Food 3D Printer using syringe pump extruder

Summer Internship Report

Submitted by:

Karan .P

3rd Year B.Tech ECE

Vellore Institute of Technology, Vellore

Submitted to:

Dr. Lakshminath Kundanati

Assistant Professor

Department of Applied Mechanics and Biomedical Engineering

Indian Institute of Technology, Madras.

Department of Applied Mechanics and Biomedical Engineering

Indian Institute of Technology, Madras- 600036

JULY 2025

ACKNOWLEDGEMENT

I would like to express my deepest gratitude to my mentor Dr. Lakshminath Kundanati, Assistant Professor, Department of Applied Mechanics and Biomedical Engineering, Indian Institute of Technology, Madras , for his invaluable guidance, support, and encouragement throughout the duration of my summer internship. His expertise and insightful feedback greatly enhanced my learning experience and contributed significantly to the completion of this project.

I also want to express my heartfelt appreciation to my colleagues and friends in **Inspired Lab** for their continuous support and collaboration, which made this journey both productive and enjoyable.

Thank you all for your support and encouragement.

Sincerely,

Karan P

TABLE OF CONTENTS

1. Introduction
2. Components used and Justification
   - Mechanical Componenets
   - Electronic Components
3. System architecture and Cartesian Kinematics
4. Electrical Wiring and Power Distribution
5. Syringe Pump Extruder
6. User Interface and Control System
7. Assembly, Calibration, and Testing
8. Inference
9. Future Scope
10. References

Food 3D Printer Using Syringe Pump Extruder

1. Introduction

The concept of 3D printing is now being extended beyond plastic and metal into the realm of edible materials. This project explores the development of a **Food 3D Printer** using a **custom syringe-pump extrusion system**. Unlike conventional filament-based 3D printers, which rely on melting and depositing thermoplastics, this machine is designed to extrude semi-solid or paste-like edible materials such as chocolate, icing, mashed potatoes, and fruit purees.

The printer employs a **Cartesian motion architecture**, where movement is segregated across three orthogonal axes (X, Y, Z). The extruder (a syringe pump mechanism) is motor-driven and controlled via G-code instructions sent through an open-source firmware, **Marlin**, running on an **MKS Robin Nano V3** board. A **MKS TS35 touchscreen** provides a user-friendly interface.

The primary motivation for this build is to serve as a **proof of concept** for affordable, customizable, and open-source food printing applications, ideal for research, culinary design, or healthcare dietary personalization.

2. Components Used and Justification

The components selected for the design and development of the food 3D printer were chosen based on a balance of performance, affordability, availability, and compatibility with open-source platforms. The system is broadly categorized into mechanical and electronic subsystems, each detailed below with justification for their inclusion.

A. Mechanical Components

a) Aluminium Linear Rails (X, Y, Z Axes)

Purpose: To facilitate precise and stable linear motion across all three axes.
Justification: Aluminium linear rails were chosen for their lightweight and corrosion-resistant properties. They offer high stiffness with minimal vibration, ensuring consistent paste deposition—a critical requirement in food printing applications.

b) NEMA 17 Stepper Motors (X, Y, E Axes)

Purpose: To drive the lateral (X), longitudinal (Y), and extrusion (E) movements of the system.
Justification: NEMA 17 stepper motors are widely used in desktop 3D printing due to their compact size and adequate torque. They are well-suited for light to moderate loads, making them ideal for the X and Y gantry movements, as well as for actuating the syringe plunger with consistent control.

c) NEMA 23 Stepper Motors (Z1 and Z2 Axes)

Purpose: To raise and lower the bed along the vertical Z-axis.
Justification: Given the increased mass of the bed assembly and the need for synchronized vertical movement, high-torque NEMA 23 motors were selected. Two motors are coupled in parallel (Z1 and Z2) to ensure even lifting and prevent mechanical binding or tilting of the bed.

d) PLA 3D-Printed Structural Parts

Includes: Motor mounts, syringe holder, structural brackets, and electronics enclosure.
Justification: Polylactic Acid (PLA) is a biodegradable, food-safe thermoplastic commonly used in 3D printing. It is easy to fabricate using standard desktop printers and offers adequate strength for non-load-bearing components. The ability to custom-design and print parts allows for seamless integration and modularity in the mechanical structure.

e) Moving Bed (Creality Ender 3 V3S Hot Bed)

Purpose: Serves as the substrate on which edible material is deposited.
Justification: A repurposed heated bed from the Creality Ender 3 V3S printer was utilized for its flat surface and proven compatibility with Marlin firmware. Although heating is not actively used in this project, the spring-mounted levelling screws allow precise calibration of the Z-height, which is essential for consistent layer thickness.

f) Custom Direct-Drive Syringe Plunger Mechanism

Purpose: Responsible for extruding paste-based food materials via syringe compression.
Justification: A direct-drive configuration was employed where a NEMA 17 motor presses a top-mounted plate onto the syringe plunger. This design ensures vertical force alignment, minimizing lateral stresses and improving extrusion consistency. It allows precise volumetric control synchronized with G-code instructions from the firmware.

B. Electronic Components

a) MKS Robin Nano V3 Motherboard

Purpose: Serves as the central controller responsible for interpreting G-code, coordinating axis movements, and managing all peripheral devices.
Justification: This Marlin-compatible motherboard was chosen for its robust feature set, including support for external stepper drivers and touchscreen displays. Its open-source nature and widespread community support make it ideal for prototyping and modification.

b) MKS TS35 Touchscreen Display

Purpose: Provides a graphical user interface for printer control, file loading, and real-time monitoring.
Justification: The MKS TS35 offers a plug-and-play interface with the Robin Nano board. Its touchscreen capabilities enhance usability, allowing intuitive manual controls without requiring a tethered computer.

c) DM542E Stepper Motor Drivers (5 Units)

Purpose: Amplify the step and direction signals from the motherboard to drive high-current stepper motors.
Justification: These external drivers support micro stepping and current tuning, offering superior torque and thermal management compared to onboard drivers. Their inclusion is essential for high-load applications such as vertical bed lifting and syringe extrusion.

d) LRS-350-24 Power Supply Unit (24V, 350W)

Purpose: Provides regulated 24V DC power to all electronic components including stepper drivers and the motherboard.
Justification: The LRS-350-24 is a reliable industrial-grade power supply capable of delivering sufficient wattage for simultaneous operation of multiple motors and controllers. It includes built-in safety features such as short circuit, overload, and overvoltage protection.

e) Wiring Harness and Connectors

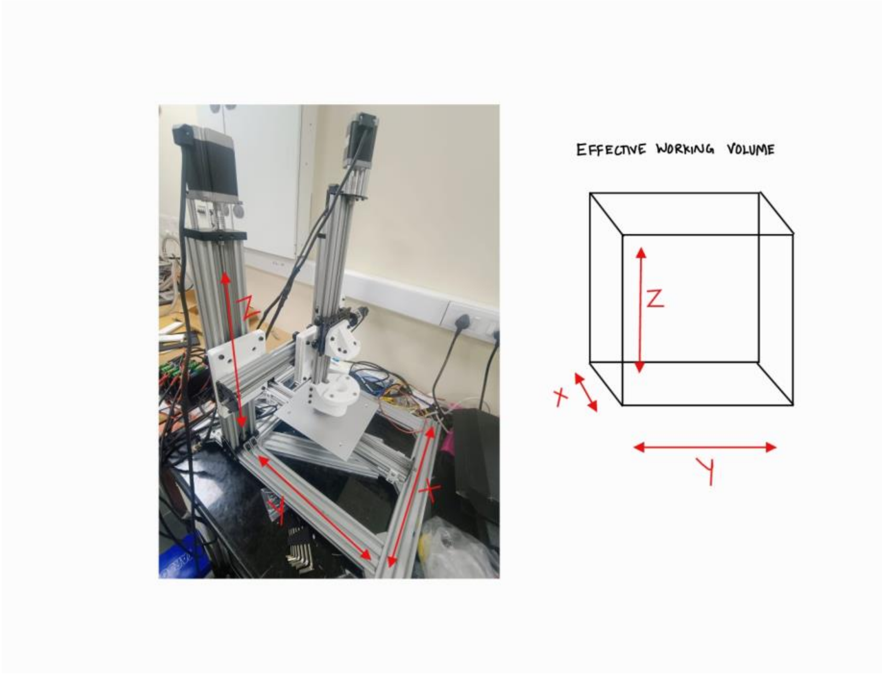
Includes: 4-pin motor cables, crimped connectors, terminal blocks, and signal cables.
Justification: Proper cable management and connector use ensures electrical reliability, ease of maintenance, and modular assembly. It also reduces the likelihood of voltage drops, interference, and accidental disconnections during printer operation

Basic Skeleton

3. System Architecture and Cartesian Kinematics

The printer is built on a Cartesian robot architecture where each axis moves independently in linear motion. The X-axis carries the syringe extruder laterally, the Y-axis moves the print bed forward and backward, and the Z-axis provides vertical movement through two synchronously driven NEMA 23 stepper motors (Z1 and Z2). Together, these axes define a rectangular 3D working space bounded by the mechanical travel limits of each axis. This forms a volumetric workspace suitable for layered deposition of paste materials.

The extruder is a direct-drive mechanism with a top-mounted motor that presses down on a syringe plunger to extrude material. The design ensures steady, controllable paste flow based on E-axis G-code commands.



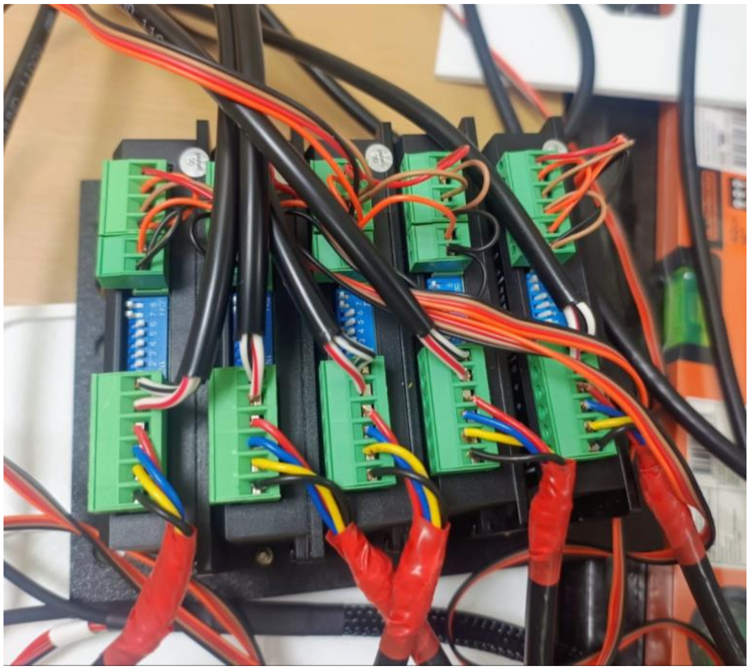
Working Volume

4. Electrical Wiring and Power Distribution

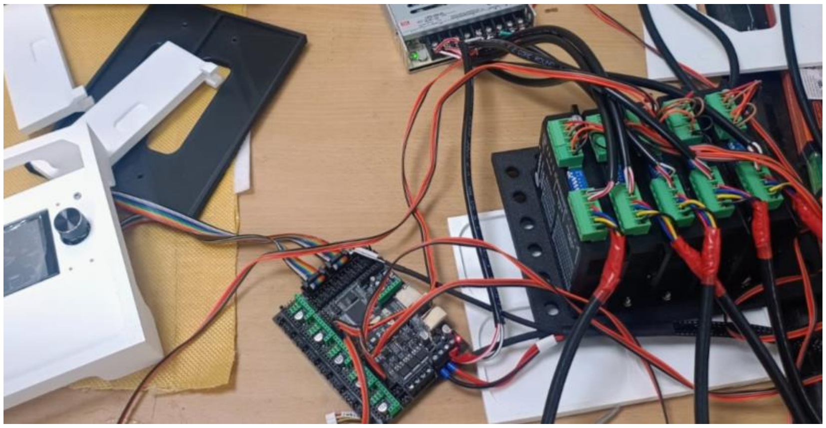
The printer's electronics are powered through an LRS-350-24 power supply delivering regulated 24V DC to all DM542 stepper drivers and the Robin Nano V3 motherboard. Each stepper driver receives power and control signals:

- Power: V+, V– directly from PSU
- Control: PUL+, DIR+, ENA+ from motherboard motor sockets; signal grounds returned
- Motors connect to A+, A–, B+, B– outputs from drivers using standard 4-pin connectors

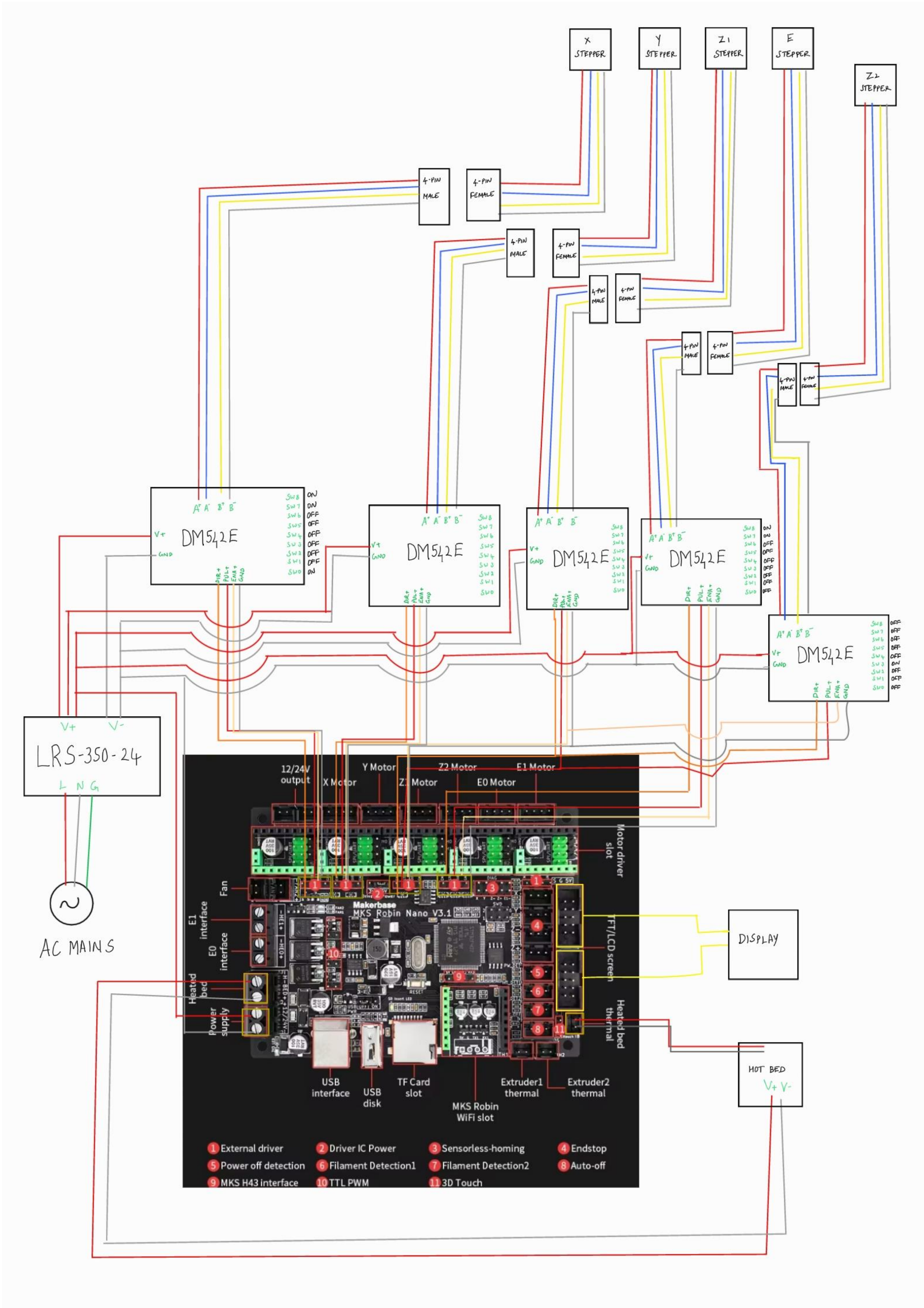
Stepper driver DIP switch settings are configured for microstepping and current control:
- X, Y, E axes: S7 and S8 ON
- Z1, Z2 axes: S3 ON
These settings ensure that 1 cm linear movement is achieved for each corresponding axis command.



Stepper Driver Wiring



Motherboard Wiring



Full Wiring Layout Schematic

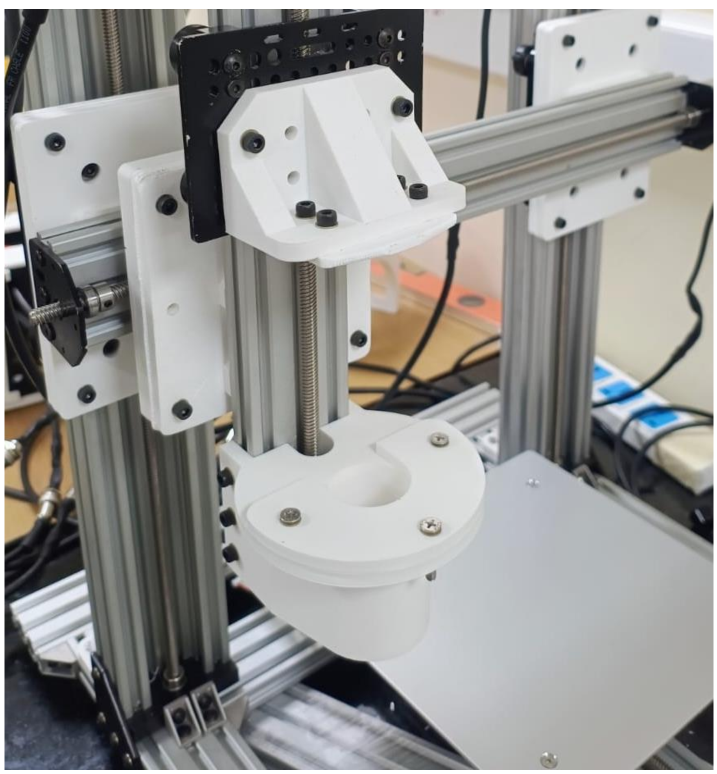
Connection Diagram Overview:

The wiring diagram shows the logical and physical connections between:
- MKS Robin Nano V3 motherboard
- Five DM542 stepper drivers
- LRS-350-24 power supply
- NEMA motors and touchscreen display

Each driver receives individual signal input and powers one motor. Z1 and Z2 motors are independently driven but operate in sync. Power flows from the PSU to all drivers and the motherboard. Control signals ensure coordinated movement based on firmware settings.

5. Syringe Pump Extruder

The extruder is a syringe-based food paste dispenser, directly driven by a NEMA 17 motor mounted above the syringe plunger. The motor pushes a top-mounted pressure plate downward to extrude the paste from the syringe. This mechanism is tightly coupled with the E-axis control in Marlin firmware, enabling precision volumetric deposition. The entire extruder module is mounted on the X-axis rail with a custom-designed holder.



Syringe pump extruder

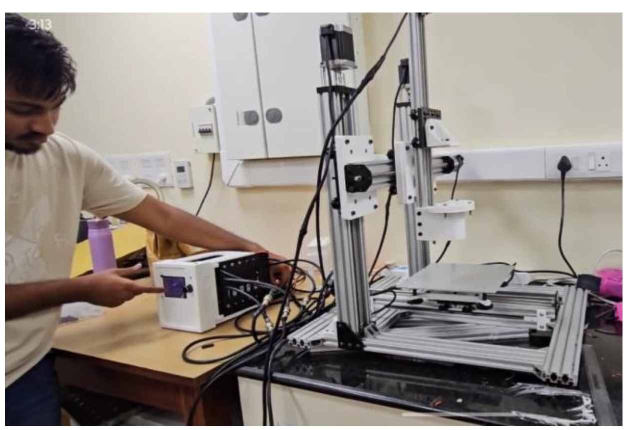
6. User Interface and Control System

An MKS TS35 touchscreen is used to interact with the printer. It provides manual axis control, file loading, and G-code execution. The firmware (Marlin) is pre-configured to support touchscreen operations, external drivers, and syringe-based extrusion logic. Repetier Host is used as the slicing software to generate compatible G-code instructions.

Enclosure Box with the Display

7. Assembly, Calibration, and Testing

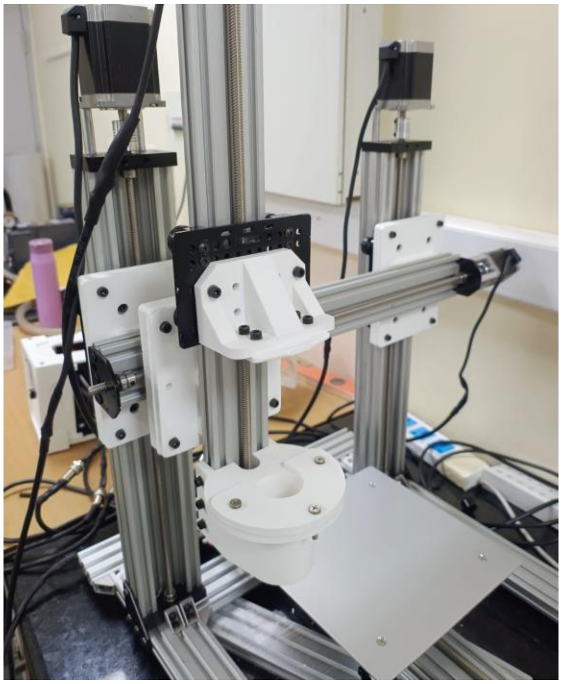
All major components are housed in a custom-designed PLA enclosure for safety and organization. After mechanical and electrical assembly, individual motors were tested for direction, homing, and response. Microstepping and driver currents were tuned to ensure consistent and linear motion. The print bed leveling is assisted by spring-tensioned screws mounted below the Creality Ender V3S hotbed. Calibration was verified using touchscreen-based movement commands to achieve precise 1 cm displacements.



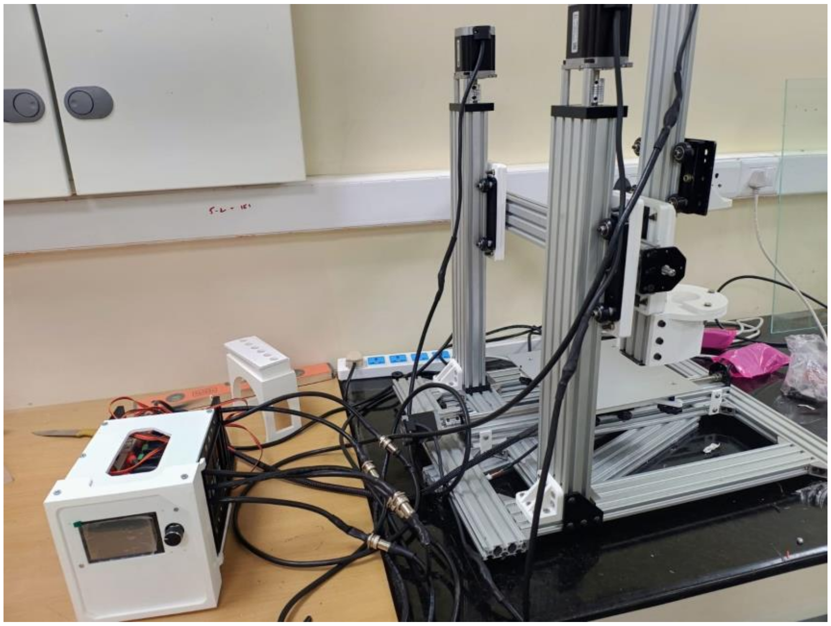
Calibrating using custom commands

8. Inference

This project demonstrates that it is possible to build a fully functional Cartesian food 3D printer using open-source hardware, custom 3D-printed components, and precise motion control. The use of external stepper drivers allows for high-torque applications such as food-grade syringe extrusion, making it suitable for complex edible 3D prints. The system is modular, customizable, and scalable for advanced food printing research.



Final Image



Full Setup

9. Future Scope

- Integrate temperature control for heated food materials like chocolate
- Add multi-syringe or tool-changing capability for complex recipes
- Explore Klipper firmware for faster motion planning
- Add Wi-Fi-based control and wireless file upload
- Enhance structural stability with metal-reinforced frames

10. References

- **Godoi, F. C., Prakash, S., & Bhandari, B. R. (2016).**
  3D printing technologies applied for food design: Status and prospects.
  Journal of Food Engineering, 179, 44–54.
  https://doi.org/10.1016/j.jfoodeng.2016.01.025

- **Liu, Z., Zhang, M., Bhandari, B., & Wang, Y. (2018).**
  3D printing: Printing precision and application in food sector.
  Trends in Food Science & Technology, 69, 83–94.
  https://doi.org/10.1016/j.tifs.2017.08.018

- **Jain, N., Taran, S., & Srivastava, A. (2021).**
  Development of open-source 3D food printer using Arduino Mega and Marlin firmware.
  HardwareX, 9, e00185.
  https://doi.org/10.1016/j.ohx.2021.e00185