DESIGN AND DEVELOPMENT OF VELOCITY SENSITIVE MIDI ELECTRONIC
DRUM KIT USING PIEZOELECTRIC SENSORS

BY
CHAN MUN HOO

A REPORT
SUBMITTED TO
Universiti Tunku Abdul Rahman
in partial fulfillment of the requirements
for the degree of
BACHELOR OF COMPUTER SCIENCE (HONS)
Faculty of Information and Communication Technology
(Kampar Campus)

MAY 2018
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CHAN MUN HOO

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Dr Chang Jing Jing
Supervisor’s name

Date: 19/8/2018
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DECLARATION OF ORIGINALITY

I declare that this report entitled “DESIGN AND DEVELOPMENT OF VELOCITY SENSITIVE MIDI ELECTRONIC DRUM KIT USING PIEZOELECTRIC SENSORS” is my own work except as cited in the references. The report has not been accepted for any degree and is not being submitted concurrently in candidature for any degree or other award.

Signature : __________________________

Name : Chan Mun Hoo

Date : 19/8/2018
ACKNOWLEDGEMENTS

I would like to express my sincere thanks and appreciation to my supervisors, Dr. Chang Jing Jing who has given me this bright opportunity to engage in designing and developing my own electronic drum kit using microcontroller and sensors. I had thought it for a long time to make one and finally I can start working it in my project. A million thanks to you.

Finally, I must say thanks to my parents and my family for their love, support and continuous encouragement throughout the course.
ABSTRACT

Drum is unquestionably one of the most significant musical instruments in the world. In the field of music, drum itself does not produce music, but gives life to it. Whether it is used for musical performance or for rituals and religious ceremonies, the status of drum has remained impregnable. While the drum kit is still relatively expensive, technology now allows people to build their own drum kit without spending a lot of money. However, there are still a lot of people that do not have the ability to develop electronic musical instruments using microcontroller and sensor due to their lack of knowledge and having misconception that it will be very complicated and difficult to learn. Nowadays developing electronic projects is not a big issue anymore because of user friendliness on learning and using those devices. This will actually help developer to save a lot of money because of no need to buy a native one. Therefore, this report will present on how to incorporate raw materials, microcontroller, piezoelectric sensors and software into a fine drum kits, along with its portable design. The performance of this drum kits is evaluated.
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<td>Ω</td>
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<tr>
<td>V</td>
<td>Voltage</td>
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<tr>
<td>DAW</td>
<td>Digital Audio Workstation</td>
</tr>
<tr>
<td>MIDI</td>
<td>Musical Instrument Digital Interface</td>
</tr>
<tr>
<td>DIY</td>
<td>Do it Yourself</td>
</tr>
<tr>
<td>LCD</td>
<td>Liquid Crystal Display</td>
</tr>
<tr>
<td>PA</td>
<td>Public Address</td>
</tr>
<tr>
<td>1M</td>
<td>1 Million</td>
</tr>
<tr>
<td>AC</td>
<td>Alternative Current</td>
</tr>
<tr>
<td>IDE</td>
<td>Integrated Development Environment</td>
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<tr>
<td>VST</td>
<td>Virtual Studio Technology</td>
</tr>
<tr>
<td>IC</td>
<td>Integrated Circuit</td>
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<tr>
<td>SD</td>
<td>Secure Digital</td>
</tr>
<tr>
<td>MHz</td>
<td>Megahertz</td>
</tr>
<tr>
<td>OS</td>
<td>Operating System</td>
</tr>
<tr>
<td>JST</td>
<td>Japan Solderless Terminal</td>
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Chapter 1 Introduction

1.1 Project Background

1.1.1 Brief introduction of drum kit

Music can have many forms depends on which and how the instruments are played. To play a relatively soft rhythmic music, a chordophone instrument such as piano and guitar will do. But to produce an arousable one, drum is unquestionably irreplaceable since it brings soul and climaxes to the music. Drums is a very old instrument as it has been found thousands of years ago and was used in ritual ceremonies (Liu, Li, 2007). In modern music, drum is very common in maintaining the beats within the whole piece of music, apart from enhancing the energy level of the music composition.

A drum kit is a collection of drums and other percussion instruments, typically cymbals, which are set up on stands to be played by a single player with drumsticks held in both hands, and the feet operating pedals that control the hi-hat cymbal and the beater for the bass drum. A standard drum kit usually consists of a mixture of drums and cymbals, and can alternatively include others extensions such as cowbell and chimes which are not a part of a standard drum kit. Drum player uses drum sticks or hands to hit on these components to produce various sounds.

![Figure 1.1 Standard drum kit](image)

The following are the introduction of the main components of a standard drum kit:

- Snare drum: produces sharp cracking sound when the drum top head is struck, which produced by a sounding vibration from the snares
Chapter 1 Introduction

- Tom-tom drums: drums with no snares, thus having a deeper tone than snare drum
- Floor tom drum: considered as a one of the tom drums family, but having deepest tone just above the bass drum, or sometimes deeper than the bass drum
- Bass drum: largest drum in the standard drum kit, bass drum makes the lowest pitch and usually used to maintain the tempo or beat in music
- Ride cymbal: Make a sustained, shimmering sound, usually struck to maintain a steady rhythm pattern
- Hi-hat cymbal: consist of two cymbals mounted to each other, enable this component to create two different kinds of sound produced by opening or closing the cymbal with the foot pedal
- Crash cymbal: produce a loud, sharp sound which usually representing or marking climaxes, changes of bar and structure

There are two common types of drum kits available in the markets which are the acoustic drum and electronic drum. Acoustic drum kit can produce sounds by striking the drum with drum sticks without any extensible support like electrical plug in. On the other hand, an electronic drum consists of synthesized or samples percussion sounds and sensors that trigger the sounds. Playing an electronic drum is similar to playing an acoustic drum, the sound is triggered by striking the sensors with drum stick. Both of these drum kits have its own pros and cons which will be discussed later.

![Figure 1.2 Electronic drum kit](image)

*Figure 1.2 Electronic drum kit*
1.1.2 Piezoelectric sensor

Piezoelectric sensor is a suitable choice to be used in this project because the sensor is triggered when a pressure is applied to it. This is similar to when the drum kit is stroke by the drum sticks. Piezoelectric sensor (will be mentioned as piezo in later writing) is a type of sensor that convert changes of pressure or mechanical stress into alternating electrical force. The prefix piezo in Greek means “press” or “squeeze”. Piezo are made of crystallize materials, usually ceramic. Atom structure in a crystal are symmetrically arranged and the electrical charges are balanced. When pressure is applied to the piezo, the structure of atoms inside is deformed, causing imbalance between positive and negative charge, eventually producing net electrical charges (Woodford, 2017). This is known as piezoelectric effect. Reverse piezoelectric effect occurs the opposite way when the crystal structure is going back to its original shape. Piezo is the major technology that is essential to build an affordable DIY electronic drum kit.
Chapter 1 Introduction

1.1.3 Musical Instrument Digital Interface (MIDI)

MIDI is a protocol that allows computers, musical instruments, and music-related devices to communicate. MIDI is normally used for recording and playing back music from a digital instrument or synthesizer. When using a MIDI instrument, a MIDI note or MIDI event is created each time the instrument is played. Each MIDI note carries a series of instructions including notation, volume, tempo, note on/note off signal, etc. Instead of real audio playback, MIDI tells the machine how it should playback according to instruction mapped to an actual sound. Because it is not the actual audio clip, each MIDI note can be edited independently without affecting the overall performance of the whole playback.

![Figure 1.6 MIDI note](image)

1.2 Motivation and Problem Statement

The portability of a drum kit is relatively low because of its size and weight. Transporting a basic drum set requires a large vehicle. Attaching and detaching the drum set is also a tiring work and will use up a lot of time. Besides that, it is very difficult to afford a drum kit for a person with average income. Even if they do afford it, there are still problems that they need to face. A normal professional drum kit occupies a lot of space and sounds uncontrollably high if there are no sound-proof facilities. A normal house is not friendly to placing a drum kit and even if it is big enough to keep it, the neighbours nearby will likely to be irritated by the high-volume drum sounds. The high volume is also a problem when having a band practice, other musical instruments in the band need to increase their volume to match the drums. Therefore, redesigned electronic drum kit using relatively cheap materials is a solution for those amateur drummers because of its low cost, high portability and controllable volume.
Chapter 1 Introduction

1.3 Objective

The main objective of this project is to develop a velocity sensitive DIY electronic drum kit which is portable, affordable and space friendly. Therefore, more specific sub-objectives are stated as below:

- Design a portable a drum kit model that is easy to build and keep, velocity sensitive, in addition not occupying large spaces
- Develop the drum kit according to the model and establish connection between the drum kit and DAW through piezo to make the drum kit playable

1.4 Proposed study/approach

To build the drum kit, multiple piezos will be connected parallelly. Resistor is connected parallelly along with the piezos to keep the analog line at zero volt until the piezos produce voltage. Positive sides of the piezos are attached to the drum pads and connected to different analog pins while the negative sides are connected to the ground pin of the microcontroller board. The microcontroller board is programmed to allow MIDI communication between the circuit and Digital Audio Workstation (DAW). Each drum pad will be mapped to different MIDI notes to trigger different drum sounds configured in the DAW. The drum kit is velocity sensitive where the volume of playback will vary according to how hard the drum pad was stroke.

1.5 Achievement

At the end of the project, a velocity sensitive DIY electronic drum kit is developed. The analog voltage value produced by hitting the drum pad is converted to velocity which is responsible of the volume of the drum sound playback.

1.6 Report Organization

The report contains 6 chapters. Chapter 1 described the background, problem statement, motivation, objectives and proposed study of the project. Chapter 2 reviewed some of the electronic musical instruments, strength and weaknesses of various drum kit, and some usage of sensors in electronic instruments. Chapter 3 described the system architecture and system flow of the project. Chapter 4 explained the methodology and tools used in this project. Chapter 5 explained on how to implement the project and demonstration of testing result. Chapter 6 concludes the project.
Chapter 2 Literature Review

2.1 Review of some electronic musical instrument

There are many musical instrument projects developed using Arduino. Generally, there are two categories of this project, which is the hybrid instrument where an acoustic instrument is attached with electronic components, and the DIY instrument where the whole system is developed by the developer.

2.1.1 Electrumpet

![Electrumpet](image)

*Figure 2.1 Electrumpet (Hans Leeuw, 2008)*

The electrumpet is a hybrid electroacoustic instrument that started developed by Hans Leeuw in 2008. The electrumpet is an enhancement of a normal trumpet with a variety of electric sensors and buttons (Hans Leeuw, 2008). The idea of electrumpet is attaching sensors, switches and Arduino boards which function as controller on the trumpet. The device has a wireless connection with the computer through Arduino Bluetooth board. Sensors are directly placed on the instrument with normal arrangement so it does not affect the handling. An LCD screen controlled by Mini Arduino is attach to the trumpet.
2.1.2 Utopiano

Figure 2.2 Utopiano (Oskar Schuster, 2016)

Utopiano is an Arduino controlled piano developed by a German composer Oskar Schuster where an electro-mechanical device is replacing the traditional mechanical piano keys (Oskar Schuster, 2016) to play his 100 years old instrument. In Figure 2.2, only a computer keyboard is used to play the piano. Buttons on the keyboard are connected to different artificial “hammers” used to strike the strings.

2.2 Review of commercial drum kits

Apart those drum kits mentioned in Chapter 1, there are many types of commercial drums in the market. These drums are to be chosen by users according to their usage and preferences. Although percussion instruments such as Cajon and bongo drum are quite a demand in the market, review and comparison of standard drum kits will be focused in this chapter.

2.2.1 Acoustic drum kit

The development of acoustic drum kit has started in the 18th century and were mostly used in military and orchestral music. At first, drums and cymbals are played separately by different percussionist. After a few decades, use of foot pedals allows the drummer to play multiple drums at the same time. In the early 19th century, drum kits become a significant part in jazz music. Later, the drum kit undergoes evolution after adding of tom-tom drums, crash cymbals and hi-hat cymbals.
Chapter 2 Literature Review

Unquestionably, acoustic drum kit has the best sound among the others. This is because of its native properties: sounds are produced from the components itself without any extension plugin. However, it produces very loud sound even without amplification, and thus not a good choice for practicing at home. Moreover, to extend its versatility, extra money is needed to be spent to buy a new component to equip on the drum kit. One good quality drum component could cost the same as a whole beginner drum set with below average quality.

2.2.2 Electronic drum kit

Electronic drum kit consists of a set of drum pads that is mounted on stands or racks. The configuration is similar to an acoustic drum kit. Rather than the materials used to make real drum components like copper alloy, wood, skin membrane and various metal, the drum pads are often made by rubberized or siliconized materials and each drum pad has a sensor that generates electric signal when struck.

![Figure 2.3 Simmons SDS 5 electronic drum kit](image)

The first electronic drum kit was created in the early 1970s by Graeme Edge. Later in 1978, the Simmons company was created to produce commercial electronic drum kit and their first successful product, Simmons SDS 5 electronic drum kit (shown in Figure 2.3) was released in 1981. The drum pads are hexagon-shaped and the kit consists of 3 tom-toms, 1 bass drum and 1 snare. This is the first drum synthesizer that can stand alone and allows adjustment of individual parameters of the drum sounds.

Recently, electronic drum kit manufacturers have developed some high-end professional electronic drum kit which focus on creating sounds and playing experiences that are indistinguishable from playing a real professional acoustic drum kit. These drum kits offer high quality modeled drum sounds, more realistic drum components (striking on different part a single drum pads will produce different sounds
like the original kit does) and velocity-sensitive (change of volume of sound depends how firmly or softly the drum pad is hit). An example of high-end electronic drum kit is the Roland TD 25KV electronic drum kit which is shown in Figure 2.4.

![Roland TD 25KV Electronic Drum Kit](image)

*Figure 2.4 Roland TD 25KV Electronic Drum Kit*

The electric signal is transmitted through cables into synthesizer or electronic drum module, and then produces sound associated with the drum pads. Difference configuration can be done on these devices to change the effect, volume level and dynamics of sound produce by the electronic drum kit. Different type of connectivity is allowed on these devices shown in Figure 1.3 and 1.4 such as connecting the drum kit to a monitor or amplifier, an auxiliary port which allows the connection of MP3 players, and USB/MIDI connection to a computer for composition of songs or use as a MIDI controller.

Although electronic drum kit is considered the best alternative to the traditional acoustic drum kit because of its playing experience and improving sound quality, the high cost is still the main issue of this kit. A basic electronic drum kit for beginner already cost up to thousand and above. Since the quality of sounds are very dependent on the drum module and the samples, “basic” means cheaper synthesizer with lesser presets, causing the sound quality to be below average.

### 2.2.3 Table-top electronic drum pad kit

Table-top electronic drum, also known as portable electronic drum, is an electronic drum kit that has all of its pads (except pedal) and the drum sound module
one a single table-top and usually flat unit. This type of drum kit usually has a small amplifier and loudspeaker attached on it thus making the sound generation relatively simple compare to the native electronic drum kit. Because of its size and everything necessary like sound samples, amplifier and configuration interface are already incorporated with it, there is no need to reserve a large space for placing it and setting it up is easier and time-saving. The table-top also known for its relatively low cost compared to a full-size drum.

![Table-top Drum Kit](image)

*Figure 2.5 Alesis CompactKit 7 7-Pad Table-top Drum Kit*

Figure 2.5 shows a type of table-top electronic drum kit. As mentioned before, the pads are compact together thus making it very space friendly. However, the experience of playing a table-top electronic drum is very different from a full-size electronic drum kit due to its small size are all pads are packed together. This kit may satisfy the requirement of an acoustic drummer, but not a professional drummer in terms of feeling when playing the drum.

### 2.2.4 Conclusion

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<th>Advantage</th>
<th>Disadvantage</th>
<th>Price range</th>
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<td>Acoustic drum</td>
<td>- Best sound</td>
<td>- Barely portable</td>
<td>Approx.</td>
</tr>
<tr>
<td></td>
<td>- Best playing experience</td>
<td>- Expensive</td>
<td>RM 1200 -</td>
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<tr>
<td></td>
<td>- Free of incompatibility problem</td>
<td>- Occupy a lot of space</td>
<td>RM 40000</td>
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<tr>
<td></td>
<td>- Audible in small space without amplification</td>
<td>- Customizing and recording is troublesome</td>
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<tr>
<td></td>
<td>- Wireless</td>
<td>- Noisy for home practice</td>
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<tr>
<td>Electronic drum</td>
<td>- Can switch sound easily</td>
<td>- Barely portable</td>
<td>Approx.</td>
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<tr>
<td></td>
<td>- Less acoustic noise</td>
<td>- Expensive</td>
<td>RM 1000 -</td>
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<tr>
<td></td>
<td>- Allow silent practice</td>
<td>- Usually does not</td>
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Chapter 2 Literature Review

<table>
<thead>
<tr>
<th></th>
<th>- Recording is easier than acoustic drum</th>
<th>reproduce sound of acoustic drum kit</th>
<th>RM 20000</th>
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<tr>
<td></td>
<td>- Volume is adjustable</td>
<td>- incompatibility problem</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Support line in</td>
<td>- sound quality is dependent on the quality of PA system</td>
<td></td>
</tr>
<tr>
<td>Table-top drum</td>
<td>- Highly portable</td>
<td>- Different from playing a real full-size drum kit</td>
<td>Approx. RM 100 - RM 1000</td>
</tr>
<tr>
<td></td>
<td>- Space friendly</td>
<td>- Sound generation is simple</td>
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Table 2.1 Comparison of drum kits

Although acoustic drum set functions the best in terms of sound quality and experience, its disadvantages especially high cost and difficulty for home practicing are big issues for drummers. On the other hand, although electronic drum and table-top drum may be more flexible in terms of volume adjusting, sound switching and recording, but still they cannot reproduce exactly the same sound of an acoustic drum set and moreover reducing the playing experience. Future work must be done to achieve a balance between these issues.

Currently, quite a number of people are making their own electronic drum kit under Arduino environment using various techniques and components. However, most of the projects are just prototypes and not fully developed. For example, the user just connects everything together and do some configuration in order to make things work. In short, the project shall adopt some features of the existing design and enhance upon them. Some implementations are required to improve the current design. These implementations can be associating more sensors to the project in order to produce different effects and level of sounds, or dexterity in making the pads more realistic to enhance playing experience.
2.3 Use of sensor in electronic musical instrument

2.3.1 Overview

In this era where electronic musical instruments are widely used because of its convenience, sensors become an important part to enable and enhance the playing experience of the instruments. For example, without sensor, an electronic drum kit does not produce any sounds as it is just a few pieces of rubber pads. It is the electric sensors included in the drum pads that do the task to trigger the sounds. Another example is a touch-sensitive keyboard; sensors are included within the piano keys to detect the touch pressure while playing. The harder the key is touched, the louder the sound is produced.

2.3.2 Piezoelectric sensor

As mentioned in Chapter 1.1.2, piezo is a device that uses the piezoelectric effect to generate electric voltage through measuring change of pressure. Piezoelectric effect is mainly used for industrial sensing application in medical, aerospace and nuclear implementation (Zhu, 2010). In music industry, piezo is mainly used in detection of pressure in the form of sound. For example, in microphone and guitar pickup, the sound waves transmitted will deform the piezo material, creating a displacement in voltage. Thus, it is a useful technology when come to detect pressure and force. Since the sounds of the drum are triggered when the drum pads are stroke, piezo will detect the pressure when striking the drum pads, converting the analog voltage into instruction that is readable by MIDI protocol and trigger the drum sound.
Chapter 3 System Design

3.1 System Architecture

Figure 3.1 shows the whole system design of the project. The project components and connection are exactly the same with Figure 3.1.
3.2 System flow

Figure 3.2 System flow design

Figure 3.2 shows the system flow of the project. When the drum pad is stroke, the piezo senses change of pressure and the piezoelectric effect produce an analog voltage. The resistor pulls down the voltage and the final analog value is sent to the microcontroller board along with other information to process. After processing, the information is converted to MIDI message and sent to DAW. Every time the drum pad is hit, new MIDI event is created to trigger the drum sound.
Chapter 3 System Design

3.2.1 Circuit connection

![Circuit design](image)

*Figure 3.3 Circuit design*

The piezos and resistors are connected parallelly as shown in Figure 3.3. Piezo senses force and pressure from the striking of the drum pads attached. It then converts the displacement to electrical energy. The pull-down resistors prevent the AC from directly flowing into the board and keep the voltage remain at zero until electrical energy is produced by the piezo.

3.2.2 Programming the microcontroller board

In this project, Bare Conductive Touch Board is used as it has similar configuration to Arduino Leonardo microcontroller board and it supports USB port for programming. Arduino IDE is used to write sketch that will be uploaded to the microcontroller board. The board is connected to Arduino IDE through USB communication port.

3.2.3 MIDI communication

Information such as the analog value and source analog pin are sent to the microcontroller board for processing. Each analog pin is assigned to different MIDI note. When respective drum pads are stroke, *noteOn* message will be triggered and the analog value will be converted to MIDI velocity which is responsible for the output volume. All the information is wrapped into a MIDI event and sent to DAW to trigger the drum sound.
Chapter 4 Methodology and Tools

4.1 Methodology

The evolutionary prototyping approach is chosen as the most appropriate methodology for the development of this project. The evolutionary prototyping model is shown in Figure 3.1.

![Figure 4.1 The model of the evolutionary prototyping](image)

This project aims to develop an electronic drum kit that is portable, affordable, space-friendly. In the analysis phase, existing drum kits were reviewed and comparison of their strength and weaknesses was done so that improvements can be made on this project based on their weaknesses and existing features. Besides that, usage of sensors in music applications are reviewed too.

For the design phase, a simple prototype will be designed at first to make testing easier. At the later stage, a simplified standard design will be implemented on this project which will consists of one crash cymbals, one hi-hat cymbals, one snare, one tom drum and the bass. In this project, bass drum is not required as the sound will be triggered by just stepping on the bass pedal.

The development process will start simultaneously with the design phase. Basic prototype of the drum kit will be constructed eventually according to the designed model. Prototype version of the project will be developed by adding components and features incrementally and tested at the end of each iteration of the development phase.
Chapter 4 Methodology and Tools

Final version of the project will be implemented when the electronic drum kit has undergone various testing, error-free and safety assured.

4.2 Tools and components

4.2.1 Tools and environment

Bare Conductive Touch Board

Figure 4.2 Bare Conductive Touch Board

Bare Conductive Touch Board is used for development of the project since it has similar configuration to Arduino Leonardo and it supports USB port and 3.5mm audio aux port which make testing process easier without need to purchase extra tools such as converter, external audio port module and wired speaker. The Touch Board has been based around the ATmega32U4 microprocessor and has a 16 MHz clock speed runs at 5V operating voltage. The Touch Board includes 3.5mm audio jack, micro SD card holder, micro USB connector, JST connector, power switch and a reset button.
Chapter 4 Methodology and Tools

Arduino IDE

Arduino IDE is used to program the microcontroller. This software is an open source IDE which is powered by Arduino and available free on Arduino website. There are a lot of open source libraries and header files that can be found in Arduino, which make development process much easier. The development language used is C language.

Ableton Live 9 Suite

Ableton Live is a digital audio workstation for MacOS and Window OS. Ableton Live can be used as musical instruments for live performance, as well as mixing and mastering, recording and composing. Ableton Live supports Virtual Studio Technology (VST) plugin and MIDI instruments which are the essential parts for triggering the drum sounds. With the aid of DAW, the drum kit will support MIDI recording.
Chapter 4 Methodology and Tools

EZdrummer 2

Figure 4.5 EZdrummer 2

EZdrummer is a sample-based drum synthesizer developed by Toontrack. EZdrummer contains a large amount of drum samples and a mixer that allow users to adjust the independent volume of each of the drum. In this project, EZdrummer 2 is used as a VST plugin and imported to Ableton Live. Each drum component is mapped with a MIDI key.

4.2.2 Components

Piezoelectric sensor

Figure 4.6 Piezoelectric sensor

Disk-shaped piezo is used in this project. Red wire is soldered to the ceramic material (positive side) whereas black wire is soldered to the rim of the piezo (negative side). Piezo can be purchased via internet with a cheap prize.
Chapter 4 Methodology and Tools

Figure 4.7 Piezo attached to drum pads

The piezo is attached to the drum pads using black cloth tape.

Figure 4.8 Resistor

In this project, resistor is used as a pull-down resistor, which directing the AC produced by the piezo from flowing into the microcontroller board. Resistor is also used to suppress the overall circuit voltage to zero until the piezo produces voltage from the displacement.
In this section, simple prototype which using only two drum pads are setup for implementation and testing. In this case, sounds of snare drum and crash cymbals are used. More drum pads can be added later on onto the drum kit.

5.1 Implementation

5.1.1 Setup for drum pads

In the setup, snare drum pad is connected to analog pin 0 and crash cymbal pad is connected to analog pin 1. To setup the drum pads, few variables need to be defined:

- `numberOfPiezo`: since the piezo are attached to the drum pad, this variable indicated the number of drum pads included in the drum kit
- `snareDrumThreshold` & `crashCymbalThreshold`: analog values produced by the drum pad must exceed this threshold value in order to cause a drum hit
- `snareDrumMIDINote` & `crashCymbalMIDINote`: each drum pad is assigned to a MIDI value which is mapped to different drum sounds in the sampler

5.1.2 Setup for processing the analog value

Few variables are declared to process the analog value produced by the piezo:

- `maxPlayTime`: this variable indicates the maximum play time of a drum pad before second hit is allowed. The larger the value of this variable, the larger the interval between two drum hits between two drum hits.
• **analogPin**: indicates which analog pin of the microcontroller board is producing the analog value

• **padPlayTime**: time counter since the drum pad is hit

• **threshold**: this threshold array is filled with threshold values mapped to respective drum pads. As shown in Code Snippets 5.2, analog pin 0 and 1 are mapped to `snareDrumThreshold` and `crashCymbalThreshold` respectively.

• **drumPadIsActive**: array of flags that indicates whether the drum pad is currently being played

### 5.1.3 Triggering a drum hit

```c
piezoAnalogReading = analogRead(analogPin[numberOfPin]);
```

*Code Snippets 5.3 Reading analog value*

![Image of COM8 Board with Touch Board Connections]

*Figure 5.1 Noises produced by piezo before hitting*

The analog voltage value produced by the drum pad is read by `analogRead` function. The analog value is varied between some small values before the drum pad is hit. The threshold value set for each drum pad before is to eliminate these noises.
Chapter 5 Implementation and Testing

```
if analog value is more than threshold
  if the pad is not active
    write note on MIDI event
    set counter to 0
    set the pad to active
  else
    add counter by 1
  endif
else if the pad is active
  add counter by 1
  if counter is more than max play time
    set the pad to inactive
    write note off MIDI event
  endif
endif
```

*Code Snippets 5.4 Pseudocode to trigger a drum hit*

As shown is Code Snippets 5.4, if the analog value is larger than the threshold set and the drum pad is not being played, the drum sound is triggered and the drum pad is set to active. After one system loop, the counter will be added by 1 and if the counter exceeds the maximum play time for one hit, the drum pad is set to inactive and note off event will be triggered. In this case, each system loop is 1 millisecond so the maximum play time is X millisecond depending on what value is set to the maximum play time. The larger the value of maximum play time, the larger the interval between two drum hits.

### 5.1.4 Velocity Sensitivity

```
convert analog value to velocity
if velocity is more than 127
  set velocity to 127
```

*Code Snippets 5.5 Velocity Sensitivity*

The *velocity* variable is the final volume output after hitting the drum pad. To make the drum pad velocity sensitive, the volume of the drum sound is depending on how much force is used to hit the drum. The analog value produced is processed according to user preference. The maximum value of analog value is 1023 and the maximum volume is 127. Thus, the analog value can be converted to volume for example dividing the analog value by 8 to get the highest sensitivity.
Chapter 5 Implementation and Testing

5.1.5 MIDI event

MIDIObjects[pin].type = MIDI_NOTE;
MIDIObjects[pin].noteNumber = midi_note_for_drum_sound;

*Code Snippets 5.6 MIDI objects*

A MIDI object is initialized for each drum pad. Only first two attributes of the object are set which are the type of MIDI object and the MIDI note number. The first attribute is MIDI_NOTE which allow the microcontroller to act as a MIDI instrument. The note number is set depends on which MIDI key is mapped to each drum components in the drum sampler.

```
MIDIEvent{
    type, m1, m2, m3
}

midiEvent.type = 0x08(noteOff), 0x09(noteOn)
midiEvent.m1 = 0x80(noteOff), 0x90(noteOn)
midiEvent.m2 = noteNumber
midiEvent.m3 = velocity
```

*Code Snippets 5.7 MIDI event*

MIDIEvent object allows the drum pad to communicate with the drum sampler. The four parameters of this object to be set are:

- **type**: MIDI control type, 0x08 for note off control and 0x09 for note on control
- **m1**: MIDI event type, 0x80 for note off event and 0x90 for note off event
- **m2**: MIDI note number mapped with MIDI key for drum components set in the drum sampler
- **m3**: velocity which is the volume of output sound

5.2 Testing

Result link:
https://drive.google.com/open?id=1Od0s8c6lmFoxC7uGp9C8juPibzsBmvEW

The black colour drum pad is snare drum whereas the drum pad without any added colour is crash cymbal. The drum pads are tested from two perspective. First is to test the velocity sensitivity, second is to test the polyphonic playback. From the first part of the video, the drum pad is hit softer for the first 4 times and harder at last time. The volume of the sound produced successfully varied according to force exerted on the drum pads. From the second part of the video, two drum pads are played together and the demonstration is successful as well.
Chapter 6 Conclusion

6.1 Project Review, Discussions and Conclusions

As mentioned, drum is a significant instrument not only in the era of music, but also in some traditional occasion. But its big size, high cost, heavy weight and recording inconvenience discourage many amateur drummers and budget music producer to purchase a full drum kit. Although there are alternatives available in the market, limitations in terms of flexibility and other factors are still some issues that need to be think of. Fortunately, the advancement of modern technology allows people to develop their own electronic project. With the aid of microcontroller and sensors, developing an own electronic drum kit is not a big issue anymore. User can develop their own electronic drum kit according to their preference, whether to follow or not follow the standard design and choose drum sampler they want. This cannot be done on any other types of drum kit where the configuration is fixed in terms of building model and sound samples.

In this project, developing a MIDI electronic drum kit using piezoelectric sensor is not that difficult to implement and the cost of the materials to build the circuit is definitely lower than purchasing a drum kit. Although the microcontroller board used to develop this project which is Bare Conductive Touch Board seems to be a bit expensive, user can choose any microcontroller board from Arduino platform such as Arduino Uno if user wish to build a smaller size drum kit, or Arduino Mega if user wish to build a larger one.

However, the performance of drum kit still heavily depends on few aspects. The quality of piezos is one of the main aspects that need to be think of. If the piezo is not good in quality, this will affect the sensing ability and the durability of the piezo. Besides that, the drum pad itself is also an issue. Because the piezos are to be attached to the drum pads, the drum pad cannot be too thick or too large in term of size since it will affect the sensing ability of the piezo as well. The quality of drum pad also needs to be good to endure strikes from drum sticks. Lastly, analog value produced by the piezo is somehow not stable which will cause latency or multiple sounds produced within one drum hit. The algorithm and the circuit design need to improved in order to improve the performance of the drum kit.
Chapter 6 Conclusion

6.2 Future Work

Few improvements can be done to improve this project. Firstly, modifying the circuit design to prevent noises produced from the piezo and power loss that will affect the performance of the drum kit. Secondly, circuit components such as piezo and wires with higher efficiency should be implemented in the circuit to maximize the performance of the drum kit. Lastly, since this project is developed because of its portable potential, a standalone drum module can be developed and connect to the circuit to make the drum kit more convenient to carry. In conclusion, through the finding of this project, future developers can have a reference to develop a more complex electronic drum kit.
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Bachelor of Computer Science (HONS)
Faculty of Information and Communication Technology (Kampar Campus), UTAR.
Project Overview
Drum is unquestionably one of the most significant musical instrument in the world. But drum kit is well known with its low portability and high cost which discouraged people to purchase it. Fortunately, technology now allows people to make their own drum kit without spending a lot of money. Nowadays developing electronic projects is not a big issue anymore. This will actually help developer to save a lot of money because of no need to buy a native one. Therefore, this proposal will present on how to incorporate raw materials, microcontroller, piezoelectric sensors and software into a fine, portable drum kits.

Problem Statement
i. Big size and heavy weight make the drum kit having extremely low portability
ii. Drum kits are expensive and may not affordable by amateur drummer.
iii. Uncontrollable volume make practicing difficult without sound-proving facilities.

Project Objective
i. Design a portable drum kit that is easy to build and keep, velocity sensitive, in addition not occupying large spaces
ii. Develop the drum kit according to the model and establish connection between the drum kit and DAW through sensors to make the drum kit playable

Conclusion
Despite the bad characteristics of a native drum kit, modern technology allows people to develop their own electronic drum kit. In this project, developing a MIDI electronic drum kit using piezoelectric sensor is not that difficult to implement and the cost of the materials to build the circuit is definitely lower than purchasing a drum kit. Through the finding of this project, future developers can have a reference to develop a better, more complex electronic drum kit.

Result
The drum pads are tested from two perspective, velocity sensitivity and polyphonic playback. The volume of the drum sound produced successfully varied according to force exerted on the pads and the drum pads are supporting polyphonic playback as well.
Design and Development of Velocity Sensitive MIDI Electronic Drum Kit using Piezoelectric Sensors

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