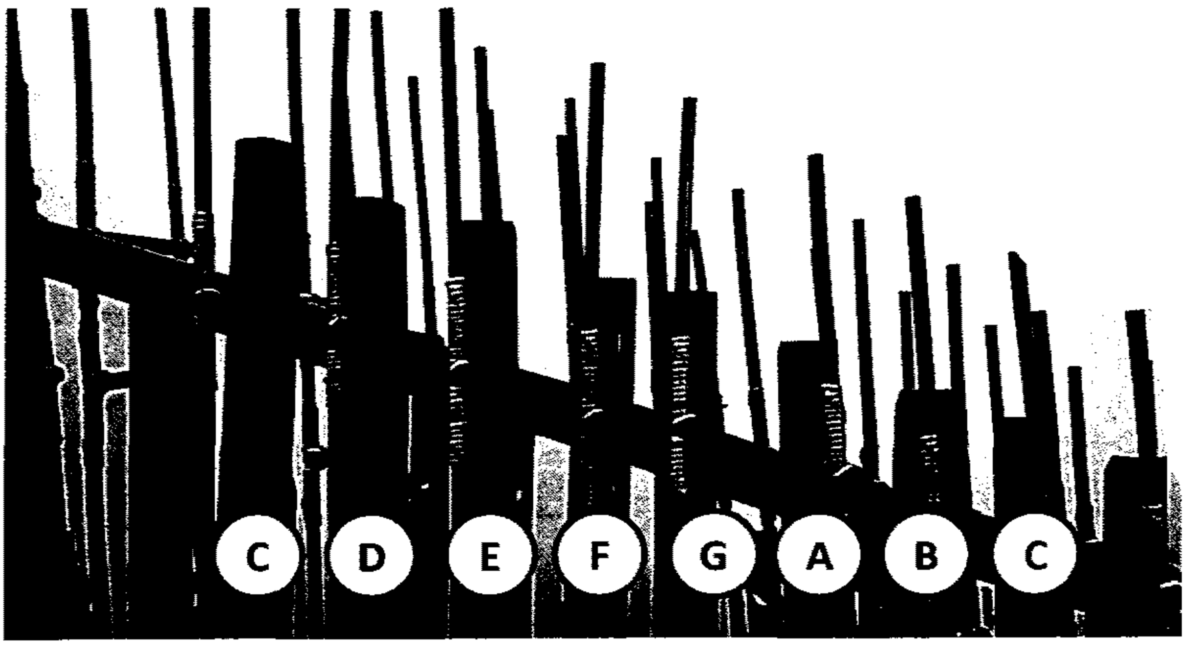


Figure 2.2: One Octave of the Angklung

2.3.2 The Chromatic Scale

The word "chromatic" comes from the Greek word chroma meaning "color." The chromatic scale consists of 12 notes each a half step apart. It is from the chromatic scale that every other scale or chord in most Western music is derived. On the piano/keyboard when you play all the black and white keys of an octave in an ascending or descending order you are playing a chromatic scale. We will take the C chromatic scale as an example on Table 2.2.

Table 2.2: Example Chromatic Scale

Notes in C major	C	C#	D	D#	E	F	F#	G	G#	A	A#	B	C

2.4 Type of Data Communications

There have a few standards to choose from when considering a communications protocol that can be implement in this project. Those are:

(i) Parallel Communication
(ii) Synchronous Serial Communication
(iii) Asynchronous Serial Communication

2.4.1 Parallel Communication

Parallel communication implies sending a whole byte (or more) of data over multiple parallel wires. Figure 2.3 shows example parallel communication. (Silicon Laboratories)

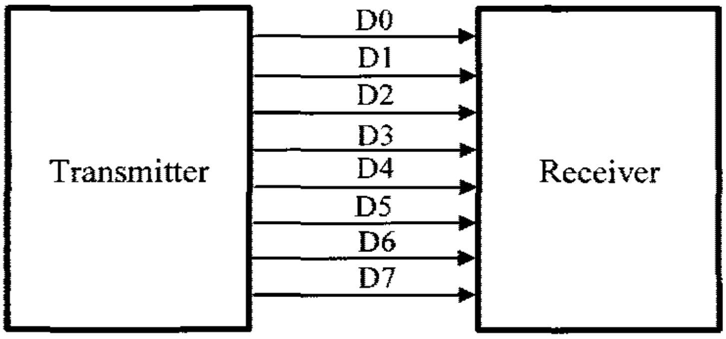


Figure 2.3: Example Parallel Communication

2.4.2 Synchronous Serial Communication

Serial communication implies sending data bit by bit over a single wire. Synchronous serial requires the clock signal to be transmitted from the source along with the data. Figure 2.4 shows example synchronous serial communication. Data rate for the link must be the same for the transmitter and the receiver. (Silicon Laboratories)

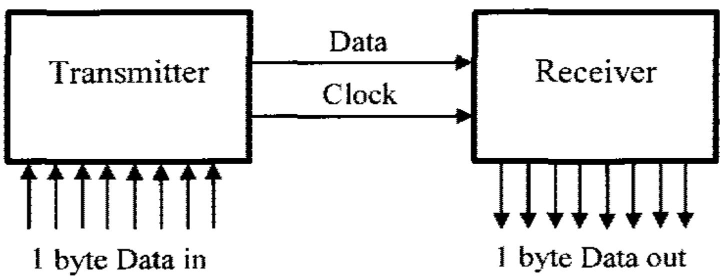


Figure 2.4: Example Synchronous Serial Communication

In the synchronous mode, the transmitter and receiver share a common clock signal. Figure 2.5 shows example signal out from transmitter to receiver. The transmitter typically provides the clock as a separate signal in addition to the serial data. (Silicon Laboratories)

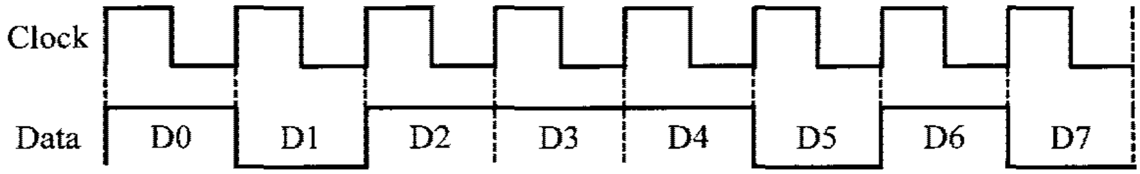


Figure 2.5: Example signal out from transmitter to receiver

2.4.3 Asynchronous Serial Communication

Serial communication implies sending data bit by bit over a single wire as shown in figure 2.6. Asynchronous transmission is easy to implement but less efficient as it requires an extra 2-3 control bits for every 8 data bits. Figure 2.7 shows example signal out from transmitter to receiver that contains extra bit. This method is usually used for low volume transmission. (Silicon Laboratories)

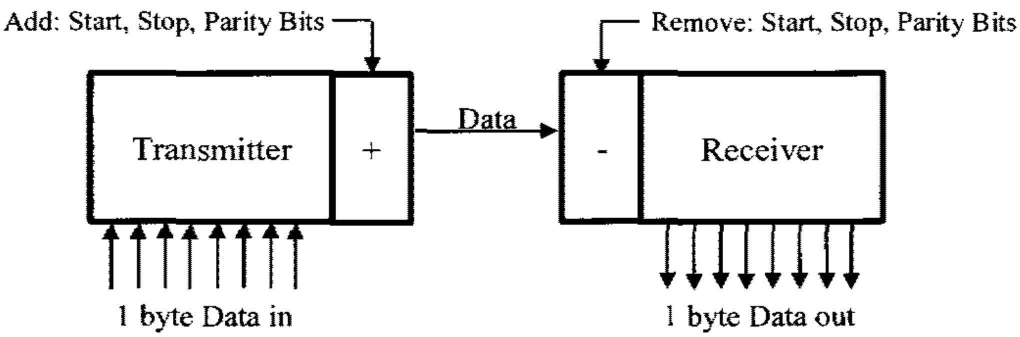


Figure 2.6: Example Asynchronous Serial Communication

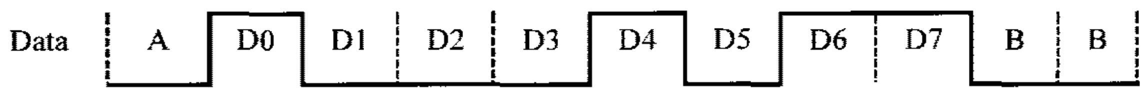


Figure 2.7: Example signal out from transmitter to receiver

A - Start bit, indicates the beginning of the data word.

B - Stop bit, indicates the end of the data word

D0-7 – 8 Data bit, indicates the actual data to be transmitted

2.5 Shift Register for Data Communications

2.5.1 Shift Register Serial In/Parallel Out

Shift register serial in/parallel out can be used as serial-to-parallel data converter. Serial data transmission from one digital system to another is commonly used to reduce the number of wires in the transmission line. For example, eight bits can be sent serially over one wire, but it takes eight wires to send the same data in parallel. Serial data transmission is widely used by peripherals to pass data back and forth to a computer. (Floyd)

2.5.2 Parallel-Access Shift Register

For shift register with parallel data inputs, the bits are entered simultaneously into their respective stages on parallel lines rather than on a bit by bit basis on one line as with serial data inputs. Once the data are stored, each bit appears on its respective output line, and all bits are available simultaneously. (Floyd)

2.6 Rotary to Linear Motion Conversion Concept

2.6.1 Crank Mechanism

Slider-crank mechanism (or a simple crank), shown in Figure 2.8, converts rotary to linear motion and vice versa, depending on its application.

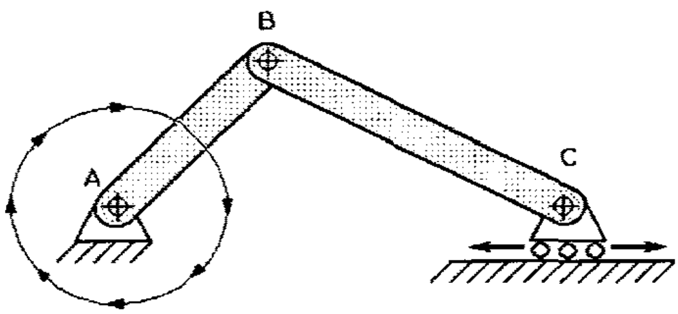


Figure 2.8: Slider-crank mechanism

Link AB is free to rotate 360° around the hinge while link BC oscillates back and forth because point C is hinged to a roller which restricts it to linear motion. Either the slider or the rotating link AB can be the driver. (Neil Sclater)

2.6.2 Scotch-Yoke Mechanism

Scotch-yoke mechanism, pictured in Figure 2.9, functions in a manner similar to that of the simple crank mechanism except that its linear output motion is sinusoidal.

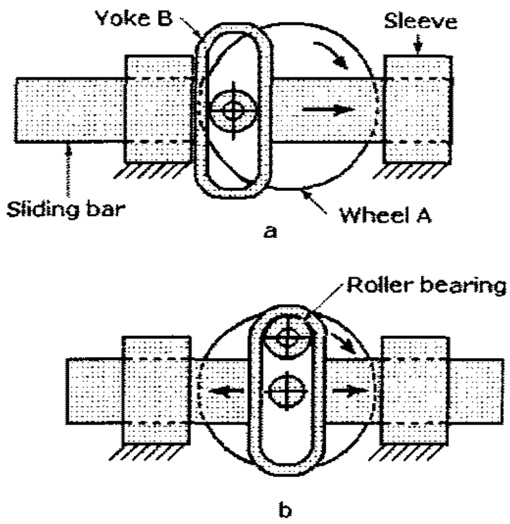


Figure 2.9: Scotch-yoke mechanism

As wheel A, the driver, rotates, the pin or roller bearing at its periphery exerts torque within the closed yoke B; this causes the attached sliding bar to reciprocate, tracing a sinusoidal waveform. Part A shows the sliding bar when the roller is at 270°, and Part B shows the sliding bar when the roller is at 0°. (Neil Sclater)

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will described about the procedures analysis on the serial data that being sending to motor driver to control the motor. Research methodology is a set of procedures or methods used to conduct research. Methodology is needed for a guideline in order to ensure the result is accurate based on objective. There are several steps need to be followed to ensure the objective of the research can be achieve starting from finding literatures until submitting the final report.

3.2 Flow Chart of Methodology

Flowchart is represents a process by showing the steps as box of various kinds, and their order by connecting with arrows. Flowchart is important in doing research by helping viewer to understand a process flow and help to visualize what is going on. Flow chart methodologies were constructed related to the scope of product as a guided principal to formulate this research successfully, in order to achieve the objectives of the project research. This is important to ensure the research experiment is on the right track. The terminology of work and planning for this research was shown in the flow chart in Figure 3.1.

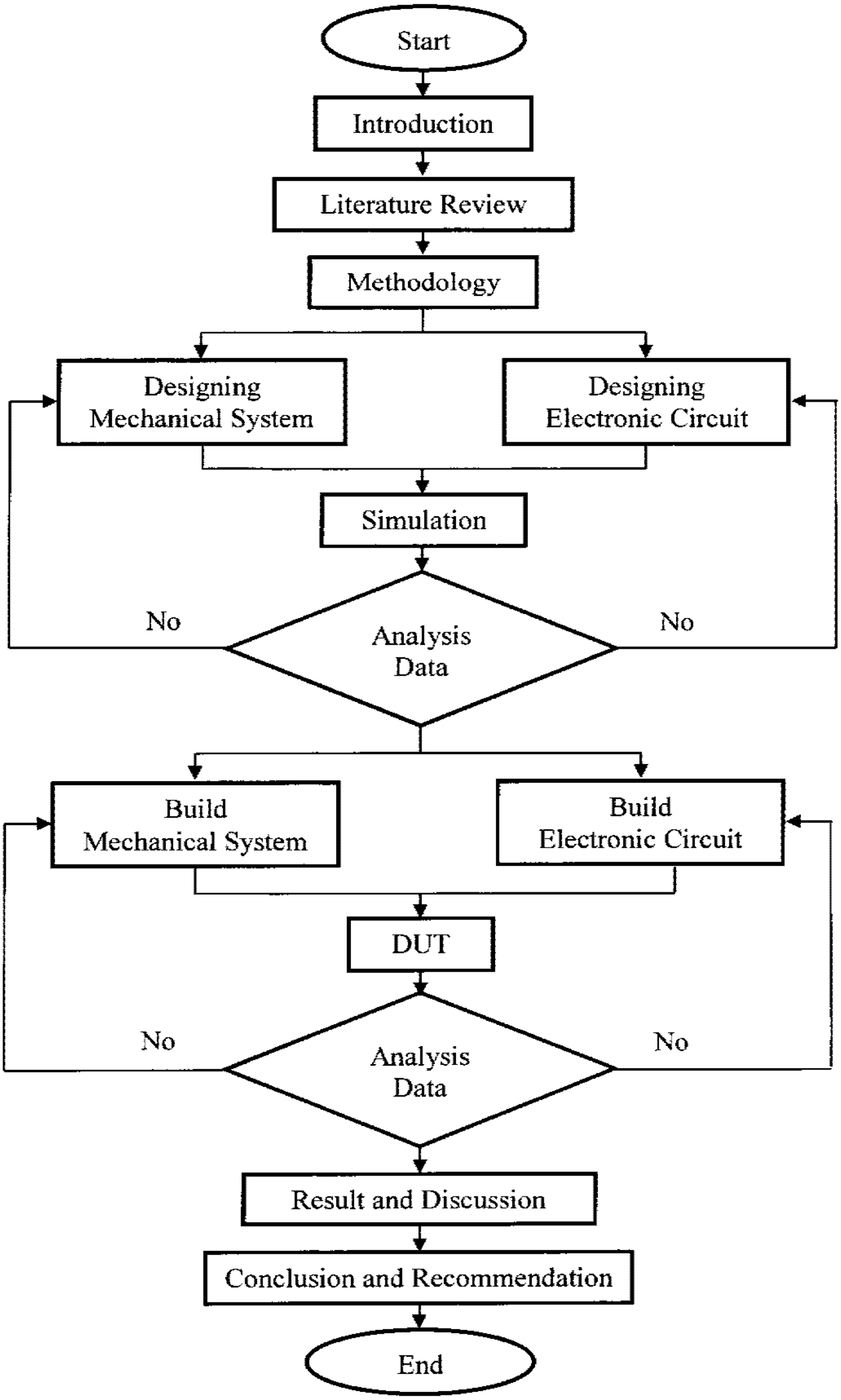


Figure 3.1: Project Flow Chart

3.3 Selection Communications Techniques.

Today, serial communication technology can be divided by 2, which are Synchronous and Asynchronous as shown in Figure 3.2 and Figure 3.4. This technology are still being apply for communicating with one or more peripheral devices over short or long distances. Both technologies just have different on timing coordination. Figure 3.3 and Figure 3.5 shows the different in signal transmitted to receiver on both technologies.

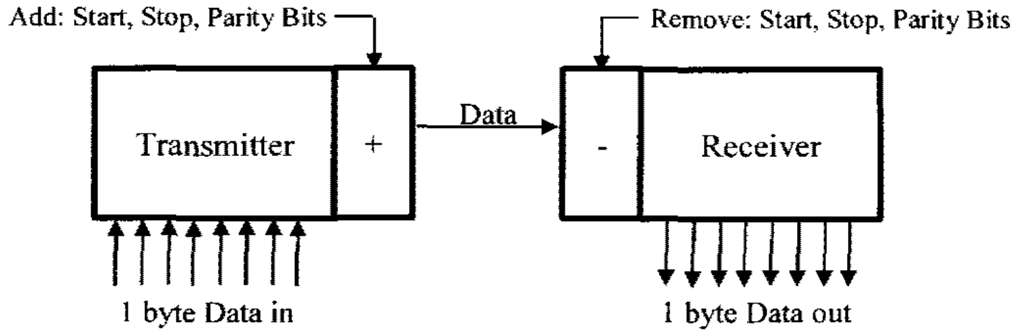


Figure 3.2: Example Asynchronous Serial Communication

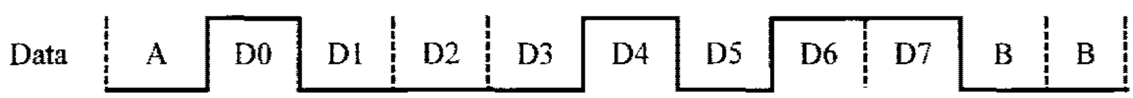


Figure 3.3: Example signal out from transmitter to receiver

A - Start bit, indicates the beginning of the data word.

B - Stop bit, indicates the end of the data word

D0 to D7 - 8 Data bit, indicates the actual data to be transmitted

Asynchronous communication utilizes a transmitter, a receiver and a wire without coordination about the timing of individual bits as shown in Figure 3.3. The receiving device has to look at the incoming signal and figure out what it is receiving and coordinate and retime its clock to match the incoming signal. UART is one example of Asynchronous communication.

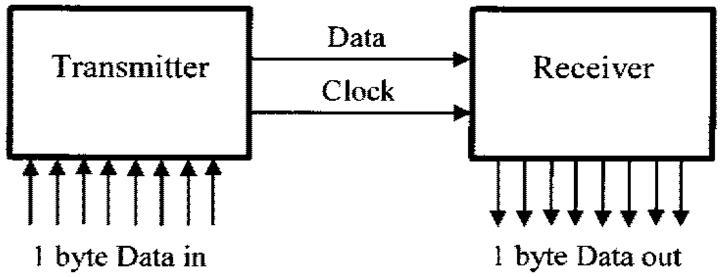


Figure 3.4: Example Synchronous Serial Communication

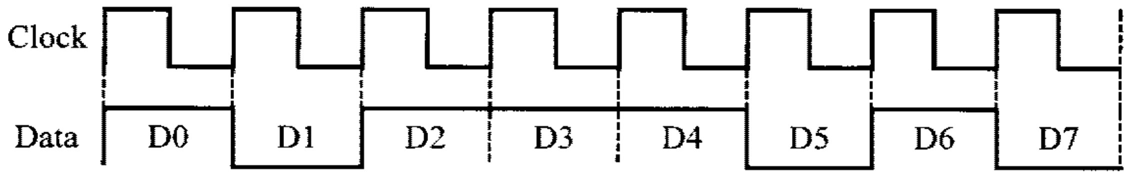
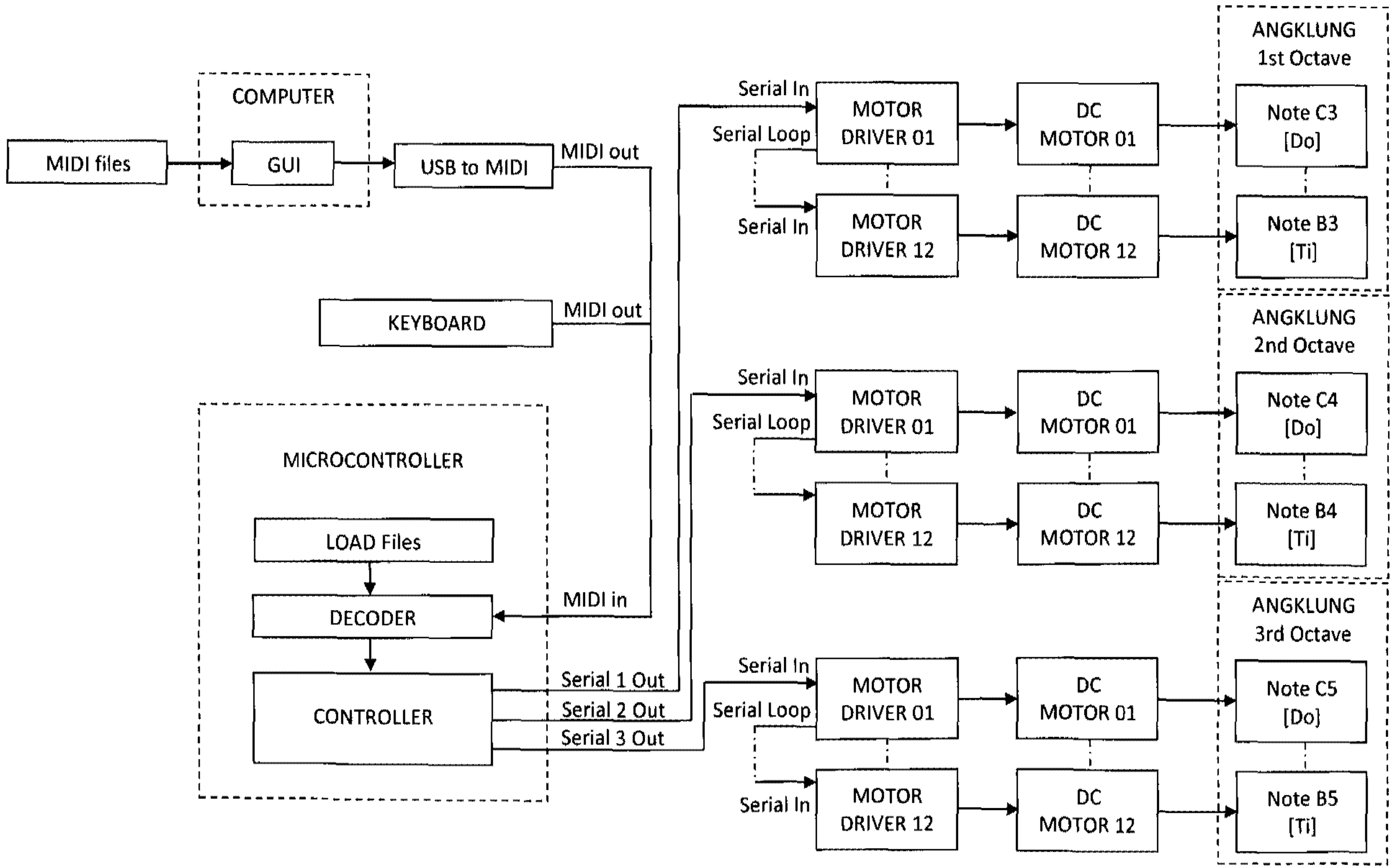


Figure 3.5: Example signal out from transmitter to receiver

Basic synchronous systems will synchronize the signal clocks on both sides before transmission begins as shown in Figure 3.5. Usually, there is a process to decide which end should be in control. Some transmitter send latch signal to end the serial data. This requires another wire connected to receiver. SPI is one example of Synchronous communication.

For this project synchronous serial communication is more practical. Motor driver those not require generating own clock to receive serial data. This will reduce component on motor drive and thus can reduce power consumptions.

3.4 Whole System Block Diagram



3.5 Signal Out From Controller

The Serial Peripheral Interface Bus or SPI bus is one of synchronous serial data link standard. Block diagram in Figure 3.6 shows the connection from controller to motor driver. Serial Peripheral Interface (SPI) is a synchronous serial data protocol used by microcontrollers for communicating with one or more peripheral devices quickly over short distances. With an SPI connection there is always one master device (microcontroller) which controls the peripheral devices (motor driver).

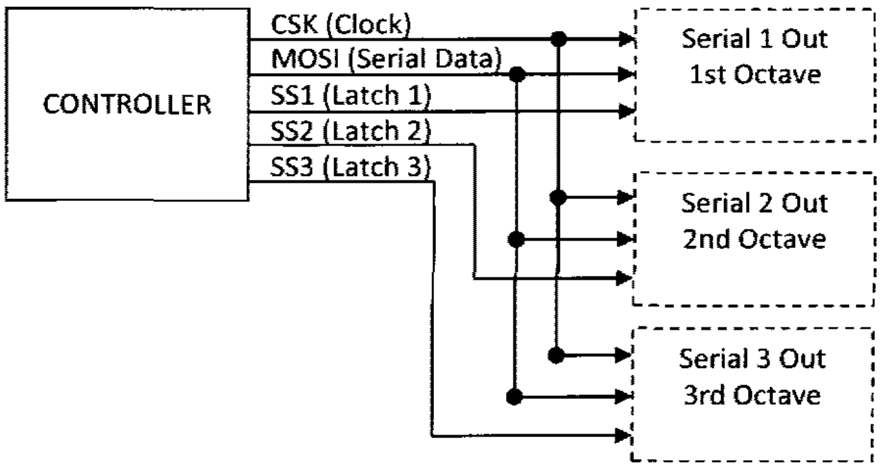


Figure 3.6: Signal out Diagram

Devices communicate using a master/slave protocol, in which the master starts the data frame. When the master generates a clock then selects a slave device, data may be transferred in either or both directions simultaneously. It is up to the master and slave devices to know whether a received byte is meaningful. This may require a device to discard the received byte in a "transmit only" frame or generate a dummy byte for a "receive only" frame. Typically there are three lines common to all the devices:

(i) **MISO** (**M**aster **I**n **S**lave **O**ut) - The Slave line for sending data to the master,

(ii) **MOSI** (**M**aster **O**ut **S**lave **I**n) - The Master line for sending data to the peripherals,

(iii) **SCK** (Serial Clock) - The clock pulses which synchronize data transmission generated by the master, In this project the motor driver does not sending feedback to the microcontroller. So MISO line is being disabling. Thus, MOSI and SCK line will provide Serial Data and Clock pulse for each set octave of angklung.

and one line specific for every device:

(iv) **SS** (Slave Select) - the pin on each device that the master can use to enable and disable specific devices.

All three SS line is needed to control each of octaves. This SS line will produce Latch signal for the motor driver. Figure 3.7 shows the 3 socket that being used to sending signal to motor driver. When a device's Slave Select pin is low, it communicates with the master. When it's high, it ignores the master. This allows each set octave of angklung sharing the same MOSI, and CLK lines.

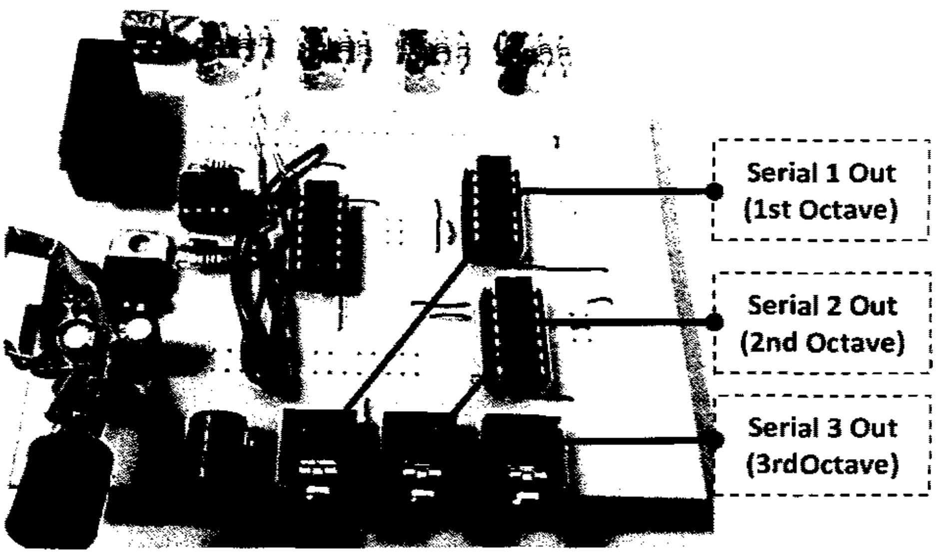


Figure 3.7: Actual Circuit on Microcontroller

In this project, audio jack connector is being used to transmit the signal controller from microcontroller to motor driver as shown in Figure 3.7. This audio connectors are available in three standard sizes, its 6.35 mm, 3.5 mm and 2.5 mm. The 3.5 mm audio jack with three conductor being choose because it easy to get in the market. Figure 3.8 shows the design of audio jack.

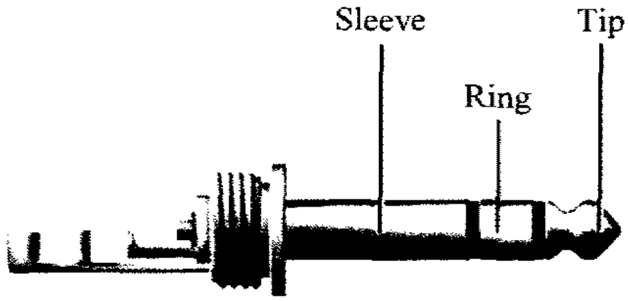


Figure 3.8: Design of Audio Jack (TRS)

Figure 3.7 shows a three-conductor TRS (Tip Ring Sleeve) audio connector. The upper connector is the tip will carry SCK signal. The ring used for transmit the MOSI signal and sleeve will carry SS signal.

3.6 The Bit Position in a Binary

Before the Serial Data being sending to motor driver, which order to shift out the bits will be used; either MSB or LSB. (Most Significant Bit First, or, Least Significant Bit First). This bit order is depending on how serial data will be decoded by motor driver. Figure 3.9 shows that MSB in an 8-bit binary number represents a value of 128 decimal and LSB represents a value of 1.

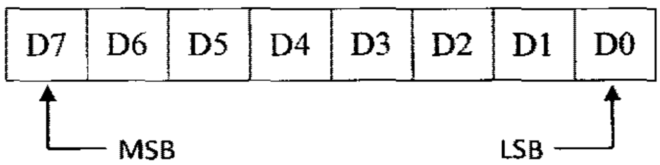


Figure 3.9: Example 1 byte 8 bit Serial Data

In this project, shift register will be used to convert the serial data to parallel and Least Significant Bit order being chooses. Figure below show the effect of MSB and LSB on output of shift register.

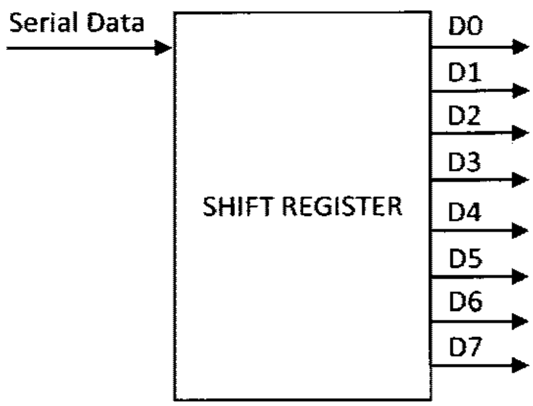


Figure 3.10: LSB Effect

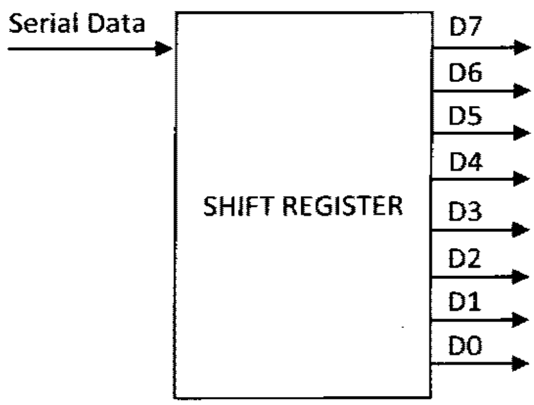
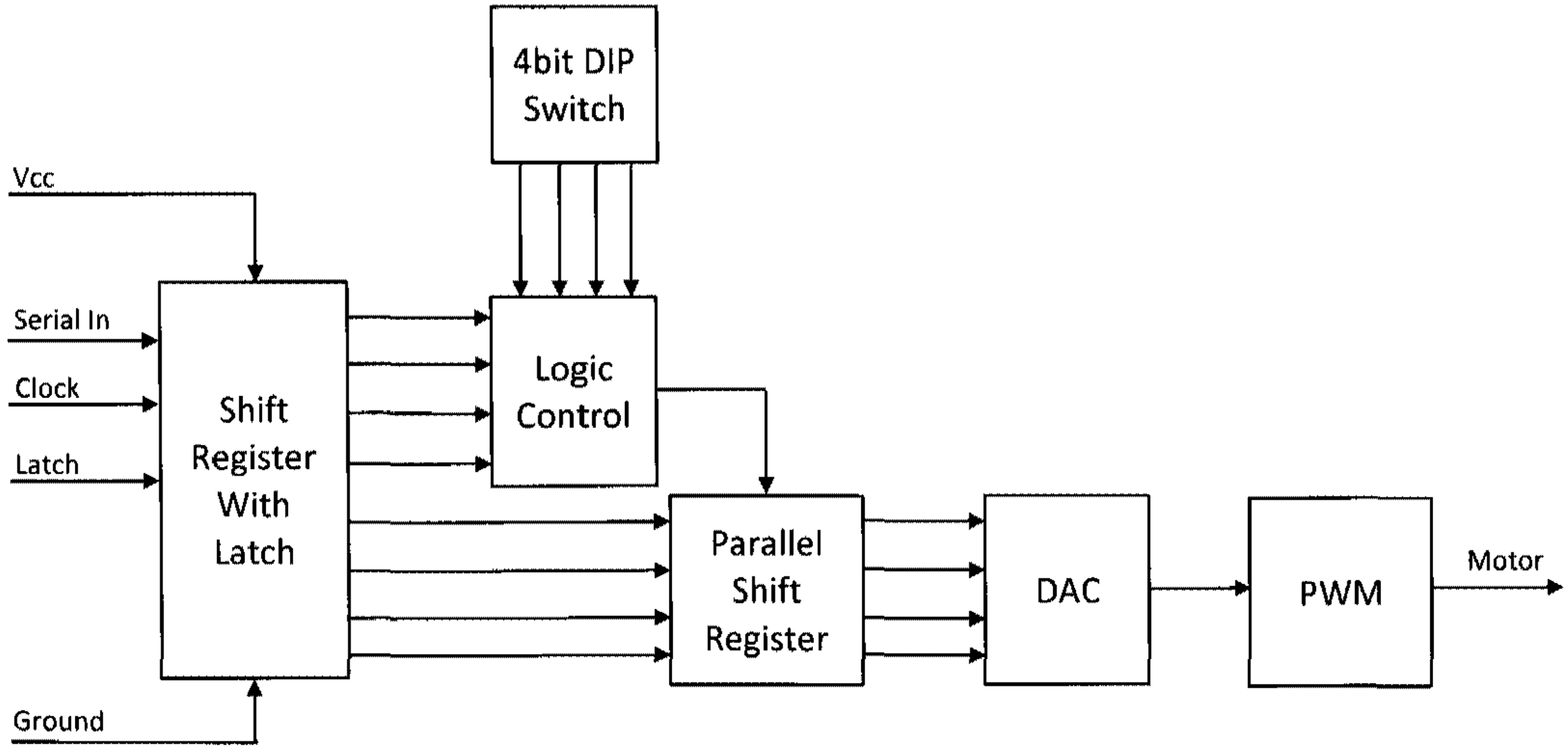


Figure 3.11: MSB Effect

3.7 Motor Driver Block Diagram



3.8 Fundamentals of Motor Driver

The Signal input to motor driver consist of 3 parts, Serial Data, Clock Pulse and Latch signal. The serial data signal transmission from microcontroller contained 8 bits in each byte. This byte can be categorize by two main classes as shown in Figure 3.12.

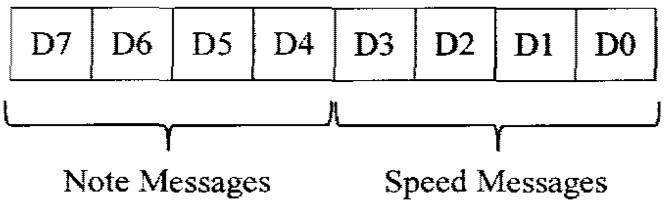


Figure 3.12: Example Serial Data signal

3.8.1 Note Messages

This note messages is consist of 4 bit and can be arrange to 16 combinations as shown in Table 3.1. This messages use to control which motor want to be trigger.

Table 3.1: Note Messages

BINARY	DECIMAL	MEANING
0000	0	Null
0001	1	Note 1 - C (Do)
0010	2	Note 2 - C#
0011	3	Note 3 - D (Re)
0100	4	Note 4 - D#
0101	5	Note 5 - E (Mi)
0110	6	Note 6 - F (Fa)
0111	7	Note 7 - F#
1000	8	Note 8 - G (So)
1001	9	Note 9 - G#
1010	10	Note 10 - A (La)
1011	11	Note 11 - A#
1100	12	Note 12 - B (Ti)
1101	13	Null
1110	14	Null
1111	15	Null

3.8.2 Speed Messages

This channel messages is same like note messages consist of 4 bit and can be arrange to 16 combinations as shown in Table 3.2. This messages use to control the speed of motor that have being trigger by channel message.

Table 3.2: Speed Messages

BINARY	DECIMAL	MEANING
0000	0	Motor Off
0001	1	Motor Run at Speed 1 (Lowers Speed)
0010	2	Motor Run at Speed 2
0011	3	Motor Run at Speed 3
0100	4	Motor Run at Speed 4
0101	5	Motor Run at Speed 5
0110	6	Motor Run at Speed 6
0111	7	Motor Run at Speed 7
1000	8	Motor Run at Speed 8
1001	9	Motor Run at Speed 9
1010	10	Motor Run at Speed 10
1011	11	Motor Run at Speed 11
1100	12	Motor Run at Speed 12
1101	13	Motor Run at Speed 13
1110	14	Motor Run at Speed 14
1111	15	Motor Run at Speed 15 (Highest Speed)

Meanwhile, if we want to control note D for first octave that have being attach to note 3 with Speed 5. The Serial Data byte that will be sending from microcontroller to motor driver is 00110101. And because serial data bit being set in MSB, Serial Data will be 10101100.

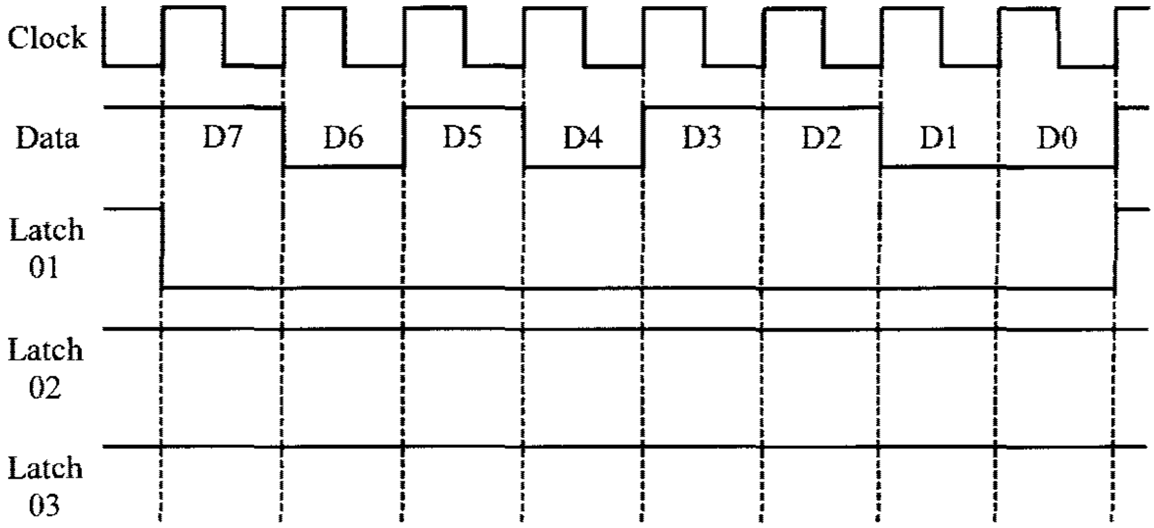
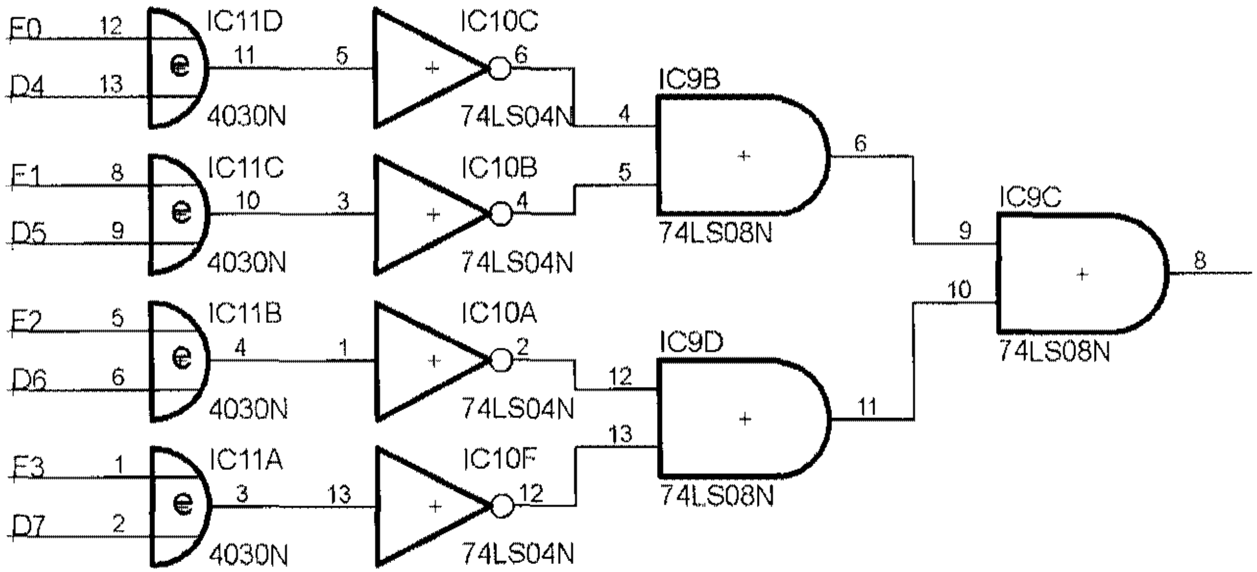


Figure 3.13: Example signal out from microcontroller

3.9 Logic Control Circuit



$$output = (\overline{F0D4} + F0D4)(\overline{F1D5} + F1D5)(\overline{F2D6} + F2D6)(\overline{F3D7} + F3D7)$$

Logic circuit being construct by following this 5 rule.

(i) Data F0 is equal to D4

Table 3.3: Rule 1

Input		Output	Product Term
F0	D4	X	
0	0	1	$\overline{F0D4}$
0	1	0	
1	0	0	
1	1	1	$F0\,D4$

$$POS = (\overline{F0D4}) + (F0\ D4)$$

(ii) Data F1 is equal to D5

Table 3.4: Rule 2

Input		Output	Product Term
F1	D5	X	
0	0	1	$\overline{F0D4}$
0	1	0	
1	0	0	
1	1	1	$F0\,D4$

$$POS = (\overline{F1D5}) + (F1\ D5)$$

(iii) Data F2 is equal to D6

Table 3.5: Rule 3

Input		Output	Product Term
F2	D6	X	
0	0	1	$\overline{F0D4}$
0	1	0	
1	0	0	
1	1	1	$F0\,D4$

$$POS = (\overline{F2D6}) + (F1\ D6)$$

(iv) Data F3 is equal to D7

Table 3.6: Rule 4

Input		Output	Product Term
F3	D7	X	
0	0	1	$\overline{F0D4}$
0	1	0	
1	0	0	
1	1	1	$F0\,D4$

$$POS = (\overline{F3D7}) + (F3\,D7)$$

(v) If all above rules is true, send output HIGH otherwise send LOW

So,

$$output = (\overline{F0D4} + F0D4)(\overline{F1D5} + F1D5)(\overline{F2D6} + F2D6)(\overline{F3D7} + F3D7)$$

Input								Output
F0	F1	F2	F3	D4	D5	D6	D7	X
0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	1	0	0
0	0	0	0	0	0	1	1	0
0	0	0	0	0	1	0	0	0
0	0	0	0	0	1	0	1	0
0	0	0	0	0	1	1	0	0
0	0	0	0	0	1	1	1	0
0	0	0	0	1	0	0	0	0
0	0	0	0	1	0	0	1	0
0	0	0	0	1	0	1	0	0
0	0	0	0	1	0	1	1	0
0	0	0	0	1	1	0	0	0
0	0	0	0	1	1	0	1	0
0	0	0	0	1	1	1	0	0
0	0	0	0	1	1	1	1	0
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3.10 Design of Vibrator Mechanism

Conventional crankshaft/scotch yoke mechanisms have been used for many years to convert linear motion into rotary motion and vice versa. Figure 3.14 shows the exploded view of the vibrator mechanism that was used to vibrate the angklung.

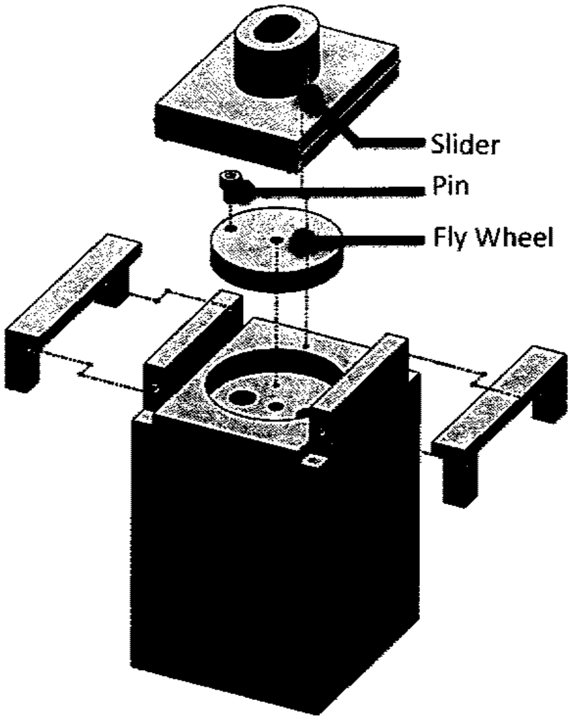

Figure 3.14: Exploded View

Figure 3.15 shows the cross section view that will be used to show how the vibrator works.

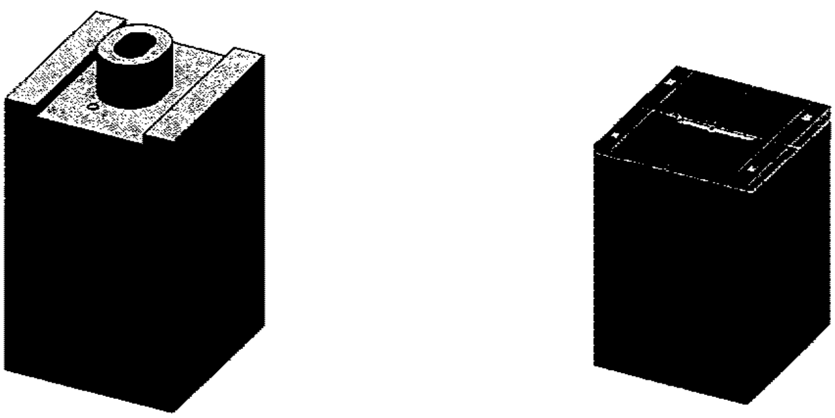

Figure 3.15: Cross Section View

Figure 3.16 shows cross section view inside the vibrator. In such mechanisms, the reciprocating rotary movement of the fly wheel causes the linear movement of the slider by causing a pin-mounted to fly wheel to move back and forth along a slot formed in slider.

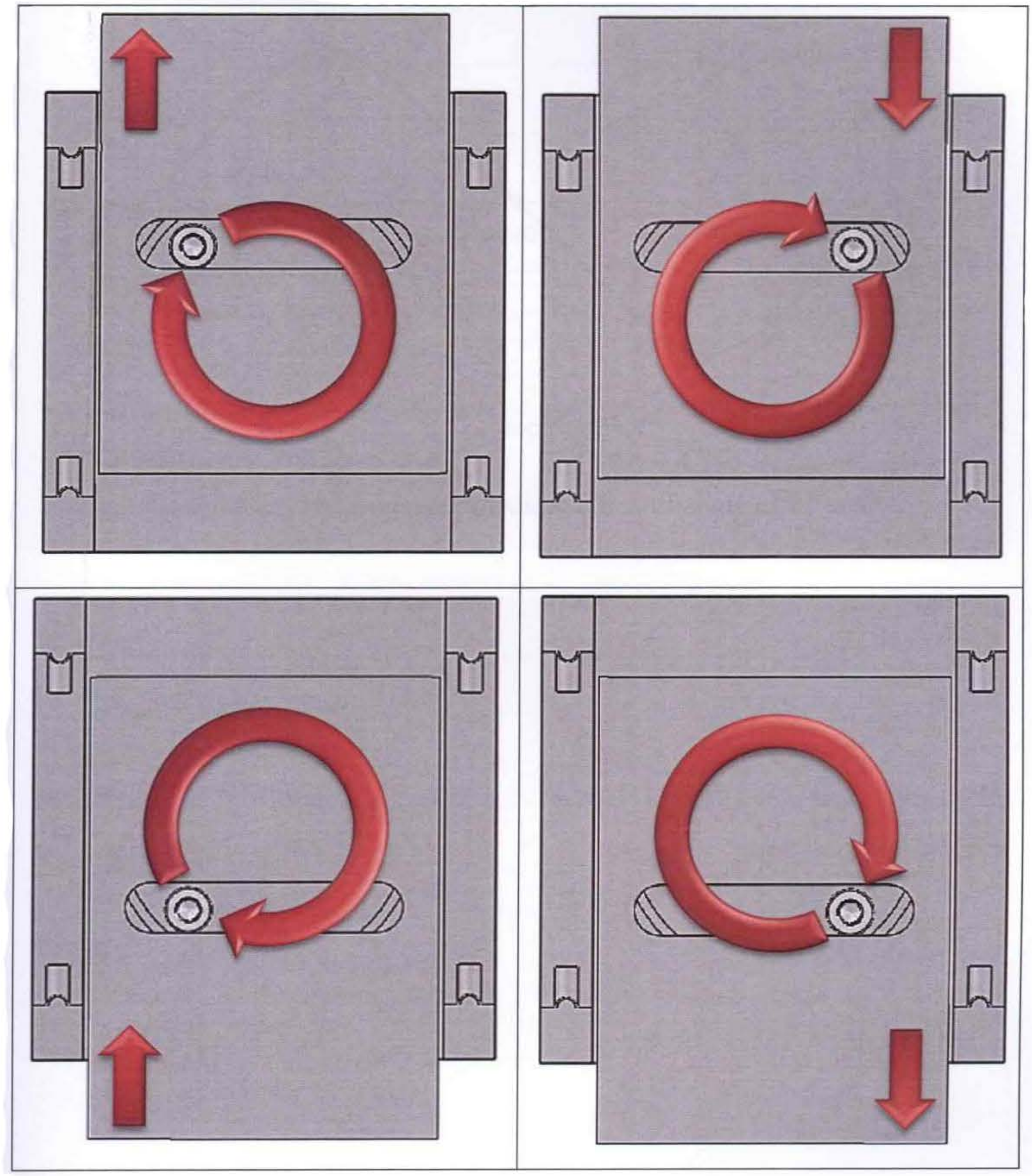

Figure 3.16: 4 step of Fly Wheel movement.

Under ideal engineering conditions, force is applied directly in the line of travel of the assembly and cause the sinusoidal motion. Figure 3.17 shows that the mechanism will work as vibrator.

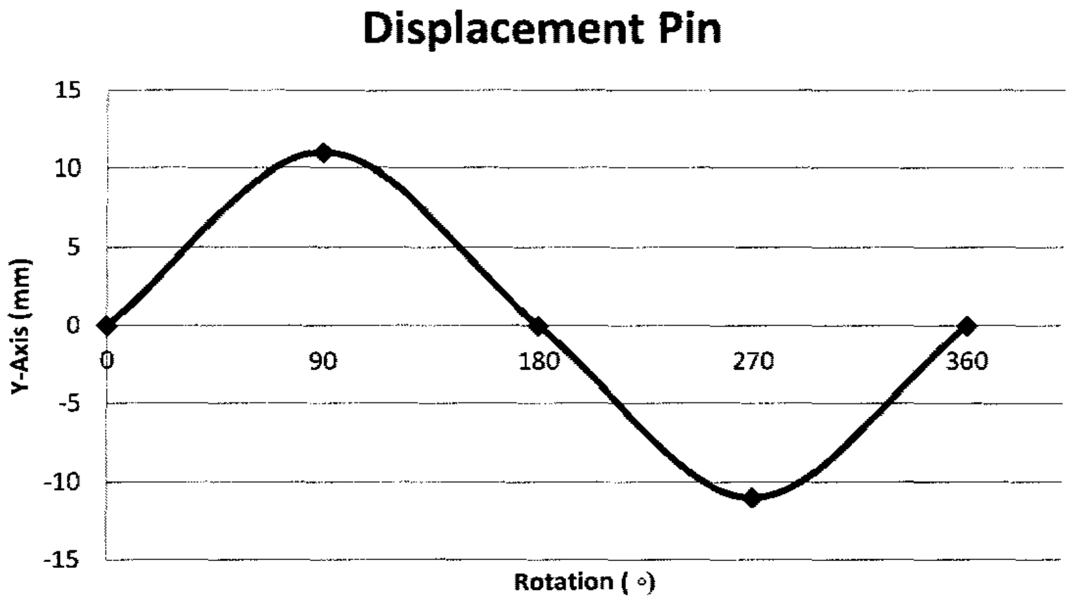

Figure 3.17: Displacement of slider effect of angle of fly wheel.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

The chapter will discuss every experiment on the methodology or the flow of work is come out with the result and analysis. The result of this project will include the signals that have being handled by motor drive to drive the motor. This chapter will discuss mainly about the problems encountered during the whole project was been carried out.

4.2 Results Simulation

Before the actual circuit being construct. The simulation of the circuit must be make. These will proof that circuit will work. The software that being chosen to run the simulation is OrCADPSpice because they have all component that we want to use in the library.

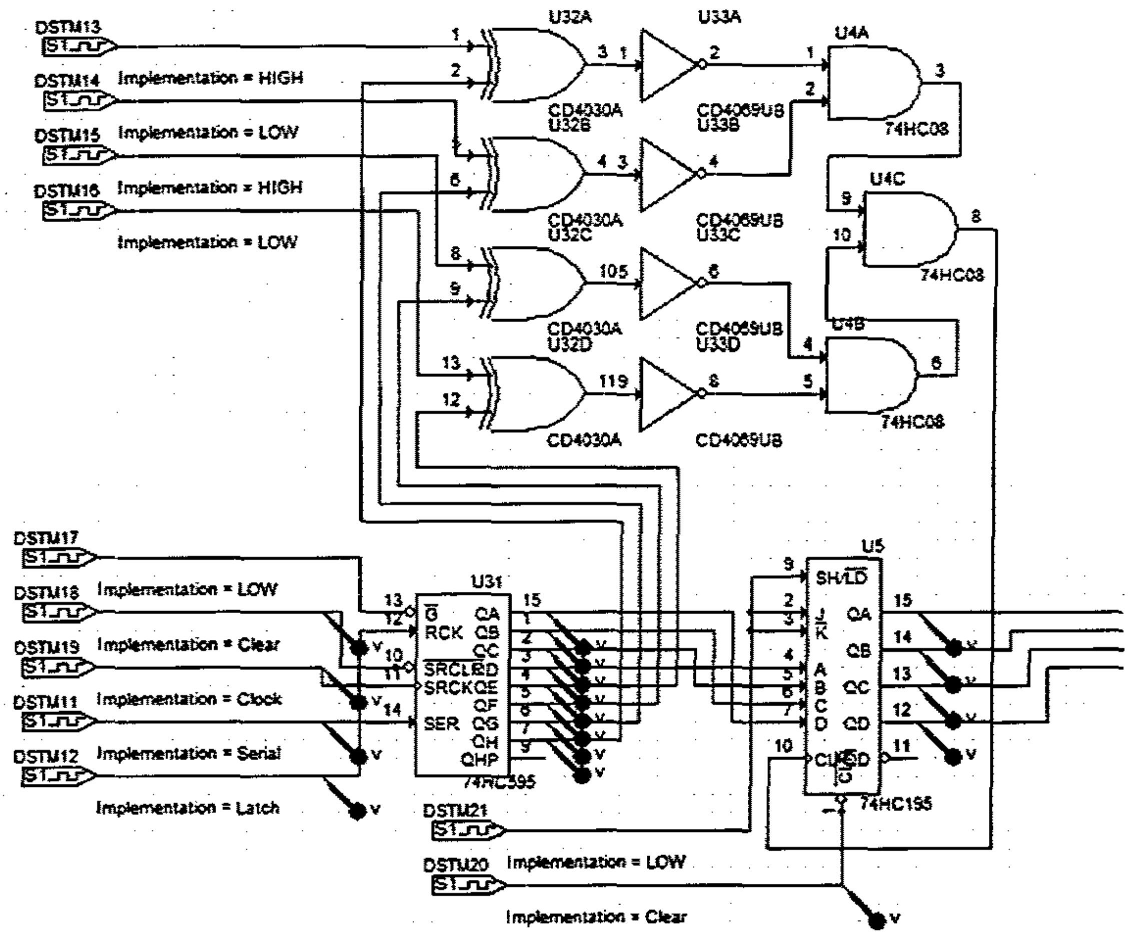

Figure 4.1: Motor Driver Circuit

From the result of simulation as shown in Figure 4.2, we see that 8 bit in 1 byte of data Serial In is 10101001. This byte is being complete registered in after 8 cycle clock pulses. At 9th clock pulse, Latch signal being trigger and all 8 bit data that have being stored being send out.

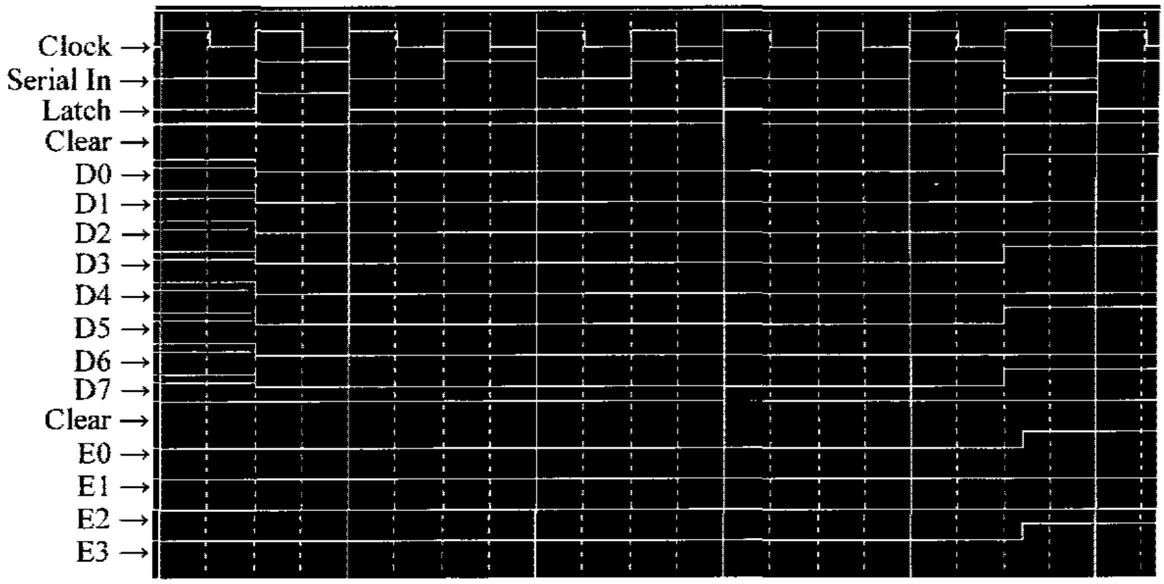

Figure 4.2: Motor Driver Circuit Sample Signal

This show on data D0 to D7, because effect of shift register, the data first come in will be at D7 and the last come will be at D0. The data from D7 to D4 will be compare to DIP switch before data from D3 to D0 being used to control the DC motor. The comparing done by using logic control circuit and because the DIP switch being set to 1010 and it same with output D7 to D4 (1010), so logic control produce the HIGH signal that will be send to parallel to parallel shift register. This parallel to parallel shift register use to store the output D3 to D0.

4.2.1 Propagation Delay Times

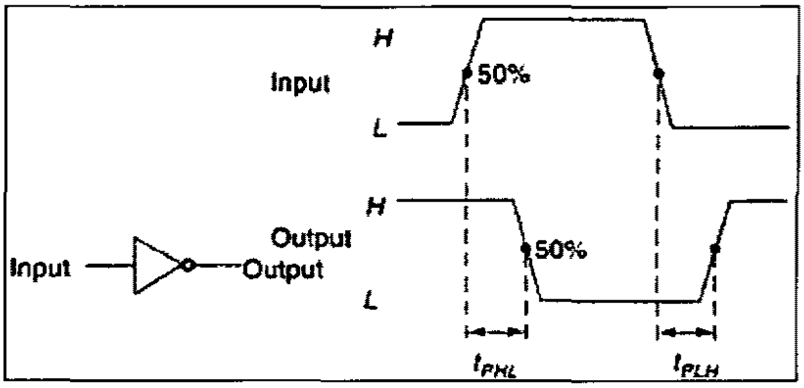

Figure 4.3: Example Propagation Delay Times

From logic circuit diagram, there have 6 IC is used to construct the circuit follow the rule that have been discussed before. Every component has their own propagation delay times. So total logic circuit propagation delay times is:

$$\sum t = t_{CD4030} + t_{CD4069} + t_{74HC08} + t_{74HC08}$$

$$\sum t = 150ns + 60ns + 25ns + 25ns$$

$$\sum t = 0.26\mu s$$

4.2.2 Clock Rate

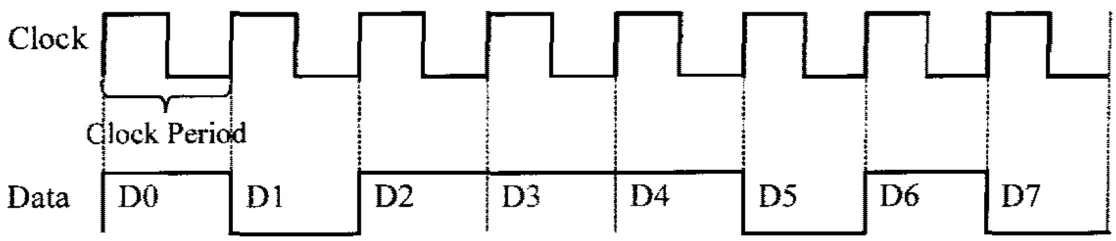

Figure 4.4: Clock Period

In this simulation, clock period being setting to 1μs. So the frequency for clock pulse is about:

$$f = \frac{1}{(Clock\ Period)}$$

$$f = \frac{1}{1\mu s}$$

$$f = 1MHz$$

4.2.3 Data Rate

Time for 1 bit is 1μs. So, speed for 1 bit will be;

$$Speed_{1\ bit} = \frac{1bit}{1\mu s}$$

$$Speed_{1\ bit} = 1 \times 10^{6} bits/second$$

$$SSpeed_{1\ bit} = 1Mbps$$

Because 1 byte contained 8 bits, So, speed for 1 bytes is;

$$Speed_{1\ byte} = 1M\frac{bits}{s} \times \frac{1\ byte}{8\ bits}$$

$$Speed_{1\ byte} = 125 \times 10^{3}\ bytes\ per\ second$$

$$Speed_{1\ byte} = 125\ kBps$$

How fast this system works.

$$Speed = 125\ kBps$$

Or

1 byte for 8μs

Is this fast enough?

The fast tempo musicians play is 220bpm (beats per minutes)

$$Speed = 220\ \frac{beats}{minutes} \times \frac{1\ minute}{60\ second}$$

$$Speed = \frac{11}{3}\ bps$$

That is speed for 1 beat is 3/11 second

$$T = \frac{3}{11}s = 0.27s = 270ms$$

From this result, speed of data rate is good enough to control the angklung.

4.3 Results Actual Circuit

Motor driver being construct base on circuit that has done simulated before (Refer figure 4.1). In this analysis, arduino microcontroller will be used to generate the serial data signal base on format protocol (Refer Chapter 3) that contain note and speed message. Because of that, basic program on the arduino must be construct.

4.3.1 Programing in Arduino

In this project, we using Arduino Due model as microcontroller. This device has capability to use SPI communication standard. To enable this features, this program must be write:

```
#include <SPI.h>
```

And this program must be write to setup SPI function.

```
void setup()
{
  SPI.begin(10);
  SPI.begin(4);
  SPI.begin(52);
  SPI.setDataMode(10,SPI_MODE0);
  SPI.setDataMode(4,SPI_MODE0);
  SPI.setDataMode(52,SPI_MODE0);
  SPI.setBitOrder(10,MSBFIRST);
  SPI.setBitOrder(4,MSBFIRST);
  SPI.setBitOrder(52,MSBFIRST);
  SPI.setClockDivider(10,84);
  SPI.setClockDivider(4,84);
  SPI.setClockDivider(52,84)
}
```

SPI.begin(slaveSelectPin)

Initializes the SPI bus by setting SCK and MOSI to outputs, pulling SCK and MOSI low. The extended API can use pins 4, 10, and 52 for *slaveSelectPin*.

SPI.setDataMode(slaveSelectPin, mode)

Sets the SPI data mode: that is, clock polarity and phase.

SPI.setBitOrder(slaveSelectPin, order)

Sets the order of the bits shifted out of and into the SPI bus, either LSBFIRST (least-significant bit first) or MSBFIRST (most-significant bit first).

SPI.setClockDivider(slaveSelectPin, divider)

Sets the SPI clock divider relative to the system clock. On the Due, the system clock can be divided by values from 1 to 255. The default value is 21, which sets the clock to 4 MHz (84MHz divided by 21) like other Arduino boards.

To make the programing easy to loop, these programs being write as:

```
void write_serial_1(byte value)
{
  SPI.transfer(10, value);
}
```

For analysis, arduino will sending note message 1001 and speed message 0110. After delaying about 1 second, speed message changes to 0001. These programs being write as:

```
void loop()
{
  write_serial_1(B10010110);
  write_serial_1(B00000000);
  delay(1000);
  write_serial_1(B10010001);
  write_serial_1(B00000000);
  delay(1000);
}
```

Figure 4.5 shows the actual circuit that being connected to arduino and position of the component inside motor driver.

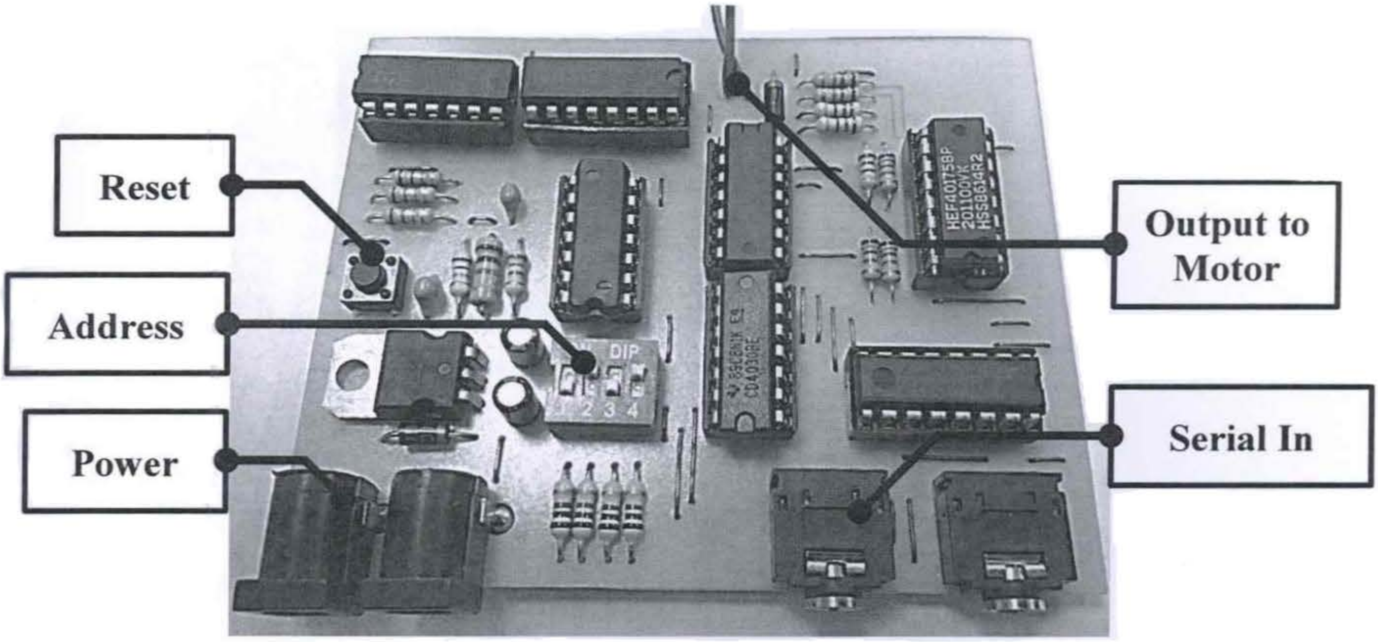

Figure 4.5: Actual Circuit Motor Driver

After programing done sending to arduino, output signal was observed. At the beginning, DIP switch is being setup at LOW, LOW, LOW and LOW (0000) as shown in Figure 4.6.

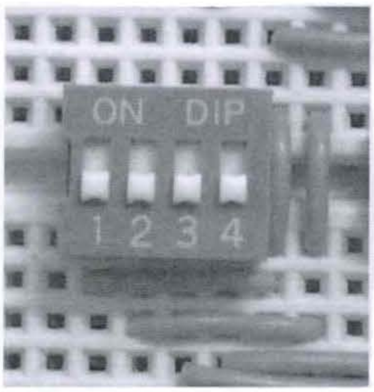

Figure 4.6: DIP set to 0000

Because the serial signal contained message 10010110, 00000000 and 10010001. So output that comes out is shown in Figure 4.7:

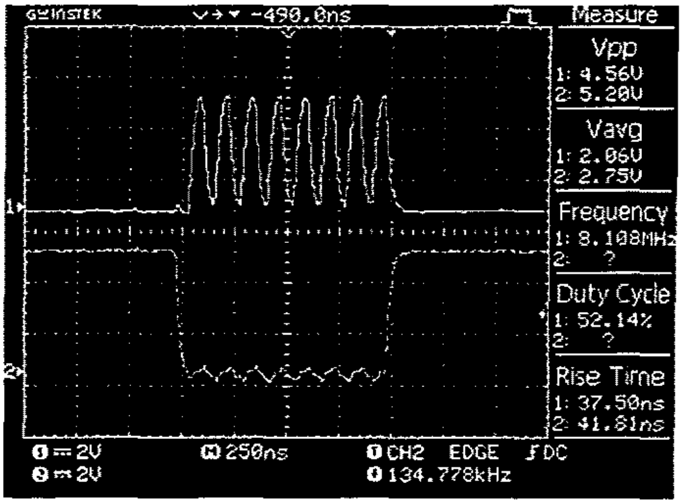

Figure 4.7: Output comes up as 00000000

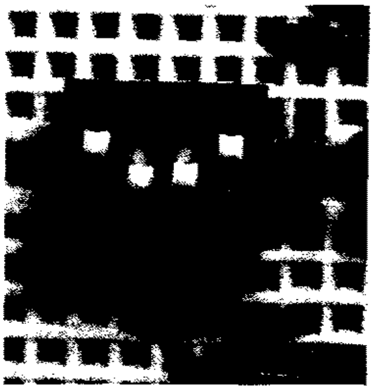

Figure 4.8: DIP set to 1001

After DIP switch being change to HIGH, LOW, LOW and HIGH (1001) as shown in Figure 4.8. So output that comes out is shown in Figure 4.9.

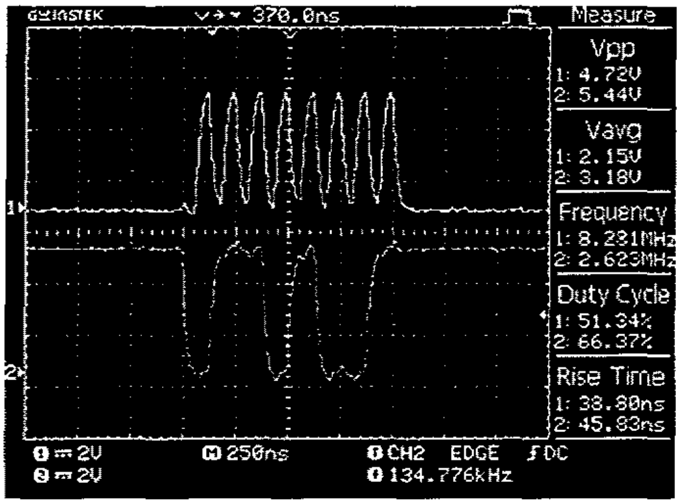

Figure 4.9: Output comes up as 10010110

After 1 second, output change to:

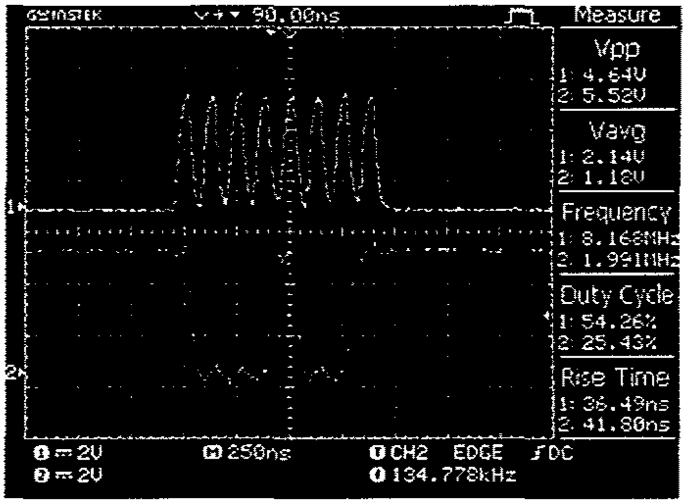

Figure 4.10: Output comes up as 10010001

These speed message keep changing between 0110 and 0001 with delay in 1000 micro second (1 second). When the DIP switch being setup or change to LOW, LOW, LOW and HIGH (0001). Because the SPI signal being setup as (most-significant bit first), the output is inverted in position and become 01101001 and 10001001.

4.3.2 Clock Rate 1MHz

Figure 4.11: Clock Pulse with 1MHz frequency

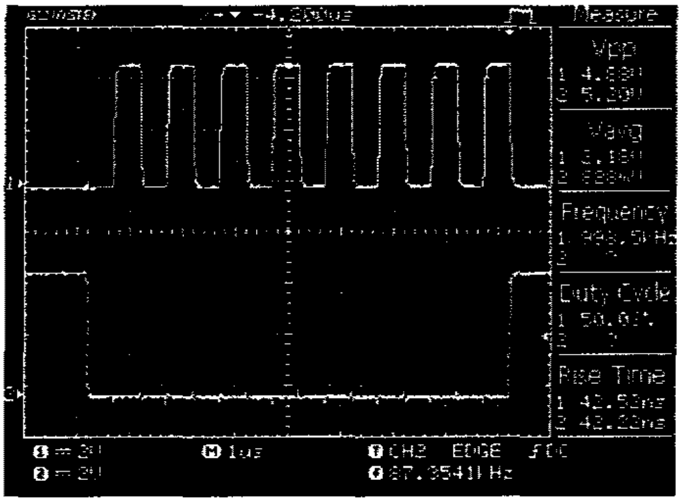

Figure 4.12: Clock Pulse and Serial Out (00000000)

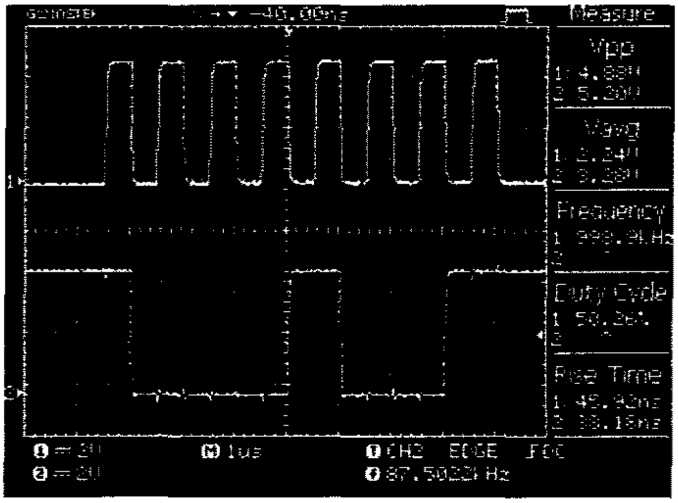

Figure 4.13: Clock Pulse and Serial Out (10010001)

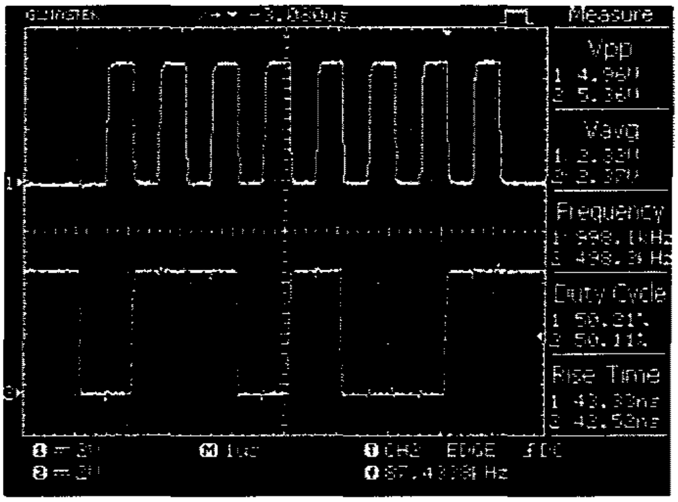

Figure 4.14: Clock Pulse and Serial Out (10010110)

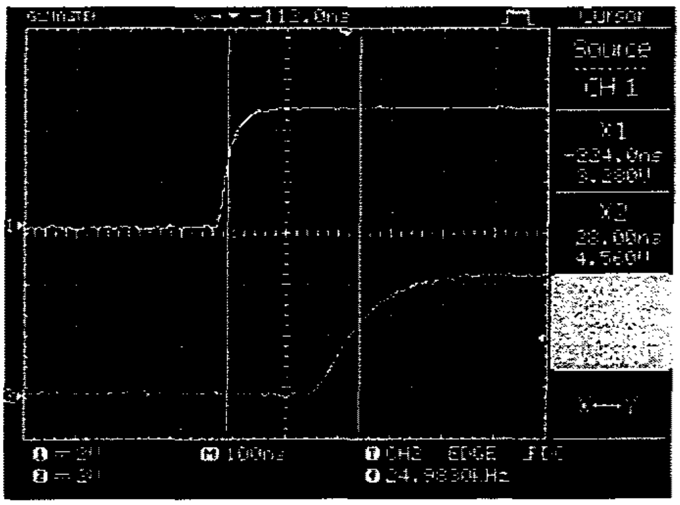

Figure 4.15: Delay when transition between motor off to motor on (252.0ns)

Figure 4.16: Delay when transition between motor off to motor on (192.0ns)

4.4 Discussions

In the audio world, "latency" is another word for "delay". It's the time it takes for midi into the device, for the decoded the midi, for the motor drive to shake the angklung, and for the sound to reach your ear.

$$\sum Latency = Latency_{Microcontroller} + Latency_{Motor\ Driver}$$

Our brain is wired so that it doesn't notice if sounds are delayed 3 to 10 milliseconds (ms). Latency in Motor Driver after receive SPI signal is 252.0 ns. The latency for whole system must not exceed 3ms to make the system fast enough to decode the midi signal from music instrument and play the angklung music instrument in real time processing.

$$\sum Latency \leq 3ms$$

$$3ms = Latency_{Microcontroller} + 252\ ns$$

$$Latency_{Microcontroller} = 3ms - 252ns$$

$$Latency_{Microcontroller} = 2.999\ ms$$

So, to archive the latency below 3 ms, latency encode midi signal inside Microcontroller must below than 2.999 ms.

$$Latency_{Microcontroller} \leq 2.999\ ms$$

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This final chapter represents about conclusion and recommendation for the project. In this chapter will discuss mainly about the conclusion of the project, concluding all the process that involved. Besides that this chapter also contains recommendation about the project. So for this recommendation it can make further improvement for future reference.

5.2 Conclusion

From results and discussions on chapter 4 before this, we can conclude that motor driver will work very well for single motor driver. The SPI standard shows that it can send the data to motor driver follow the protocol that has being agreed upon before. Latency inside motor driver has being ensured that it doesn't notice by human ears. The mechanism to vibrate or shaken the angklung has being simulated and work very well.

5.3 Future Development

For future improvement, it is suggested to minimize the motor driver that use to receive SPI signal control from microcontroller. With this minimization, it can reduce space, power consumption and latency inside the motor driver. Redesign construction on mechanism to shaken the angklung by using less moving part. This will reduce noise inside mechanism system when it operates.

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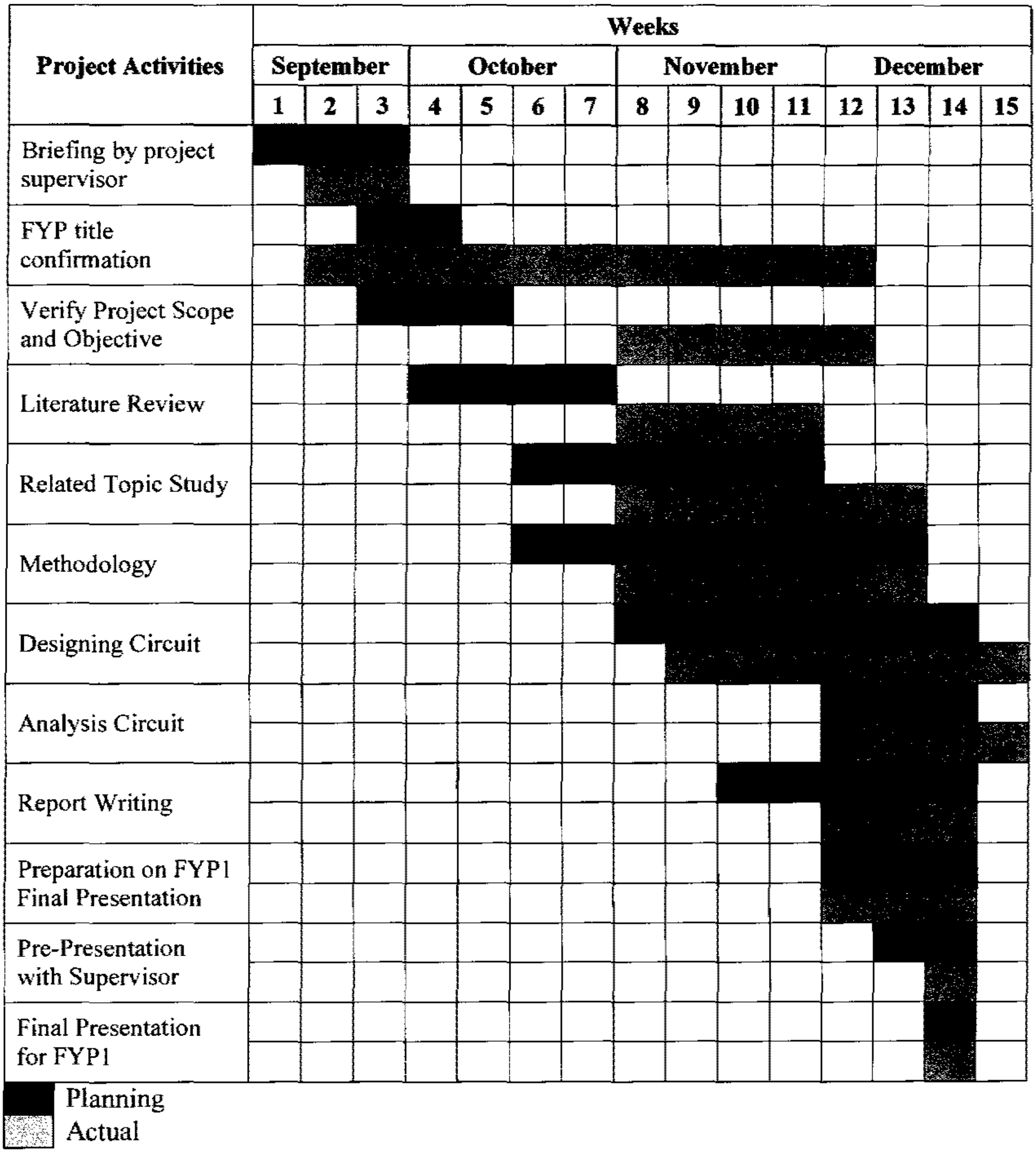
APPENDIX A

Gantt Chart of the Project (Semester 01)



APPENDIX B

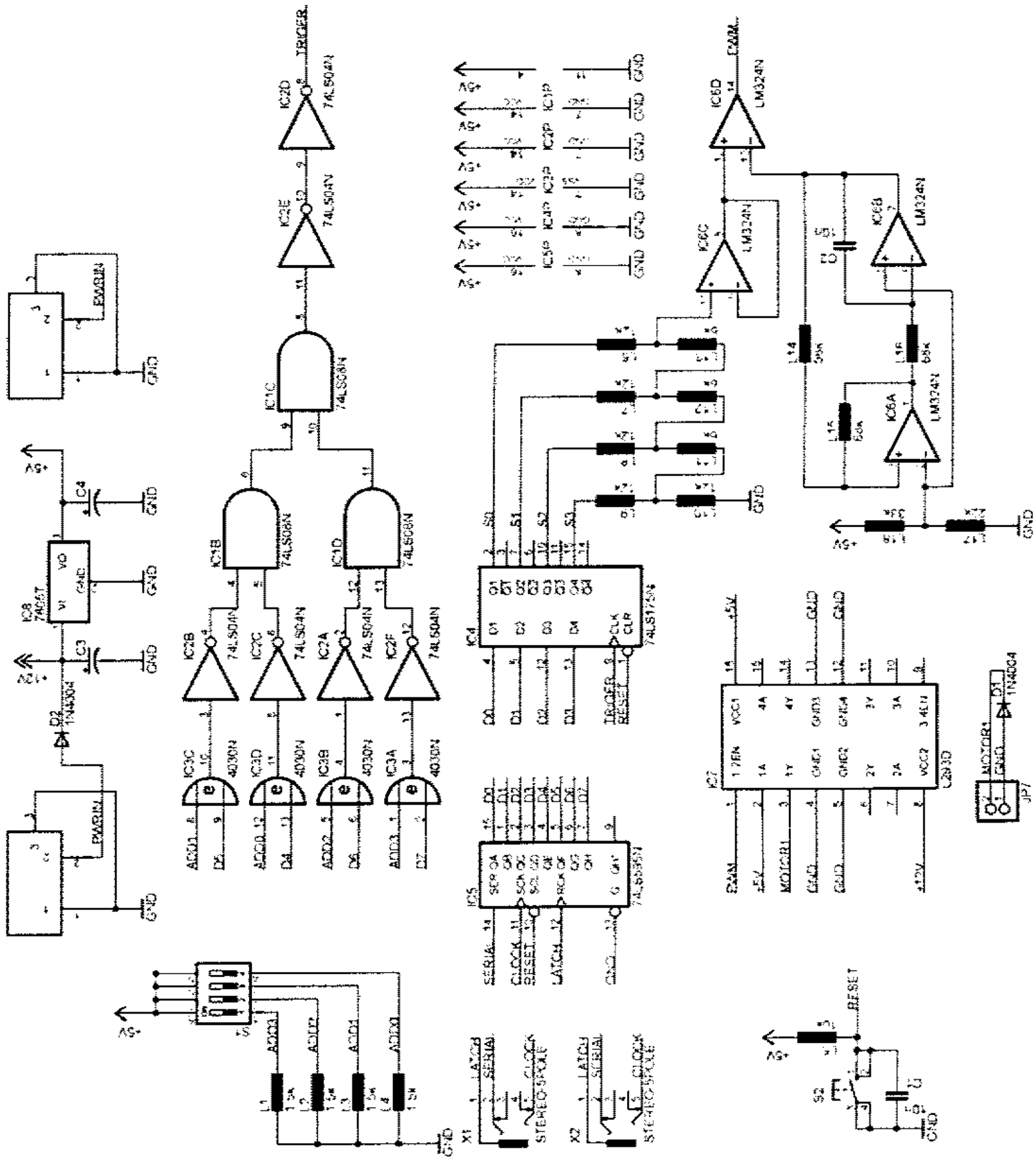
Gantt Chart of the Project (Semester 02)

Project Activities	Weeks															
	Feb.		Mach				April				Mei				June	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Briefing by project supervisor	■	■	■	■	■	■										
			▒	▒	▒	▒										
Literature Review (finalize study)	■	■	■	■	■	■										
	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒						
Methodology (Testing)						■	■	■								
						▒	▒	▒	▒	▒	▒					
Prepare for project proposal									■	■	■	■	■	■		
									▒	▒	▒	▒	▒	▒		
Methodology (design experiment setup)									■	■	■					
										▒						
Result and Discussions											■	■	■			
											▒	▒	▒			
Prepare for Final Presentation PSM 2													■	■		
													▒	▒		
Final Presentation PSM 2															■	
															▒	▒
Report for PSM 2 and log book																■
																▒

■ Planning
▒ Actual

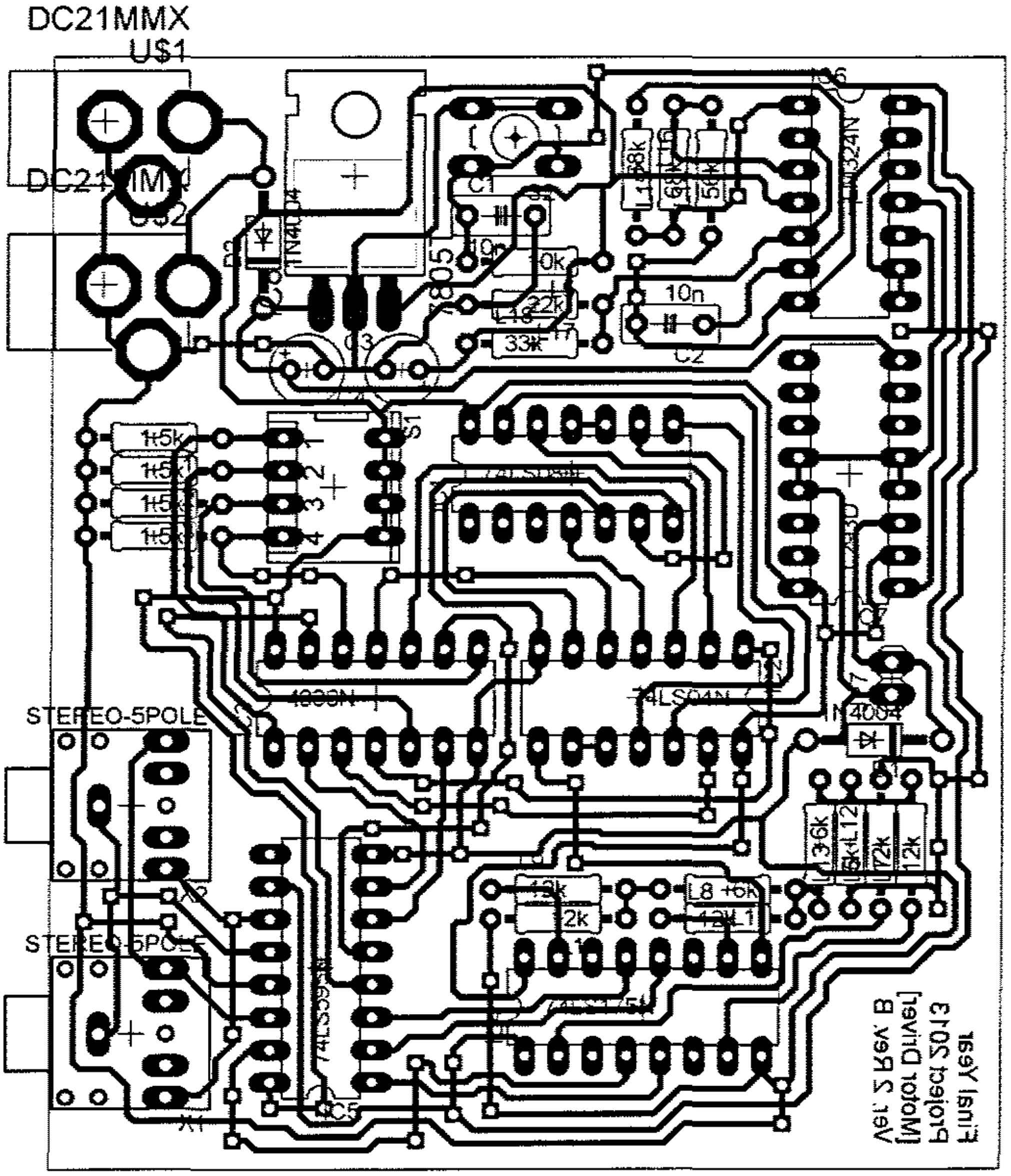
APPENDIX C

Schematic Drawing for Motor Driver



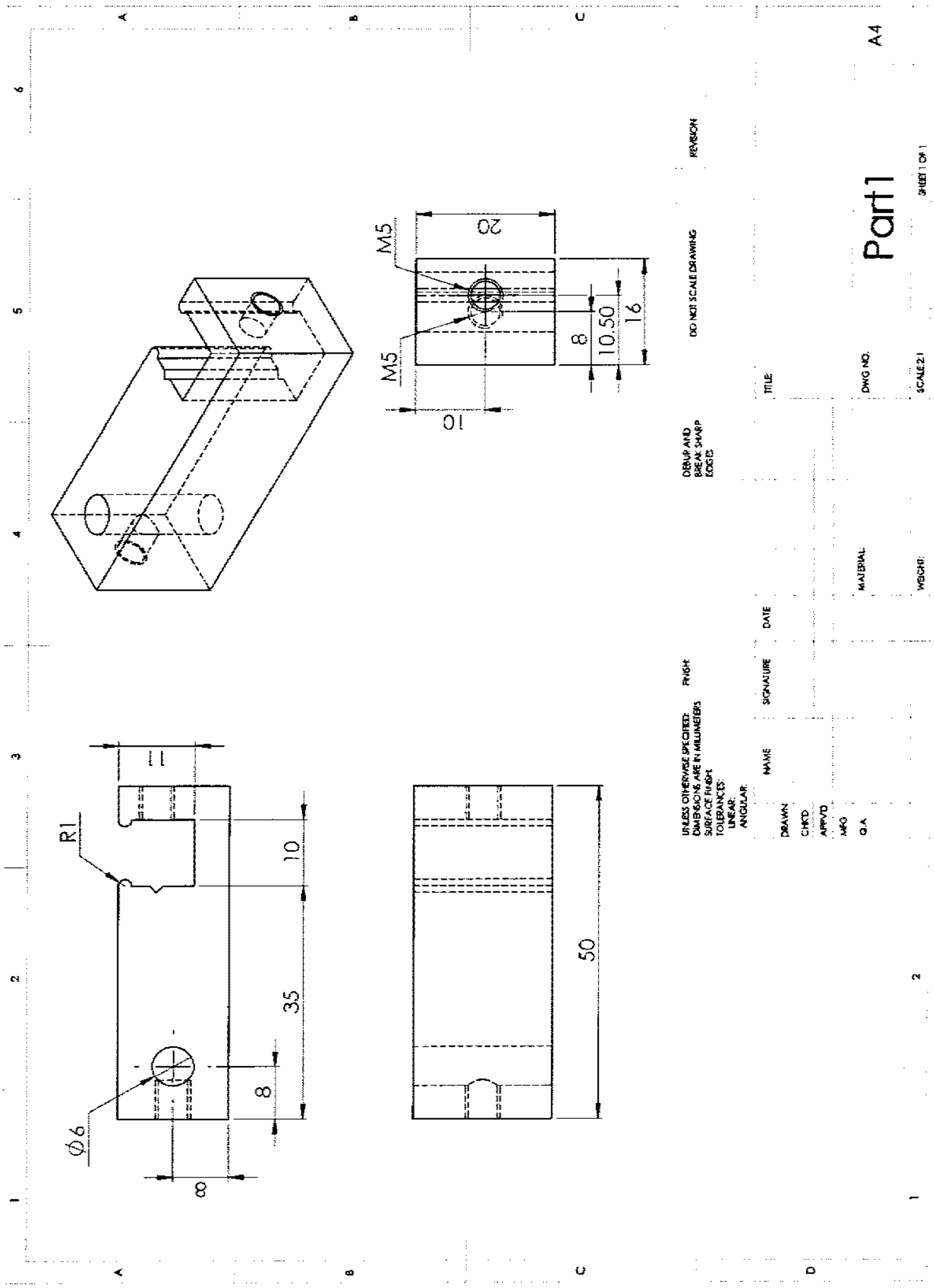
APPENDIX D

PCB Drawing for Motor Driver



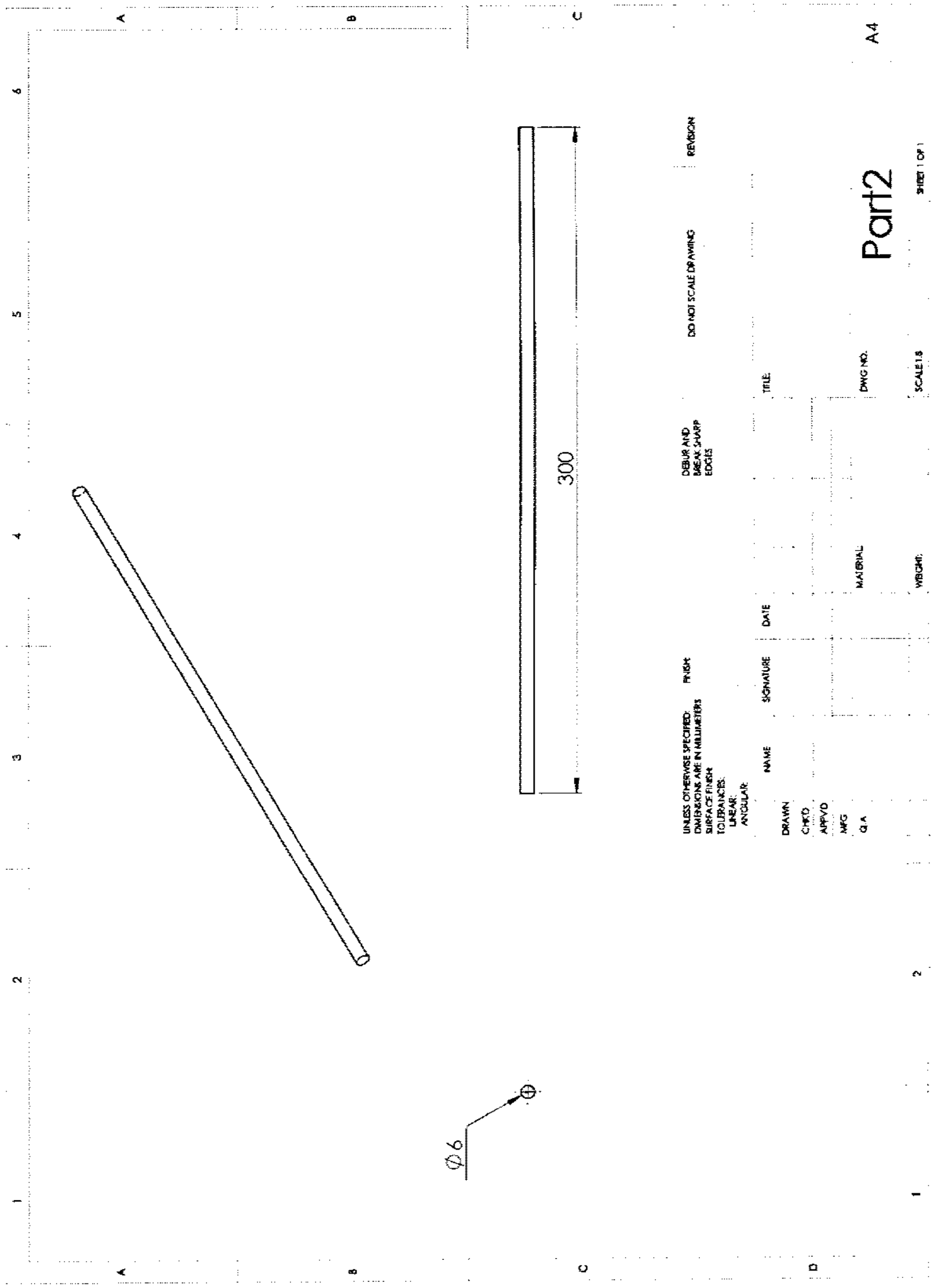
APPENDIX E

Part 01



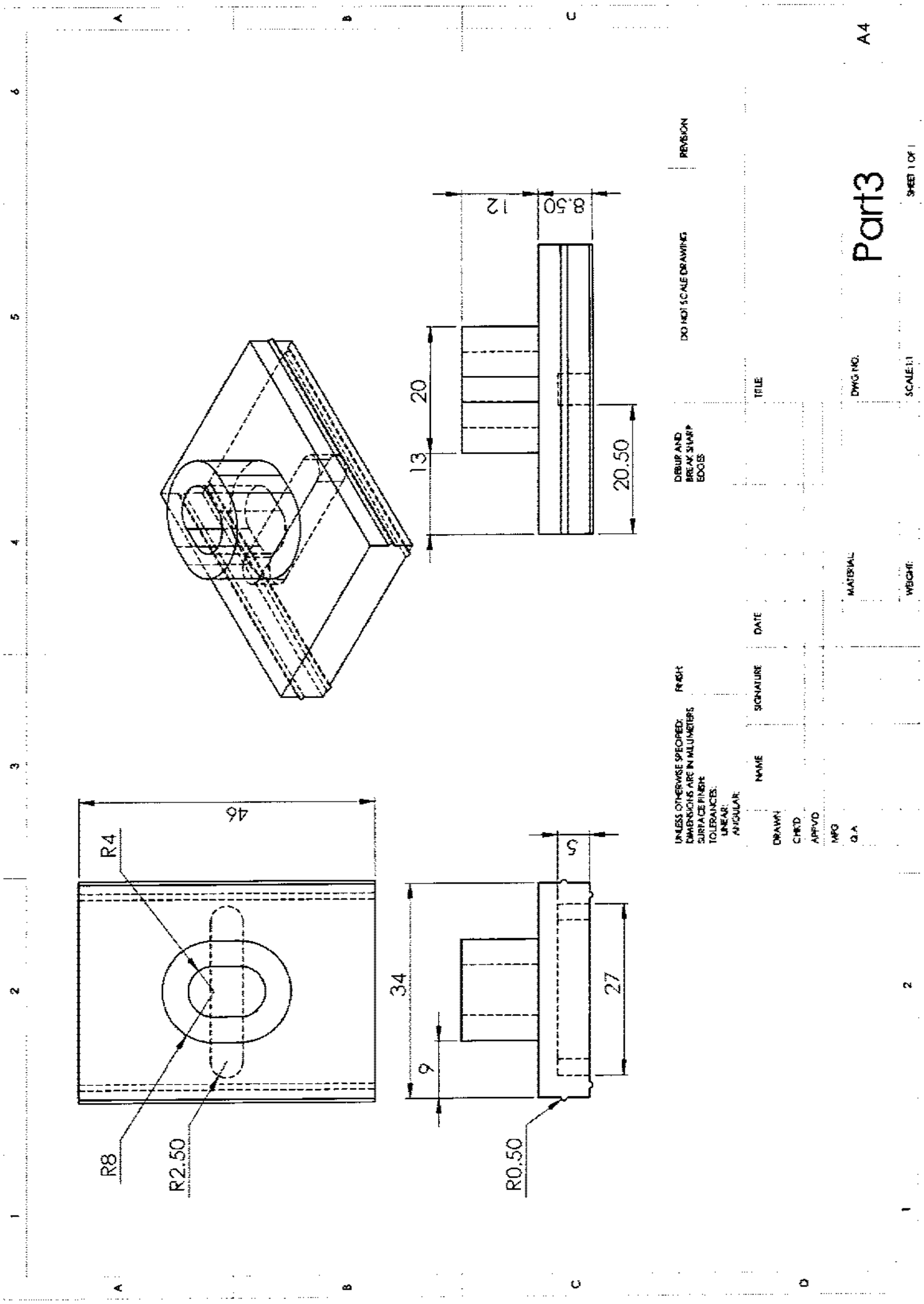
APPENDIX F

Part 02

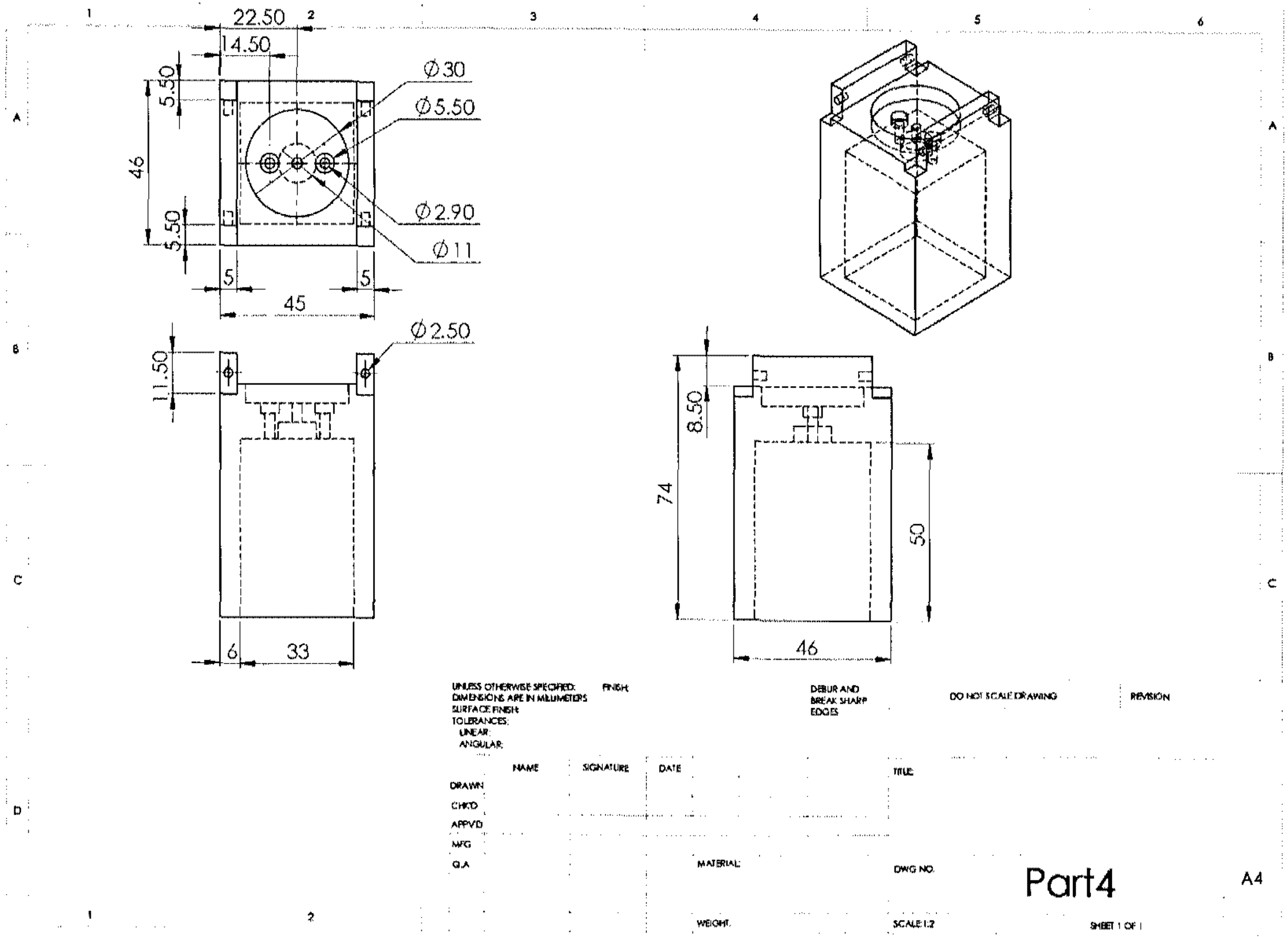


APPENDIX G

Part 03

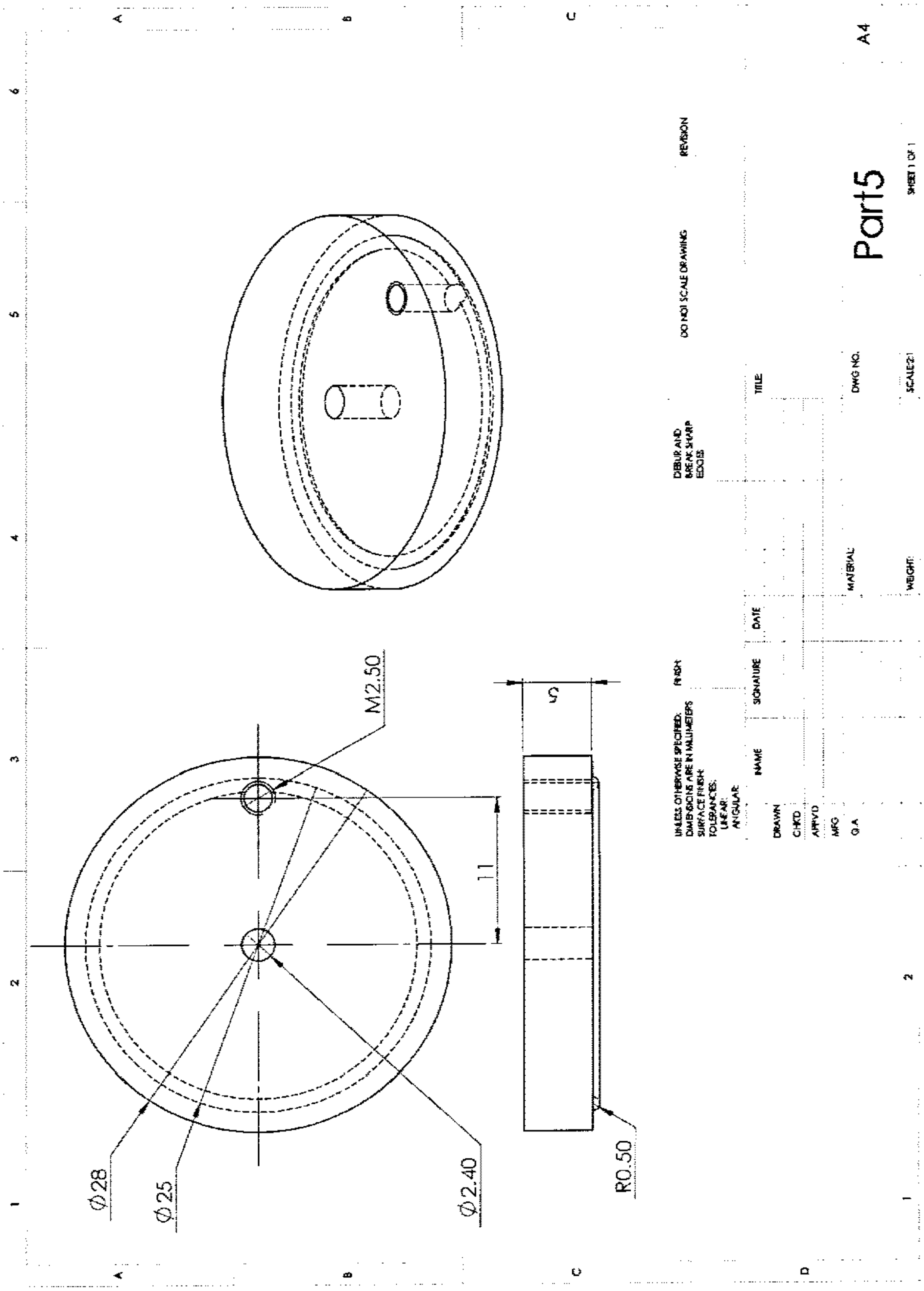


APPENDIX H
Part 04



APPENDIX I

Part 05



APPENDIX J

Part 06