Cricket Bowling Machine
(Design & Development)

Author

Muhammad Saad (20-EE-103)
Ali Hassan (20-EE-87)
Muhammad Hassan (20-EE-161)

Supervisor

Dr. Ahsan Ali
Associate Professor

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FACULTY OF ELECTRONICS & ELECTRICAL ENGINEERING
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A thesis submitted in partial fulfillment of the requirements for the degree of

B.Sc. Electrical Engineering

Supervisor

Dr. Ahsan Ali

Associate Professor (EED)

External Examiner Signature: ____

Thesis Supervisor Signature: ____

DEPARTMENT OF ELECTRICAL ENGINEERING

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UNDERTAKING

I certify that research work titled "*Cricket Bowling Machine (Design & Development)*" is my own work. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged / referred.

Muhammad Saad, Ali Hassan, Muhammad Hassan

20-EE-103, 20-EE-87, 20-EE-161

DEDICATION

This research is in the name of the brave and oppressed Palestinian Muslims who are facing persecution by the Israeli occupation forces. Although I cannot help directly, my heart and soul are always with you. Your pain and difficulties cannot be ignored. Your courage and perseverance is an inspiration to us all.

O zealous Muslims of Palestine, we can never forget your sorrows and troubles. We are well aware of the hardships you are facing, and it is our duty to inform the entire Muslim world of your plight. We pledge to make your support and assistance a top priority for every Muslim.

Your unparalleled courage and perseverance inspire us, and this research is just a small expression of my selfless love and commitment to serving you. May Allah keep you safe and bless you with freedom soon.

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ABSTRACT

Cricket Bowling Machine (Design & Development)

Author: Muhammad Saad, Ali Hassan, Muhammad Hassan
20-EE-103, 20-EE-87, 20-EE-161

Thesis Supervisor: Dr. Ahsan Ali
Associate Professor
(EED, UET Taxila)

The objective of the Cricket Bowling Machine project was to provide players with an automatic, reliable and configurable machine that could bowl balls at different speeds, angles and swings. In this research work, a two-wheeled bowling machine was designed and implemented which consisted of iron frame, CM808-157 motors, BTS 7960 motor drivers and Arduino Mega 2560 microcontroller. A 24V supply was obtained by connecting two 12V batteries in series to power the machine, while an LM2596 buck converter was used to provide a 5V supply for other components. The control system of the machine used PWM technique, which effectively controlled the speed of the motors. Various testing phases included speed of motors, functionality of Arduino code, performance of motor drivers, Proteus simulation, and field testing. The results showed that the machine performed to the required standard and provided full control over the speed and direction of the ball. During the execution of the project we faced various challenges which we successfully solved. In the future, several aspects including machine weight reduction, automatic feeding system, and digital interface improvements can be worked on to further improve machine performance and usability. The project not only enhanced technical skills but also supported the training of cricket players.

Keywords: Cricket Bowling Machine, Motor Control, PWM (Pulse Width Modulation), Arduino Mega 2560, BTS 7960 Motor Driver, Mechanical Design, Speed Control, CM808-157 Motors

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Chapter 1

Introduction

1.1 Background and Motivation

Cricket is a very popular sport in Pakistan which is played and watched by people of all ages. Cricket has given us many great moments in the history of Pakistan and the game has become an important part of our culture. Pakistan has won many victories in the field of cricket, including the 1992 World Cup, the 2009 T20 World Cup and the 2017 Champions Trophy. Cricket is not only a sport but also an expression of passion for the people of Pakistan.

The game of cricket has also played an important role in attracting the youth towards positive activities in the country. There is a trend of street cricket in various cities and villages which strengthens the roots of this sport. But unfortunately, non-availability of proper and quality equipment for cricket training has hampered the development of many young players.

1.1.1 Importance of cricket in Pakistan

Cricket is not only a sport in Pakistan but also a part of national pride and cultural heritage. The game has given us memorable moments like World Cup, T20 World Cup, and Champions Trophy. For the youth, this sport is not only a means of physical fitness but also helps in developing qualities of hard work, teamwork, and sportsmanship. There is a trend of street cricket in various cities and villages which strengthens the roots of this sport.

Our achievements in the field of cricket are a beacon for the younger generation and the game has also promoted national unity and enthusiasm.

Figure 1: Local Cricket in Pakistan [25]

1.1.2 Need for affordable cricket training equipment

Despite the popularity of cricket in Pakistan, there is a lack of cheap and effective equipment for cricket training. Most of the cricket training equipment are expensive and out of reach of common people. One of the biggest challenges in cricket training is that players need quality and consistent speed balls to practice bowling properly. Cricket bowling machines available in the current market are very expensive and often out of the reach of players and clubs. Development of an affordable and efficient cricket bowling machine is essential so that more people can benefit from it and the game of cricket in the country can be promoted. The development of this machine will not only improve the training of the players but also promote the game of cricket in the country.

1.2 Objectives

The objective of this project is to design and develop a versatile two-wheel cricket bowling machine capable of delivering cricket balls at variable speeds with precise spin and swing control. The machine aims to provide an automated and user-friendly training tool for cricket players to improve their batting skills and adaptability against different ball deliveries. The project focuses on creating a compact, cost-effective, and reliable solution to enhance players' performance in the game of cricket.

1.2.1 Main goal

- Design and development of an affordable and effective cricket bowling machine.

1.2.2 Specific objectives

- Designing an affordable cricket bowling machine for the Pakistani sports market.
- Implementing a speed control system to generate swing by varying the speed of the motors.
- Optimizing performance parameters to ensure machine efficiency and consistency.

Under these objectives, we have paid special attention to the key performance parameters while developing the cricket bowling machine to provide the best experience for the players. Using the machine is made easy and efficient through a user-friendly interface. Our machine can swing the ball by varying the speed of the motors which gives players a variety of bowling opportunities.

1.3 Scope of the Project

1.3.1 What is covered in the project

Under this project we have designed and developed an affordable and effective cricket bowling machine. This machine includes the following components:

- Two motors that can operate at different speeds.
- A control system that controls the speed of motors.
- User-friendly interface that makes it easy for players to use the machine.
- A machine that can swing a ball at different speeds.

1.3.2 Limitations and constraints

The project also has some limitations and restrictions which are as follows:

- ***Lack of consistent ball delivery system:*** We could not complete the automatic ball delivery system.
- ***Use of the machine is limited to tape balls:*** The machine currently only works well with tape balls; its performance with other types of balls has not been determined.

- ***Limitation of Power Supply:*** Motors require a stable and robust power supply to provide adequate power, which may not be available everywhere.
- ***Safety Issues:*** Since the machine includes high-speed motors, safety measures must be followed to ensure the safety of the players.

Despite these limitations and restrictions, the project has achieved its main goals and offered an affordable and effective bowling machine for cricket players.

1.4 Significance of the Project

1.4.1 Contribution to sports training

This project plays an important role in sports training. Sports training is a specific practice process in which athletes are trained to prepare and improve skills in various sports. Through this project, the players get an opportunity to practice different types of balls which prove to be important for improving their playing performance. This machine is capable of hitting different balls better at each specific angle, which enhances the player's skills and improves their playing performance. Apart from this, this machine also plays an important role in skill training and helps in teaching different techniques and behaviors to the player. Thus, this project is an important and necessary step for the improvement of sports training.

1.4.2 Alignment with Sustainable Development Goals (SDGs)

The project is aligned with various Sustainable Development Goals (SDGs). In particular, the project will support **SDG 4** (Quality Education), **SDG 8** (Dignified Work and Economic Growth), **SDG 9** (Industry, Innovation and Infrastructure), **SDG 10** (Reducing Inequality), and **SDG 11** (Sustainable Cities and communities). Through this machine, opportunities for sports education will increase, new jobs will be created, and sports technology will advance. In addition, the project also helps to reduce inequality by bringing sports training to different segments of the population.

Chapter 2

Literature Review

2.1 Overview of Existing Cricket Bowling Machines

2.1.1 Commercially available machines

The use of cricket bowling machines plays an important role in the training of players. These machines deliver balls in a variety of ways, such as rotating wheels, catapult mechanisms, rotating discs, or pressure ball delivery methods. Through these machines players get opportunities to face different types of balls, which improves their cricketing skills. These machines are useful for bowlers and batsmen and help in their training.

There are different styles of commercial availability of machines. Some models are also old in the market while others use new and latest technology. The prices of these machines

Figure 2 : Bola Cricket Machine [13]

also vary, and usually their prices are based on their features, capabilities, and brand. Include the main features of a commercial cricket bowling machine. Some of the leading machines such as **BOLA**, **Pro Batter**, **Merlyn**, **Iron Mike**, **ATEC Power Hummer**, **Leverage** and **Kanon** are commercially available.

Some of the prominent designs for existing cricket bowling machines are:

- One rotating wheel
- Two rotating wheels
- Three rotating wheels
- Four rotating wheels
- Catapult
- Compressed air

2.1.2 Pros of existing solutions

- ***Stability:*** One of the major advantages of the best cricket bowling machines is that they are stable and can be used for a long time. These machines are made with different materials and old or new technology which adds to their strength and durability.

- ***Different Hairs:*** Another great advantage is that these machines provide different hair types. Players get opportunities to play balls of different speeds, angles, and materials that improve their cricketing skills.

- ***Easy to use:*** Another great feature of the best machines is that they are easy to use. Some machines are automatic, which gives the player the possibility to use the machine carelessly.

- ***Framework Extension:*** Some bowling machines also have a framework extension feature, which allows the player to deliver balls at different levels.

2.1.3 Cons of existing solutions

- ***Price:*** Bowling machines vary in price and are usually priced based on their features, capabilities, and brand. Hence their prices can be very high which can be a problem for the players.
- ***Restrictions on machine capabilities:*** Certain machines have limitations on capabilities, such as certain speeds or angles, which may limit the athlete's training.
- ***Machine quality problems:*** Some machines have quality problems, which can affect the training of athletes and make it difficult for them to practice.
- ***Machine Service and Repair:*** Some machines are difficult to service and repair and require special repair performance which can cause inconvenience to the players.

Considering the advantages and disadvantages of bowling machines, they are an important tool for players to improve their cricketing skills.

2.2 Technological Developments

2.2.1 Advances in motor control

Recent advances in motor controls have led to significant advancements in various areas of technology, particularly in cricket bowling machines. The latest techniques include the use of sensors, inverters and microcontrollers that precisely control the speed and direction of the motor. Inverters can be used to increase or decrease the speed of the motor as needed, while microcontrollers help control various parameters. Sensor technology monitors motor performance in real time and provides instant feedback.

One of the most advanced motor control technologies is the technique of "vector control", also known as "field-oriented control". This technique controls the magnetic field of the motor to achieve maximum efficiency. In contrast, traditional "VF control" adjusts voltage and frequency to control motor speed but does not have the same precision as vector control. With the use of modern technology, cricket bowling machines have become very effective and reliable, which play an important role in the training of players. Using these new techniques has also made energy savings possible, as the motor's energy consumption can be better managed with the help of inverters and drivers. Moreover, thanks to digital control systems and advanced algorithms, motor control is getting further improvements,

which not only improve performance but also increase the lifespan of machines. Thus, advanced motor control technologies in cricket bowling machines have made the training methods of players better and more effective.

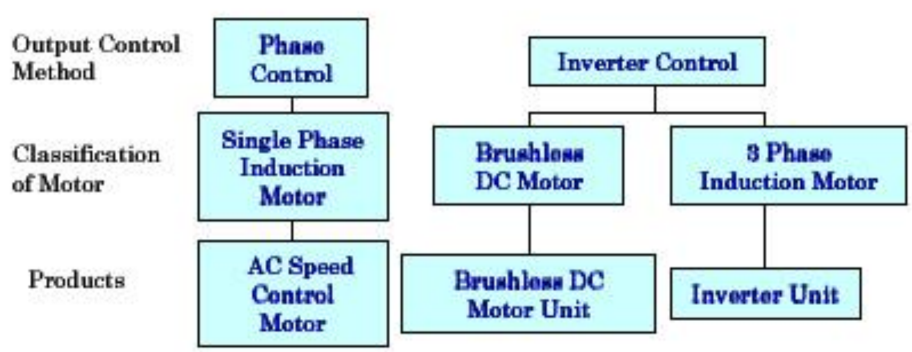

Figure 3 : Motor Speed Control Methods [26]

There have been revolutionary changes in the field of motor control developments that help improve the technique and art of sports, especially cricket. Now the performance of the bowling machines has improved with the use of motor control. Here, advances in motor control have helped control ball speeds, angles, and movements, preparing players for different gameplay scenarios. With this development, bowling machines can be tailored for different techniques and situations with the help of highly suitable speeds, different angles, and movements. By using motor control, the understanding and skill of playing the ball increases, becoming a valuable training tool for players.

2.2.2 Use of microcontrollers in sports equipment

Microcontrollers are very important in sports equipment. These small, yet powerful devices are used in various sports equipment to improve their performance. For example, electronic scoreboards, fitness trackers and digital gadgets measure and analyze data with the help of microcontrollers. These devices monitor the performance of the players and help them improve. In addition, microcontrollers have enabled the latest sensor technology that provides real-time information during gameplay.

The use of microcontrollers in cricket bowling machines has also proved to be very useful. These machines throw balls at different speeds and angles with the help of microcontrollers, allowing players to experience different types of bowling. Thanks to microcontrollers, these machines control the speed and direction of the ball with great precision. This gives the players training to play in different conditions and improves their batting skills. In addition, these machines also make the coaching process more effective, as coaches can better understand players' weaknesses.

Both these developments have played a significant role in improving the level of training and matches in cricket. Their use has improved the performance of the players and strengthened their techniques and techniques.

2.3 Size and Weight of cricket ball:

A cricket ball is one of the important components of the game and its composition and properties are governed by special rules. A standard cricket ball has a red or white leather surface with layers of cork and thread inside. A cricket ball weighs between **155.9** and **163 grams** and has a diameter of **22.4** and **22.9 centimeters**. The surface of the cricket ball has a six-over stitch that makes it strong and balanced.

In some informal cricket matches, especially in the early stages of the game, a tennis ball is used. A tennis ball, which usually consists of a soft rubber and flannel surface, is lighter and softer than a cricket ball. A tennis ball weighs approximately **56.7** to **58.5 grams** and has a diameter of **6.54** to **6.86 centimeters**. Playing cricket with a tennis ball is easier as it reduces the risk of injury and is also cheaper.

Figure 4 : Cricket Ball [29]

2.3.1 Comparison of different type of Cricket Balls

2.3.1.1 Hardball

Weight: 155.9 to 163 grams

Diameter: 22.4 to 22.9 cm

Materials: Leather, Cork, Thread

Usage: In professional and formal matches

2.3.1.2 Tennis Ball:

Weight: 56.7 to 58.5 grams

Diameter: 16.6 to 17.42 cm

Material: Rubber, Flannel

Usage: In informal and amateur matches

2.3.1.3 Rubber ball:

Weight: 70 to 80 grams (Approx.)

Diameter: 17.78 to 20.32 cm (Approx.)

Material: Pure rubber

Usage: For children and novice players

Chapter 3

System Design & Implementation

3.1 User Requirements

3.1.1 Interviews with coaches and players

During the research activity, meetings were held with coaches and players to analyze the user needs of cricket training machines. These meetings were instrumental in understanding the specific needs and preferences of end users in the athlete's training environment. Through these meetings, an attempt was made to get into the details of the functionalities and features received in the training machines. These directly interact with coaches and athletes to help identify important criteria for users, which ultimately improves the training experience for athletes.

The meetings provided valuable feedback on various aspects, such as technique, pace, angles, and other cricket machines' performance in standard situations. This feedback helps identify key criteria for the received functionality. Overall, the suggestions obtained from these meetings played an important role in shaping the understanding of user needs and guiding the selection process of cricket training aids.

3.1.2 Identified needs and preferences

The identified needs and priorities were analyzed during the meetings. These meetings brought up several important points, such as:

- ***Speed Adjustment:*** Ability to throw balls at different speeds, so players can face fast and slow balls.
- ***Angle adjustment:*** Facility to throw balls at different angles, allowing players to experience different bowling techniques.
- ***Consistency and Accuracy:*** Consistency and accuracy of the balls so that every ball is the same and gives the player better training.
- ***Different types of ball:*** Ability to bowl different ball types, such as yorkers, bouncers, and spin balls.
- ***Ease of use:*** Ease of use and simple controls so that any player or coach can easily operate the machine.
- ***Portability:*** The machine should be light and easily portable so that it can be used anywhere.
- ***Security Features:*** Safety measures such as overheat protection and safe operation to avoid any accidents.
- ***Remote Control:*** Remote control facility so that players or coaches can control the machine from a distance.
- ***Battery or Power Options:*** Can be battery operated or connected to different power sources for use in different situations.

- ***Durability and low maintenance:*** The machine is robust and requires less maintenance to last for a long period of time.
- ***Programmable settings:*** Facilitation of different training programs and settings to meet the specific needs of athletes.
- ***Price:*** Reasonably priced so that more players and coaches can afford it.

3.2 Mechanical Design

Various mechanical designs of cricket bowling machines are available, including one spinning wheel, two spinning wheels, three spinning wheels, four spinning wheels, catapult, two spinning discs, and compressed air. Among these, choosing a two-wheel design is an effective and beneficial choice based on various technical, practical, and performance factors. Detailed reasons for choosing this design and its benefits are highlighted below:

- ***Accuracy and consistency:*** The main advantage of the two-spinning wheel design is its accuracy and consistency. In this design, two wheels in parallel catch the ball and throw it under pressure. This method provides great accuracy in ball speed and direction, thanks to which every ball is almost identical. Consistency is very important for training athletes, as it allows them to improve their reactions and technique.
- ***Different types of balls:*** Another great feature of the two spinning wheel design is that it is capable of throwing a variety of balls. This design helps control the speed, angle, and spin of the ball, allowing for a variety of balls like yorkers, bouncers, swings, and

spin balls. This gives the players an opportunity to experience different bowling techniques and diversify their batting skills.

- ***Facility of adjustment:*** Ball speed and spin can be easily adjusted in the design of two rotating wheels. The speed of the ball can be changed by increasing or decreasing the speed of the wheels, while spinning the wheels in the opposite direction can create spin in the ball. This facility is very useful for coaches and players as they can adjust the machine according to different training needs.
- ***Portability and setup:*** The portability and easy set-up of the two-spinning wheel design is also a big plus. This design is lighter and easier to carry than other complex designs. This allows the machine to be used in different locations and takes less time to set up and pack up, which saves time in training sessions.
- ***Performance and durability:*** The two-spinning wheel design provides long-term performance and durability. This design has fewer moving parts, resulting in less maintenance and longer machine life. The design is robust and reliable, which works well in various weather conditions.
- ***Price and cost savings:*** The design of two spinning wheels also costs less than other complex designs. Due to its relatively simple design, it is available at low cost and is also low maintenance. For coaches and players alike, it proves to be an excellent performance machine at a reasonable price.
- ***User friendly controls:*** The two-spinning wheel design has user-friendly controls and a simple interface, making it easy to operate and adjust the machine. This feature is

very beneficial for new players and coaches, as they can use the machine without complicated training.

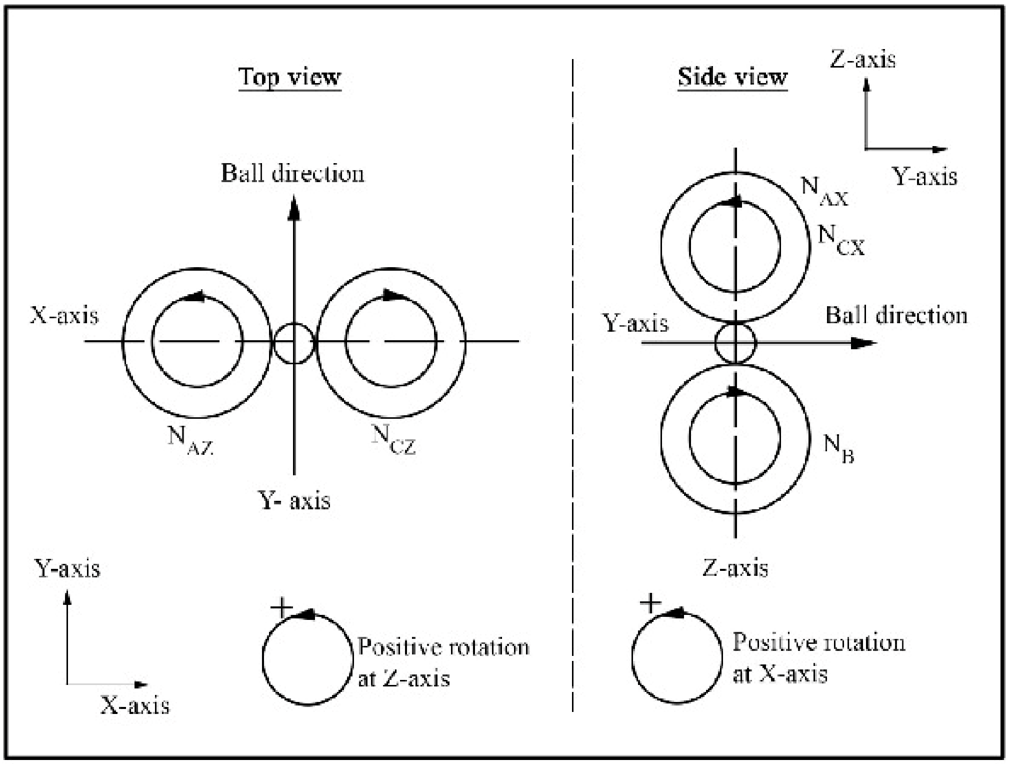

Figure 5 : Wheel Configuration [30]

The two-wheel design allows independent control of each wheel's speed, enabling us to simulate a wide range of ball deliveries, including inswings, outswings, leg spins, and off spins. This design also offers enhanced precision in ball placement, allowing cricket players to practice against different bowling styles and adapt their gameplay accordingly. Furthermore, the two-wheel configuration offers a compact and lightweight setup, making it easier to transport and operate in practice sessions. It aligns well with our objective to create a user-friendly and efficient cricket training machine that caters to players of all skill levels.

3.2.1 Mechanism of bowling machine:

The basic mechanism of a cricket bowling machine involves motors that powers a set of wheels or a disc. The ball is fed into the machine, and the wheels or disc spin at a high speed, propelling the ball towards the batsman.

The speed of the ball can be adjusted by changing the speed of the motor, and the direction of the ball can be altered by adjusting the angle of the wheels or disc. The spin and swing can be adjusted by changing the orientation of the wheels or disc.

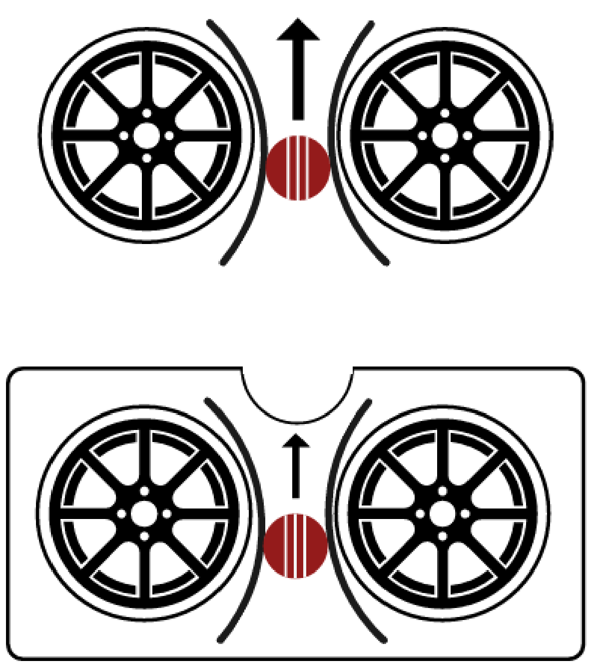

Figure 6 : Bowling Machine Mechanism

3.3 Frame Design

We have considered various factors such as stability, attack, and economics in the design of the frame. In the design of the frame, we have used iron which can best withstand the thrusts and shocks caused by the motor and the ball. The dimensions of the training machine frame and the materials used are important in terms of its strength and durability. A strong and stable frame keeps the player in a safe and stable position, while the appropriate dimensions make them easy to use.

Following are the frame dimensions and material details of our cricket bowling machine designs:

- ***Height:*** 5.5 feet (167.64 cm)
- ***Width:*** 3 feet (91.44 cm)
- ***Depth:*** 1.5 feet (45.72 cm)
- ***Material:*** Iron

Cricket bowling machines generally use lightweight frames for easy portability and ease of setup. But our prototype uses a heavy iron frame. Some of its main justifications and advantages are as follows:

- ***Strength and durability:*** Heavy iron frame increases the strength and stability of the machine. This feature enables the machine to work effectively in a variety of conditions, especially when balls are thrown at high speeds.
- ***Low Vibration:*** The heavy weight frame reduces vibration in the machine, which ensures accuracy and consistency of balls. The lack of vibration improves the performance of the machine and makes the results of the balls consistent.
- ***Durability of Prototype:*** Since this is Prototype 1, we used a heavy frame so that we don't have to change the frame frequently. This heavy frame will be useful for a long time and we are confident of its strength in future prototypes.
- ***Low maintenance:*** A heavy iron frame requires less maintenance. Due to its strength and durability, it will remain functional for a long time without any major repairs or maintenance.
- ***Trial and research:*** Using a heavy frame allows us to better test the performance of the machine under different conditions and different forces. This will help us develop better designs for lightweight frames in the future.
- ***Ease of use:*** The heavy iron frame keeps the machine stable in one place, making it easy to use. Players and coaches do not feel the need to adjust the machine frequently and it stays firmly in place.

3.4 Motor Selection

Motor selection and characteristics are critical to machine performance. We have selected the motor keeping in mind the machine's high acceleration, robustness, and critical functions. When selecting motors for our cricket bowling machine, the following parameters were considered:

- ***Horsepower (HP)*** - The amount of power the motor can generate
- ***Torque*** - The amount of force the motor can generate to rotate the bowling wheel
- ***RPM (Revolutions Per Minute)*** - The speed at which the motor can rotate the bowling wheel
- ***Voltage*** - The voltage required to power the motor
- ***Current*** - The amount of electrical current required to power the motor
- ***Duty Cycle*** - The amount of time the motor can operate continuously without overheating
- ***Efficiency*** - The amount of power the motor can convert into mechanical energy
- ***Size and weight*** - The physical dimensions and weight of the motor and its compatibility with the machine design and space limitations.
- ***Noise level*** - The amount of noise produced by the motor while operating.

3.4.1 Power of motor:

To calculate the rating of motors for your cricket bowling machine, we need to consider the weight of the machine, the size and weight of the cricket ball, the desired speed of the ball, and the power source you plan to use.

Here is a general formula you can use to calculate the power requirements of the motors for your cricket bowling machine:

Power (W) = (0.5 x Ball Weight (kg) x Desired Speed (m/s) ^2) / Efficiency

Efficiency refers to the efficiency of the motors you plan to use and can typically range from **60%** to **95%.**

3.4.2 Torque of the motor:

The torque required will depend on the weight of the machine and the size of the wheels. For example, larger wheels will require more torque to spin at the same speed as smaller wheels. As a rough estimate, you can assume that you'll need a torque of around 10 Nm to spin the wheels at 3500 RPM.

Relation of Speed of ball with torque of motor:

The speed of the ball in a cricket bowling machine is directly related to the torque of the motor that powers the machine.

- Torque is a measure of the rotational force of the motor, and it determines how quickly the wheels or disc can spin and how much force can be applied to the ball.
- A motor with a higher torque rating will be able to spin the wheels or disc at a higher speed, resulting in a faster delivery of the ball and vice versa.

- Other factors, such as the size and weight of the ball, the friction between the wheels or disc and the ball, and the angle of delivery, can also affect the speed of the ball.

Torque of the motor is just one of several factors that can impact the speed of the ball in a cricket bowling machine.

Consider using a gearbox to increase torque:

If motor can't deliver the required torque directly, we can use a gearbox to increase the torque. This will allow to use a smaller motor while still achieving the required torque.

3.4.3 RPM of Motor:

To calculate the required RPM of the motor for a cricket bowling machine, we can use the following formula:

$$\mathbf{RPM = (V \times 1000) / (\pi \times D)}$$

RPM = revolutions per minute of the motor

V = desired ball speed in km/h

D = wheel diameter in inches

3.4.4 Voltage of the motor:

We will select the motor that take input voltage same as our voltage source. Or we have to design or use the voltage source for input according to the requirement of motor.

3.4.5 Current of the motor:

We will select the motor that require the current our source can supply. Or we have to design or use the source according to the requirement of motor.

3.4.6 Duty cycle of motor:

The amount of time the motor can operate continuously without overheating. It will depend upon:

- Usage of our machine
- Budget

3.4.7 Efficiency of motor:

The amount of power the motor can convert into mechanical energy is efficiency. More efficient motors are most costly. Parameter for efficiency:

- Supply we are using
- Budget

3.4.8 Size & weight of motor:

(Size of motor)

To determine the size of the motors we need to consider several factors such as:

1. Weight of the machine

2. Size of the wheels

3. Speed of machine we want to achieve

4. Amount of power required to spin the wheels at that speed

(Calculating the weight of Machine)

To calculate the weight of your machine, we need to consider the materials we are using for the frame, wheels, and other components. We have to estimate the weight of each component and add them together to get a rough estimate of the total weight. We also have to add some extra weight to ensure that the machine is stable and doesn't move around too much during use.

3.4.9 Noise level of motor:

The noise level will depend upon:

- Where we want to use the machine

- Safe for other components of machine

3.4.10 Types of Motors that we can Use:

- Brushless DC (BLDC) Motors

- AC Induction Motors
- Servo Motors
- High Power Stepper Motors
- PMDC (Permanent Magnet) Motors

3.4.11 Comparison of Motors for our Machine:

- ***Efficiency:*** BLDC motors are known for their high efficiency and can provide more power for a given amount of input energy compared to PMDC motors.
- ***Durability:*** BLDC motors have a longer lifespan compared to PMDC motors due to their design, which eliminates the need for brushes that can wear out over time.
- ***Control:*** BLDC motors provide more precise control over the motor speed and torque, which can be beneficial for achieving accurate ball speeds and spin rates.
- ***Maintenance:*** BLDC motors require less maintenance compared to PMDC motors due to their brushless design.

(Pros of BLDC motors)

- ***High efficiency:*** BLDC motors are highly efficient due to their brushless design, which eliminates the energy losses due to friction between the brushes and commutator in conventional brushed DC motors.

- ***High torque-to-weight ratio:*** BLDC motors can generate high torque for their weight, making them ideal for applications where weight is a concern.
- ***Low maintenance:*** As BLDC motors don't have brushes, they require minimal maintenance.
- ***Long lifespan:*** BLDC motors have a longer lifespan compared to brushed DC motors due to the absence of brushes, which can wear out over time.
- ***Good speed control:*** BLDC motors have excellent speed control capabilities, making them ideal for applications that require precise speed control.

(Cons of BLDC motors)

- ***Cost:*** BLDC motors are generally more expensive than brushed DC motors due to their more complex design and control electronics.
- ***Complex control:*** BLDC motors require complex electronic control systems to operate, which can add to the cost and complexity of the overall system.
- ***Limited low-speed torque:*** BLDC motors can have limited torque at low speeds, which can make them less suitable for applications that require high torque at low speeds.

(Pros of Servo motors)

- ***High torque:*** Servo motors are capable of generating high torque, making them suitable for applications that require high torque.

- ***Good speed control:*** Servo motors have excellent speed control capabilities, making them ideal for applications that require precise speed control.
- ***High accuracy:*** Servo motors are highly accurate and can maintain a specific position even under load or in the presence of external disturbances.
- ***Easy to control:*** Servo motors are relatively easy to control compared to other types of motors.

(Cons of Servo motors)

- ***Limited torque-to-weight ratio:*** Servo motors can be heavy for their torque output, making them less suitable for applications where weight is a concern.
- ***Limited lifespan:*** Servo motors have a limited lifespan compared to other types of motors due to the wear and tear of their brushes.
- ***High maintenance:*** Servo motors require regular maintenance due to the wear and tear of their brushes.

In the case of a double wheel bowling machine, BLDC motors may be a more suitable option due to their high efficiency and excellent speed control capabilities. However, the choice of motor ultimately depends on the specific requirements of the application and the cost constraints.

Table 1 : Motor Parameters w.r.t Ball Speed

Radius of wheel	Power of motor	Liner velocity of ball (desired Velocity)	Angular velocity	Torque of motor	Speed of motor

10 cm	116.22 W	38.89 m/s	388.9 rad/sec	0.2987 Nm	3716 RPM
20 cm	116.22 W	38.89 m/s	194.45 rad/sec	0.5976 Nm	1858 RPM
25 cm	116.22 W	38.89 m/s	155.56 rad/sec	0.7471 Nm	1487 RPM

3.4.13 Power Ratings of Motor under Consideration:

- 0.25 hp (186 W)
- 0.33 hp (247 W)
- 0.50 hp (373 W)
- 0.75 hp (560 W)

Our calculated motor power is 116.22 W required for your bowling machine. There are several reasons of not recommending a 0.33 hp motor:

- ***Speed:*** A motor's speed is directly related to its power output. A higher power motor can rotate at higher speeds than a lower power motor. For our machine, we need a motor with a speed of at least 4000 RPM. A 0.33 hp motor may not be able to achieve this speed.
- ***Torque:*** Torque is the twisting force that the motor produces. Higher power motors typically produce more torque than lower power motors. Your machine needs to produce a certain amount of torque to achieve the desired ball speed. A 0.33 hp motor may not be able to provide enough torque to achieve the required ball speed.
- ***Durability:*** A motor that is not powerful enough for the application can burn out quickly, which can result in frequent replacement and maintenance costs.

3.4.14 Motor characteristics

Our selected motor is **CM808-157**. We are using a pair of these motors in our project for two rotating wheel setup. Below are the reasons to use this motor in our project:

- ***Suitable voltage:*** Because of the 24V DC motors, it is easy to manage the power supply and ensure safety. This voltage level adapts to different project needs, and also works with inverter or battery power.
- ***High performance and efficiency:*** The CM-808-157 motor has a maximum efficiency of 78.28% which improves the performance of the motor. Higher efficiency means less energy is wasted and more power is used to throw the ball, which improves machine performance.
- ***Suitable torque and speed:*** The performance of the motor at normal load is excellent with a torque of 5 Kg-cm and a speed of 3514 RPM. These features provide the required power and speed for the bowling machine to throw the balls at different speeds and angles.
- ***Strong and reliable performance:*** At maximum power the motor delivers 41.4 Kg-cm of torque and a speed of 1870 RPM. This robust performance enables the machine to work effectively in different conditions, especially when different ball speeds and spins are required.
- ***Durability and Durability:*** The CM-808-157 motor is ideal for long-term use due to its robust construction and heavy-duty materials. This motor can handle high current and power requirements, which is important for our prototype.

- ***Vibration and Stability:*** The use of two motors helps reduce machine vibration and increase stability. This improves ball accuracy and consistency.
- ***Flexible and adjustable:*** Motor speed and torque can be easily adjusted, which suits different bowling techniques and training needs. This feature makes the machine more useful for coaches and players.

Table 2 : Electrical Parameters of Motor (CM808-157)

Voltage 24V dc	**Torque**	**Speed**	**Current**	**Power**	**Efficiency**
	Kg-cm	**rpm**	**A (max)**	**W (ref)**	**% (ref)**
Free Load	0	3740 (10% tolerance)	1.5	0	0
Normal Load	5	3514 (10% tolerance)	9.7	180.4	77.51
@Max Efficiency (ref)	7.3	3422	13.16	247.2	78.28
@Max Power (ref)	41.4	1870	71.5	794.5	46.3
@Stall (ref)	82.7	0	141.86	0	0



3.5 Wheel Selection:

The selection of the wheel plays an important role in the performance of our cricket bowling machine. In our machine, the wheel is connected to the motor shaft by bushings and screws. The following is a description of the wheel:

Figure 7 : CM808-157 Motor for Our Cricket Bowling Machine

- ***Diameter:*** 11 inches (27.94 cm)
- ***Radius:*** 5.5 inches (13.97 cm)
- ***Width:*** 3.5 inches (8.89 cm)

The ball is protected using a soft air rubber coating, which provides an article of protection during use of the machine. In addition, other benefits of rubber coating include:

- ***More grip and control:*** The rubber coating gives the ball more grip, giving the ball more control in the direction of the machine's movement.
- ***Low Vibration:*** The rubber coating reduces vibration, which is important for ball consistency and accuracy.

- ***Longevity:*** The presence of rubber coating helps the machine to throw the ball at different speeds with quick activation and locking.

Figure 8 : Wheels for Our Cricket Bowling Machine

3.6 Electrical Design

3.6.1 Power supply and battery configuration

In the initial stages, we decided to provide a 24 Volt electrical power. We used it in our early stages, but I encountered some limitations. One of the limitations was that a socket was always required.

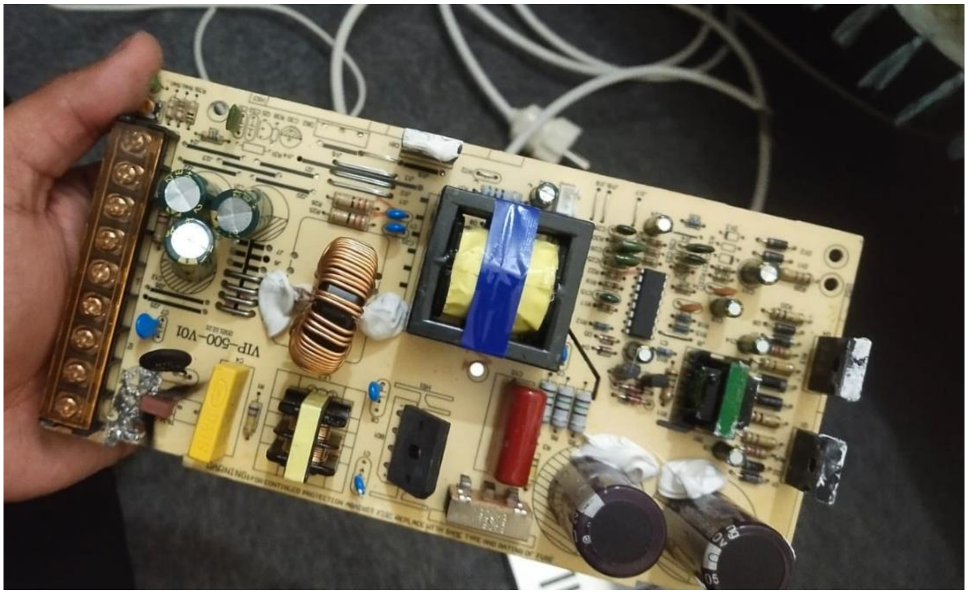

Figure 9 : 24 Volt Power Supply

In other considerations, we decided to connect two batteries in series. These batteries have a rating of 20 ampere hour and are dry batteries.

(Battery Specifications)

- ***Voltage:*** 12 volts (each battery)
- ***Rating:*** 20 ampere hours (each battery)
- ***Type:*** Dry-Cell

Below are the reasons to use batteries instead in our project:

- ***Flexibility and mobility:*** By using batteries, we don't need any specific socket, which makes the machine easy to use. This allows the machine to be easily transported to different locations.

- ***Long term capacity:*** Batteries have a long lifespan, providing continuous electrical power while the machine is in use.
- ***Constant electrical power supply:*** By using batteries, we get constant electrical power supply, which is very important in the performance of the machine.
- ***Modifiers:*** The modifiability of the batteries helps to save and reuse, which extends the life of the machine.

3.6.2 Power distribution

Power distribution plays a vital role in the success of our machine. Our machine is powered by two 12 Volt batteries which are connected in series and derive the main electrical power which is supplied on 24 Volt base. Our motors run on 24 volts directly.

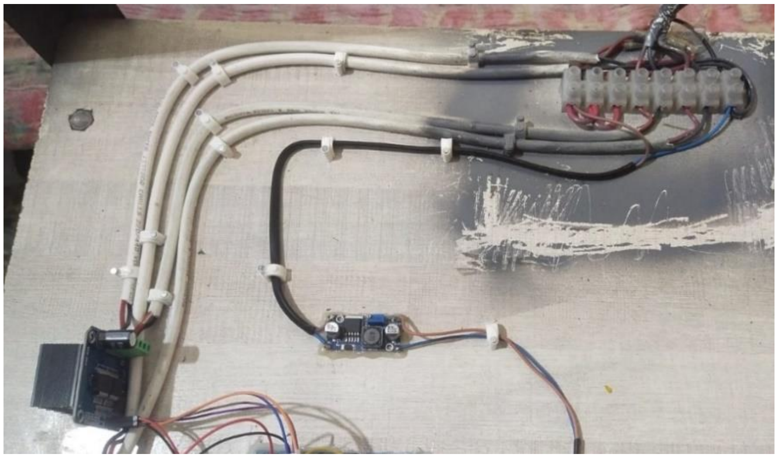

Figure 10 : Power Distribution for Our Machine

Also, other important components in our machine such as microcontroller and control circuit components run on five volts. For this purpose, we use a buck converter such as LM2596 which is a differential output buck converter. This buck converter has a special functionality with switchable output, which allows us to operate the microcontroller and other components efficiently at 5 Volts.

These organizational measures ensure accuracy and consistency in our machine's performance. In this way, we supply the various electrical components at their corresponding voltage, which increases the efficiency and lifespan of the machine.

3.7 Control System Design

3.7.1 Comparison of Controllers for our Machine:

3.7.1.1 STM

(Pros)

- Better real-time performance and control compared to Raspberry Pi due to its faster clock speed and dedicated hardware resources.
- More efficient use of power compared to Raspberry Pi, making it more suitable for battery-powered applications.
- Wide range of microcontrollers available with different capabilities and features, allowing you to choose the best fit for your project.

(Cons)

- Less powerful than Raspberry Pi in terms of computing power and memory, limiting its ability to run complex algorithms and handle large datasets.

- Not as beginner friendly as Arduino or Raspberry Pi, requiring some knowledge of microcontrollers and embedded systems.

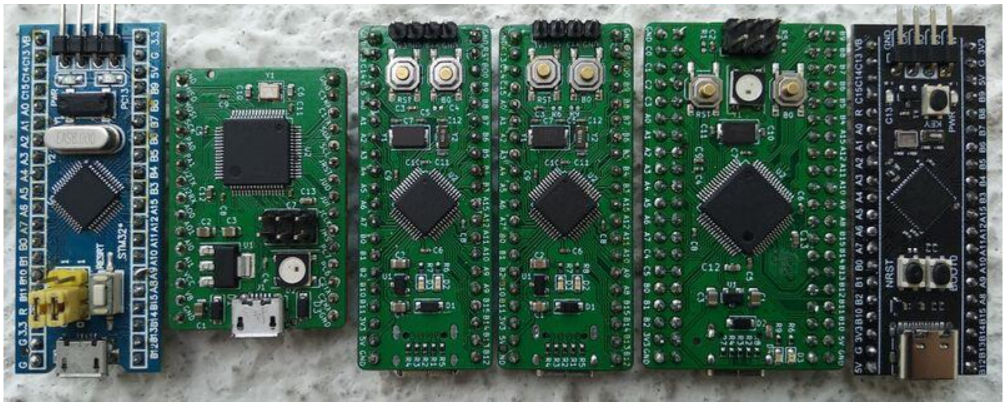

Figure 11 : STM MCU Boards [31]

3.7.1.2 Raspberry Pi

(Pros)

- More powerful than STM in terms of computing power and memory, making it more suitable for running complex algorithms and handling large datasets.
- Wide range of open-source software and libraries available for different sensors and components, making it easier to develop your project.
- Beginner-friendly with a large community and online resources available for support.

(Cons)

- Less efficient use of power compared to STM, making it less suitable for battery-powered applications.

- Less real-time control and performance compared to STM, limiting its ability to perform tasks that require precise timing and control.

Figure 12 : Raspberry Pi Board [32]

3.7.1.3 Arduino

(Pros)

- Beginner-friendly and easy to use, making it ideal for beginners and hobbyists to quickly prototype and develop projects.
- Wide range of shields and modules available, simplifying the process of adding different sensors and components to the project.
- Cost-effective, with various affordable boards and components available.

(Cons)

- Limited computing power and memory compared to Raspberry Pi and STM, making it less suitable for complex projects and data-intensive applications.

- Not designed for high-performance or real-time applications, making it less suitable for projects that require precise timing and control.

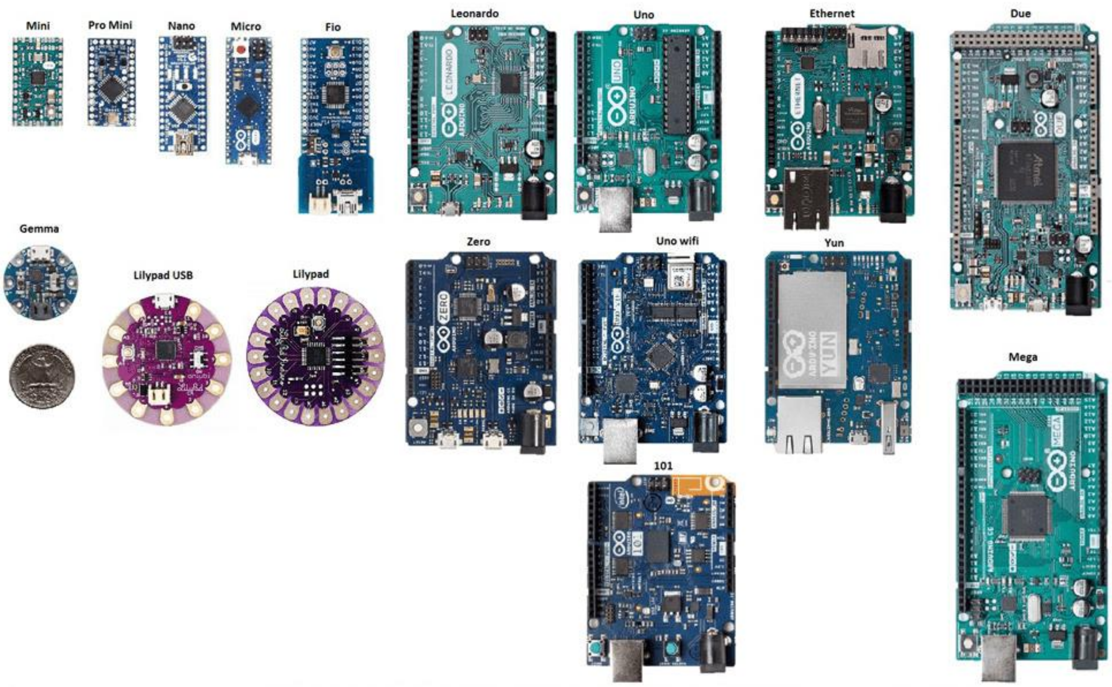

Figure 13 : Different Arduino Boards [33]

3.7.1.4 ESP 32

(Pros)

- Powerful dual-core microcontroller with a Wi-Fi and Bluetooth connectivity, making it suitable for IoT applications.
- Ample memory and computing power, allowing it to handle data-intensive tasks and run complex algorithms.
- Supports a wide range of communication protocols and interfaces, providing versatility in connecting to other devices and systems.

(Cons)

- Relatively more complex than Arduino, requiring some knowledge of microcontrollers and embedded systems for development.
- Higher power consumption compared to Arduino, making it less ideal for battery-powered applications, although it offers deep sleep modes for power management.

Figure 14 : ESP 32 MCU Boards [34]

3.7.2 Use of Arduino Mega 2560

Arduino Mega 2560 microcontroller is an important and reliable component used in our machine. Its role is important as it is capable of interfacing various sensors, motors, and other machine components. Some of its key features are as follows:

- The operating voltage of the Mega 2560 microcontroller ranges from 5 volts to 12 volts, which allows different electrical components to be powered at different voltages.
- Its 54 pins are more than just input/output pins, which provide the option of interfacing various components with the machine.
- This mega microcontroller has a processing power of 16 MHz, which offers the possibility to control the speed of various sensors and motors in an optimal way.

- Its presence of USB (Universal Serial Bus) ports allows it to be connected to a computer or other components via USB.

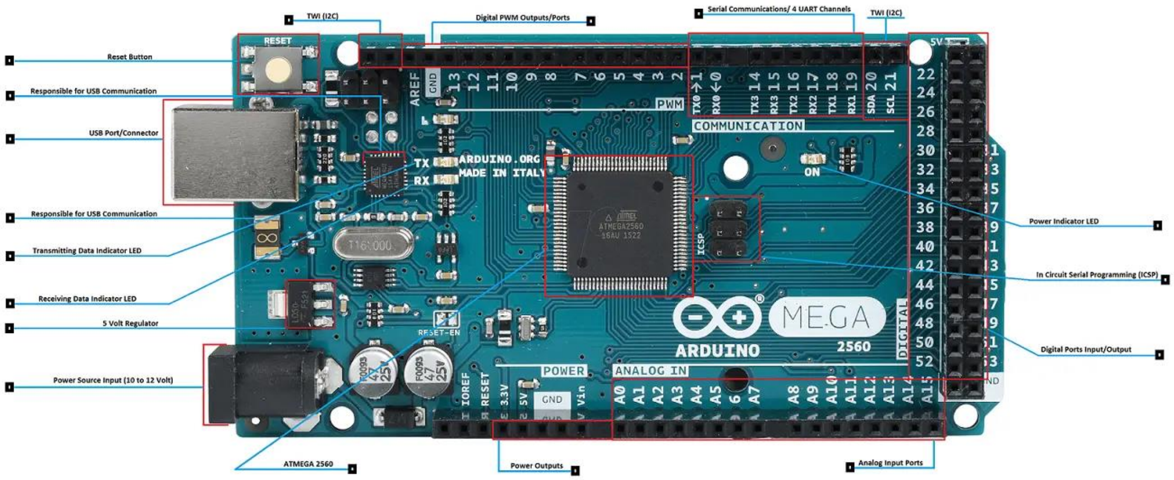

Figure 15 : Arduino Mega MCU [35]

3.7.3 PWM Control:

PWM (Pulse Width Modulation) is a technique used to control electrical power in various ways. In this technique, a balanced alternating current (DC) electrical power is diverted from a cyclic substrate for a specified period of time. A combination of electrical power, which produces an average electrical voltage by alternating the duration of the "on" and "off" periods. The process of PWM control can be understood through a simple example, such as controlling the brightness of a fluorescent light. When we make a light brighter with PWM control, we keep it "on" for a longer period of time. And when we want to make it less bright, we "flip" it for a shorter duration. Thus, the brightness of the light will be reduced on average. To understand this process mechanically, we can think of a water channel that is half blocked. When we release a small amount of gas into such a channel, it produces a high charge for a short period, and when we release the gas for a long period, it produces a low charge for a longer period.

PWM control is used to control the speed, lighting, or other features of various devices. With its help, we reduce errors in the form of electrical power, and optimize components in terms of performance.

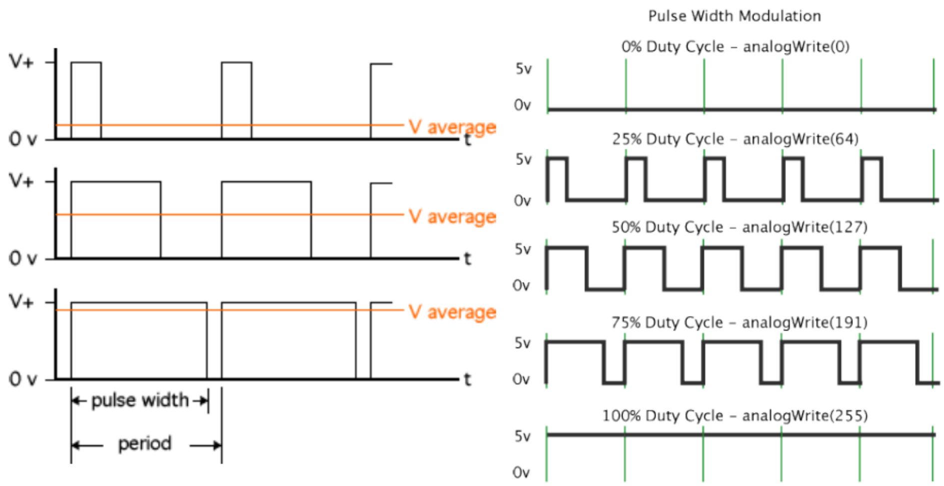

Figure 16 : PWM Control [36]

3.7.4 Feedback Control:

Feedback control, also known as closed-loop control, is a mechanism used to continuously monitor and adjust system performance. It compares the actual output of the system with desired reference values. It uses sensors to measure the output of the system and send the frame to the feedback controller, which then makes adjustments to operate the system in the desired state. The process of feedback control can be explained through an empirical example, such as a thermostat that controls the temperature of a room. When the room temperature deviates from the set range (desired temperature), the thermostat senses the difference using its temperature sensor. It then adjusts the heating or cooling system accordingly to bring the temperature back to the desired level.

Feedback control systems typically consist of four main components: a reference input (the desired set point), a controller, a plant (the system being controlled), and a feedback loop. The controller continuously compares the actual system output with the desired reference values and obtains an error signal. This error signal is then used to adjust plant inputs to bring the system to the desired state by minimizing system disturbances. Feedback control is widely used in a variety of applications, such as temperature control, speed control of motors, robotics, and process automation.

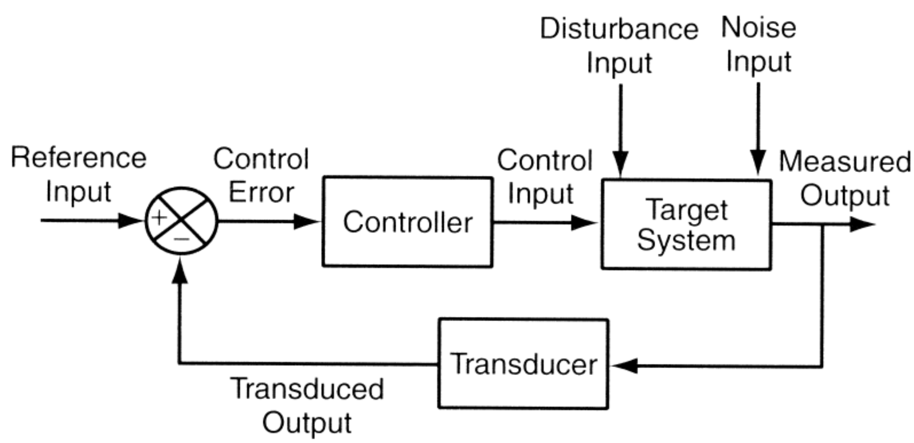

Figure 17 : Feedback Control [37]

Although this system identifies errors and corrects deviations, it is not being used in our machine, due to various reasons:

- ***Normal Use:*** Our machine operates under normal conditions where feedback control is not required.

- ***Differential Control:*** PWM control provides control over the various components of our machine and does not require a feedback loop.
- ***Cost:*** Using feedback control can increase project costs, which negatively affects our budget.
- ***Complexity:*** Feedback control requires more hardware and software complexity, which is unnecessary for our relatively simple machine.

For these reasons, we have used PWM control instead of feedback control, which is the best and most straightforward approach for our project.

3.7.5 Control circuit:

Our control circuit is used to control the machine on various parameters. We are using two BTS 7960 motor drivers (one for each motor). The details of these motor drivers are as follows:

(BTS 7960 Motor Driver Details)

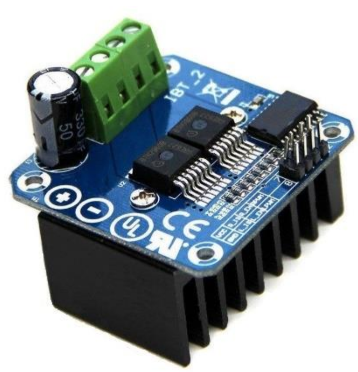

Figure 18 : BTS7960 Motor Driver [

- ***Voltage range:*** 7-36 volts
- ***Current Range:*** 25 Amps
- Has a heat sink
- Safe thermal control

Our motors are connected to the motor driver. The microcontroller is driving the H-bridge. User controls input via three rotary switches (one for speed level, one for delivery type: straight, inswing, outswing, and one for inswing level). According to the user inputs, the microcontroller drives the motors through H-bridge using PWM technique.

3.7.5 Control mechanism:

First, the user selects his preferences with the help of rotary switches. Then, the microcontroller reads these inputs and selects the appropriate commands and drives the motor driver using the PWM technique. These settings give the user complete control over various preferences and actions.

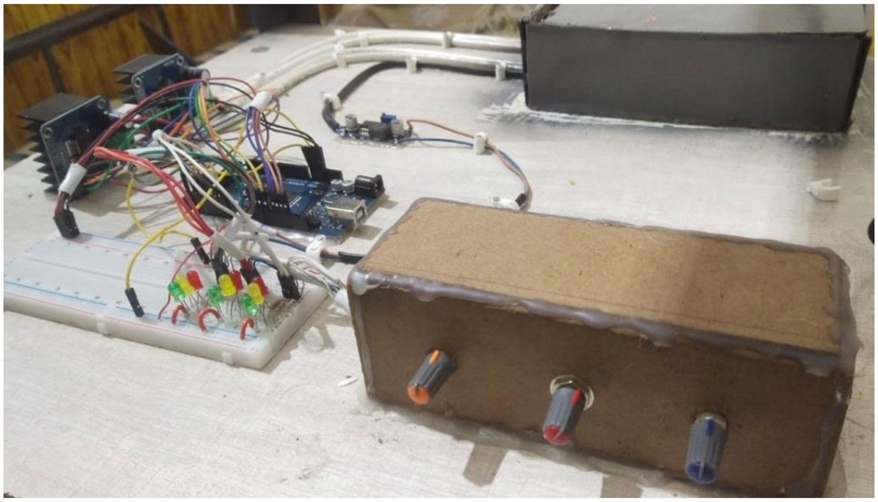

Figure 19 : Control System for Our Machine

3.8 Software Used

Our project uses various software and programming tools to design and test various aspects of a cricket bowling machine. These software have not only helped us in designing the circuit but also in testing the parameters of the motor and coding the microcontroller.

3.8.1 Proteus:

Proteus is a comprehensive software used for electrical circuit design and simulation. With this software we designed our control circuit and simulated the performance of various components. Proteus helped us see how our circuit would work in practice, allowing any potential problems to be addressed ahead of time.

Figure 20 : Proteus Software Logo [38]

3.8.2 Simulink:

Simulink is a software used for model-based design and simulation. We used this software to check the parameters of the motor. Simulink allowed us to simulate the speed, torque, and other characteristics of the motor under various conditions, thereby improving the performance of our machine.

Figure 21 : Simulink Software Logo [39]

3.8.3 Arduino IDE:

Arduino IDE is an open source software used for programming microcontrollers. We coded for Arduino Mega 2560 microcontroller using this IDE. Arduino IDE helped us program various sensors, motors, and control circuit components. This IDE is easy to use and contains many libraries that make microcontroller programming fast and easy.

Figure 22 : Arduino IDE Logo [40]

3.9 Programming Process:

3.9.1 Control Circuit Design:

The control circuit design process was an important part of our project, which was carried out with the help of Proteus software. Proteus is a comprehensive software used for electrical circuit design and simulation. First, we added all of our control circuit components to the Proteus, including the BTS 7960 motor driver, the Arduino Mega 2560 microcontroller, the H-bridge, and the rotary switch. After connecting each component correctly, we performed a simulation of the circuit to detect any potential problems. Proteus allowed us to see the performance of the circuit and fix any errors early. This helped us to ensure that our control circuit would function correctly in practice and control the motors effectively.

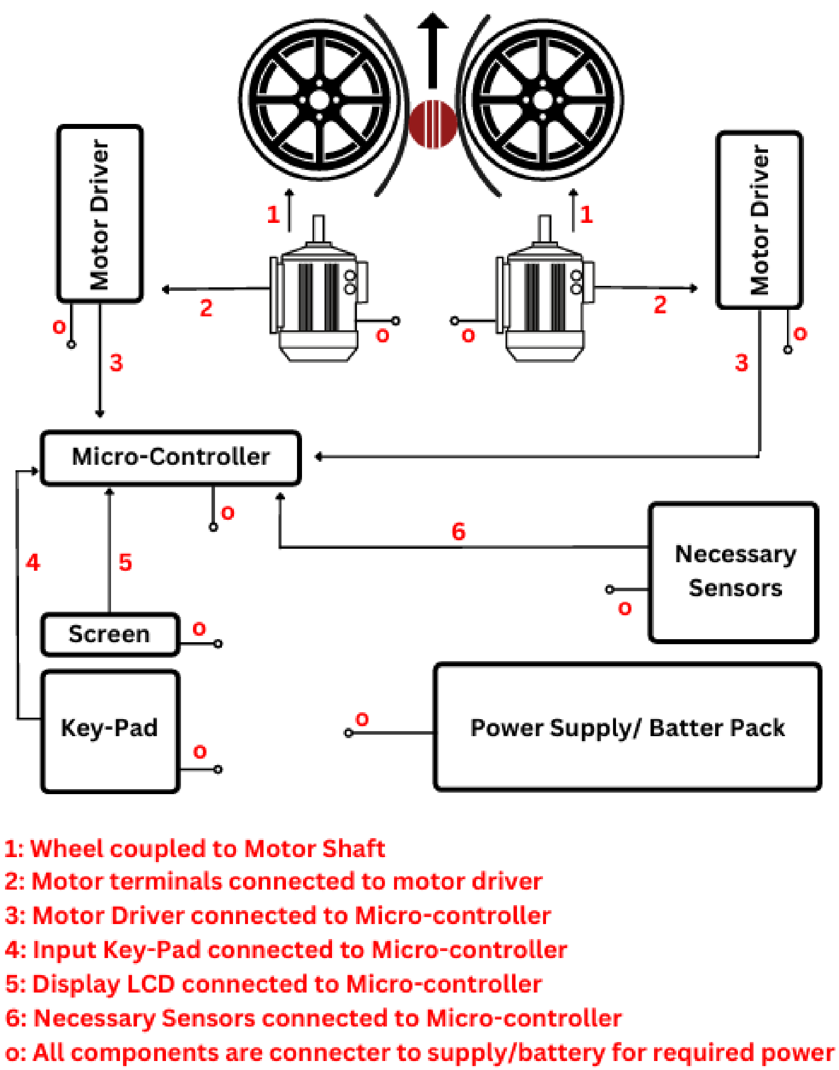

Figure 23 : Control Mechanism for Our Cricket Bowling Machine

3.9.2 Checking motor parameters:

Testing of motor parameters was another important step, which we performed using Simulink software. Simulink is a powerful software for model-based design and simulation, which allows us to test the performance of motors under different conditions. We modeled the motor in Simulink and simulated various parameters such as speed, torque, and power consumption under different conditions. This process allowed us to make the necessary changes to improve the performance of the motor. With the help of Simulink, we ensured that the motors would work according to our machine requirements and run efficiently under different operating conditions.

3.9.3 Programming of Microcontroller:

The programming of the microcontroller was done using Arduino IDE, which is an open-source platform used for coding the microcontroller. Arduino IDE helped us write code for the Arduino Mega 2560 microcontroller, including PWM control, motor drivers, and user inputs. First, we wrote code to read user inputs from various rotary switches, which control speed, delivery type, and suction level. Next, we wrote the code to control the motors using the PWM technique. With the help of the Arduino IDE, we uploaded the code to the microcontroller and performed practical tests to ensure that all the components were working properly. The programming of the microcontroller provided us with a complete and effective control system that works according to the user's needs.

Chapter 4

Testing & Results

4.1 Testing Methodology

4.1.1 Test Environment:

All tests were conducted in controlled indoor and outdoor environments to test the performance of the machine under various conditions. In the indoor test, various experiments were conducted in a controlled environment while the outdoor test was conducted in cricket nets. Safety equipment and measuring instruments such as tachometers were used during the test.

4.1.2 Test Cases:

The following test cases were created to test the various features of the machine:

- Motor speed change test
- Straight, in-swing, and out-swing testing
- Delivery accuracy test
- Continuous operation test
- Vibration and stability test

4.1.3 Test Details:

The details of each test included the following steps:

- Setting up the machine according to the test requirements.
- Collecting and recording machine performance data.
- Making observations and taking note of any unexpected behavior.

4.1.4 Arduino Code Test:

Purpose: To verify the functionality of the Arduino code.

Methodology: The code was uploaded to the hardware using Arduino IDE and the functionality of the code was tested with various machine components.

Results and Observations: The Arduino code successfully controlled the motors and correctly read the input from the rotary switches.

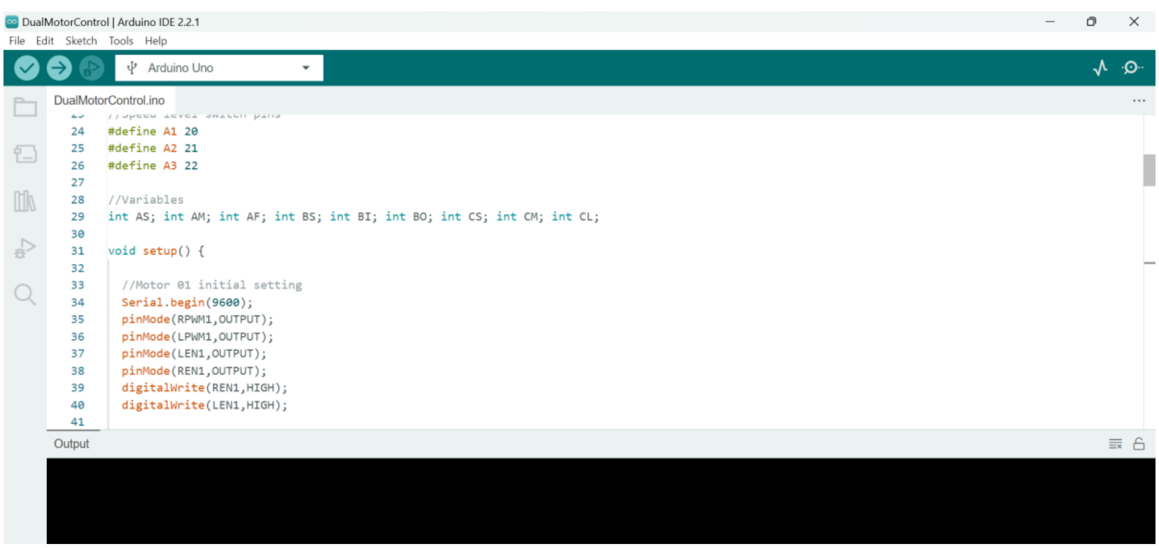

Figure 24 : Arduino Code Testing

4.1.5 BTS 7960 Motor Driver Test:

Purpose: To verify the functionality of the BTS 7960 motor driver.

Methodology: The motor driver was connected to the motors and the speed and direction of the motors were controlled by Arduino microcontroller.

Results and Observations: The motor driver worked correctly and effectively controlled the speed and direction of the motors.

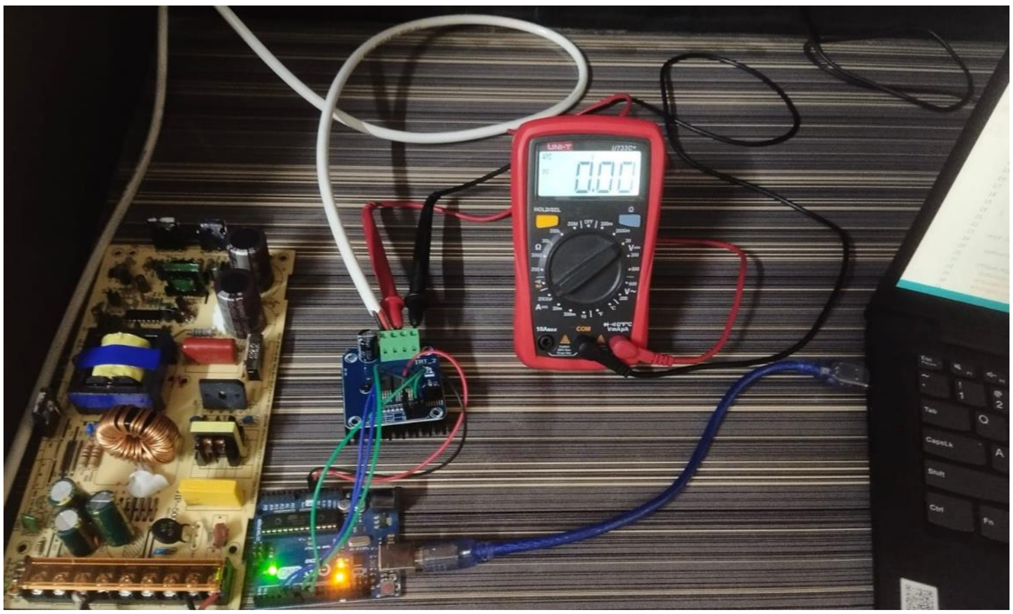

Figure 25 : BTS7960 Testing

4.1.6 Proteus Simulation:

Objective: To validate the initial design and interface.

Methodology: Simulation of keypad and LED interfacing was done in Proteus, to ensure input and output handling. After practical considerations, rotary switches were used.

Results and Observations: The simulation results confirmed the functionality of the design, but the rotary switches provided a more user-friendly interface.

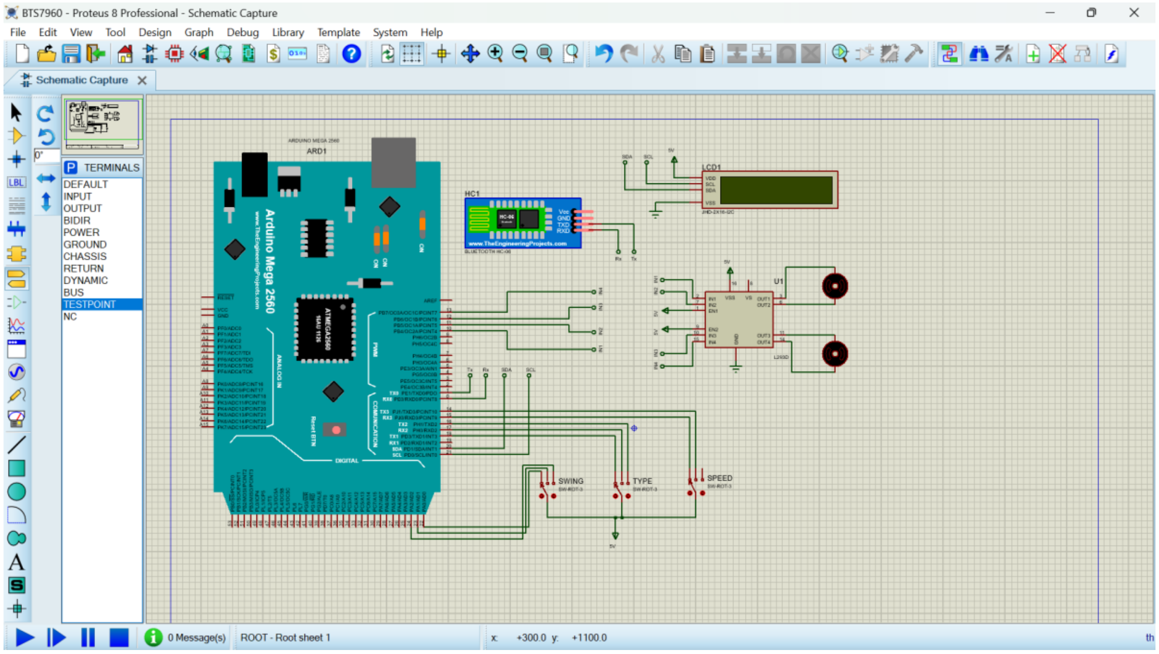

Figure 26 : Proteus Simulation

4.1.7 Motor Simulink Simulation:

Purpose: To verify the characteristics and performance of the motor.

Methodology: CM808-157 motor was modeled in Simulink software and the performance of the motor was simulated at different input voltage and load conditions.

Results and Observations: Simulation results measured motor speed, torque, and power consumption at different input voltages.

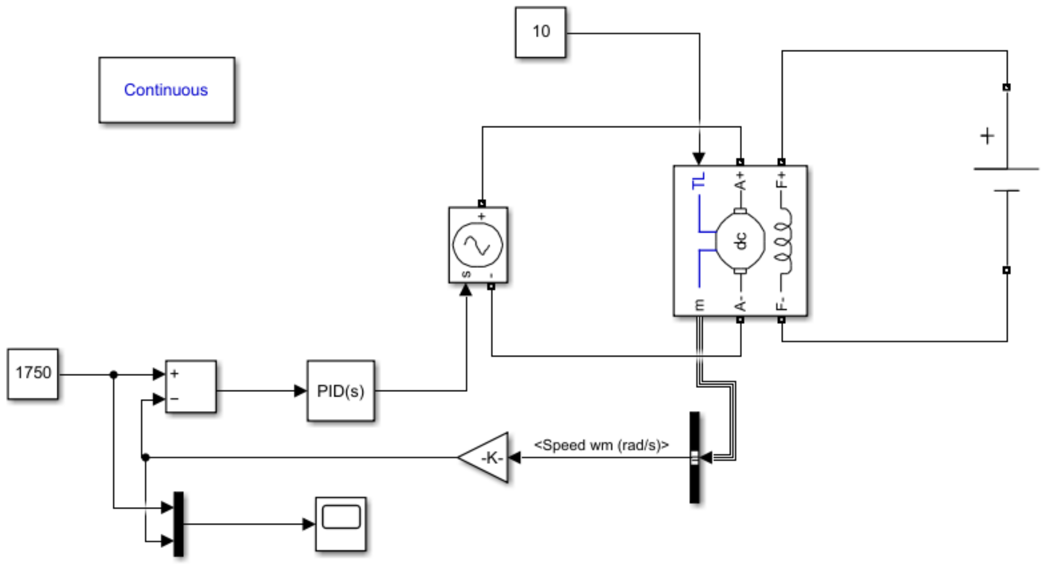

Figure 27 : Simulink Circuit for Motor

4.1.8 Motor Speed Test:

Purpose: To verify motor speed at different PWM settings.

Methodology: Motor speed was measured at different PWM levels using a tachometer to ensure speed consistency and accuracy.

Results and Observations: The motors performed correctly at all tested PWM levels, and the speed showed a reliable relationship with the PWM input.

4.1.9 Machine Stability and Vibration Test:

Objective: To identify and solve machine stability and vibration problems.

Methodology: Tests were conducted for vibration observations, and bearings were added to the wheels to reduce vibration.

Results and Observations: The addition of bearings significantly reduced vibration and improved machine stability.

Figure 28 : Frame Design for Better Stability & Less Vibration

4.1.10 Ball Speed and Accuracy Test:

Objective: To evaluate machine speed and accuracy of delivery.

Methodology: The machine was tested in cricket nets, ball speed was measured using a tachometer and delivery accuracy was evaluated based on feeder input.

Results and Observations: The machine threw the ball with a constant velocity, and the accuracy depended on the skill of the feeder.

Figure 29 : Ball Feeding during Speed & Accuracy Test

4.1.11 User Experience Test:

Objective: To get user feedback regarding the use of the machine.

Methodology: Users were allowed to use the machine and asked for feedback on the interface and overall experience.

Results and Observations: Users found the machine easy to use, and general feedback was positive. Suggestions for further improvements were also received.

4.2 Results

4.2.1 Arduino Code Test:

While testing the functionality of the Arduino code, we uploaded the code to the hardware along with various components of the machine. The results showed that the Arduino code successfully controlled the motors and correctly read the input from the rotary switches. The Arduino Mega 2560 processed all the input signals correctly and drove the motors in the correct speed and direction. In addition, the stability and performance of the code was excellent. This test proves that our code and microcontroller system are fully functional.

4.2.2 BTS 7960 Motor Driver Test:

To verify the functionality of the BTS 7960 motor driver, we connected the motor driver to the motors and controlled the speed and direction of the motors using an Arduino microcontroller. The results showed that the motor driver worked correctly and effectively controlled the speed and direction of the motors. The motor driver provided the required current and voltage and there were no heating problems or overloading. This test proves that the BTS 7960 motor driver is perfect for our project.

4.2.3 Proteus Simulation:

Keypad and LED interfacing is simulated in Proteus, to ensure smooth input and output handling. The simulation results verified the functionality of the design, and the interfacing of the various machine components was properly tested. Simulations showed that interfacing with keypads and LEDs was correct, but after practical considerations, rotary switches were used. This test helped us determine the best choice of interface.

4.2.4 Motor Simulink Simulation:

We modeled the CM808-157 motor in Simulink software to verify the motor characteristics and performance and simulated the motor performance at various input voltage and load conditions. The results showed that the motor speed, torque, and power consumption were measured accurately. The speed changes of the motor at different voltage levels were examined, and the torque performance of the motor at different load conditions was analyzed. The motor showed stable and high performance in all conditions. This test confirms that the motor's performance is as expected under various conditions and is suitable for our project.

4.2.5 Motor Speed Test:

We tested the motor speed at different PWM settings. Using a tachometer, the speed of the motor was accurately measured. The results showed that the motors provided consistent and reliable speeds at all PWM inputs. The motors performed perfectly on 24V supply and no unexpected behavior was observed. Speed measurements at all levels met our expectations and there were no issues with speed control. This test confirms that the effect of PWM on the motors speed is as expected.

4.2.6 Machine Stability and Vibration Test:

While testing machine stability and vibration issues, we made vibration observations and added bearings to the wheels to reduce vibration. The results showed that the addition of bearings significantly reduced vibration and improved machine stability. The machine now showed stable performance and no unexpected movements or vibrations were observed. This test helped us to ensure the stability of the machine.

4.2.7 Ball Speed and Accuracy Test:

While evaluating machine speed and delivery accuracy in cricket nets, we measured ball speed using a tachometer and evaluated delivery accuracy based on feeder input. The results showed that the machine threw the ball with a constant velocity, and the accuracy depended on the skill of the feeder. Both ball speed and swing were effectively controlled. This test helped us evaluate the performance of the machine under real conditions.

Table 3 : Slow Speed Mode

PWM of left motor	Left Motor (RPM)	PWM of right motor	Right Motor (RPM)	Speed of ball (Kph)	Sub mode
160	**1984**	**160**	**2090**	**107**	**Straight**
170	**2100**	**150**	**1960**	**107**	**In swing (L1)**
180	**2233**	**140**	**1837**	**107**	**In swing (L2)**
190	**2360**	**130**	**1704**	**106**	**In swing (L3)**
150	**1868**	**170**	**2340**	**110**	**Out swing (L1)**
140	**1745**	**180**	**2356**	**108**	**Out swing (L2)**
130	**1620**	**190**	**2485**	**108**	**Out swing (L3)**

Table 4 : Medium Speed Mode

PWM of left motor	Left Motor (RPM)	PWM of right motor	Right Motor (RPM)	Speed of ball (Km/h)	Sub mode
185	2300	185	2415	124	Straight
195	2420	175	2286	123	In swing (L1)
205	2543	165	2155	123	In swing (L2)
215	2667	155	2026	123	In swing (L3)
175	2174	195	2540	125	Out swing (L1)
165	2046	205	2670	124	Out swing (L2)
155	1920	215	2798	124	Out swing (L3)

4.2.8 User Experience Test:

Users were allowed to use the machine and asked for feedback on the interface and overall experience. Users found the machine easy to use, and general feedback was positive. Users found the performance of the machine correct according to various inputs and suggested some improvements. This test helped us better understand the needs and expectations of the customers.

Chapter 6

CONCLUSION

The objective of our cricket bowling machine project was to develop a machine capable of throwing balls of varying speed, direction, and swing. During this project we reviewed various components, design, and technical aspects and implemented them in practice. We used the two spinning wheel technique that was most suitable for our needs. The frame of the machine was made of strong iron with a height of 5.5 feet and a width of 3x1.5 feet to reduce vibration and ensure the stability of the machine. Despite the heavy weight, this design proved beneficial for the initial phase of our project. In the selection of motors we preferred CM808-157 motors which performed best on 24V supply. Simulink simulation was done to check the speed and torque of the motor and the results gave us positive results. We also tested various motor drivers such as the BTS 7960 which effectively controls the speed and direction of the motor. For the power supply we initially used a 24V power supply, but later used two 12V batteries connected in series which gave us portability and eliminated power source restrictions. We used LM2596 buck converter to provide 5V supply to other components of the machine. Arduino Mega 2560 microcontroller was used to control the various components of the machine. PWM technique was successfully implemented for Arduino code testing and motor control. Bearings were used to reduce the stability and vibration of the machine and the project was optimized. During the field testing, the speed and accuracy of the machine was tested in cricket nets which showed the practical performance of the machine. User experience testing revealed that the machine is easy to use and meets customer expectations. Overall, our project met our expectations and we produced a successful cricket bowling machine that has room for further improvement and renewal in the future. We learned a lot from this project and mastered various technical aspects.

Chapter 7

DISCUSSION

During the cricket bowling machine project we faced various challenges and technical issues, which we successfully solved. In this section we will consider various aspects that occurred during the development of the project and discuss its results.

Initially, we used heavy iron for the frame of the machine. While normally cricket bowling machines are light, we opted for a heavy frame to reduce stability and vibration in the prototype. Also, the heavy frame saved us from frequent changes in the early stages of the project. In the future, we plan to reduce the weight of the machine by using lighter and stronger materials. We chose CM808-157 motors which provide excellent performance on 24V supply. Simulink simulation and practical testing of the motors speed and torque proved that these motors are suitable for our needs. The BTS 7960 motor driver effectively controlled the speed and direction of the motors. The Arduino Mega 2560 microcontroller properly processed the various input signals and drove the motors in the desired speed and direction. Optimal control over the speed of the motors was achieved by using PWM technique. Initially, we used a 24V power supply but this proved unsuitable for portability and field testing. Connecting two 12V batteries in series gave us a 24V supply which proved to be more suitable. Batteries allowed us portability and field testing, and we no longer needed a constant power source. During field testing, we tested the speed and accuracy of the machine in cricket nets. The results showed that the machine threw the ball at the desired speed and direction. Accuracy was dependent on feeder skill, indicating that feeder training is also important. Users praised the interface and overall performance of the machine and also suggested some improvements. To solve the machine's stability and vibration problems, we added bearings on top of the wheels. The results showed that the addition of bearings significantly reduced vibration and improved machine stability. After solving the stability issues, the machine showed stable performance and no unexpected movement or vibration was observed. The results of the project told us that our design and control system is effective. However, there is room for improvement in some areas. In the future, we will use lighter materials to reduce the weight of the machine and further improve the control system. More field testing opportunities will also help us improve machine performance.

This cricket bowling machine project was an educational and practical experience for us. We faced various technical challenges and used various techniques to solve them. This project gave us an opportunity to understand and master various aspects of engineering in practice. In the future, we are determined to improve the performance of the cricket bowling machine by further improving this project.

Chapter 8

SUGGESTIONS FOR FUTURE WORK

After completing the Cricket Bowling Machine project, we found several aspects that have room for further improvement. The following suggestions may be considered for future work:

Weight Loss: The current prototype is built with a heavy iron frame that provides stability, but poses difficulties in portability. In the future, the weight of the machine could be reduced by using lighter and stronger materials such as aluminum or carbon fiber.

Adding feedback control: Although feedback control is not included in the current system, feedback control may be added in the future to more effectively control the speed and direction of the motor. This will improve the accuracy and efficiency of the machine.

Automatic feeding system: An automatic feeding system can be added to automatically feed balls into the machine to reduce reliance on feeder skill. This will increase the accuracy and consistency of delivery.

Different Bowling Techniques: The current machine is capable of throwing balls of different speeds and swings. In the future the machine could be made capable of bowling different bowling techniques such as yorkers, bouncers, and spin balls.

Digital interface and remote control: The machine's control system can be further upgraded with a digital interface and remote control. This will allow users to control the machine more easily and adjust various settings remotely.

Improved Battery Life: Advanced and efficient battery technology can be used to increase the performance of existing batteries. Longer battery life will improve the machine's performance during field testing and gaming.

Safety measures: Safety measures can be improved while using the machine. This may include adding safety guards, and using sensors to prevent accidents.

Additional Sensors and Data Logging: By adding various sensors to the machine, ball speed, angle, and other parameters can be accurately measured. In addition, machine performance can be recorded through a data logging system so that further improvements can be made in the future.

Mobile Application Integration: A mobile application can be developed for the control and monitoring of the machine which will allow users to control various settings from a mobile device.

Reduction of Vibration and Noise: The current prototype used bearings to reduce vibration, but future research and development could further reduce vibration and noise.

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