DE-41 (MTS) Muaaz, Hafiz Jawad, Jawad Shah,

COMMERCIAL PIEZOELECTRIC BUZZER, DESIGN AND MANUFACTURING

COLLEGE OF
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COLLEGE OF ELECTRICAL AND MECHANICAL ENGINEERING

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PROJECT REPORT

TITLE HERE

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Sponsoring DS:
Dr Hamid Jabbar
LE Hafiz Umar Aslam

Submitted By:
Muaaz ul Hassan
Hafiz Muhammad Jawad
Syed Jawad Ali Shah

DECLARATION

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ACKNOWLEDGEMENTS

Alhamdulillah, our project has been successfully finished, and we are grateful to Allah for providing us with the courage and motivation to keep moving forward and for assisting us along the way. Thanks to our supervisor, and Dr. Hamid Jabbar, who helped us a lot, tremendously, on every single issue, their help and guidance became a source of strong determination for us. We also want to express our gratitude to our parents and friends because without their unwavering encouragement and support, we might not have been able to finish our project. We will always be grateful to them for the extraordinary part they played in our journey. We accomplished more than we could have imagined thanks to their unwavering support, and when we had lost all hope for ourselves, they gave us fresh hope.

ABSTRACT

A piezoelectric buzzer is a type of sound-producing device that utilizes the piezoelectric effect to generate sound waves. The piezoelectric effect is a phenomenon in which certain materials generate an electric charge in response to applied mechanical stress or pressure.

Piezoelectric buzzers are made up of a housing, a diaphragm, and a piezoelectric element. The diaphragm vibrates when an electrical voltage is supplied to the piezoelectric element, causing it to physically deform and produce sound waves. By altering the voltage and the physical characteristics of the piezoelectric element and diaphragm, the frequency and amplitude of the sound wave can be changed.

Due to its small size, low power consumption, and great durability, piezoelectric buzzers are frequently employed in electronic devices like alarms, timers, and electronic toys. Their dependability and quick response times are crucial in the automotive and medical device industries.

The physical characteristics of the piezoelectric element and diaphragm determine the frequency range at which piezoelectric buzzers are normally intended to operate. They can create audible sound waves between 20Hz and 20kHz as well as ultrasonic waves over 20kHz.

In conclusion, piezoelectric buzzers are devices that produce sound by using the piezoelectric phenomenon to create sound waves. Due to their small size, low power consumption, and high durability, they are frequently used in electronic devices. They can also produce sound waves in a specific frequency range depending on the physical characteristics of the piezoelectric element and diaphragm.

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LIST OF SYMBOLS

DB decibel

PCB Printed circuit board

RF Resonance frequency

T4 Fast Switching Diode

ABS Acrylonitrile Butadiene styrene

PP Polypropylene

MS Mild steel

L6 NPN Transistor

Chapter 1 – INTRODUCTION

1.1 Introduction

The frequency and volume of a piezo buzzer, an electromechanical component, can be altered by changing the voltage applied to it. It can generate pulse-like noises when a specific voltage is applied. Because a control circuit may change its frequency, it is especially well suited for usage in digital electronics, computers, and alarm systems. Voltage and volume controls on the piezo buzzer allow for precise sound control and more practical usage. Additionally, it makes clear, persistent voices that sound like pulses. The benefits of a piezo buzzer include stronger sound effects, more straightforward sound control, and precise frequency and loudness control. It is more practical than other buzzers because to its smaller size, and it is frequently used in goods from the automotive, communication, home appliance, security, and other industries for applications like alarms and message alerts [4].

1.2 Problem Statement

Piezoelectric buzzers' commercial design and production encounter several difficulties when it comes to maximizing sound output, assuring reliable performance, and satisfying market needs for low-cost, dependable devices. Existing designs frequently have issues with frequency response, sound quality, and production scalability. The creation of high-performance piezoelectric buzzers is further hampered by the absence of thorough guidelines and standardized production practices.

In terms of optimizing sound output, maintaining consistent performance, and satisfying market demands for affordable and dependable goods, the commercial design and manufacturing of piezoelectric buzzers faces several obstacles. The sound quality, frequency response, and manufacturing scalability of existing designs frequently show limitations. The creation of high-performance piezoelectric buzzers is also complicated by the absence of detailed instructions and standardized practices for the design and production process.

1.3 Solution

The frequency response and sound quality of piezoelectric buzzers should be improved, and this should be the main emphasis of future research and development. Advanced methods for material selection and design optimization can help with this. Exploring novel design configurations and making investments in the creation of new materials with improved piezoelectric capabilities can help to increase sound production and boost performance. The creation of standards and best practices for the design and manufacture of high-performance piezoelectric buzzers can be facilitated through cooperation amongst industry players, including manufacturers, researchers, and regulatory agencies. This joint effort can contribute to addressing the existing dearth of detailed instructions and offer a guide for manufacturers to use, assuring the production of trustworthy and affordable products.

1.4 Scope

Electronics and consumer goods are the main fields in which piezoelectric buzzers are used. They are frequently employed as audio indicators or alarms in gadgets including wearable technology, smartphones, tablets, computers, and household appliances. They are perfect for informing users of notifications, alarms, and other significant events due to their small size, low power consumption, and capacity to create high-pitched sounds.

1.5 Deliverables

Following are the deliverables of commercial piezoelectric buzzer, design and manufacturing:

- To provide a reliable and improved design for a piezoelectric buzzer.
- To provide improved sound output for a piezoelectric buzzer.
- A wider frequency ranges.
- Increased dependability.

1.6 Structure

The structure of the final year project report is:

- Chapter-2 Mainly deals with background and literature review including different existing models of buzzers.
- Chapter-3 Includes the methodology we adopted to design and manufacture our project and explains how the project is different from existing products.

- Chapter-4 Deals with the results of working projects at different stages.
- Chapter-6 Consists of concluding the report and exploring future possibilities and directions in which the project can be taken.

Chapter 2 – BACKGROUND AND LITERATURE REVIEW

2.1 Background

An inversion of the piezoelectricity principle, which Jacques and Pierre Curie discovered back in 1880, led to the discovery of the use of the piezo ceramic buzzer [1]. They discovered that certain materials could produce electricity when mechanical pressure was applied to them, and the opposite was also true. Therefore, the piezo buzzer element—often made of man-made piezo ceramic material—stretches and compresses in step with the frequency of the current when certain piezoelectric materials are exposed to an alternating field of electricity. It consequently makes an audible sound.

2.2 Existing Models of Buzzer

Different models of buzzer have been developed over the years. Some of them are given below:

2.2.1 Magnetic Buzzer

A ferromagnetic disc that is fastened to a pole is present in a magnetic buzzer. The disc is kept in a resting position by magnets that are positioned all around the pole [2]. Underneath the ferromagnetic disc is a coil that functions as an electromagnet. The disc is drawn to the coil when current is applied to it. The disc returns to its resting position when there is no current flowing through the coil. The disc's vibrations are controlled by a weight above it. The electromagnetic field produced by the coil oscillates when an oscillating signal is applied to it, which causes vibrations in the ferromagnetic disc. In this manner, the magnetic buzzer generates sound at the same frequency as the supplied oscillating signal. There are transducer and indicator options for magnetic buzzers. The working voltage range for magnetic buzzers is limited to 1V to 16V [2]. These buzzers have modest sound pressure levels and produce lower-rated frequencies. When compared to piezo buzzers, these consume a little more current. Their maximum 100 mA current draw is possible. These buzzers are typically utilized in high-end consumer applications and have a compact footprint.

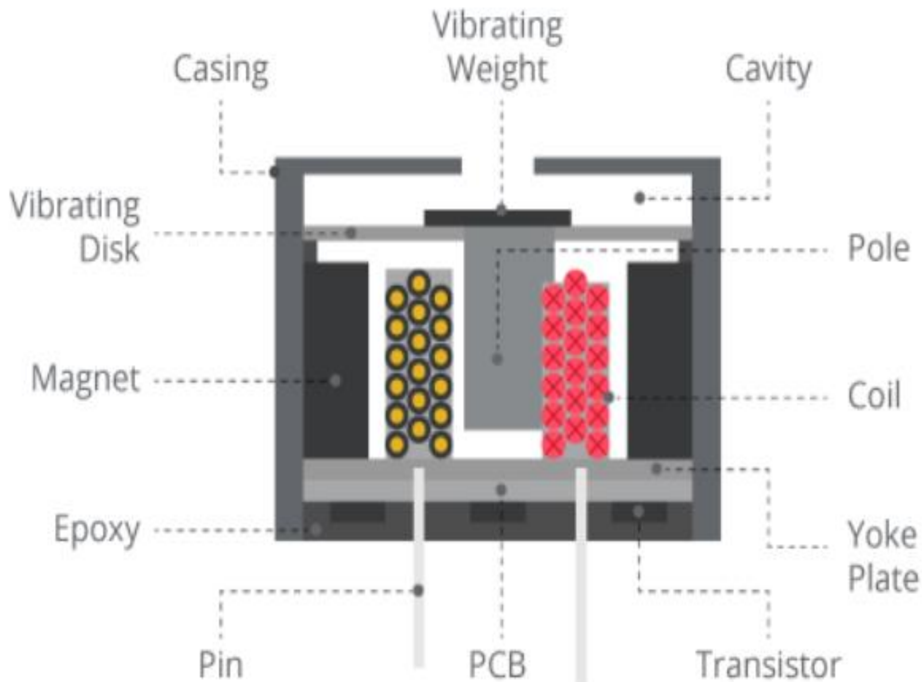


Figure 1 Construction of Magnetic Buzzer

2.2.1.1 Specification

Rated Voltage (Vo-p)	3.0
Operating Voltage (Vo-p)	2~4
Rated Current (mA)	MAX.80
Sound Output at 10cm (dBA)	MIN.6
Coil Resistance (Ω)	15±2
Resonant Frequency (Hz)	2731
Housing material	ABS
Weight (g)	0.9

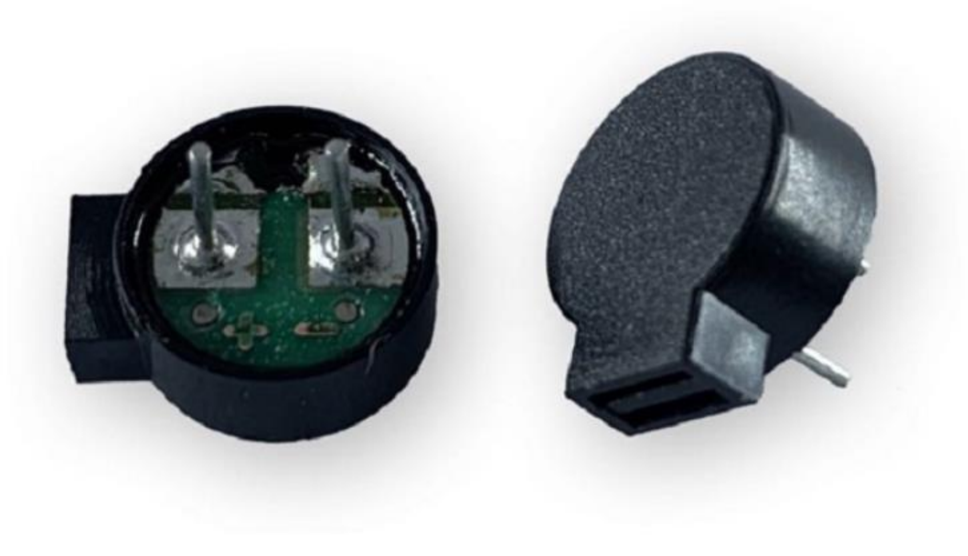


Figure 2 Overview of the passive magnetic buzzer[5]

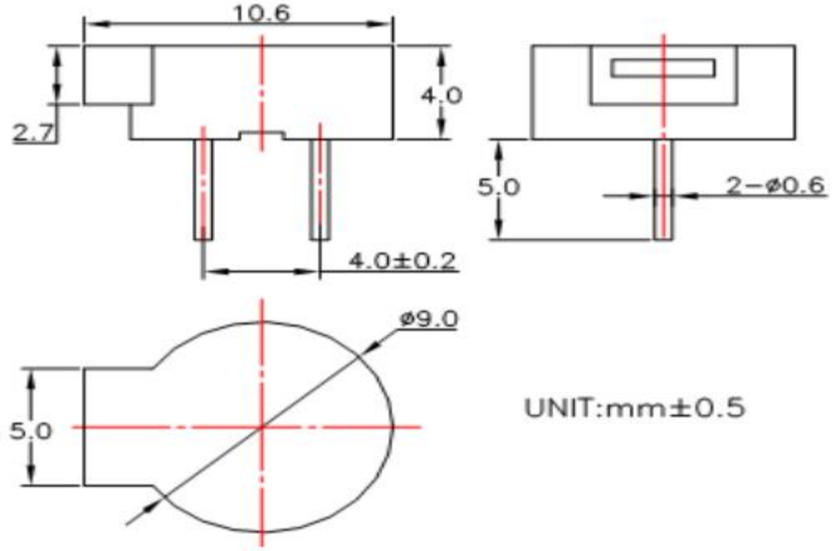


Figure 3Dimension of magnetic buzzer [5]

2.2.2 Piezoelectric Buzzer

The piezoelectric effect is the underlying theory behind how a piezoelectric buzzer works. A piezoelectric element is the primary part of a piezoelectric buzzer. The element is made up of a metal plate and a piezoelectric ceramic. The metal plate and piezoelectric disc are joined by an adhesive. There are electrodes attached to the piezo ceramic Disc [3].

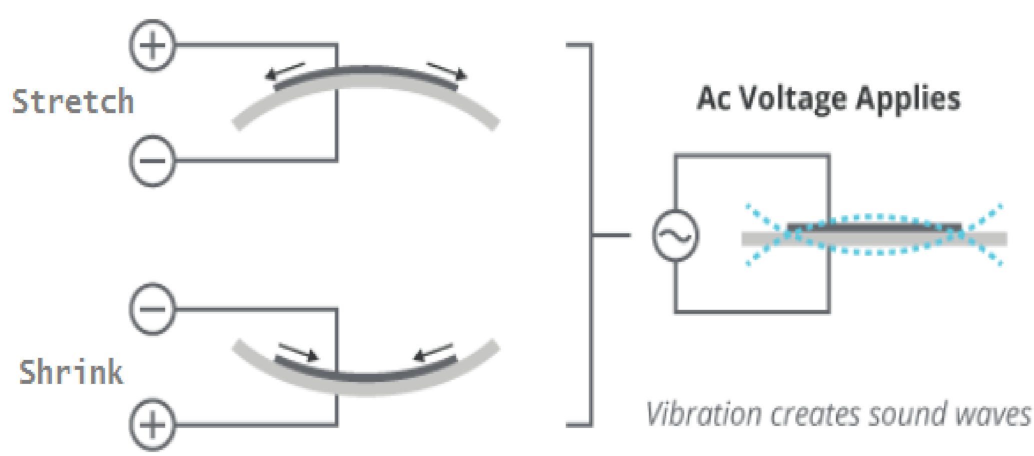


Figure 4Working principle of piezoelectric buzzer [7]

When an alternating current is given to the piezoelectric disc, it expands and contracts in opposite directions. This causes the piezoelectric element to vibrate, which in turn produces sound at a specific frequency or range of frequencies. An oscillator circuit provides alternating current to the piezoelectric device. The oscillator circuit is integrated into indicator-type piezo buzzers to produce a fixed frequency or range of frequencies. Piezo buzzers of the transducer kind need an external oscillator circuit. Typically, this oscillator circuit produces square waves.

A feedback line is seen on a lot of piezo buzzers. The piezoelectric element is split into two electrically independent portions in these buzzers. A feedback voltage is created when the main piezo element is triggered and squeezes the feedback component [3]. Typically, a transistor/OP-AMP circuit receives the feedback signal, which blocks or amplifies the current supply to the piezoelectric element.

The operational voltage of piezo buzzers ranges from 3V to 250V. Most piezo buzzers utilized in electronic circuits operate between 3V and 12V. High sound pressure levels are present in these buzzers. They consume very little current. The piezo buzzer's current consumption is lower the higher its frequency or tone. Current consumption for buzzers used in electronic applications can be as low as 30 mA. Piezo buzzers are recommended for usage in cost-concerned electronic applications because of their wide footprint.

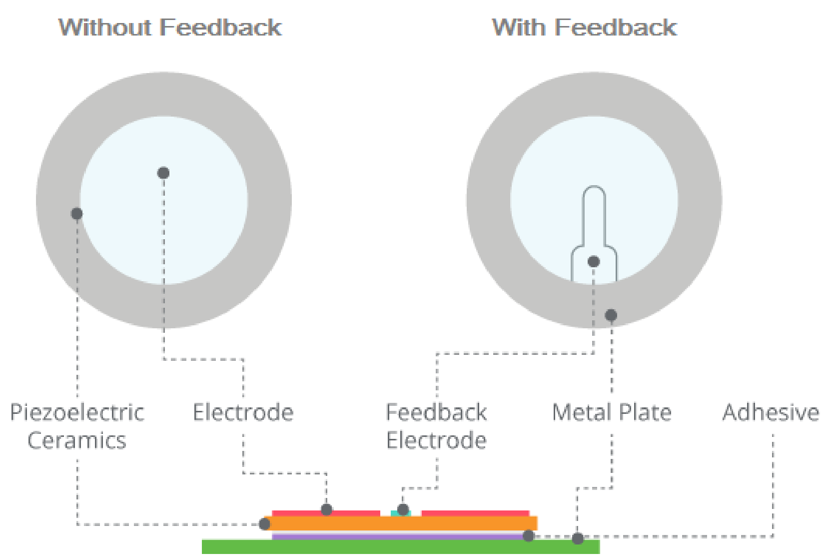


Figure 5Construction of piezoelectric buzzer[7]

2.2.3 Buzzer as transducer vs. indicator

Buzzers and beepers are made to function in electronic circuits as either a transducer or an indication. Buzzers that are made to function as transducers lack an internal driving circuit. Such buzzers need a square wave input to function when they are interfaced in a circuit. The buzzer requires an external driving circuit to supply it with square wave input. Transducer buzzers have the advantage of being driven to produce various frequencies depending on the application's needs. However, this makes the design-in more complex and expressly calls for creating an external buzzer driving circuit.

The drive circuit for the buzzers intended as indicators is already there and produces a fixed frequency or tone. Such buzzers can be activated with just a source current. A simple DC voltage can be used to drive the indicator buzzers. The digital I/O of a controller or computer, with or without supporting hardware, can frequently be used to activate these buzzers. Most buzzers used are of this sort. They are simple and convenient to operate because they frequently do not need any complicated external equipment [8].

Constant tones and slow/fast pulse noises can be produced by indicator and transducer buzzers, respectively. A transducer buzzer requires a continuous fixed frequency square wave to produce a constant tone, but an indication buzzer requires a constant DC voltage. A transducer buzzer needs to be supplied with square wave pulses of a defined frequency to produce a slow/fast pulse sound. In contrast, indication buzzers must be turned on and off alternately, much like when using a PWM signal.

The only way to make high/low tones, siren sounds, or chimes is using a transducer buzzer. By quickly alternating a square wave signal to a transducer buzzer between two frequencies, high and low tones can be produced. By frequently escalating square wave frequencies to a transducer buzzer from low to high, a siren-like sound can be created. A single slow cycle of alternating high and low square wave frequencies can be applied to a transducer buzzer to create the sound of a chime (like a doorbell) [16].

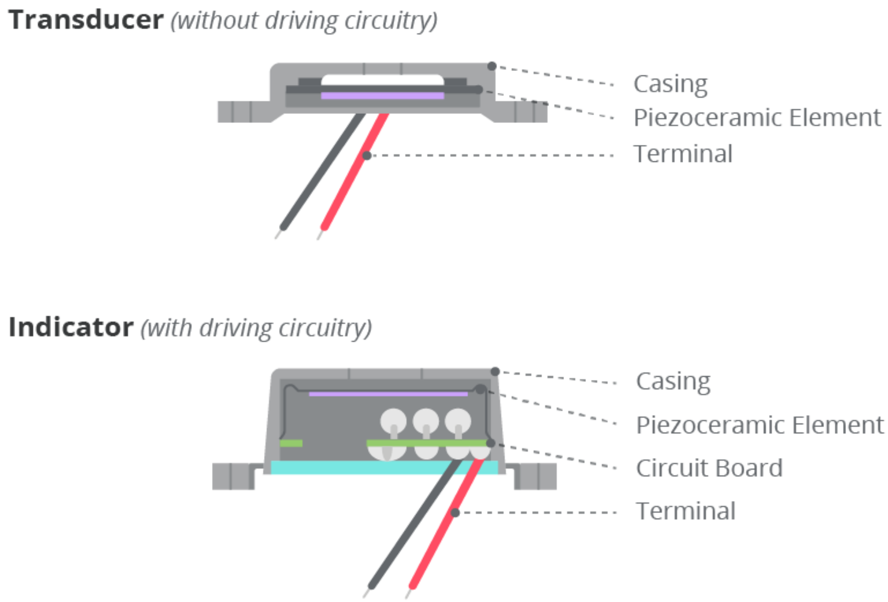


Figure 6 CUI Devices [9]

Chapter 3 – METHODOLOGY

3.1 Overview

Selecting an appropriate piezoelectric material, usually a crystal or ceramic having piezoelectric capabilities, is the first stage. Quartz, lead zirconate titanate (PZT), and barium titanate are frequently utilized substances.

Sandwiched between two metal plates or electrodes is the piezoelectric material of choice. These electrodes serve to distribute the electrical field uniformly and also offer electrical connections to the piezoelectric material [11].

The electrodes get an alternating current (AC) signal by attaching the buzzer to an electronic circuit, which is the most common method. Mechanical vibrations are produced as a result of the piezoelectric material's quick expansion and contraction in response to the AC signal.

A certain frequency of mechanical vibrations is produced as the piezoelectric material flexes in response to the electrical input.

The surrounding air is subjected to mechanical vibrations caused by the piezoelectric material, which results in compression and rarefaction waves that travel as sound waves. The electrical signal delivered has a frequency that matches the frequency of the sound produced.

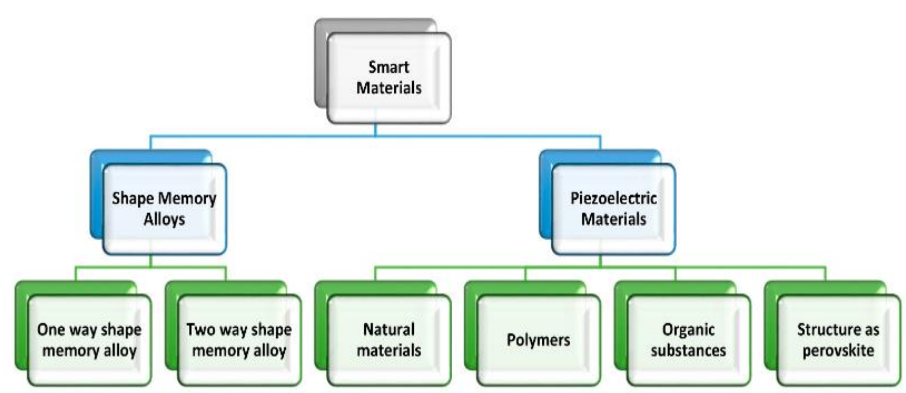


Figure 7Most common smart material [9]

3.2 Piezoelectric Materials

Piezoelectric materials are straightforward, inexpensive, lightweight, and controllable smart materials that can be used in structural actuation. Piezoelectric materials are renowned for their adaptability in a wide variety of applications in diverse structures; they can be easily shaped into numerous forms such as patches, thin films, cylinders, and fibers. The lead zirconate titanate (PZT), lead titanate (LT), sodium potassium niobate (SPN), lead magnesium niobate (PMN), and lead metal niobate (LMN) are the piezoelectric materials that are currently employed often in automotive and aerospace engineering. Due to its wide range of uses as a pyroelectric material, which is frequently utilized for the restoration of the structure, Lead Zirconate Titanate (PZT), one of the five types of piezoelectric material listed above, is one of the most frequently investigated ferroelectric materials [10].

Over the past century, a variety of piezoelectric materials have been developed, but the most widely used is PZT, a polycrystalline monolithic piezoelectric ceramic that is frequently doped with lanthanum or niobium to provide both soft and hard piezoelectric materials. Although PZT is the most common material, it includes lead, therefore finding other formulations requires a significant and ongoing research effort. A PNN PZT ceramic with a remarkable high coupling coefficient that is substantially greater than traditional PZT ceramics was recently produced by Gao et al. Piezoelectric ceramics are dense and brittle despite being affordable and providing strong coupling. PZT thin films have been developed to achieve flexibility on a tiny scale.

The production of dense and porous films with a range of solvent evaporation temperatures involved solvent casting and screen-printing techniques. By replica molding, patterned P(VDF-TrFE) microstructures were created utilizing prefabricated molds acquired using standard microfluidic processing technologies. Electrospray/electrospinning methods were used to produce microstructures with varying copolymer contents, from semi-spheres to fibers. According to the physicochemical and electrical characterization, the samples' copolymer phase, degradation and melting temperature, degree of crystallinity, dielectric constant, and piezoelectric coefficient are not significantly impacted by the various microstructures obtained using the various techniques. As a result, these structures have a lot of potential for use in a range of biotechnological applications, such as filtration, energy storage, sensors, and actuators

[14].

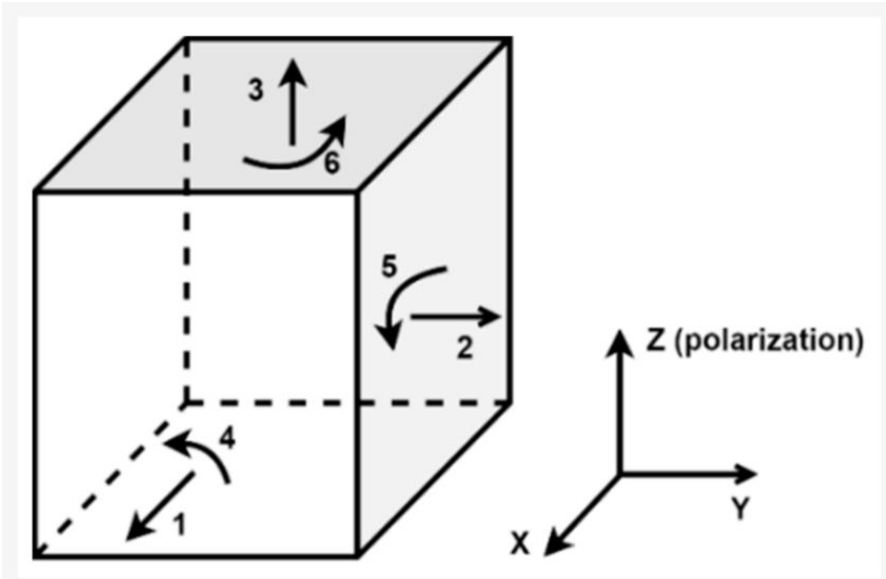


Figure 8 Structure of piezoelectric materials [10]

3.2.1 Types of piezoelectric material configurations

The following configurations of piezoelectric materials transducers are offered: cantilever beam (Figure 8), circular diaphragm (Figure 9), cymbal type (Figure 10) and stacked type (Figure 11).

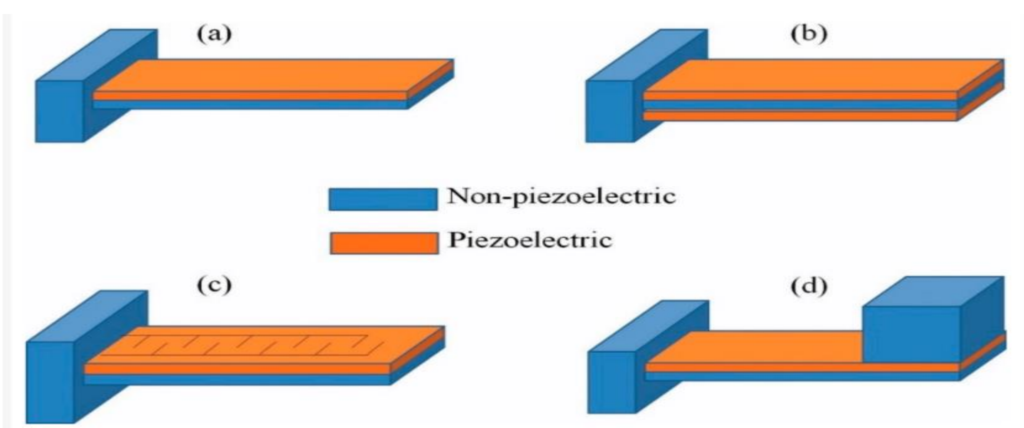


Figure 9 Cantilever beam transducer (a) Unimorph; (b) bimorph; (c) cantilever with interdigitated electrodes; (d) cantilever

with proof mass at its free end [10]

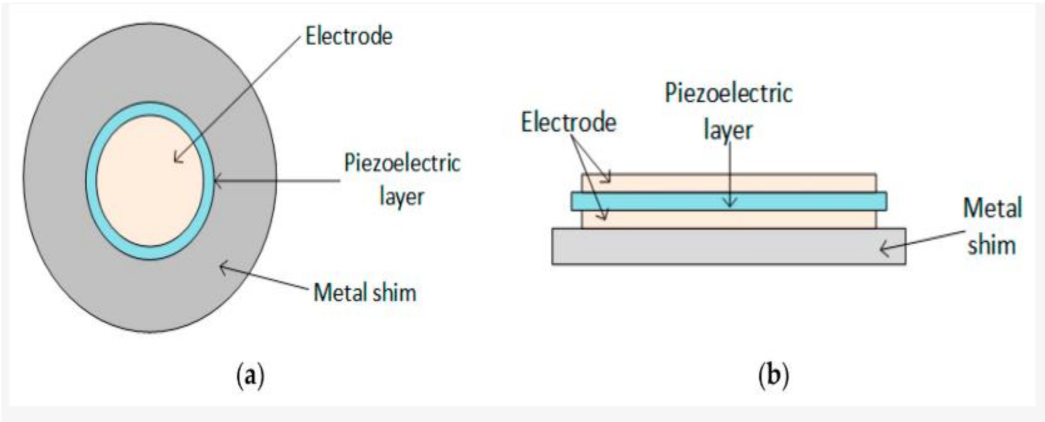


Figure 10 Circular diaphragm transducer: (a) Front view; (b) Side view [10]

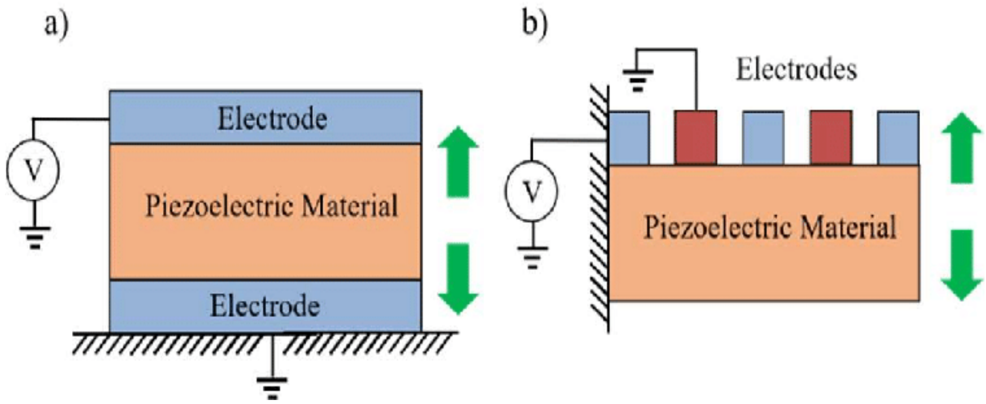


Figure 11 Piezo configuration[11]

3.3 Piezo disk

Both the monolayer and multilayer production processes are very similar. One layer of piezo ceramic material is compressed with a force of up to 1 MN to create a monolayer. Multilayers are created by depositing extremely thin layers of electrode material on top of very thin layers of piezo ceramic material that has been tape cast. The last 100 layers are laminated.

Figure 12 piezo disk

3.3.1 Manufacturing of Monolayer

The pressing of shaped bodies using spray-dried granular material is the fundamental method for creating piezo ceramic components. High-capacity presses with a compacting force of up to 1 MN are used to achieve this.

The shaped bodies are either produced with machining excesses that are eliminated to obtain the necessary precision, or they are built true to size while accounting for the sintering contraction [17].

Components (discs, plates, tubes, etc.) with a thickness of as little as 0.2 mm can be produced utilizing high-production inboard diamond sawing machinery.

3.3.2 Process Flow

The manufacturing flow diagram for Noliac's monolayer and multilayer piezo processing is displayed below. Below the diagram is a description of each step.

Figure 13 Process Flow [16]

3.3.3 Mixing

A certain particle size of piezo ceramic powder is combined with additives and solvents. Everything is accurately weighed in accordance with an established prescription.

3.3.4 Calcining

After mixing, the materials are calcined at 900–1000 °C to eliminate any remaining organics, water, or volatiles.

3.3.5 Milling

To create a very uniform suspension, the calcinated materials are milled. The viscosity of the suspension is evaluated before it is approved for tape casting or monolayer manufacture.

3.3.6 Granulation

By spray drying, the powder with binder is now granulated.

3.3.7 Pressing

Depending on the shape being produced, several pressing tools are used to press the piezo ceramic material.

3.3.8 Binder Burn Out

By gradually heating the green sections to a temperature of 500–700 oC, the organic compounds in the components, binder materials, additives, and leftover solvents are destroyed and evaporated off the ceramic.

3.3.9 Sintering

The fired pieces must be heated above 1000 °C for the piezo ceramic grains to expand and converge into a solid polycrystalline structure. With this method, a number of parameters must be optimized, including temperature ramp rates, holding times, and atmospheric conditions [10]. The components will shrink by around 15% during sintering [7].

3.3.10 Machining

Depending on the exact product, all goods are machined or tooled in some way either before or after termination. The abrasive employed in the slurry has a range of grain sizes, and this affects how harsh the surface is.

3.3.11 Termination

For multilayer items, external electrodes are used to connect the internal electrodes inside the component to the external electrodes outside the product. The exterior layer of monolayer goods offers external electrodes for polarization and connectivity.

The components are attached with a conductive electrode paste, commonly made of Ag, after being carefully cleaned. The most popular application method is screen printing. Depending on the material, the electrode paste is burned at a temperature between 600 and 800 °C, forming a conductive layer that adheres well to the ceramic surface.

3.3.12 Polarization

The "poling" process is the activation of the piezoelectric ceramic characteristics. The dipoles in the grains must be aligned in order to produce the piezoelectric action in the piezoelectric material. In the poling procedure, which involves applying a strong electrical field of 2-3 kV/mm to the exterior electrodes at high temperatures (100–150 °C) for a duration of 1–10 minutes, this alignment is achieved.

3.3.13 Final Inspection

The components and stacks will undergo a final examination after poling that combines a statistical method with level AQL 0.65 and 100% measurements, depending on client requirements or corporate policies. It is possible to test a variety of mechanical and electrical parameters, also in accordance with customer requirements. The main parameters for inspection are capacitance, dielectric loss, and mechanical strain level (stroke) [20].

3.3.14 Stacking

Element stacking is possible for both single monolayer and single multilayer elements. The components are joined using epoxy glue. Electrical insulation is applied using non-active piezo ceramic endplates. Usually, a bus wire is used to electrically connect the single stack.

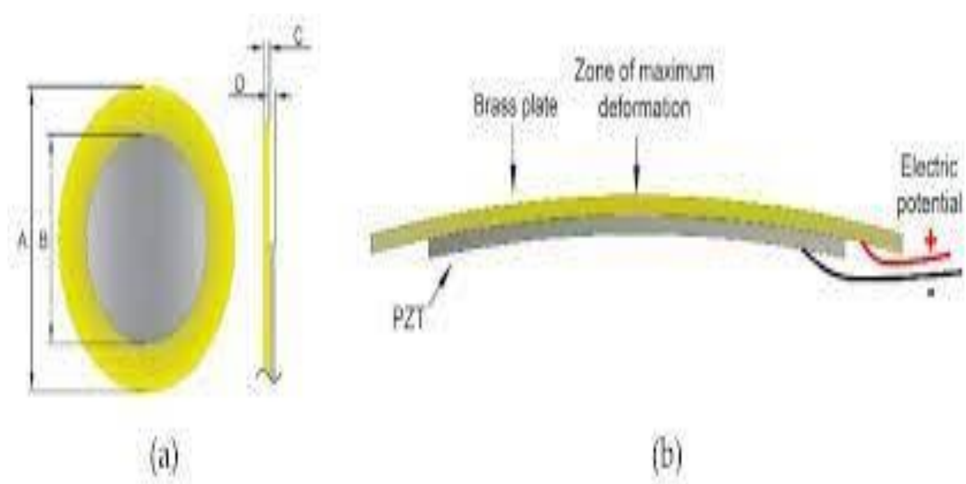


Figure 14 piezo disk component [5]

3.4 Electrical Design and Manufacturing

There are several approaches to design and manufacture the piezo electric buzzer some of which are given below.

3.4.1 Approaches of Design and Manufacturing

Preliminary Research: The design concepts of buzzer circuits have been the subject of extensive research. The functionality and performance of existing circuit designs and their constituent parts were investigated.

Project Requirements: The intended oscillation frequency range, operating voltage, and sound pressure level, among other details, were all designated as the buzzer circuit's special needs. Additional factors like space restrictions and necessary power usage were also considered.

Circuit Design Selection: A appropriate circuit topology was chosen after careful consideration of the project's requirements and objectives. The circuit topology was chosen after considering elements including circuit complexity, performance benefits, and restrictions.

Component Choosing: The circuit design and the desired performance parameters were taken into consideration when choosing the components. For the appropriate sound pressure level and frequency response, transducers like piezoelectric components or speakers were chosen. The oscillator and amplifier sections of the circuit were supported by other parts such as resistors, capacitors, and operational amplifiers [13].

Circuit Simulation and Analysis: To simulate and analyze the operation of the circuit design, circuit simulation software, such as LTspice or Multisim, was used. The intended oscillation frequency, voltage range, and overall functionality were confirmed by entering the selected parts and circuit topology. To attain the intended performance, adjustments and optimizations were done when needed.

Circuit Simulation and Inspection: To simulate and analyze the operation of the circuit design, circuit simulation software, such as LTspice or Multisim, was used. The intended oscillation frequency, voltage range, and overall functionality were confirmed by entering the selected parts and circuit topology. To attain the intended performance, adjustments and optimizations were done when needed.

Evaluation of Performance: The buzzer circuit's performance was thoroughly tested and evaluated. The project's needs and desired specifications were compared to key parameters that were measured. During the performance evaluation, variables including stability, dependability, and efficiency were considered. Observations were recorded, along with any improvements or modifications that were required.

3.4.2 With active circuit Internal Oscillator

The external oscillator circuit is essential to the buzzer's design because it generates the exact and constant oscillation frequency needed to provide the correct sound output. To identify and maintain the oscillation frequency with high accuracy and stability, timing devices like crystals or resonators are typically used in combination with auxiliary components like capacitors and resistors.

The external oscillator circuit may also include buffer or amplification stages to efficiently drive the transducers in addition to frequency regulation, assuring the buzzer's best performance and dependability. The oscillation signal is amplified by these stages, which also supply the transducer with enough power to drive it, producing a loud and clear sound output.

A reset resistor and an electronic switch, such as a field-effect transistor (FET) or bipolar junction transistor (BJT), are two components that are frequently used in the external oscillator circuit. Engineers may benefit from this drive circuit's simplicity and low cost because it just calls for a few cheap components. It is shown in the figure [16].

It's crucial to consider the drawbacks of this circuit design, though. It is important to consider how much power the reset resistor dissipates because this can impact the buzzer's overall effectiveness and efficiency. Additionally, this circuit arrangement is restricted to working with positive supply [9] voltages only since it depends on the supply voltage (+V) to operate the buzzer.

It's important to note that whether the buzzer terminal is connected to ground or the +V supply, the basic driver circuit and buzzer will work the same way. This adaptability makes it easier to construct the circuit since it enables various wire arrangements while keeping the buzzer's desired functionality and sound output.

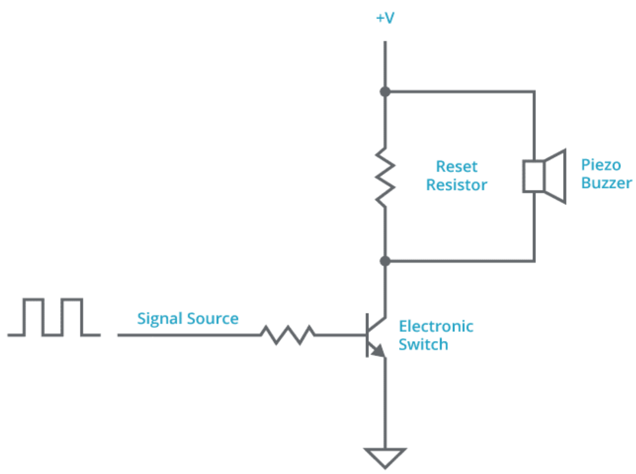


Figure 15 Internal circuit [5]

3.4.3 Circuit Designing

To achieve its functionality, the buzzer circuit design in the Kicad program makes use of several components. Two BJTs, or more technically, bipolar junction transistors, are used in the circuit. The first BJT is set up as a switch, managing the circuit's on-off function. It controls how much current flows through the circuit, giving the ability to precisely control how sound is produced.

Within the context of the circuit design, the second BJT acts as a buffer. It increases and maintains the oscillation frequency that the circuit produces. The transducer must be driven at this frequency to produce the required tone sound. An exact and dependable oscillation frequency is maintained by the buffer BJT, resulting in a dependable sound output.

Along with the BJTs, the circuit design includes resistors that are essential for regulating the circuit's current flow and voltage levels. By preserving the correct operating conditions, these resistors help the buzzer circuit operate steadily and effectively.

A quick-switching diode is also incorporated into the design. Within the circuit, this diode offers safety and effective switching capabilities. It helps to regulate the flow of current, stop undesirable oscillations, and guarantee smooth operation.

These parts may be used to create a buzzer with effective switching, precise frequency control, and dependable sound production. To satisfy the specified performance standards of the buzzer, the characteristics and values of the components are carefully chosen.

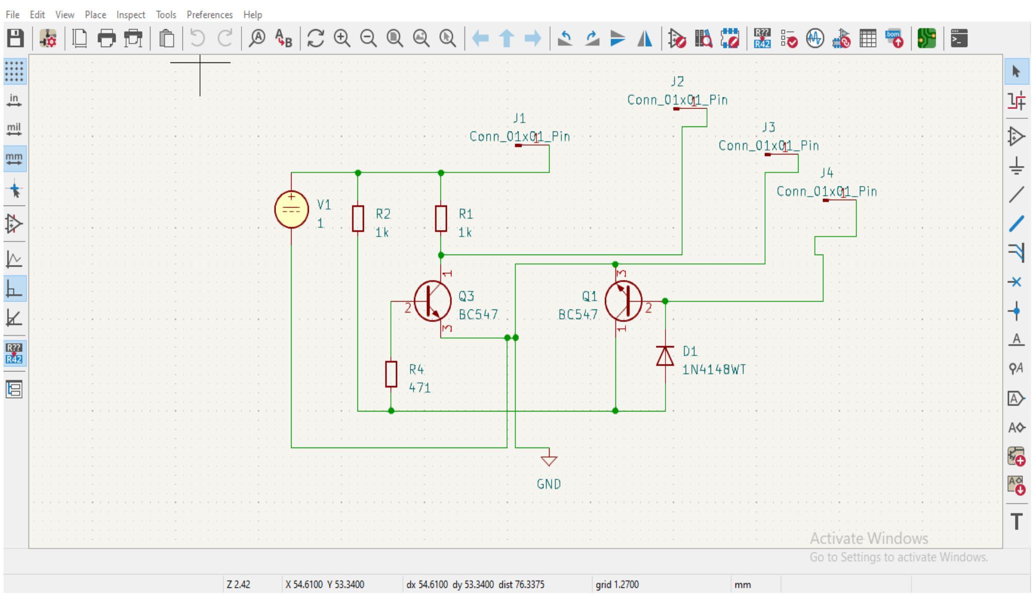


Figure 16 Circuit Layout

3.4.4 Components of the Circuit

For the buzzer circuit design to perform as intended, several components are included. The BJT (Bipolar Junction Transistor), more precisely the 2SC1623 transistor, is an essential component. Based on its characteristics and compatibility for the circuit's needs, this BJT was chosen. The 2SC1623 transistor has many functions depending on how it is set up and connected in the circuit, such as switching or amplifying. It makes it easier to regulate and manipulate current flow, which enables the circuit to work as planned.

The diode, namely the 1N484W diode, is yet another essential component. This diode is chosen because it has quick switching abilities that help the circuit run smoothly. The diode controls the flow of current to ensure that the circuit operates consistently and safeguards against reverse voltage. Its inclusion in the plan improves the buzzer circuit's overall performance and stability.

Resistors are fundamental components in the circuit design, serving to control the flow of current and voltage levels. The circuit incorporates two resistors with specific resistance values. One resistor has a value of 1K ohms, while the other resistor has a value of 471 ohms. These resistors are strategically placed within the circuit to regulate the current and voltage, ensuring that the buzzer operates within the desired parameters. By carefully selecting appropriate resistance values, the resistors contribute to the overall functionality and performance of the buzzer circuit.

For the buzzer to work as intended and perform at its best, these components must be carefully chosen and integrated into the circuit design. To guarantee that each component is compatible with the circuit's needs and to improve the buzzer circuit's overall operation, its unique qualities and attributes are taken into account.

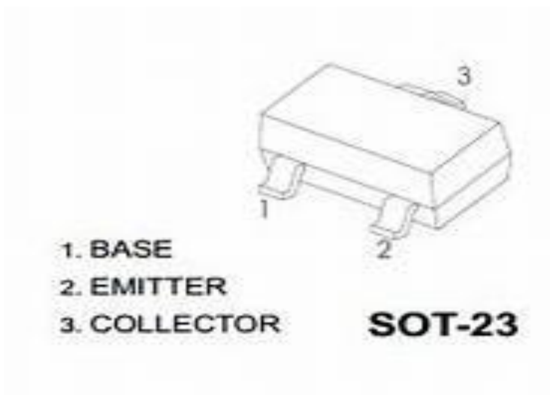


Figure 17 BJT: 2sc1623-L6 [13]

Figure 18 Fast Switching Diode[14]

3.4.5 Transient Analysis

The buzzer circuit's transient analysis was carried out using the LT spice program me, allowing for a thorough understanding of the circuit's behavior over time. We were able to learn a lot about the circuit's performance by modelling its dynamics and predicting how it would react to various inputs and circumstances.

In order to monitor the voltage and current waveforms within the circuit during transient events like the circuit turning on or going through abrupt changes, transient analysis was performed. The transient analysis gave a thorough insight of how the circuit responded and how its components functioned in actual-world circumstances by recreating these scenarios.

The assessment of various circuit parameters and properties was made possible via LTspice simulation. This involved measuring voltage levels, current flows, and various components' transient responses. The simulation findings offered useful information that assisted in comprehending the behavior of the circuit, spotting possible problems or inefficiencies, and improving the circuit design.

The transient analysis also assisted in optimizing or improving the circuit design by pointing out potential improvement areas. To attain the necessary performance and stability, it enabled for iterative alterations and adjustments to the circuit parameters, component values, or topology. The buzzer circuit was improved through several simulations and analytical iterations, resulting in the buzzer's ideal performance.

Overall, the transient analysis and application of LT spice revealed important details about the operation and behavior of the buzzer circuit. It was an effective tool for comprehending the circuit's transient reaction, assessing its properties, and optimizing the design.

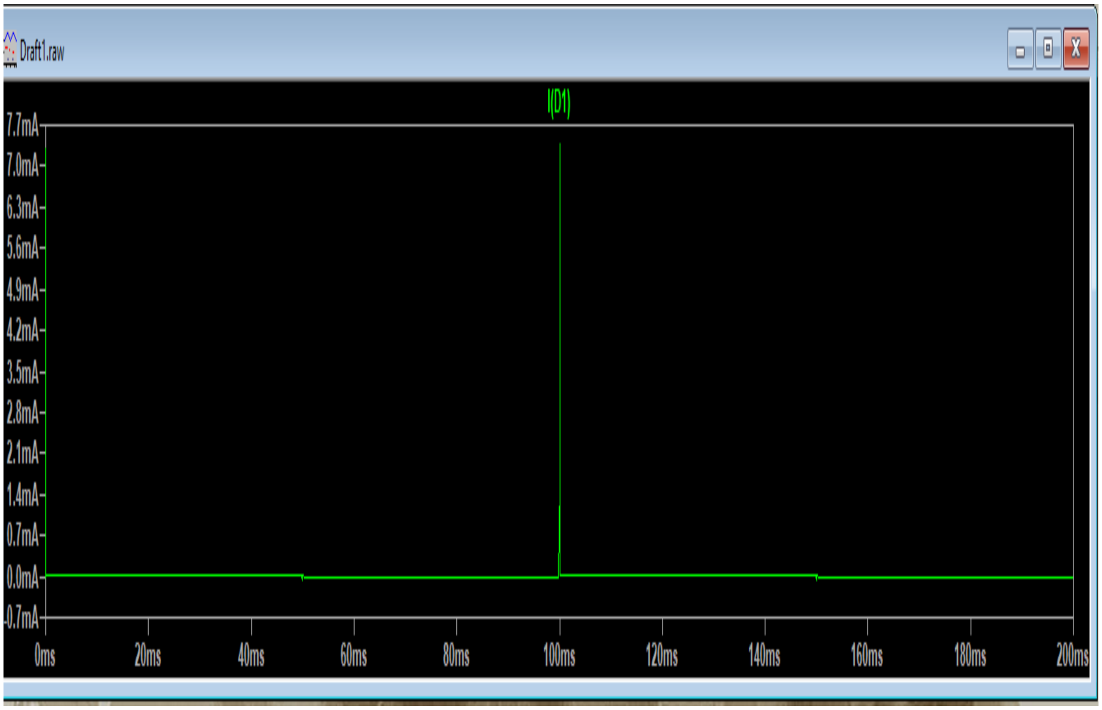


Figure 19 Current through diode

The graph above shows the current through the diode which is jerk of current to make the frequency visible on the output. It also helps in biasing the BJT1.

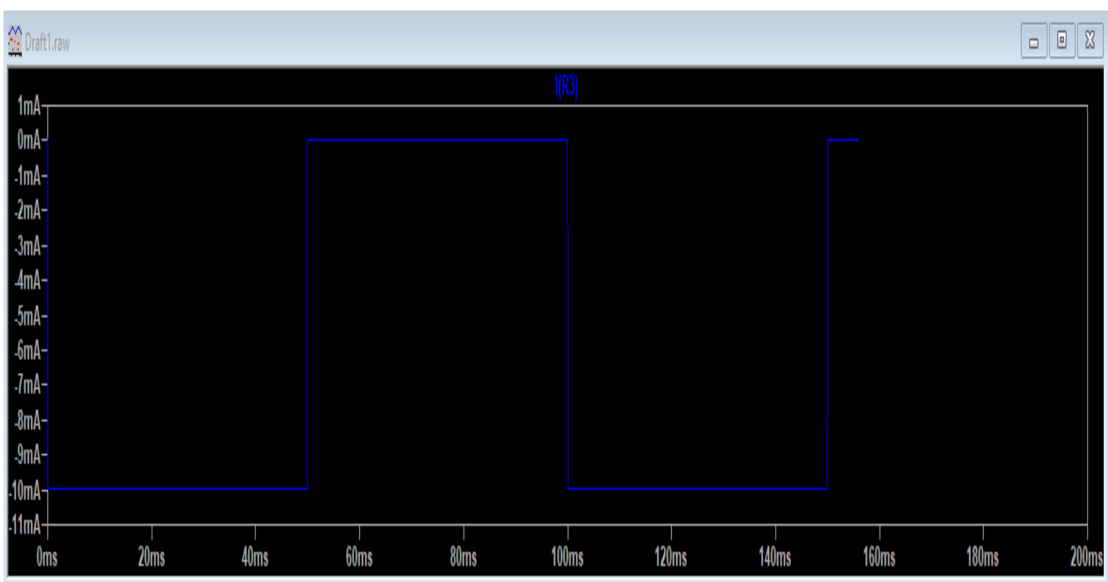


Figure 20 Current through R3

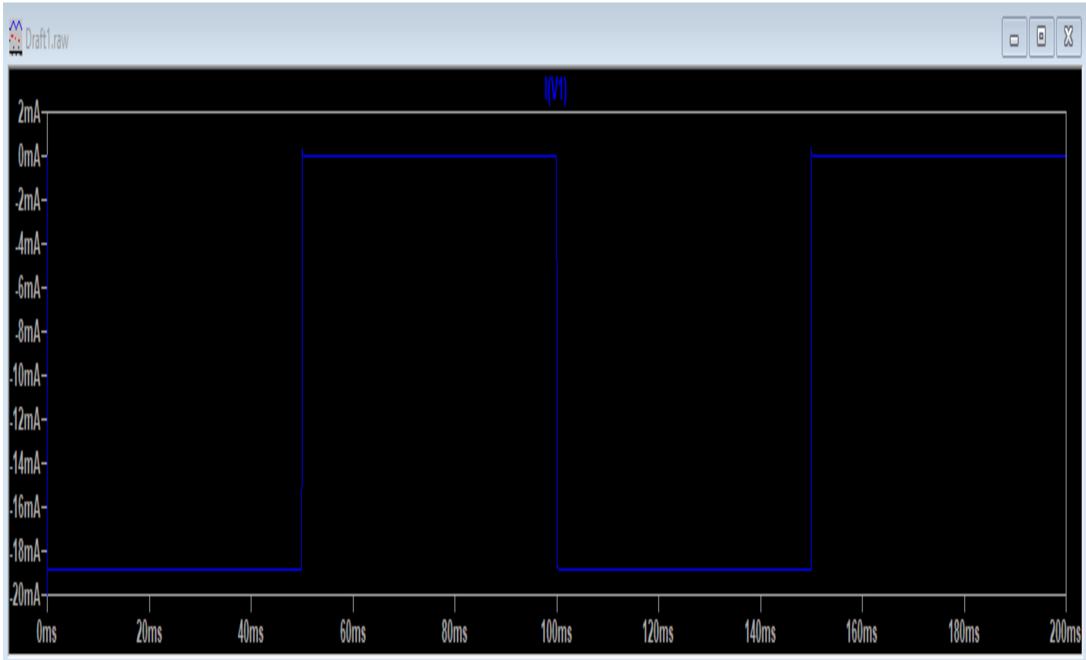


Figure 21 Input Current

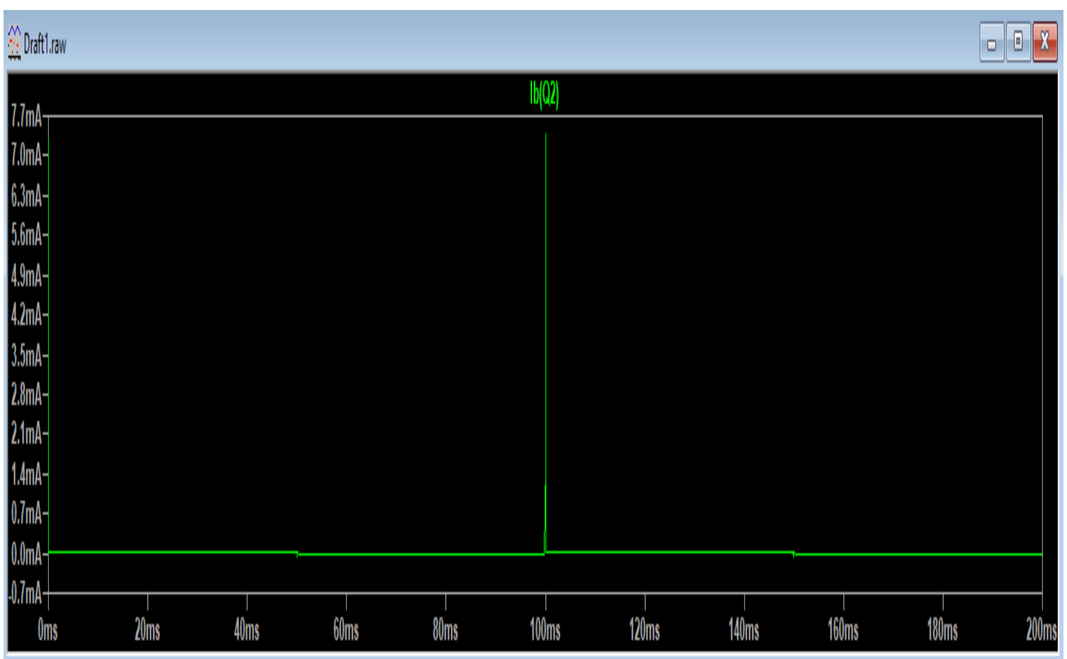


Figure 22 Current through Q2

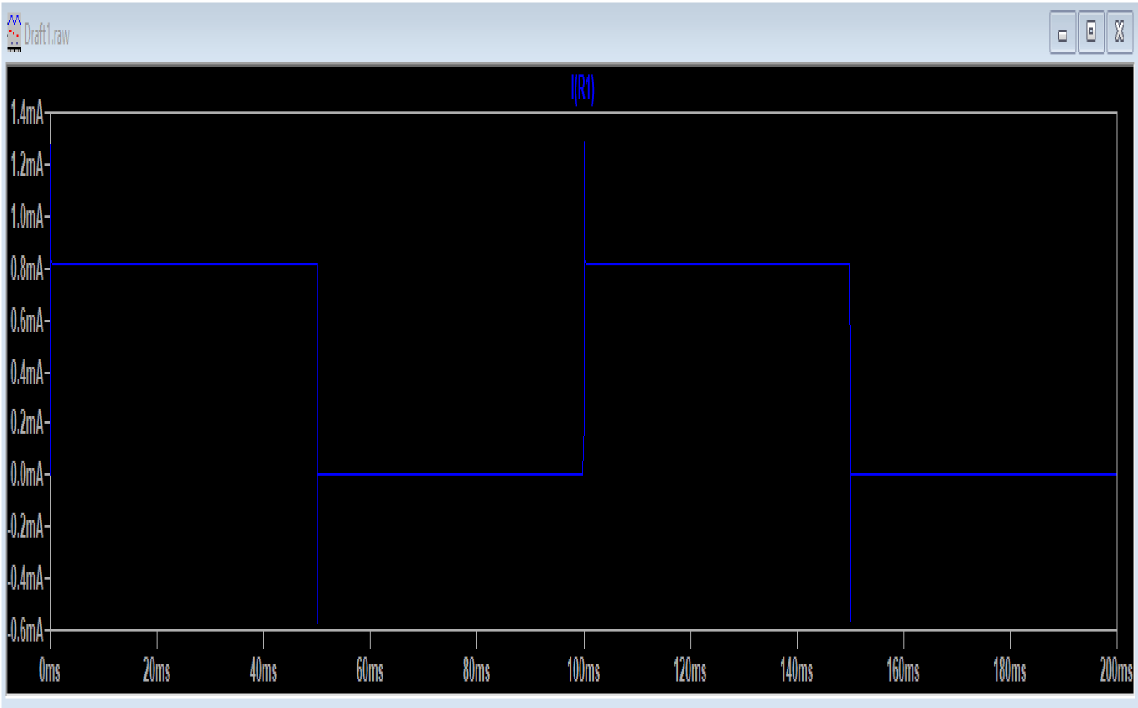


Figure 23 Current through R1

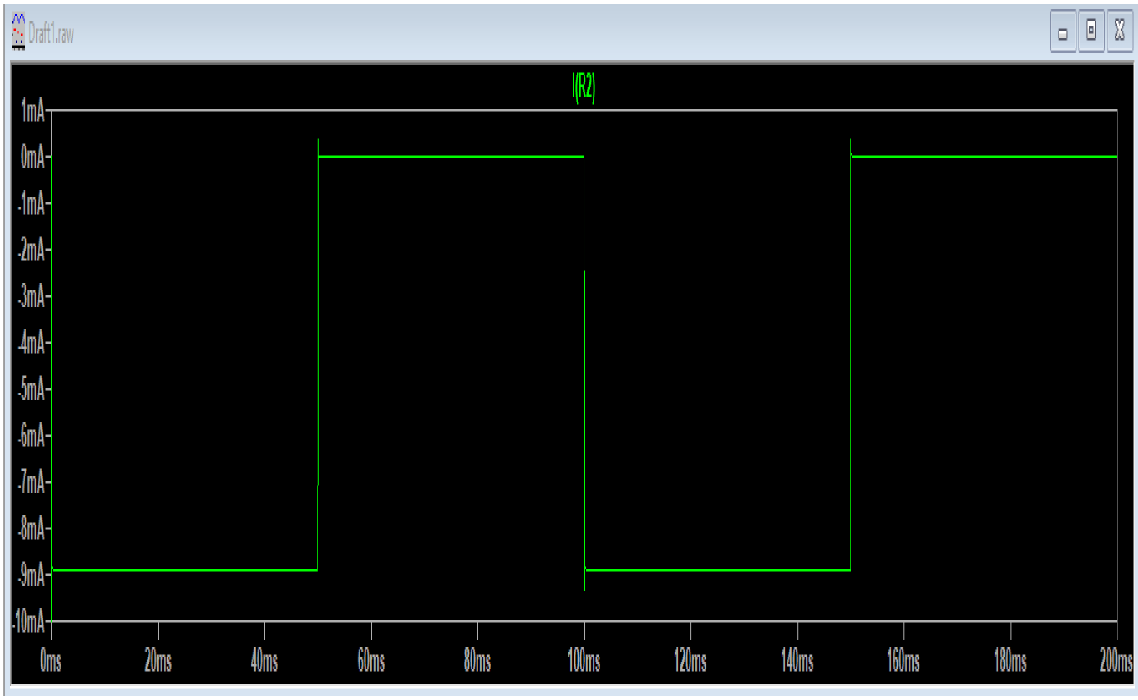


Figure 24 Current through R2

3.4.6 Testing The Circuit

As shown in the following figure, the circuit was successfully tested on a breadboard and revealed a frequency response that ranged from 3 kHz to 6 kHz. This frequency range shows that, in accordance with the stated design goals, the circuit successfully creates the expected oscillation within the designated frequency range.

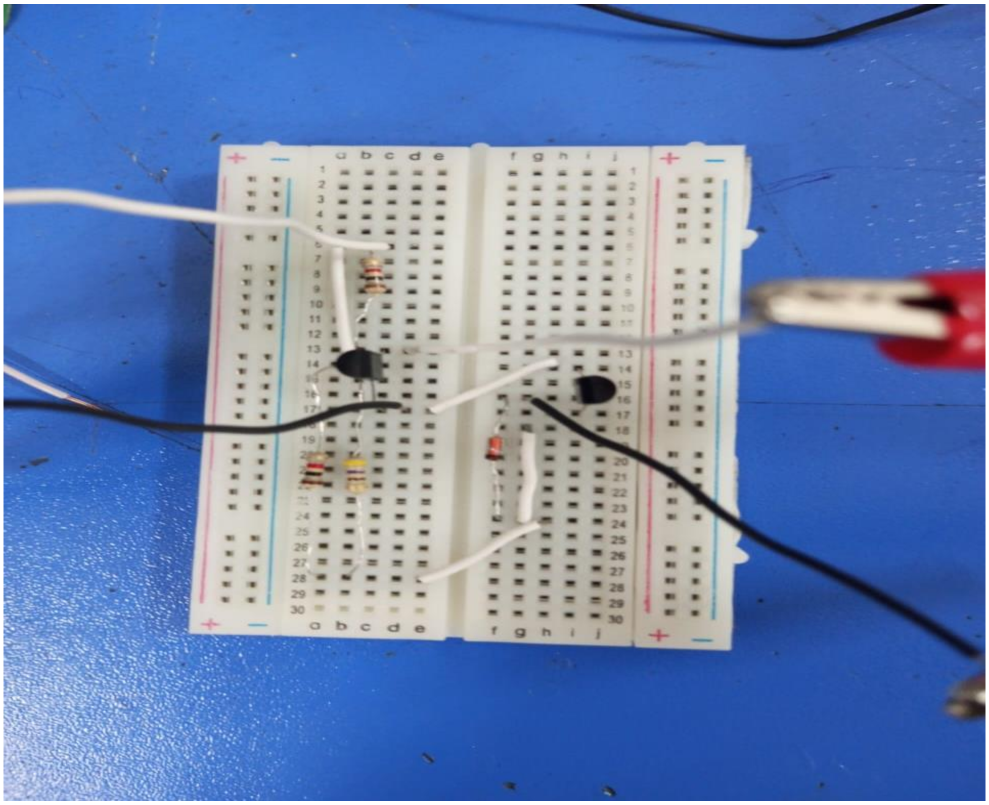


Figure 25 Circuit testing breadboard

3.4.7 Output of the Circuit

The output waveform showed a ripple effect with a certain frequency after the circuit had been tested on a breadboard, as shown in the accompanying figure. This ripple effect shows that the output signal has changes or fluctuations, which are often brought on by things like component tolerances, parasitic capacitances, or noise interference. The stability and efficiency of the circuit may be learned a lot by examining the ripple frequency and amplitude.

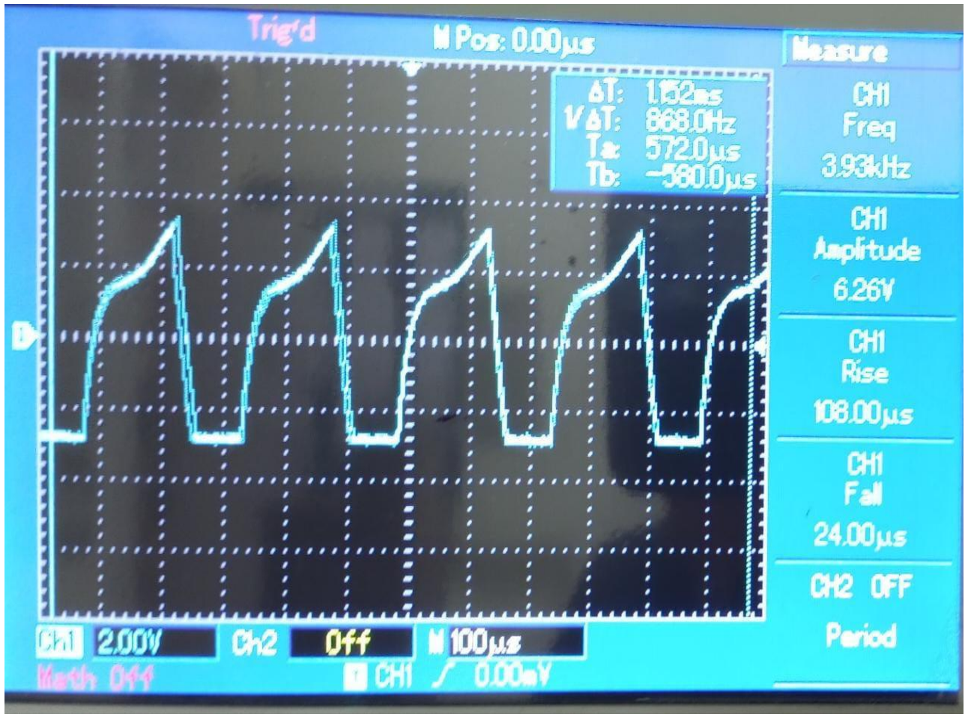


Figure 26 Output frequency response of circuit

3.4.8 PCB designing

The Kicad program was utilized to create the buzzer circuit's PCB in a successful manner, allowing for accurate and effective layout generation. The PCB design included the BJTs and diode, which are the main circuit components, along with the appropriate footprints.

The SOT23 footprint was designated for the BJTs. Small-signal transistors are frequently housed in the SOT23 package, which provides an efficient surface-mount option. The PCB design made use of this footprint to guarantee precise positioning and soldering of the BJTs onto the board, maximizing space utilization and streamlining the production process.

The diode was given the SOT123 footprint, a surface-mount package appropriate for diodes. To ensure effective integration into the circuit design, this footprint ensured appropriate alignment and soldering of the diode onto the PCB.

A tiny and efficient circuit architecture was made possible by using footprints for the BJTs and the diode. The PCB design used surface-mount packaging to maximize space usage, resulting in a small and efficient architecture. This small-footprint design not only decreases the PCB's overall size but also makes it easier to manufacture, allowing for mass manufacturing and integration into a variety of electronic devices.

In conclusion, the Kicad program was used to create a successful PCB design for the buzzer circuit that included the correct footprints for the BJTs and diode. The use of SOT23 and SOT123 surface-mount packages ensured precise placement, soldering, and reduced size, all of which contributed to a circuit layout that is effective and producible.

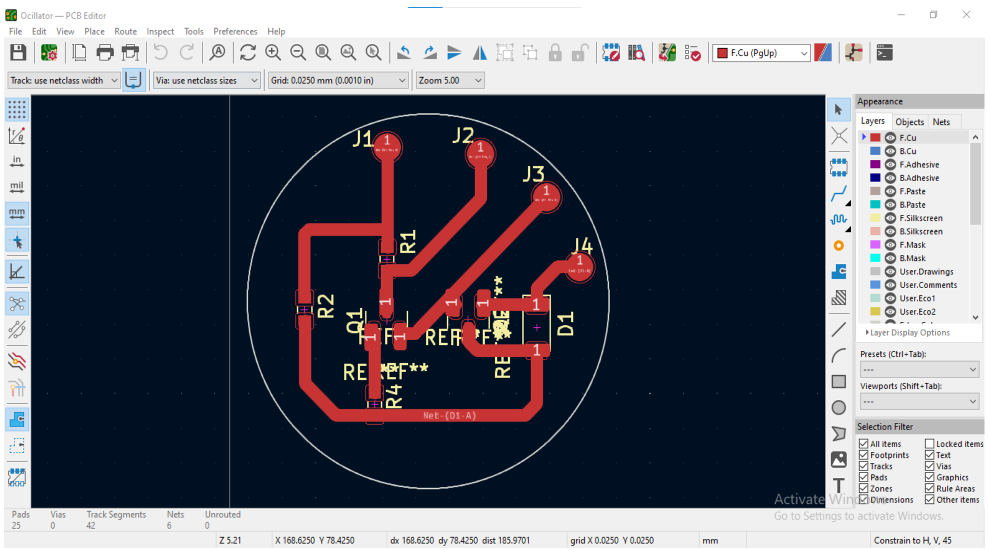


Figure 27 PCB layout of oscillator circuit

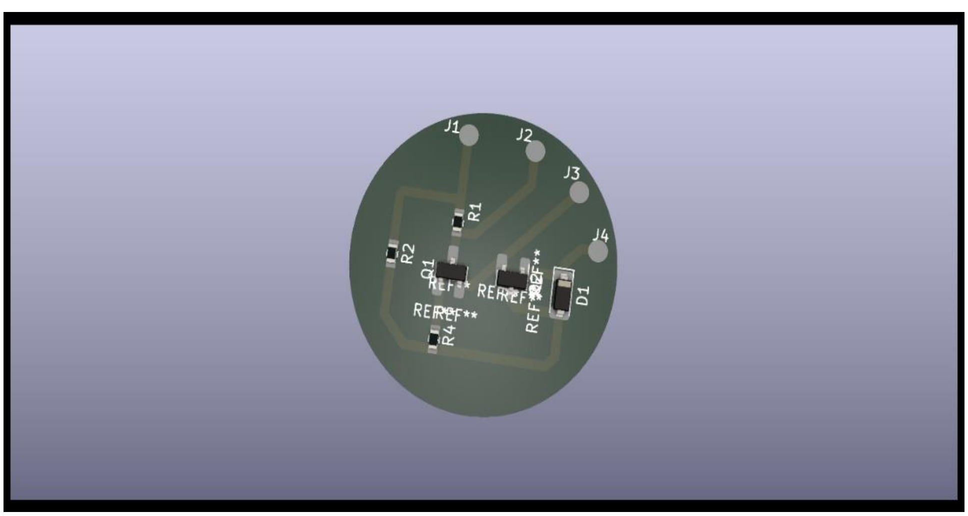


Figure 28 3D model of Oscillator circuit in KiCad

3.4.9 PCB Fabrication

Traditional methods including ironing and ferric chloride etching were used throughout the PCB fabrication process for the buzzer circuit. A copper-clad board was first prepared, then an etch-resistant ink or toner layer was applied to its surface. On the board's planned locations for circuit traces, this coating served as a protective mask.

The circuit design was then transferred or printed with an iron onto a transparency sheet. To accomplish perfect circuit placement, it was essential to make sure that the printed design was precisely aligned with the copper-clad board. The printed design on the transfer paper or transparency sheet was carefully positioned on the copper surface of the board.

The transfer procedure included pressure and heat. This included pressing down on the transparency sheet or transfer paper with a hot iron. The ink or toner was transferred from the paper or transparency onto the copper surface of the board because of the combination of heat and pressure. To make sure that the circuit layout was properly transferred, the ironing procedure was methodically carried out.

The board went through the etching process following the transfer. It was immersed in a ferric chloride solution that served as an etchant. The copper that was not covered by ink or toner progressively disintegrated in the ferric chloride solution, essentially etching away the undesirable copper. As a result, the required circuit architecture was defined by the circuit traces that remained on the circuit board.

To guarantee equal and controlled etching throughout the whole surface, the board was periodically shaken or lightly rocked. To get consistent and accurate circuit traces, this step was crucial.

After achieving the desired circuit traces, the board was carefully cleaned to get rid of any etchant residue. The etch-resistant ink or toner was removed from the board's surface using a suitable solvent, leaving behind clear and distinct circuit traces.

The finished PCB was then prepared for component soldering and assembly. The buzzer circuit's PCB was made using the conventional manufacturing methods of ironing and ferric chloride etching, which allowed for prototype and small-scale production.

Figure 29 Etched PCB's of Oscillator

3.5 Manufacturing of Mold

Mold Manufacturing Process Includes:

3.5.1 Mold Design

Make the most of the research findings to improve piezoelectric buzzer design and production. Apply iterative improvements based on the analysis of the data and the goals of the study. To find the ideal parameters and configurations that can improve the buzzer's performance, reliability, or efficiency, consider approaches like numerical modelling, computer-aided design (CAD), or optimization algorithms.

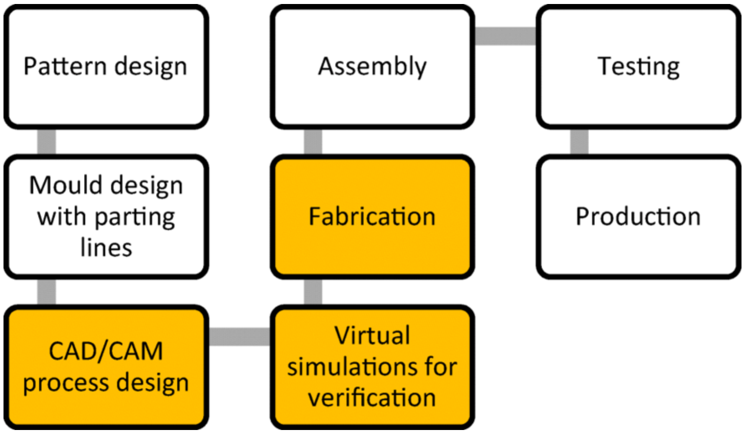


Figure 30 Mold Design and Fabrication Process

3.5.2 Designing

SolidWorks is a market-leading 3D CAD program that provides a wide range of features and capabilities, making it a top option for designing molds in a variety of sectors. SolidWorks offers an extensive collection of tools for mold design that let designers make complex and accurate mold designs quickly and accurately.

The parametric modelling capabilities of SolidWorks are one of its main advantages for mold design. By specifying and adjusting characteristics like size, angles, and features, designers may quickly generate 3D models of molds. This parametric method ensures flexibility throughout the design process by enabling quick and seamless revisions to the mold design as needed. Additionally, SolidWorks provides strong surfacing tools that are essential for mold design. Smooth and precise mold surfaces can be made by designers, resulting in excellent mold performance and effective part ejection. SolidWorks gives designers the tools they need to make molds with precise details and complex geometries thanks to features like fillets, chamfers, and curvature analysis.

SolidWorks also offers simulation and analysis tools that are crucial for mold designers. Design professionals can use the software to simulate mold filling, cooling, and part deformation to spot potential problems or improve mold design for better performance. Designers can ensure correct material distribution and reduce production problems by doing a mold flow study.

In sectors like automotive, consumer goods, and electronics where mold design is crucial, SolidWorks is commonly employed. SolidWorks offers the required tools and functions to design molds for plastic injection molding, die casting, or blow molding and produce molds that adhere to exacting design specifications and industry norms.

In conclusion, SolidWorks is an effective CAD program that provides a full range of tools for designing molds. Mold designers can build complex, accurate, and effective mold designs with the help of SolidWorks' parametric modelling capabilities, surface tools, and simulation features. Its vast application across numerous industries attests to its potency in satisfying the requirements of contemporary mold design, making it a crucial tool for experts in the field.

3.5.3 3-D Design of casing of buzzer

In this project we are designing two buzzers of different sizes, one is small and the second one is large. The dimensions of both the buzzers are different. The 3-D design of the casing of the buzzer is designed on solid works software. The phases of designing the buzzer's casing are following:

3.5.4 Dimensions

The dimensions of both buzzers are given below respectively, and all the dimensions are in millimeters.

3.5.5 Large Buzzer dimensions

The dimensions of buzzer that is bigger in size are given in the table below.

Externa diameter of the buzzer	42
Internal diameter of the buzzer	40
Width of the buzzer	18
Diameter of the support for piezo disk	29
Width of the central support	5 (from bottom)
Diameter of the support for placing circuit	40
Width of the circuit support	9 (from bottom)
Diameter of the holes for nuts	3.5
Distance between the center of both holes	50
Diameter of closing cap of buzzer	40
Thickness of the cap	2

Table 2 Dimensions of large buzzer(mm)

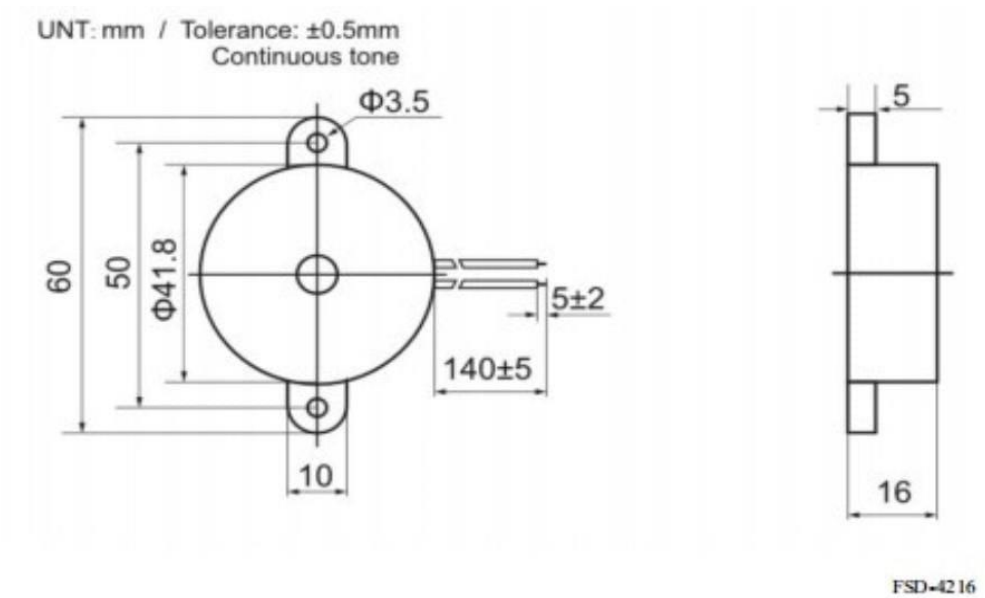


Figure 31 Dimensions(mm)

3.5.6 Small Buzzer dimensions

The dimensions of buzzer that is smaller in size are given in the table below.

Externa diameter of the buzzer	30
Internal diameter of the buzzer	28
Width of the buzzer	15
Diameter of the support for piezo disk	27
Width of the central support	3 (from bottom)
Diameter of the support for placing circuit	27.5
Width of the circuit support	12 (from bottom)
Diameter of the holes for nuts	3.5
Distance between the center of both holes	40
Diameter of closing cap of buzzer	28
Thickness of the cap	2

Table 3 Dimension (small buzzer)

3.5.7 Procedure of drawing the 3-D casing

- To create 3D drawing of a buzzer using SolidWorks software, the step-by-step procedure outlined below:
- Launch SolidWorks on your computer and to achieve precise dimensioning, set the units to millimeters.
- When designing the buzzer, open the "Sketch" tab and choose the "Front" plane, for example.
- To create a circle with a 42 mm diameter, use the "Circle" tool.
- To precisely set the diameter, use the "Smart Dimension" tool.
- To extrude the cylinder, click the "Features" tab and select "Extruded Boss/Base."
- To provide the cylinder volume and shape, enter the desired extrusion depth, such as 10 mm.
- Verify the extrusion and carry out the subsequent actions.
- Use different sketch tools, like lines, arcs, and circles, to add the buzzer design's crucial details.
- Consider components like mounting holes, decorative accents, or other unique design specifications.
- Use the "Smart Dimension" tool to make sure that every sketch entity is completely described and dimensioned.

Figure 32 3 D view of casing

To add or delete material as needed, use the "Extruded Boss/Base" or "Extruded Cut" features.

Use these features to make any additional necessary adjustments to the buzzer design, such as creating holes or slots.

Fillets and Chamfers:

By adding rounded edges or bevels with the "Fillet" or "Chamfer" tools, you can improve the design's aesthetics and functionality.

Apply fillets or chamfers to the buzzer's appropriate corners or edges.

Applying Materials and Appearance:

Give the 3D model the proper materials and appearances to create a realistic portrayal.

Use SolidWorks' "Appearances" and "Materials" tabs to make the required selections.

Review and Modification:

Review the 3D model carefully, looking for any mistakes, inconsistencies, or poor design choices.

Adjust dimensions, features, or aesthetics as necessary to maintain accuracy and the intended functionality.

Saving and Exporting:

Save the 3D drawing in the appropriate place on the computer.

Export the model in the preferred file format (such as STL or STEP) for later use in applications like 3D printing or integration with other design systems.

In conclusion the desired 3-D design of the casing of both buzzers is obtained and the different images of both buzzers are shown.

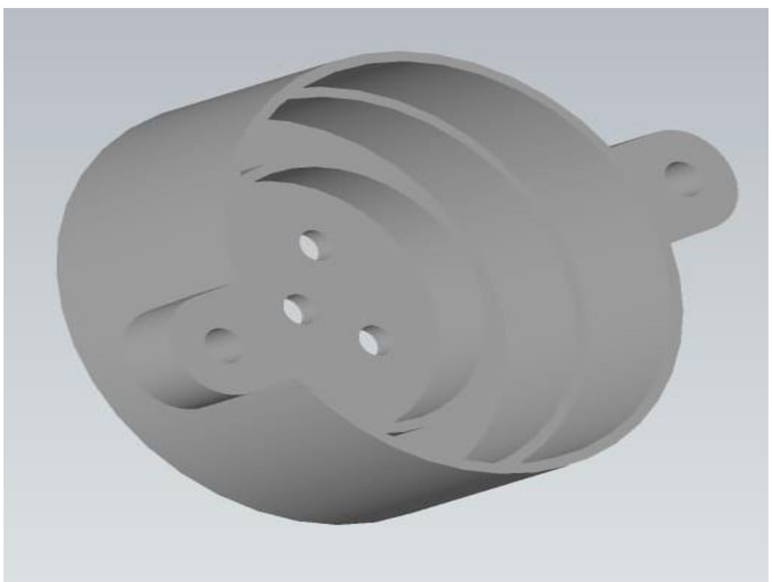


Figure 33 Buzzer Back View

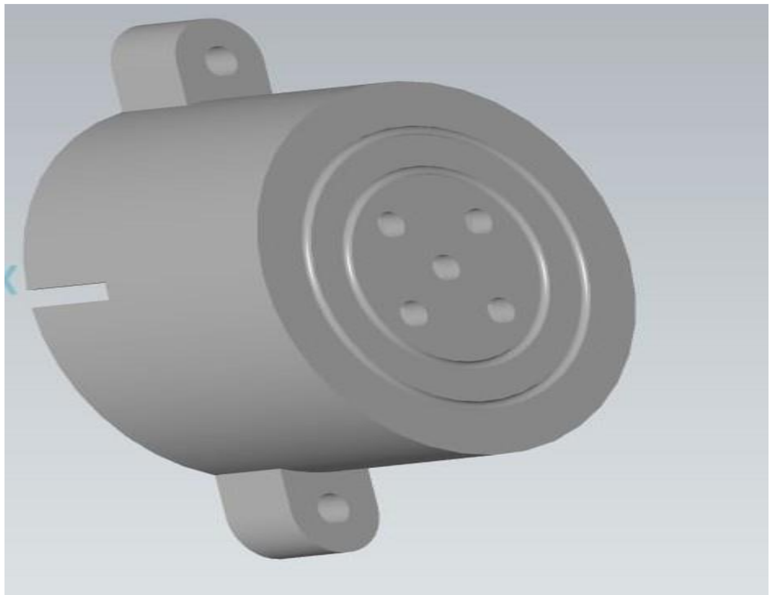


Figure 34 Front View

3.5.8 Mold Design

Next step after creating the 3-D drawing of the buzzers is designing the mold. Designing a mold for a buzzer involves several steps, from creating a 3D drawing to finalizing the mold design. Here's a complete procedure for designing a mold for a buzzer [17]:

- A buzzer's design, material, production volume, and other unique requirements should all be considered while compiling the mold's specifications. When assembling the mold's specifications, keep the following in mind:

Specifications for buzzers:

The buzzer's precise needs and specifications cover its overall size, as described above, shape, weight, and any distinctive design elements.

Material selection:

Plastic, such as ABS (Acrylonitrile Butadiene Styrene) or PP (Polypropylene), is a common material for buzzer casings, but it can vary according on the application and required features. We are utilizing ABS plastic instead of PP since the buzzer we are building may be utilized at high temperatures and pressures.

Production volume:

Ascertain the buzzer's anticipated production volume. Due to the need for more durable molds and automated procedures in high-volume production, this will have an impact on the design and manufacturing of molds.

Mold complexity:

Think about how intricate the ideal buzzer design is. Certain buzzers could have complex contours, undercuts, or many parts that call for unique mold characteristics like slides or inserts. The challenge with this buzzer is that we must create two buzzers in a single mold, each of a different size.

Parting line:

To make it simple for the molded item to be ejected from the mold, an imaginary line that divides the mold into two halves is known as a parting line. Think about how the parting line affects the buzzer's appearance and usability.

- Draft angles:

To aid in part ejection and guard against mold damage, vertical surfaces are given draught angles, which are tapered angles. Depending on the buzzer's construction and design, the proper draught angles should be used[6].

- Surface finish:

To get the ideal appearance and feel, smooth surfaces may need further mold polishing or texturing procedures.

- Tolerances:

Tolerances guarantee that the final product satisfies the relevant standards for dimensional accuracy and functionality. The material tolerance be utilized to make the buzzer's casings determine the tolerance. While tolerance for utilizing PP plastic should be 0.5mm, those for using ABS plastic should be 0.3mm. The tolerance is 0.3 mm because this mold is for ABS plastic.

3.5.9 3D model

To create a 3D model of the mold for a buzzer casing, you can follow these steps:

- Decide the computer-aided design (CAD) program you want to use. Alternatives to CAD software include SolidWorks, AutoCAD, Fusion 360, and Free CAD. SolidWorks is the software that we use to design mold.
- Prepare the workspace, appropriate dimensions and units must be used to achieve accurate modelling. The unit of measurement is millimeter.
- On the base plane, doodle the exterior shape of the buzzer housing. To draw the necessary shape, use the proper sketching tools, such as lines, arcs, circles, or splines. Make sure the sketch appropriately depicts the buzzer casing's overall measurements and shape.
- After the sketch's outside outline has been established, add elements to it to depict the buzzer casing's specifics. These features include holes, slots, or other specific elements required for the buzzer's functionality.
- Choose the drawing, then add depth to it with the extrusion tool to produce a 3D image of the buzzer casing. The needed thickness of the casing determines the desired extrusion distance.
- Add draught angles to the casing's vertical surfaces to make it easier to remove it from the mold. When demolding a part, draught angles are frequently used to keep the part from becoming trapped in the mold. Typically, a draught angle of one to three degrees is advised.
- The parting line, which marks the boundary between the mold's cavity and core. The separation line should make mold assembly and part ejection simple. Make that the separating line is clearly defined and adheres to the design specifications.
- Based on the specified parting line, break the 3D model into two parts, core, and cavity, using the splitting or parting line tools in the CAD software. In this step, the mold will be divided into two distinct halves that will combine throughout the injection molding procedure.
- Include essential mold components such cooling channels, ejector pins, runners,

and guide pins. These characteristics guarantee the mold's proper operation while assisting in the molding process.

- A detailed examination of the 3D model to look for interference, design errors, or probable manufacturing problems. Use the analysis features in the CAD program to find any problematic areas and modify the design as needed.
- As soon as the mold design is complete, provide precise engineering drawings that include all the measurements, tolerances, and distinctive features necessary for the mold's manufacture. The maker of the mold will use these drawings as a guide.

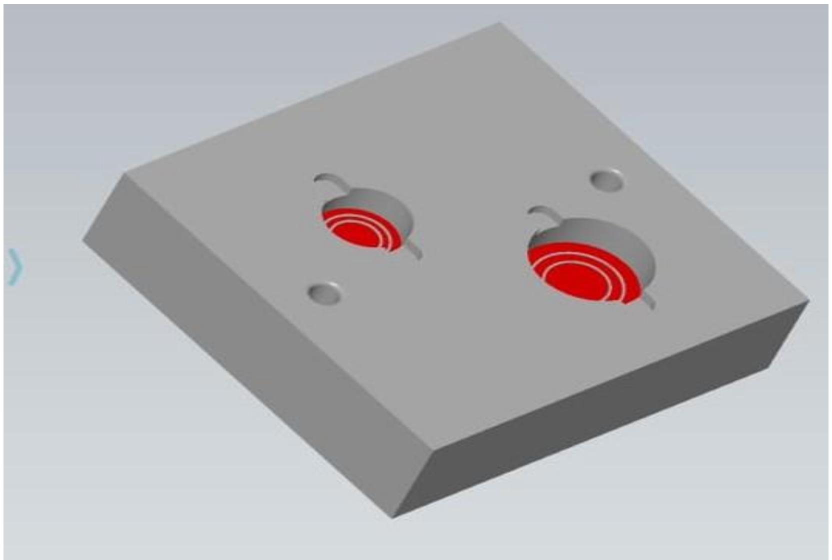


Figure 35 Mold Cavity

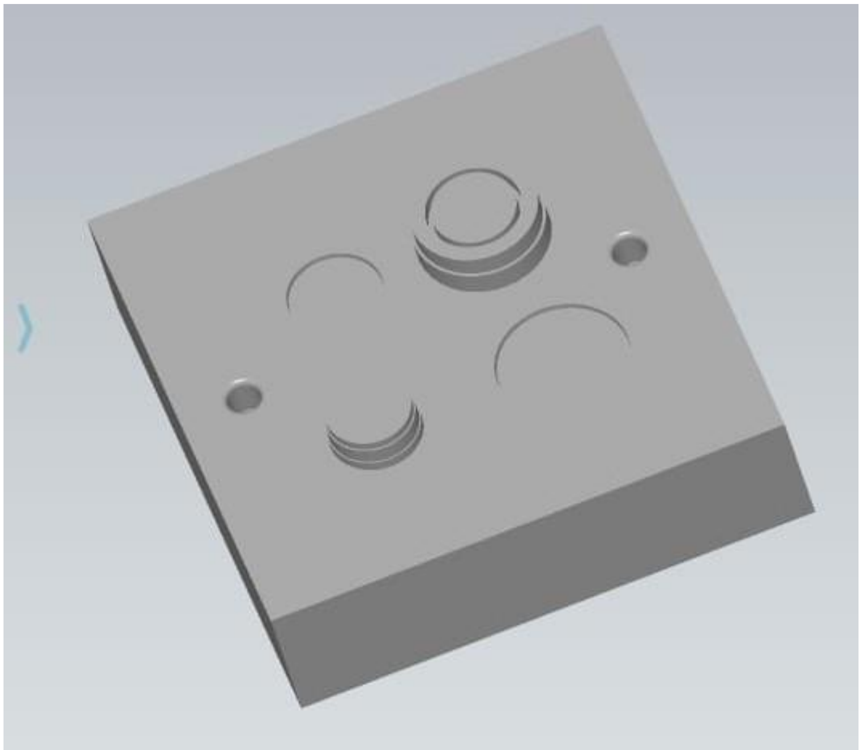


Figure 36 Mold Core

3.5.10 Fabrication of Mold

Fabricating the mold of the buzzer casing on a CNC (Computer Numerical Control) machine involves several steps. The first step is material selection for the mold.

Material Selection:

When selecting a material for the mold of a buzzer casing, several factors should be considered, including the production volume, part complexity, molding process, and budget. Here are some commonly used materials for mold making:

3.5.10.1 P20 Steel

P20 steel, sometimes referred to as P20 tool steel or AISI P20, is a well-liked mold steel that's frequently utilized in the production of plastic injection molds and die casting dies. It is a flexible and dependable material that combines toughness, hardness, wear resistance, and machinability in a fantastic way. The following are some of the primary qualities and traits of P20 steel:

- P20 steel belongs to the family of low-alloyed tool steels. Its composition typically includes the following elements:
- Carbon (C): 0.28-0.40%
- Chromium (Cr): 1.40-2.00%
- Manganese (Mn): 0.60-1.00%
- Silicon (Si): 0.20-0.80%
- Molybdenum (Mo): 0.30-0.55%
- P20 steel has good hardness, which helps shield it from chipping or splitting while molding. It is capable of being hardened to a high level of hardness, usually between 28 and 32 HRC (Rockwell hardness).
- P20 steel can endure the abrasive and high-stress conditions present during molding operations because to its good wear resistance qualities.
- P20 steel has a reputation for being exceptionally machinable, making milling, drilling, and other machining operations simple. This makes it easier to create molds that are accurate and efficient.
- The smooth surface finish of P20 steel, which is necessary to achieve the ideal aesthetics of molded parts, can be polished to achieve this.
- P20 steel exhibits good weld ability, allowing for repair or modification of molds when needed.
- •P20 steel's characteristics can be improved through heat treatment. Quenching and tempering are often used heat treatment techniques to produce the necessary hardness and toughness.
- P20 steel is frequently used to create molds for a variety of purposes, such as die casting dies, plastic injection molds, and other molding equipment. It works well with a variety of substances, including non-ferrous metals, thermoplastics, and thermosetting polymers.

3.5.10.2 MS Steel

Mild steel, sometimes referred to as Low Carbon Steel or Plain Carbon Steel, is frequently referred to as "MS steel". Due to its adaptability, affordability, and generally good mechanical qualities, it is one of the materials that is most frequently utilized in a variety of sectors. The following are some of the main qualities and traits of MS steel:

- Mild Steel primarily consists of iron (Fe) as the main element and a low percentage of carbon (typically less than 0.3%). It may also contain small amounts of other elements such as manganese (Mn), silicon (Si), and trace amounts of impurities.
- Mild steel is appropriate for many structural applications because of its modest tensile strength. It has good ductility, making it simple to shape, bend, or weld without suffering from considerable breaking or brittleness.
- MS steel has a reputation for being exceptionally machinable, making it relatively simple to cut, drill, mill, and machine into a variety of shapes and forms.
- Arc welding, MIG (Metal Inert Gas) welding, or TIG (Tungsten Inert Gas) welding can be used to join Mild Steel because of its great weld ability. It is frequently employed in fabrication and welding applications.
- Due to its adaptability, MS steel has a wide range of uses in various industries. In addition to being utilized in pipes, machines, appliances, and beams, columns, and structural components in construction.
- MS steel is prone to rust and corrosion in damp situations and when exposed to specific chemicals. It is not intrinsically corrosion resistant. Its corrosion resistance can be considerably improved by applying the proper surface treatments, such as painting, galvanizing, or applying protective coatings.
- Mild steel is widely available in a variety of forms, including sheets, plates, bars, tubes, and structural sections, making it easily accessible for

manufacturing and construction needs.

- MS steel is relatively inexpensive compared to other types of steel alloys, making it a cost-effective choice for many applications.
- In conclusion, by considering the production volume, part complexity, molding process, and budget, we have chosen Mild Steel for mold fabrication.

3.5.10.3 Fabrication

Here's a procedure for fabricating a mold using a CNC machine:

Prepare the CAD file. The CAD file should include all the necessary dimensions, features, and details required for the mold fabrication.

Select the appropriate mold material. The most suitable material for mold based on factors such as the desired mold life, production volume, and compatibility with the molding process is Milled Steel.

Set up the CNC machine for the mold fabrication process. This involves securing the selected mold material, installing appropriate cutting tools, and ensuring the machine is calibrated and ready for operation.

Program the CNC machine that translates the CAD file into machine instructions. The program should include toolpaths, cutting parameters, and specific instructions for the CNC machine to follow.

Load the mold material onto the CNC machine's worktable or chuck. Secure it firmly using clamps or other suitable methods to ensure stability during the machining process.

Set the work coordinates on the CNC machine by aligning it with the machine's axis system. This ensures accurate positioning and alignment of the mold material during machining.

Begin the machine process according to the programmed instructions. The machine will automatically move the cutting tools along the designated toolpaths, removing material from the mold block to shape it into the desired form.

Monitor the machining process to ensure that it proceeds smoothly. Pay attention to tool wear, chip clearance, and coolant/lubricant application to maintain optimal cutting conditions and prevent damage to the mold or CNC machine.

Once the primary machining is complete, perform any necessary post-machining operations such as milling, drilling, or tapping for features like cooling channels, ejector pin holes, or other mold components.

Conduct a thorough inspection of the machined mold for accuracy, surface finish, and dimensional precision. Use appropriate measuring tools like calipers, micrometers, or CMM (Coordinate Measuring Machine) to verify the mold's conformance to the design specifications. Additionally, perform any required surface finishing processes like polishing or texturing to achieve the desired mold surface characteristics.

Assemble the mold components according to the mold design and ensure proper alignment and functionality. This may involve using fasteners, inserts, or specialized assembly techniques.

Before using the mold for production, conduct mold trials by injecting the selected material into the mold to produce sample parts. Evaluate the mold's performance, identify any issues or defects, and make necessary adjustments or modifications to optimize the mold's functionality.

Fabricating mold on a CNC machine requires expertise in CNC programming, machining operations, and mold fabrication techniques. It is recommended to involve skilled mold makers or tooling specialists with experience in CNC machining and mold fabrication to ensure the successful fabrication of the buzzer mold.

Figure 37 Fabricated male part of Mold.

Figure 38 Fabricated female part of Mold

Figure 39 Complete Mold Structure

3.6 CAD SOFTWARES

3.6.1 SolidWorks

SolidWorks is a Microsoft Windows-based program for computer-aided modelling (CAD) and computer-aided engineering (CAE) [27].

Figure 40 Solid Works Logo [15]

3.6.2 COMSOL Multiphysics

A sophisticated and adaptable simulation tool for modelling and simulating numerous physical events is COMSOL Multiphysics, sometimes known as COMSOL. It is widely utilized in physics, chemistry, engineering, and other scientific subjects. COMSOL gives users the ability to combine various physical models and equations to tackle complicated Multiphysics issues [17].

Users using COMSOL can design and solve simulations incorporating a variety of physical phenomena, including structural mechanics, heat transfer, fluid flow, electromagnetics, acoustics, and chemical reactions. Users of the software are able to create and edit their models graphically because to the user-friendly interface it offers.

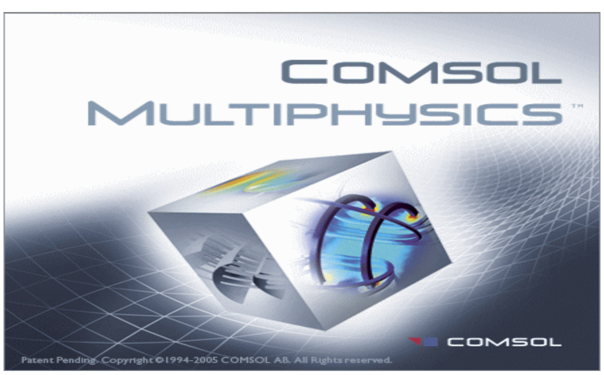


Figure 41 COMSOL Logo [16]

Chapter 4 – RESULTS

4.1 Output Frequency of Piezo Electric Buzzer

The buzzer circuit's output frequency was tested and determined to be between 3 and 3.6 kHz. The buzzer's range of sound when powered by the circuit is shown by this frequency range. Component tolerances and changes in operating circumstances are two examples of variables that may be responsible for the frequency fluctuation within this range. The circuit effectively produces the appropriate sound output within the designated frequency range, as shown by the measured frequency range's alignment with the buzzer's desired frequency specification.

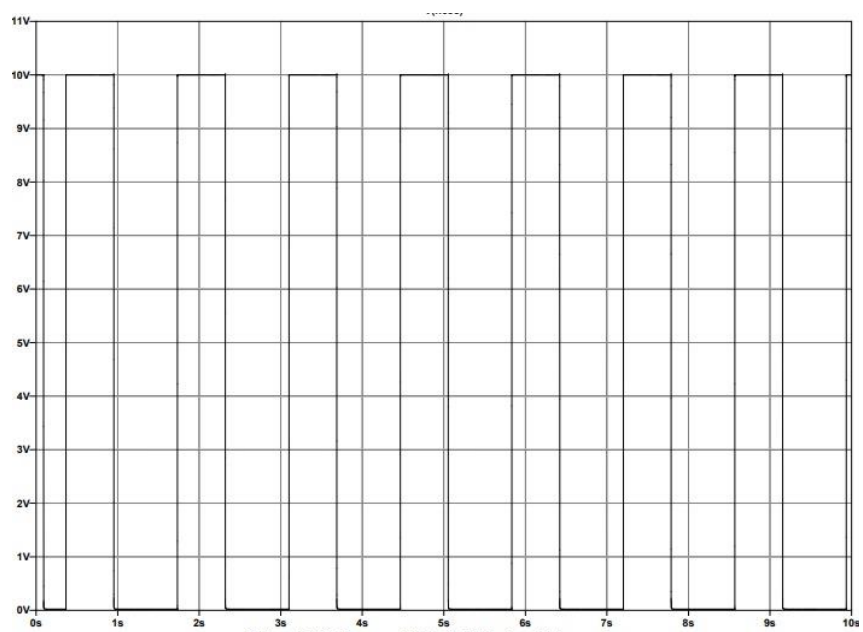


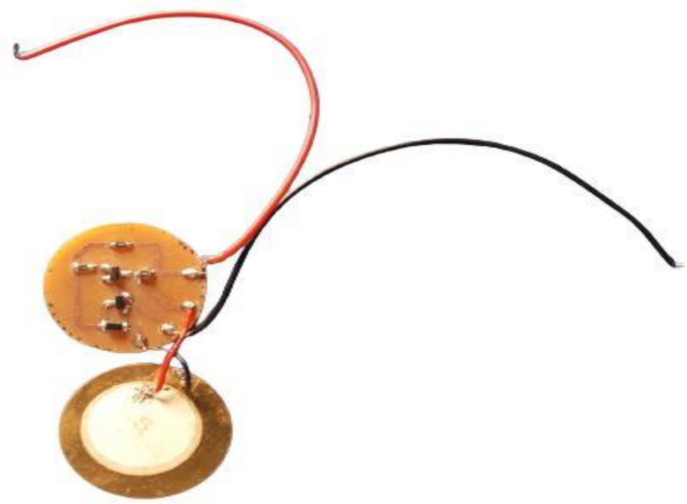
Figure 42 Output frequency in LT spice

4.2 Manufactured PCB and Piezoelectric Disk

The buzzer circuit PCB was produced using a successful PCB manufacturing procedure, yielding a usable and functioning PCB. The circuit design was precisely transferred onto the copper-clad board during production by using traditional methods like ironing and ferric chloride etching. The relevant component footprints, such as the SOT23 footprint for BJTs and the SOT123 footprint for the diode, were incorporated in the PCB layout. Assembling the buzzer circuit was made simple by correct component location and soldering as a result.

The buzzer's essential component, the piezoelectric disc, was also successfully produced. Electrical impulses are transformed into sound waves using a piezoelectric disc. The disc was created using the proper fabrication procedures and has the required dimensions and properties to provide the intended sound output.

Now that the PCB and the piezoelectric disc have been successfully produced, all the required parts may be put together to complete the buzzer's final construction. This accomplishment signifies an important turning point in the project since it guarantees the availability of crucial parts needed for the buzzer's operation.



3

Figure 43 Manufactured PCB and piezo electric disk

4.3 Manufactured Mold

The production of the mold for the piezo buzzer's enclosure was successfully finished. The buzzer's exterior shell is crucially shaped and formed by the mold, giving it the essential support and security. In this instance, mild steel was used as the mold material throughout the production process.

An important milestone in the total manufacture of the piezo buzzer was reached with the successful completion of mold fabrication. When the mold is prepared, it allows for the mass manufacture of buzzer casings, guaranteeing that the result is uniform and consistent. The robustness and dependability of the mold help to increase the production process' effectiveness and efficiency by guaranteeing that the casings are made precisely and to the required specifications.

Figure 44 Complete Assembled Mold and Casings

4.4 Fully assembled buzzer

The buzzer's whole assembly, including the circuit, piezoelectric transducer, and case, is displayed. We are pleased to announce that the buzzer is now completely functional and performing flawlessly. The circuit supplies the required signals to operate the piezoelectric transducer, which produces sound. The interior components are shielded and made to last by the well-made housing.

Figure 45 Assembled buzzer.

4.5 Buzzer Analysis

Utilizing COMSOL Multiphysics software, computational calculations are performed on the suggested micro pump design to determine the maximum flow rate at the micropump's outlet. Considered to be the working fluid is water. Additionally, simulations at the actuation frequency, at which we acquire the highest flow rate of discharge, are used to determine the overall displacement of the PDMS diaphragm.

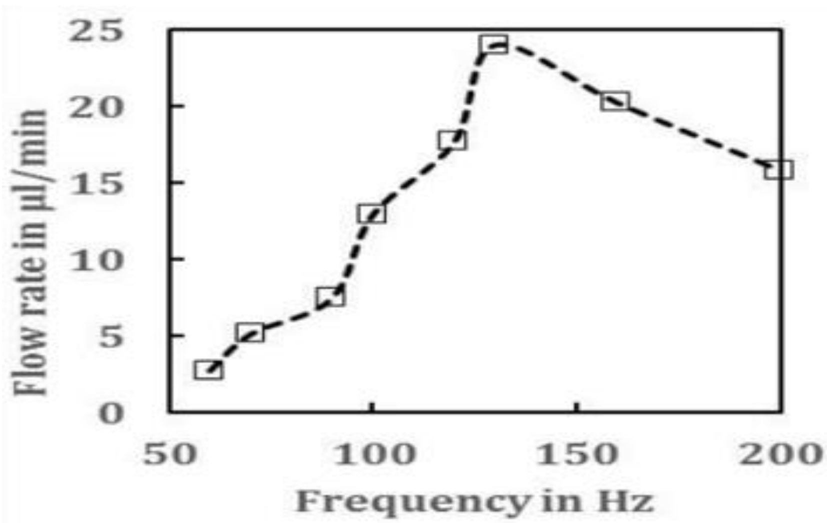


Figure 46 Flow rate as a function of actuation frequency

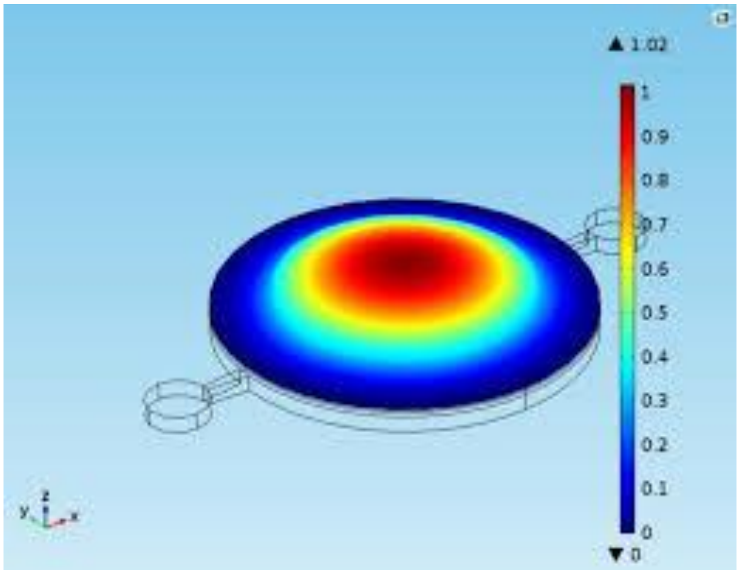


Figure 47 Total displacement at actuation frequency

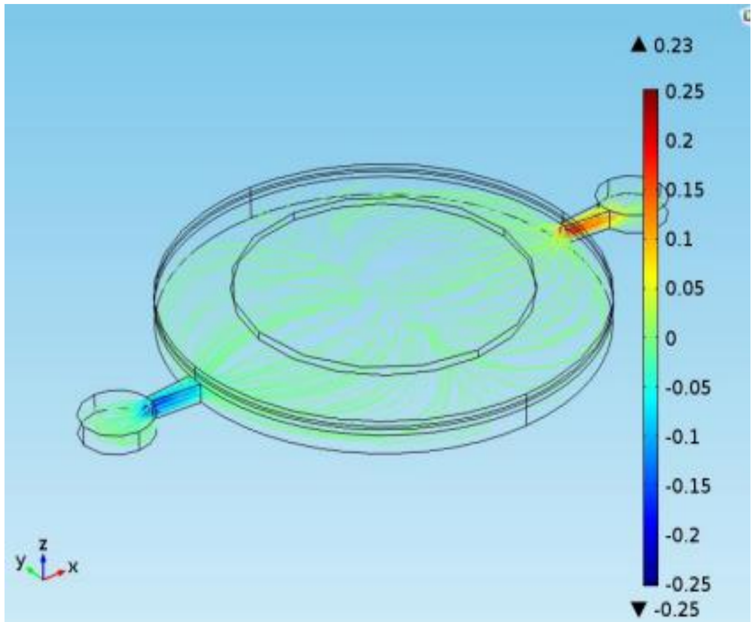


Figure 48 Streamline velocity distribution.

Chapter 5 – CONCLUSION AND FUTURE WORK

5.1 Conclusion:

In conclusion, the design and production of the industrial Piezoelectric Buzzer project have been completed successfully. The goal of this thesis has been to develop a buzzer that satisfies the required performance standards and is both dependable and effective.

A thorough investigation of the buzzer's needs and specifications, including its oscillation frequency, operating voltage, current consumption, sound pressure level, and tone kind, served as the project's starting point. These parameters served as the foundation for a thorough design process that created the internal drive oscillator circuit, the buzzer's brain.

The experimental design and testing step was extremely important in confirming the circuit's performance and usefulness. We evaluated the behavior, frequency response, and transient properties of the circuit using simulation tools and breadboard testing. As a result, we were able to optimize the design for maximum performance.

The overall functionality and dependability of the buzzer were further improved by the successful manufacture of the PCB and the production of the piezoelectric disc. We accomplished precise component placement and soldering utilizing Kicad software and conventional PCB manufacturing methods, resulting in a sturdy and long-lasting PCB assembly. The production of the casing's mold, which was composed of mild steel, gave the finished item a polished and attractive appearance.

The circuit, piezoelectric transducer, and housing were all put together throughout the assembly phase to form a buzzer that is completely operational. These parts were seamlessly combined to create a buzzer that works well and emits a constant, distinct sound.

In conclusion, our project has shown that we are capable of designing, producing, and assembling a commercial Piezoelectric Buzzer that satisfies the necessary specifications. The fact that we were able to finish this thesis successfully demonstrates our expertise in the field of electrical engineering and production.

We think that this project has possibilities for several applications that are needed for a dependable, high-performance buzzer. It lays the groundwork for further enhancements and developments in the design and production of piezoelectric buzzers.

Overall, we are pleased with the accomplishments made throughout this project and sure that our commercial Piezoelectric Buzzer will be useful and appreciated across a range of sectors.

5.9 Future Work

Future research on piezoelectric buzzers could focus on several areas, including:

Enhanced Sound Output: Research can be done to create novel designs or materials that can enhance piezoelectric buzzers' sound output, enabling the generation of louder or higher-quality sound.

Frequency Expansion: Piezoelectric buzzers can be used in a wider range of applications, including those that call for ultrasonic frequencies, by having their frequency range expanded.

Efficiency Improvements: Piezoelectric buzzers can be made more effective by looking into how to do so. This can reduce power consumption and improve energy efficiency, which is crucial for portable and battery-powered devices [23].

The ability to fit piezoelectric buzzers into even smaller electronic devices while keeping their performance characteristics can be achieved by continuing to miniaturize them.

Temperature Stability: By creating piezoelectric materials or designs that can endure greater temperatures without significantly altering their performance, buzzers would be more useful in hotter conditions [26].

Exploring the integration of piezoelectric buzzers with other cutting-edge technologies, such as wireless communication protocols or sensors, may open up new possibilities for uses and features.

Buzzers with multiple uses: Piezoelectric buzzers can have more uses than only producing sound by including additional features like haptic feedback or biometric detection capabilities [28].

Flexible or wearable applications: Piezoelectric buzzers can be integrated into flexible or conformable electronic devices, offering up new opportunities for applications in fields like healthcare, wearable technology, and smart fabrics. Researching and creating flexible or wearable buzzers can help make this possible.

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