# Design Lab Project Report: 2D Printer

This report documents the comprehensive design, fabrication, and operation of a 2D printer developed as a part of the Design Lab course. Constructed with a robust aluminium T-slot frame and a precision belt-driven motion system, the printer performs controlled planar printing using PLA filament.


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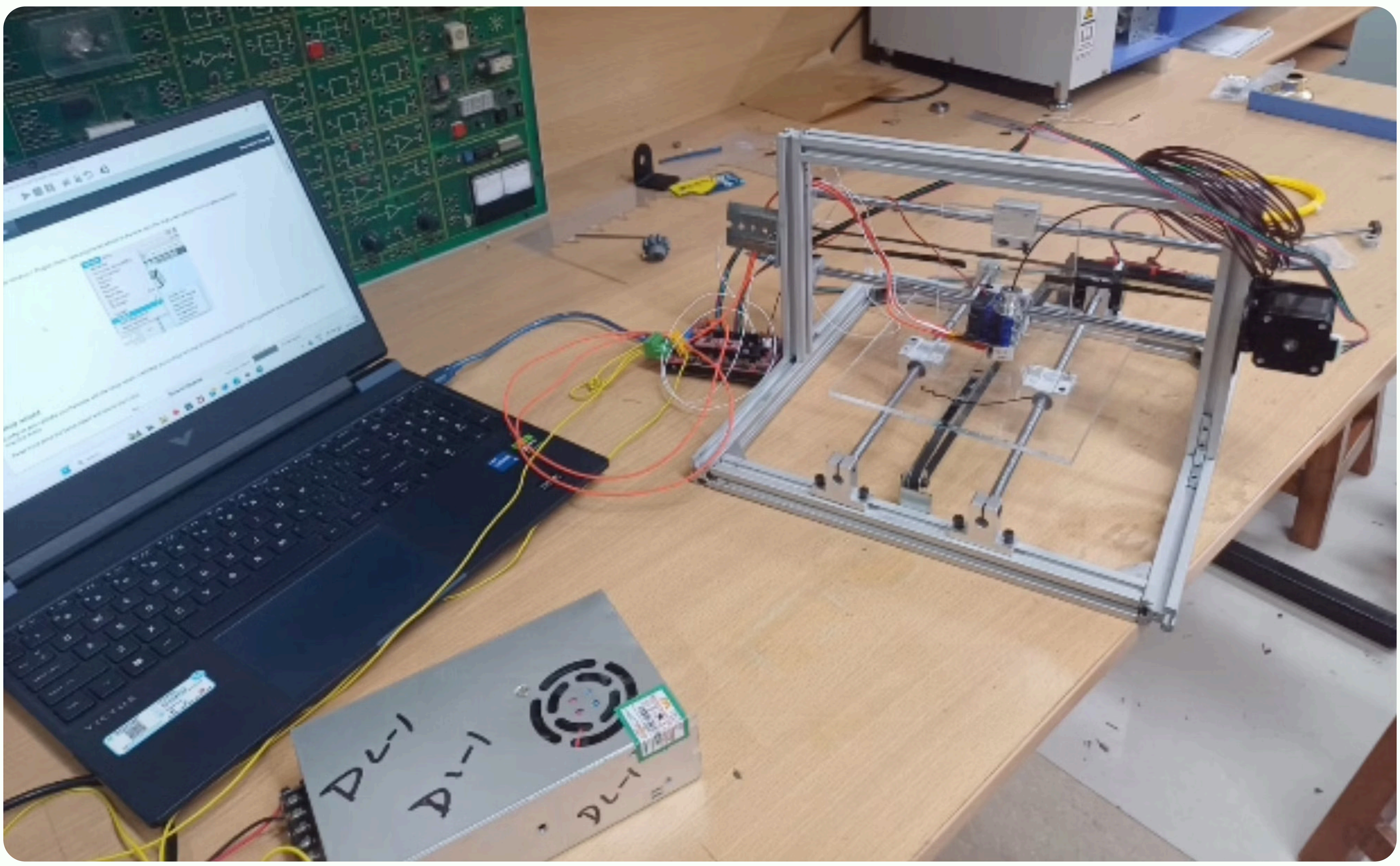


# Mechanical Design and Structure

## Frame Construction

The frame of the 2D printer was constructed using an **aluminium T-slot frame**. This type of frame is widely favored in mechanical design and prototyping because of its **modular and adjustable properties**, allowing for easy reconfiguration and upgrades during the building phase. The **T-slot design** consists of a series of vertical and horizontal aluminium extrusions, each with slots that accept T-nuts for fastening various components securely.

The overall frame of our printer is designed as a **rectangular structure**, optimized for both stability and **alignment** of the moving components. This rectangular shape also helps ensure that the beds can move along their respective axes without interference and with consistent spacing across the machine.

Additionally, the frame is designed with consideration for the **electrical components** (e.g., the Arduino Mega, RAMPS board, power supply), which are mounted securely on the frame to minimize any potential movement during operation.

## Linear Motion Setup

The **linear motion system** is one of the most crucial aspects of our 2D printer, as it ensures smooth and precise movement of the beds along the X and Y axes. For this, we employed **smooth guide rods** and **Linear Motion Ball Bearing Blocks (LM8UU)** to enable the beds to glide easily and with minimal friction along the rods.

### Linear Motion System Components:

- **Guide Rods:** We installed two smooth, **8mm diameter steel rods** for both the X and Y axes. These rods were chosen for their smoothness and strength, enabling them to withstand the forces exerted during movement while ensuring smooth motion of the beds.
- **T-slot L Brackets:** To secure the rods in place, we used **T-slot L brackets** attached to the frame. These brackets allowed us to mount the rods at the appropriate angles and distances, ensuring the motion system remained rigid and precise.
- **Linear Motion Ball Bearing Blocks (LM8UU):** These bearing blocks slide along the rods, minimizing friction and enabling the beds to move smoothly and with minimal resistance. The LM8UU bearings were specifically chosen for their durability, precision, and ability to handle the loads of the bed and extruder.

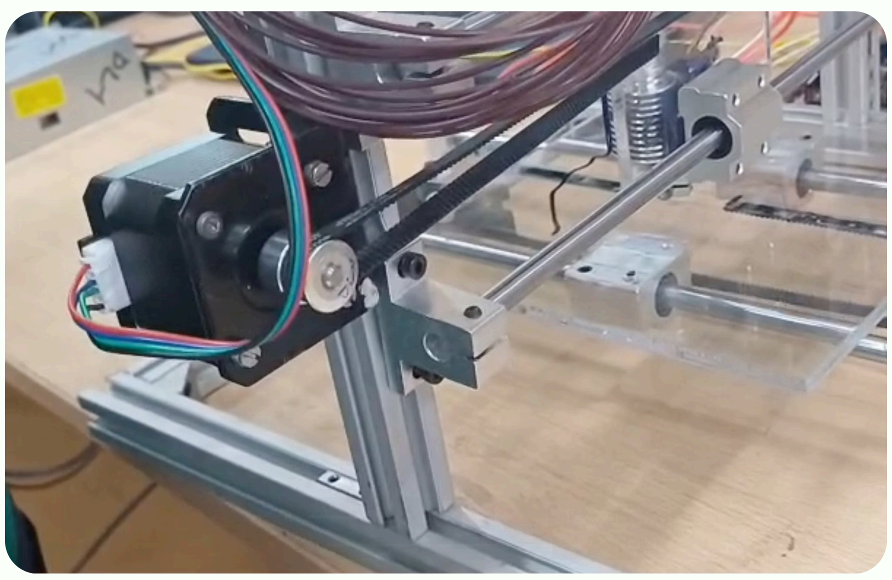
# Bed and Movement Mechanism

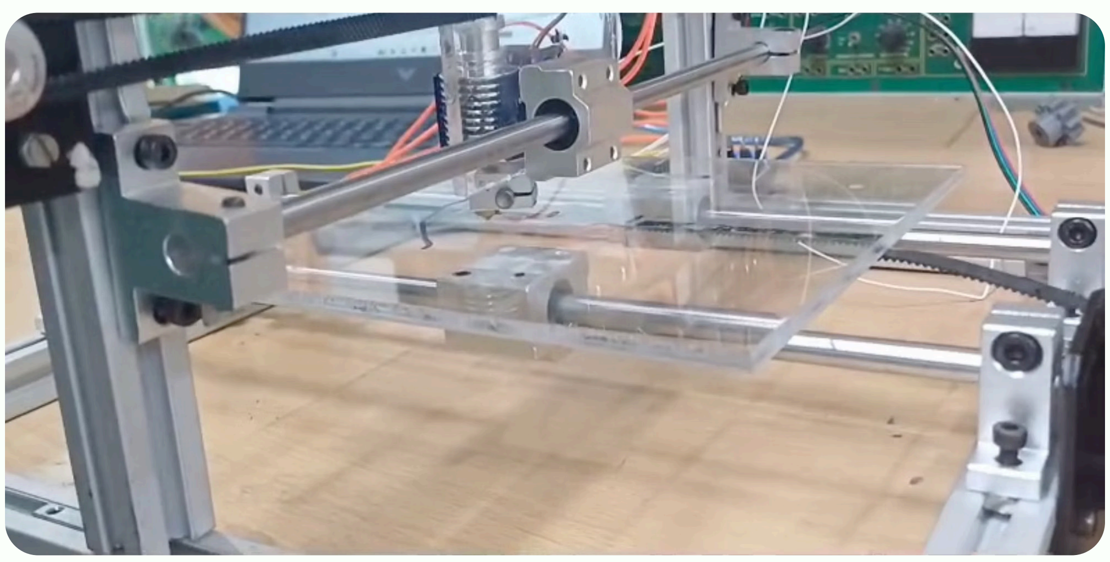
The movement mechanism of the printer involves two main beds, one for each axis (X and Y). The precise and synchronized movement of these beds is key to controlling the positioning of the extruder and ensuring accurate material deposition. The beds are connected to the frame via the linear motion system described above, and they are driven by stepper motors through a **timing belt and pulley system**.

> ### Y-Axis Bed:
>
> The **Y-axis bed** is fixed to the linear motion blocks, which are mounted on the rods for the Y-axis. The bed carries the **extruder**, which deposits the melted PLA material. As the Y-axis moves, the extruder moves with it, ensuring that the material is laid down in the correct locations according to the G-code instructions.
>
> ### X-Axis Bed:
>
> The **X-axis bed** serves as the **printing surface**. The extruder deposits molten PLA on this bed, and the bed's movement along the X-axis is just as critical to ensuring accuracy in the print. The X-axis bed is also connected to the linear motion system, moving along the smooth guide rods via the linear bearing blocks.

Each bed is connected to a timing belt, which is looped over pulleys. One pulley is attached to a stepper motor, and the other serves as a free rotating support at the opposite end. When the motor rotates, the pulley drives the belt, moving the attached bed accordingly.

*Belt connected to Stepper Motor*





*Bed movement*

# Extruder and Printing Material

## Extruder Overview

In our 2D printer, the extruder serves as the component responsible for feeding, melting, and depositing the printing material. As the Y-axis bed moves, the extruder moves with it, enabling dynamic positioning for material deposition.

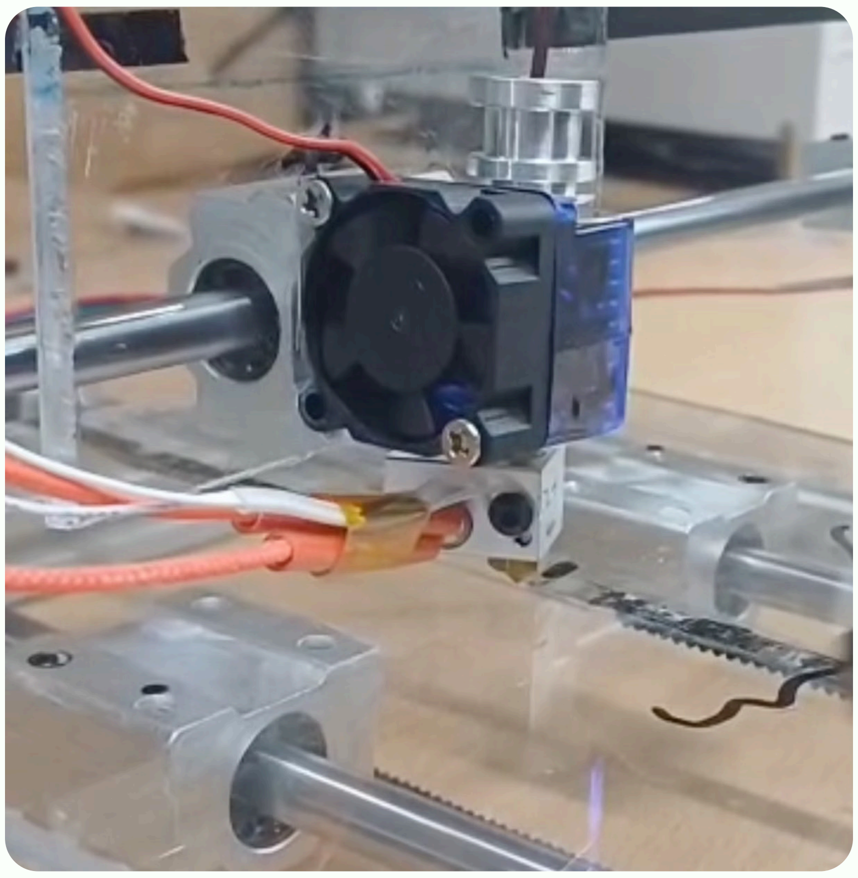
The extruder consists of several subcomponents:

- **Cold End:** Responsible for feeding the filament into the hot end using a stepper motor and drive gear mechanism.
- **Hot End:** This includes a heating block, nozzle, and temperature sensor (thermistor). The heating block raises the temperature of the filament to its melting point.
- **Nozzle:** The molten filament is extruded through a small-diameter nozzle, typically around 0.4 mm, allowing for fine detail in printed patterns.
- **Cooling Fan (optional):** Prevents heat from traveling up to the cold end and causing premature softening of the filament.

## Printing Material: PLA

We chose Polylactic Acid (PLA) as the material for printing due to its biodegradability, ease of handling, and minimal warping characteristics, making it ideal for prototyping and demonstration projects.

Operating parameters include a melting temperature range of 180°C to 220°C and a glass transition temperature near 60°C. We set the extruder to approximately 200°C to achieve optimal flow characteristics and adhesion to the printing surface.

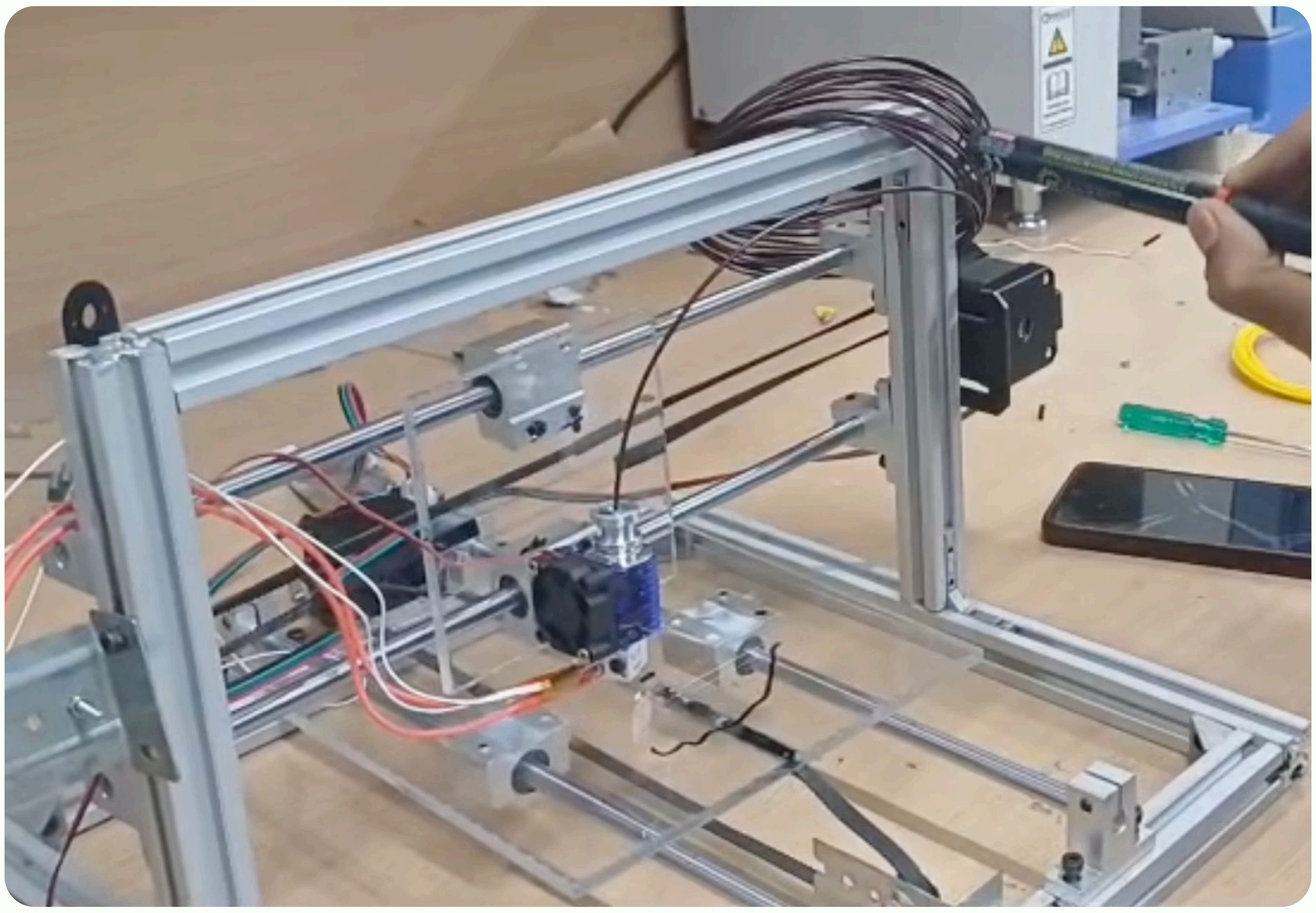


# Extruder Working Principle and Synchronization

The working of the extruder can be broken down into several steps:

1. **Filament Feeding:** A spool of PLA filament is fed into the extruder's cold end. A stepper motor drives a gear that grips the filament and pushes it downward into the hot end.
2. **Heating the Filament:** The hot end contains a heating element (resistor or cartridge heater) controlled by the Arduino and RAMPS 1.4. As the filament enters the hot end, it is heated to its melting point (around 200°C). A thermistor is placed near the heating block to monitor and regulate this temperature.
3. **Extrusion:** Once the filament is molten, it is pushed through the nozzle by continued motion from the cold end. The nozzle diameter controls the width of the deposited filament line.
4. **Deposition:** The molten PLA is deposited layer by layer (in our case, a single layer in 2D form) onto the X-axis bed. The motion of the X and Y beds—controlled by the stepper motors and timing belts—determines the pattern and path of deposition.
5. **Cooling and Solidification:** As soon as the PLA leaves the nozzle and comes into contact with the cooler surface of the X-axis bed or previously extruded material, it solidifies quickly, forming the intended shape.

Synchronization between the extruder's movement on the Y-axis bed and the X-axis bed's motion is achieved through carefully timed commands in the printer's firmware. This coordination ensures that filament deposition matches the desired pattern with positional accuracy, enabling detailed and consistent 2D prints.



# Electronics and Control System

## Hardware Components

The control system is powered by the following components:

- Arduino Mega 2560 microcontroller
- RAMPS 1.4 (RepRap Arduino Mega Pololu Shield)
- Stepper motors with drivers (typically A4988 or DRV8825)
- 12V, 10A DC power supply
- Endstops (optional, for homing functionality)

The RAMPS 1.4 board is mounted on the Arduino Mega and acts as the interface between the microcontroller and the stepper motors, extruder, and power system.

## Wiring Overview

- Motors are connected to the RAMPS board via stepper motor drivers.
- Power is supplied directly to the RAMPS board using the 12V, 10A supply.
- The extruder is connected to the heater MOSFET terminals.
- Thermistors (if used) provide temperature feedback to maintain optimal PLA melting temperature.

## Software

The firmware is written and uploaded using the Arduino IDE. The firmware can be either a basic custom script or a standard firmware like Marlin (for more advanced features). For basic functionality, we developed a simple sketch that controls motor steps and extruder heat.

Our code does the following:

- Initializes the stepper motor pins for X and Y axes
- Sends pulses to the motors to move the beds
- Activates the heater pin to maintain the extruder temperature
- Loops through G-code style instructions to create paths in X and Y

# Conclusion and Contributions

This 2D printer project successfully combined mechanical engineering, electronic control, and programming to create a precise, functional printer capable of depositing PLA filament in a planar 2D fashion. The use of modular aluminum T-slot framing and advanced linear motion components resulted in a stable and accurate mechanical platform.

The Arduino-based control system provided an adaptable and programmable environment, allowing coordinated control of stepper motors and extruder temperature, fundamental for accurate printing. Our design choices prioritized smooth motion, quiet operation, and energy efficiency.

Team Contributions:

- **Jahnavi Sharma:** played a key role in both procurement and mechanical assembly. She sourced essential components and took charge of mounting the smooth rods to the T-slot frame using L brackets. She also installed the Linear Motion Ball Bearing Blocks and ensured proper alignment of the beds. Additionally, she mounted the extruder onto the Y-axis bed and helped calibrate the belt-driven motion system.
- **Mohit Kumar:** focused on structural setup and electronics integration. He assembled the T-slot frame, ensuring stability and accurate geometry. He assisted in securing the beds to the linear bearings and supported wiring of the stepper motors. Mohit also helped mount the RAMPS 1.4 board and verified connectivity between electronic components and the power supply.
- **Palak:** worked primarily on assembling the extruder and testing its performance. She was responsible for connecting the heating element and thermistor to the hot end and securing the extruder onto the Y-axis bed. She monitored the heating process, ensured the PLA melted at the correct temperature, and helped troubleshoot early extrusion issues.
- **Priyansh Gupta:** was responsible for the electrical and control system. He connected the Arduino Mega with the RAMPS 1.4 board, stepper drivers, and the 12V power supply. He wired the extruder heating system and thermistor, ensuring correct temperature readings. He also ensured all circuit elements were safely and efficiently integrated on the printer frame.
- **Harshal Tarkase:** handled the programming and motion control. He wrote the Arduino IDE code to control X and Y axis stepper motors and configured motor direction, speed, and acceleration. He also developed code for extruder temperature control and tested movement synchronisation to ensure accurate bed motion during printing.