MECHANICAL AND ELECTRICAL SUPPORT FOR MIDI AUTO SAXOPHONE

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ABSTRACT

Saxophone is most commonly associated with jazz and classical music. As the sound waves are produced by an oscillating reed, the saxophone is categorized as woodwind instruments. Different pitches from the saxophone are produced by opening and closing keys. In order for a person to play the saxophone seamlessly, he or she need to have good respiratory control and fingering skills. Although fingering skills is much easier to be acquired compared to the respiratory control, but it still need a plenty of training and practices. As for the respiratory control, a saxophonist will have to control the volume and speed of the exhale air in order to produce a desired tone. In order to achieve that, the person should have good breath control and large lungs capacity. As conclusion from above, it is hard to develop a good saxophonist among us. The MIDI Auto Saxophone is a platform intended to be the replacement for the saxophonist for instance when a saxophonist is needed immediately. MIDI Auto Saxophone is one of the project that build autonomous device that play musical instrument by means of conversion of the MIDI message file into digital signal and then being sent to air pressure control system and fingering system. This project is then intended to develop the mechanical and electrical support for the MIDI Auto Saxophone.

ABSTRAK

Saksofon adalah alat muzik yang sering dikaitkan dengan jazz dan muzik klasik. Oleh kerana bunyi yang terhasil dihasilkan oleh getaran buluh, saksofon dikategorikan sebagai instrumen woodwind. Perbezaan nada daripada saksofon dihasilkan membuka dan menutup kekunci. Perkara yang paling penting bagi seseorang untuk bermain saksofon dengan lancer, dia perlu mempunyai kawalan pernafasan yang baik dan kemahiran pengawalan jari. Walaupun kemahiran pengawalan jari adalah lebih mudah untuk diperolehi berbanding dengan kawalan pernafasan, tetapi ia masih memerlukan banyak latihan. Bagi kawalan pernafasan, pemain saksofon perlu mengawal kuantiti dan kelajuan udara yang dihembus demi untuk menghasilkan nada yang dikehendaki. Untuk itu, seseorang itu haruslah mempunyai kawalan pernafasan yang baik dan saiz paru-paru yang besar. Kesimpulannya, adalah sukar untuk melatih seorang dari kalangan kita untuk menjadi pemain saksofon yang baik. MIDI Auto Saxophone adalah salah satu platform yang dibina dengan tujuan untuk menjadi pengganti kepada pemain saksofon sekiranya pemain saksofon diperlukan secara mendadak. MIDI Auto Saxophone adalah salah satu projek yang membina alat autonomi yang bermain alat muzik dengan cara menukar fail mesej MIDI kepada isyarat digital dan kemudian dihantar ke sistem kawalan tekanan udara dan sistem penjarian. Projek ini pula bertujuan untuk membangunkan sokongan mekanikal dan elektrikal untuk MIDI Auto Saxophone.

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LIST OF SYMBOL

Hz	Hertz
V	Voltage
°	Degree
Kg.cm	Kilogram-centimeter
%	Percentage
A	Ampere

LIST OF ABBREVIATIONS

MIDI	Musical Instrument Digital Interface
I/O	Input/Output
RC	Radio Control
PWM	Pulse Width Modulation
USB	Universal Serial Bus
DC	Direct Current
CMOS	Complementary Metal Oxide Semiconductor

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Music is an art form whose medium is sound and silence. Its common elements are pitch, rhythm, dynamics, and the sonic qualities of timbre and texture. To many people in many cultures, music is an important part of their way of life. A musical instrument is a device created or adapted for the purpose of making musical sounds. One of the instruments is the saxophone.

Saxophone is a musical instrument that belongs to woodwind instrument family. They are made of brass and played with a single reed mouth piece similar to playing clarinet. Although it is made from brass, they are not categorized as brass instruments but instead as the woodwind instruments as the sound waves are produced by oscillating reed. Originally it is popular in military bands; saxophone soon became a part of popular music and jazz.

There are many types of saxophone that exist. Some of the well-known saxophone is Soprano Saxophone, Alto Saxophone, Tenor Saxophone, and Baritone Saxophone. Soprano Saxophone is the type of saxophone that is more difficult to learn and not advisable for beginning players. The reason is that correct embouchure is critical to play this type of saxophone successfully and newbies may find it difficult to precisely form the needed embouchure. This is in the key of B flat and may either be curved or straight.

Alto Saxophone is medium sized and the most commonly played type of saxophone. The alto saxophone would be perfect for a beginner to start with. It is curved with a smaller mouthpiece and is in the key of E flat.

Tenor Saxophone is larger than the alto saxophone and is in the key of B flat. The mouthpiece is also larger, the rods and tone holes are longer. This is the type of saxophone commonly used in jazz music. The neck of the tenor saxophone is prone to damage due to its length.

Baritone Saxophone is the largest among the common types of saxophones. The baritone saxophone may or may not have an extension attached to the end of the horn. If it has an extension it is called a low A baritone. Due to its size and shape, the baritone is quite prone to damage.

1.2 PROJECT BACKGROUND

The invention of the MIDI Auto Saxophone is actually an initiative to build up an autonomous device that play saxophone instrument based on input signal in the form of MIDI. This device is combination of a few elements including MIDI decoder program, Digital I/O, reed control and electromechanical actuator. Mounting mechanism should be taken into consideration in order to house the rest of the elements and also to support function of device properly such as the actuator mechanism, without proper mounting, it cannot actuate on the right key as it was designed to.

Taking WASEDA Saxophonist Robot as an example, it is a well-known robot that is capable of playing saxophone instrument on a par with an intermediate saxophone player. These are the humanoid robots that are inspired, invented and programmed based on human's body part mechanism.

1.3 PROBLEM STATEMENT

As the device will play the saxophone without the aid from human, it will be needed to mount the saxophone onto the device. How can the saxophone be mounted so that it can be played automatically by the device? As there are total number 23 keys on the Alto Saxophone, correct actuation of key is needed in order to play the saxophone correctly. How to construct the electrical circuit so that the signal will be sent to the right actuator? How to build actuator mechanism so that it can behave like human finger? Thus, this project is intended to answer the above problem.

1.4 OBJECTIVE

- To build a support structure to firmly hold the saxophone.
- To build finger-like mechanism to mechanically press the saxophone keys.
- To construct the electrical circuit to support the finger-like mechanism.

1.5 SCOPE OF PROJECT

The scope for this project is to construct a mounting frame in order to hold and carry the weight of the saxophone. The frame should only fit alto saxophone only. Next part is to assemble 18 fingers mechanism that have the same response time. The last scope is to construct electrical circuit to initiate the correct finger mechanism based on the input signal which is the switching signal.

1.6 SIGNIFICANT OF PROJECT

The development of MIDI Auto Saxophone project may have benefits in various sector. Apart from gaining understanding on the saxophone instrument, this project can grant the researchers and the developers with valuable knowledge. Taking the frame itself, knowledge on structural and architectural could be gained.

The issue on how to mechanically press the saxophone keys will lead on to the study of the anatomy of the human body part, mainly finger. This study may give benefit in the medicine sector, which may help to develop hand prosthesis. This will later give help to those who lost their hand.

The construction and development of the electrical circuit would give knowledge on the digital I/O and logic gate system. The knowledge gained added with in-depth study may enable a person to develop microcontroller which then dedicated to a specific task or job. This would give benefit to the market and open up some job vacancies that will help our own countrymen.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter reviews about previous study that has been done in order to develop the saxophonist robot. Proper and deep understanding on the previous study is required in order to have a rough idea on how to start any project. In-depth analysis is also needed as it gives out some suitable component, device and method that can be used in this project.

2.2 ALTO SAXOPHONE

The alto saxophone is a member of the family of wind instruments that was invented by Adolphe Sax in 1840. The alto saxophone is made of brass with a tapered bore. It has single reed which is similar to a clarinet (Figure 2.1) and a fingering system is based on that of the oboe (Figure 2.2). It is smaller than the tenor saxophone but larger than the soprano saxophone.

The alto and tenor saxophone are the most common types of saxophone. The alto saxophone is commonly present in saxophone ensembles, concert and symphonic bands, and big bands. The alto saxophone is often used as solo instrument in rock, Rock n' Roll, rhythm and blues, and jazz genres. Some saxophones are nickel, silver or gold plated.

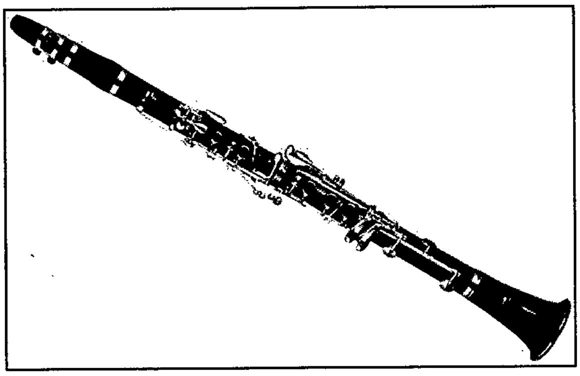

Figure 2.1: Clarinet.

Source: http://www.skymusic.com.au/images/products/5345.jpg.

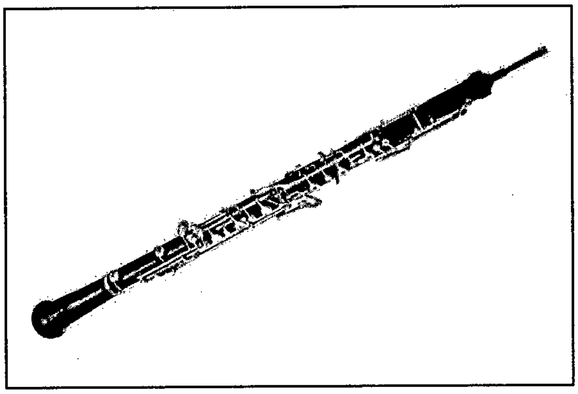

Figure 2.2: Oboe.

Source: http://www.mso.se/upload/Barn-och-Skola/Instrumentskola/oboe450.jpg.

The saxophone instrument consists of several parts. By referring to Figure 2.3, the first is "neck" or also called as the "gooseneck", which is a metal tube that is attached to the body of the saxophone. It is removable except for a soprano saxophone. Next part is "octave vent and keys" which can be divided into two parts. The "octave vent" is a single hole and key located on the neck of the saxophone. Next to that is a flat metal key called the "octave key". The next part is the "mouthpiece" which is found on the neck of the saxophone. A cork is needed so that the mouthpiece can slide in. This is where the musician places his lips and blows air into the instrument to produce sound.

The next part is the "body" which is a conically shaped brass tube that has plates attached to it and holds the rods, keys and other parts of the saxophone. The straight part of the body is called the tube. The u-shaped bottom of the sax is called the bow. The flared part of the sax is called the bell. "Thumb rest" is a hook-shaped piece of plastic or metal where you place your right thumb to support the sax.

"Keys" may either be made of brass or nickel and often some or all of the keys are covered with mother-of-pearls. The keys on the middle and lower part of the bow are called spatula keys. The keys on the bottom right side are called side keys. "Rods" is one of the most important parts of the saxophone in terms of its performance that should be strong and well maintained. "Pads" covers the holes of the saxophone enabling it to produce different sounds. The pads must completely cover the tone holes. They also have a resonator to help in sound projection.

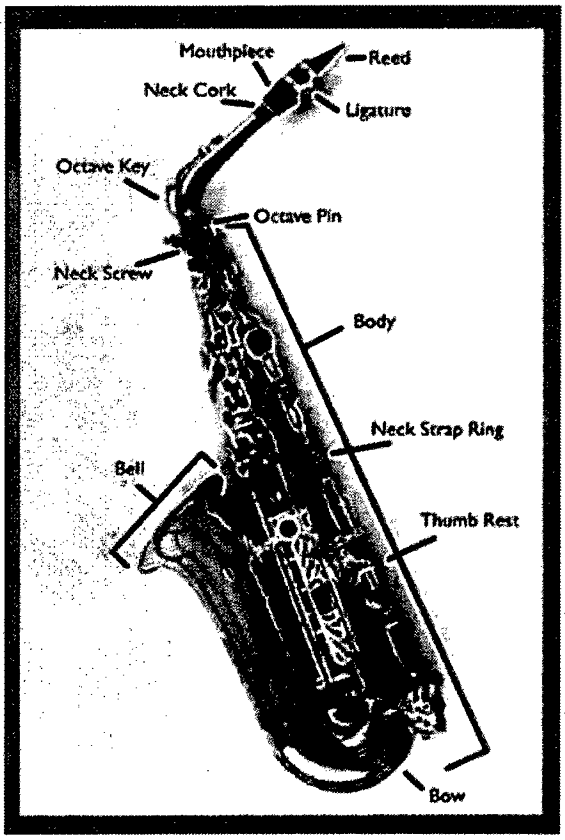

Figure 2.3: Basic saxophone structure.

Source: http://www.saxophone.com/images/saxmap.gif.

2.3 FINGERING CHART OF ALTO SAXOPHONE

In music, fingering is the choice of which fingers and hand position to use when playing certain musical instruments. Depending on the instrument, not all the fingers may be used. For example, saxophonists do not use the right thumb and string instruments usually use the fingers. A substitute fingering is an alternative to the indicated fingering, which, when applied, will produce the same desired tone.

Fingering of woodwind instruments such as saxophone is not always simple or intuitive, depending on how the acoustic impedance of the bore is affected by the distribution and size of apertures along its length, leading to the formation of standing waves at the desired pitch. Several alternate fingerings may exist for any given pitch

In order for saxophone to produce desired tone, a combination of pressed keys is needed while the air flows through the saxophone body. The combination of the keys is called the Fingering Chart (Figure 2.4).

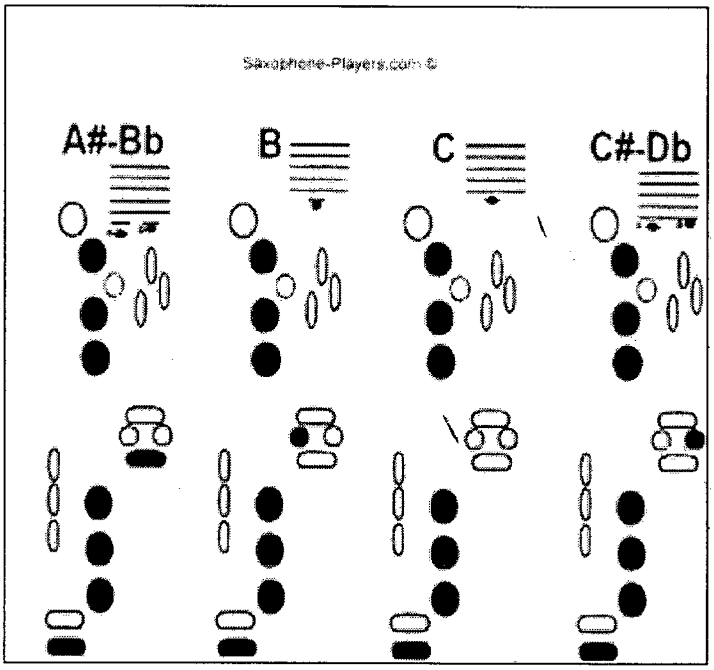

Figure 2.4: Example of saxophone fingering chart.

Source: http://www.saxophone-players.com/image-files/fc1.jpg.

2.4 SUPPORTING STRUCTURE

Supporting structure of the MIDI Auto Saxophone is important as this is where the saxophone is being put on and is where all the mechanism and accessory parts are being mounted. The support should able to withstand all weight of loads and inertia forces that subjected by the saxophone and all the fingering mechanism respectively. Referring to the WAS-2 robot (Figure 2.5), it has strong and firm structure, as the robot was able to hold the saxophone firmly.

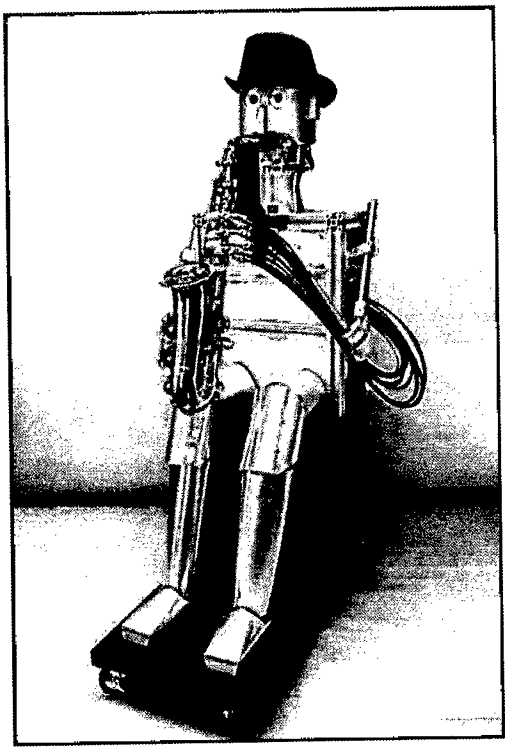

Figure 2.5: WAS-2 robot.

Source:
http://www.takanishi.mech.waseda.ac.jp/top/research/music/saxophone/was_2/img/WAS-2.jpg.

2.5 FINGERING MECHANISM

According to research by J. Solis et al.(2010) in order to enable WAS-1 to play from C3 to C#5 (two octave fingering), 11 degree-of-freedom (DOF) have been implemented. A RC servo motor has been used to control a link connected directly to the axis motor. As the end effector, an artificial finger made of silicon has been designed.

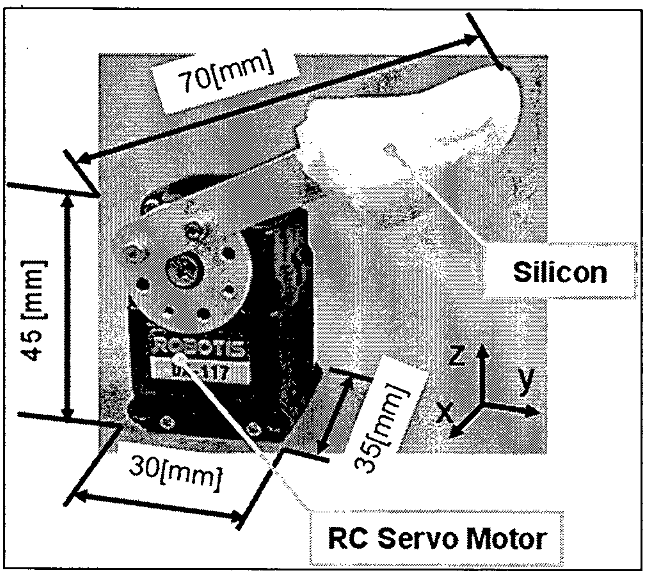

Figure 2.6: Finger mechanism composed of a RC servo motor and a direct link connected to the motor axis.

CHAPTER 3

METHODOLOGY

3.1 ACTUATOR TYPE

A servo motor is a closed-loop servomechanism that uses position feedback to control its motion and final position. The input to its control is some signal, either analogue or digital, representing the position commanded for the output shaft. The motor is paired with some type of encoder to provide position and speed feedback. In the simplest case, only the position is measured.

The measured position of the output is compared to the command position, the external input to the controller. If the output position differs from that required, an error signal is generated which then causes the motor to rotate in either direction, as needed to bring the output shaft to the appropriate position. As the positions approach, the error signal reduces to zero and the motor stops. The very simplest servomotors use position-only sensing via a potentiometer and bang-bang control of their motor. They form the basis of the simple and cheap servo motor.

Servo motors are generally used as a high performance alternative to the stepper motor. Stepper motors have some inherent ability to control position, as they have inbuilt output steps. This often allows them to be used as an open-loop position control, without any feedback encoder, as their drive signal specifies the number of steps of movement to rotate.

This lack of feedback though limits their performance, as the stepper motor can only drive a load that is well within its capacity, otherwise missed steps under load may lead to positioning errors. The encoder and controller of a servo motor are an additional cost, but they optimize the performance of the overall system relative to the capacity of the basic motor.

3.2 RC SERVO MOTOR

RC servo motor are hobbyist remote control device servos typically employed in radio-controlled models, where they are used to provide actuation for various mechanical systems such as the steering of a car, the control surfaces on a plane, or the rudder of a boat. Due to their affordability, reliability, and simplicity of control by microprocessors, RC servo motor are often used in small-scale robotics applications. RC servo motors are composed of an electric motor mechanically linked to a potentiometer.

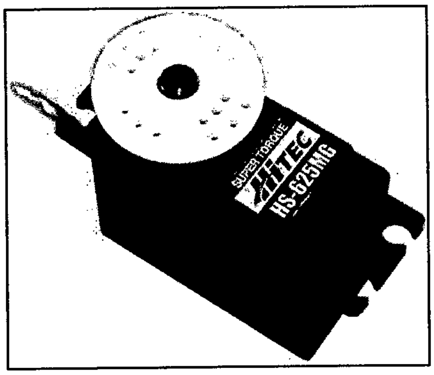

Figure 3.1: RC servo motor.

Source: http://www.servocity.com/assets/images/HS-625MG.jpg.

RC servos are composed of an electric motor mechanically linked to a potentiometer. A standard RC servo receive PWM signals with a 50Hz frame rate. The electronics inside the servo translate the width of the pulse into a position. When the servo is commanded to rotate, the motor is powered until the potentiometer reaches the value corresponding to the commanded position.

In order to measure the response time for the actuator, Agilent Modular Instrument can be used. While the servo motor is functioning, the current consumption can be measure by using Agilent USB Modular Digital Multimeter. As this experiment is developed in order to see the response time, Agilent USB Modular Oscilloscope is used to measure the actuation time of the servo motor.

3.3 ELECTRICAL BLOCK DIAGRAM

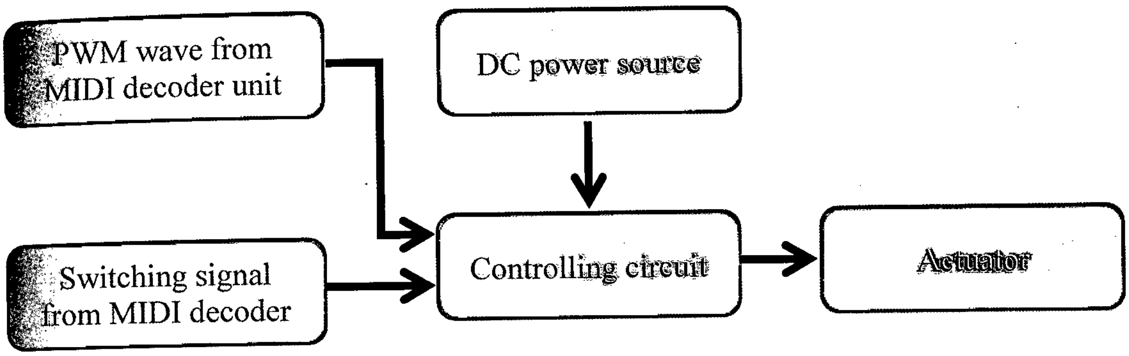

Figure 3.2: Electrical block diagram for the finger mechanism.

Since the RC servos require PWM signal for the positioning input, PWM wave are required to be supply to the servos. The MIDI decoder unit uses Arduino platform as the central processing unit, it has simplify the need for the PWM wave as the Arduino itself can generate its own PWM wave signal.

In the attempt to provide PWM wave signal, called as ON PWM signal for the total number of 18 servos, a different approach is needed. In order to reduce the demand for the PWM wave, a PWM wave signal with specific duty cycle need to be provide to several servos. This approach will then reduce the pin required for the PWM wave, as the pin for PWM output is quite limited on the Arduino platform.

Since the RC servo uses a train of reduction gears, it would need a quite high force in order to push back the servo to its previous initial position. The keys of the saxophone does not have that much of capability. Thus, an additional PWM wave, called as OFF PWM signal will be provided to every servo that is not triggered by the ON PWM signal wave. As the result, the shaft of the servo can move back to its pre-determined initial position without the need of external forces.

3.4 CONTROLLING CIRCUIT

Since every servo is provided with two PWM wave signal which is the ON PWM signal and OFF PWM signal, a controlling circuit is needed in order to determine which PWM wave will be transmit to the servo. The selection of the wave will be based on the switching signal that is generated from the MIDI message signal by the decoder unit. The switching signal is a simple digital signal.

3.5 POWER SOURCE

The RC servo are connected through a standard three-wire connector, in which one of them is use for transmitting PWM signal and the other two is for the DC power supply. Although the Arduino platform has the pin to supply 5V to other equipment, but it will not be enough to power up all the 18 servos. Thus, an external and dedicated power supply with the correct rating is needed in order to supply the servos with sufficient power.

In order to determine the power requirement of the RC servo, a simple experiment can be conducted. An Arduino platform loaded with the correct coding (APPENDIX B) which is use to move the servo to a position and some jumper wire is required in order to carry out this experiment. While the RC servo motor is holding to its position that loaded in the Arduino code, measure the current that flow through the servo while at the same time apply some external force onto the servo's output shaft.

Another experiment can be conducted in order to determine the current while the servo is moving. Load the Arduino platform with a code that vary the PWM duty cycle over time (APPENDIX C), that will make the RC servo sweep back and forth between 0° to 180°. While the servo motor is sweeping back and forth, some force is apply to counter its movement and at the same time the current flow is measured.

3.6 MECHANICAL STRUCTURE

In order for the mounting structure to be strong enough to support the saxophone and the supporting unit, which is MIDI decoder unit and reed controller unit, a sturdy and stable frame is needed. The proposed frame for this project is made from L-shape metal structure as shown in Figure 3.3. This structure can provide better support than a flat panel metal with the same thickness. This will allow less material being used for the frame and save some valuable weight.

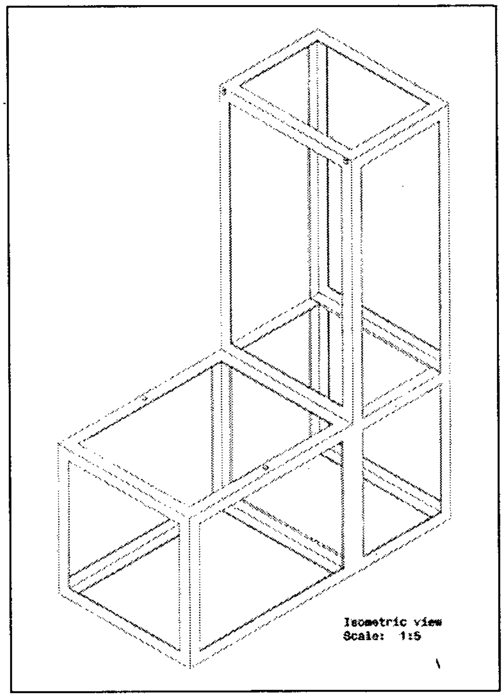

Figure 3.3: Proposed frame for the mounting structure.

In order to increase the sturdiness of the frame, four aluminium bar with thickness of 3mm in added in slanting position at some crucial point. This will help to shift the weight from the middle of the frame to the bottom corner end of the frame. This bar will also help to prevent the middle vertical frame from being pushed downward by the weight on the frame that will create a sagging effect on the bottom horizontal frame.