SRI VENKATESWARA INTERNSHIP PROGRAM FOR RESEARCH IN ACADEMICS (SRI-VIPRA)

SRI-VIPRA

Project Report of 2024: SVP-2441

"Design and Analysis of 3D Printer"

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Sri Venkateswara College
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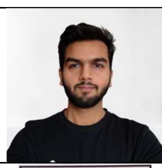
SRIVIPRA PROJECT 2024

Title : Design and Analysis of 3D Printer

Name of Mentor: Dr. Rakhi Narang Name of Department: Electronics Designation: Assistant Professor	Photo

List of students under the SRIVIPRA Project

S.No	Photo	Name of the student	Roll number	Course	Signature
1		Abhishek Kumar	1622014	B Sc. (H) Electronics	Abhishek Kumar.
2		Alok Yadav	1622046	B Sc. (H) Electronics	Alok Yadav
3		Arjit Brahma	1622004	B Sc. (H) Electronics	Arjit
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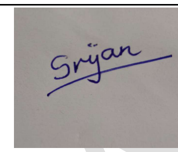
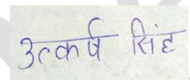
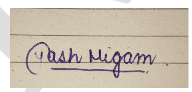
7		Srijan Bhargava	1622026	B Sc. (H) Electronics	
8		Utkarsh Singh	1622022	B Sc. (H) Electronics	
9		Yash Nigam	1622011	B Sc. (H) Electronics	
10		Himanshu	1622036	B Sc. (H) Electronics	

Signature of Mentor

Certificate of Originality

This is to certify that the aforementioned students from Sri Venkateswara College have participated in the summer project SVP-2441 titled "**Design and Analysis of 3D Printer"**. The participants have carried out the research project work under my guidance and supervision from 1st July, 2024 to 30th September 2024. The work carried out is original and carried out in an online/offline/hybrid mode.

Signature of Mentor

Acknowledgements

On the great occasion of the accomplishment of our project on "Design and Analysis of 3D Printer," we would like to sincerely thank and express our gratitude to Dr. Rakhi Narang, who has been supporting us throughout the project. Without her valuable knowledge and motivation, this project would never have been completed.

We would also like to thank our principal, Prof. V. Ravi, Sri Venkateswara College, for providing all the required facilities for the completion of this project.

We would also like to thank IEEE EDS Delhi Chapter for providing all the financial support for this project work.

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Introduction

Marlin is an open source firmware for the RepRap family of replicating rapid prototypers — popularly known as "3D printers." Originally derived from Sprinter and grbl, Marlin became a standalone open source project on August 12, 2011 with its Github release. Marlin is licensed under the GPLv3 and is free for all applications.

From the start Marlin was built by and for RepRap enthusiasts to be a straightforward, reliable, and adaptable printer driver that "just works." Marlin supports many different types of 3D printing robot platforms, including basic Cartesian, Core XY, Delta, and SCARA printers, as well as some other less conventional designs like Hangprinter and Beltprinter.

As a testament to its quality, Marlin is used by several respected commercial 3D printers. LulzBot, Průša Research, Creality3D, BIQU, Geeetech, and Ultimaker are just a few of the vendors who ship a variant of Marlin. Marlin is also capable of driving CNC machines and laser engravers.

One key to Marlin's usefulness is that it's built around the lightweight Arduino framework, so it runs on a huge number of inexpensive micro-controllers from classic Atmel AVR 8-bit boards all the way up to the latest ARM 32-bit OEM and upgrade boards from companies like BigTreeTech and Makerbase.

Marlin aims to support all possible boards and machine configurations. To be configurable, customizable, extensible, and economical for hobbyists and vendors alike. A minimal Marlin build can be very small (under 64KB), for use on a headless printer with only modest hardware. Features are enabled as-needed to support added components.

In addition to 3D printers, Marlin is generally adaptable to any machine requiring control and interaction. It has been used to drive SLA and SLS 3D printers, custom CNC mills, laser engravers (or laser beam machining), laser cutters, vinyl cutters, pick-and-place machines, foam cutters, and egg painting robots.

Main Features

- Smart motion system with lookahead, interrupt-based movement, linear acceleration
- Extendable support for Cartesian, Delta, SCARA, Core/H-Bot, and Hangprinter kinematics
- Full-featured G-code vocabulary with over 150 commands
- Complete move command suite, including lines, arcs, Bézier curves, and fast travel moves
- Optional S-Curve Acceleration for smoother acceleration
- Closed-loop PID heater control with auto-tuning, thermal protection, safety cutoff
- Support for up to 10 independent coordinated linear/rotary axes for custom applications
- Support for up to 8 extruder heaters plus a heated bed
- LCD Controller UI with more than 30 language translations
- Host-based and SD Card printing with autostart
- Bed Leveling Compensation — with or without a bed probe
- Linear Advance for pressure-based extrusion
- Input Shaping for faster motion with almost no vibration
- Support for Volumetric extrusion
- Support for mixing and multi-extruders (Cyclops, Chimera, Diamond)
- Support for Filament Runout/Width Sensors
- Print Job Timer and Print Counter

Development

Marlin firmware is hosted on GitHub, where it is developed and maintained by a community of contributors. Marlin's lead developer is Scott Lahteine (aka Thinkyhead), an independent shareware and former Amiga game developer who joined the project in 2014. His work is entirely supported by crowdfunding.
Marlin is written in optimized C++ for the Arduino API in a mostly embedded-C++ style, which avoids the use of dynamic memory allocation. The firmware can be built with Arduino IDE, PlatformIO, or Auto Build Marlin extension for Visual Studio Code. The latter method is recommended because it is very easy but it only being an Visual Studio Code extension requires Visual Studio Code to be installed on the building system first.

Setup & Usage

We saw that Marlin is an open-source firmware originally designed for FDM (fused deposition modeling) 3D printers using the Arduino platform.
Once the firmware has been compiled from C++ source code; it is installed and runs on a mainboard with onboard components and general-purpose I/O pins to control and communicate with other components. For control the firmware receives input from a USB port or attached media in the form of G-code commands instructing the machine what to do. For example, the command G1 X10 tells the machine to perform a smooth linear move of the X axis to position 10. The main loop manages all of the machine's real-time activities like commanding the stepper motors through stepper drivers, controlling heaters, sensors, and lights, managing the display and user interface, etc.

How Marlin Works

Marlin Firmware runs as a single large self-contained application on the 3D printer's mainboard. It manages all the real-time activities of the machine. It coordinates the heaters, steppers, sensors, lights, LCD display, buttons, and everything else involved in the 3D printing process.
Marlin implements an additive manufacturing process called Fused Deposition Modeling (FDM) — aka Fused Filament Fabrication (FFF). In this process a motor pushes plastic filament through a hot nozzle that melts and extrudes the material while the nozzle is moved under computer control. After several minutes (or many hours) of laying down thin layers of plastic, the result is a physical object.
The control-language for Marlin is a derivative of G-code. G-code commands tell a machine to do simple things like "set heater 1 to 180°," or "move to XY at speed F." Before you can print a 3D model you need to prepare it for printing. See below for more details.
Marlin's main loop handles command processing, updating the display, reading controller events, and running periodic tasks like monitoring endstops and filament sensors. While the command processor can be blocked by a lengthy command, other important tasks are maintained cooperatively by frequently calling the main idle() routine during long commands.
Marlin uses a shallow queue for G-code commands sent by the host or read from SD/FD during a print job. Most commands are executed right away, but movement commands are just queued up to be processed later.
Marlin handles a move command by adding one or more linear segments to the Planner Queue. Behind the scenes, linear moves are the only kind of moves Marlin actually does, so smooth G2/G3/G5 curves are converted into several small straight line segments before being added to the Planner Queue for processing.
A high priority Stepper Interrupt runs through the Planner Queue and generates precisely-timed electronic pulses to the stepper drivers. Even at modest movement speeds Marlin needs to generate thousands of

stepper pulses every second. A typical consumer 3D printer will need to generate 80 steps-per-mm at 50mm/s for a total of 4000 steps-per-second, and that’s just for a single axis!
Since CPU speed imposes a limit on how fast the machine can move, we’re always looking for new ways to optimize our motion code for MCUs with fewer resources like the AVR.

Printing Things

1. **Modeling**
   While Marlin only prints G-code, most slicers only slice STL files.
   Whatever you use for your CAD toolchain, as long as you can export a solid model, a slicer can “slice” it into G-code, and Marlin firmware will do its best to print the final result.
   Before Marlin can dream of printing, first you’ll need a 3D model. You can either download models or make your own with one of many free CAD programs, such as FreeCAD, OpenSCAD, Tinkercad, Autodesk Fusion 360, SketchUp, etc.
   A high degree of knowledge is needed to model complex objects like a T-Rex Skull, but other objects can be quite simple to model. To get ideas and test things out, explore sites like Thingiverse, YouMagine and Printables and print things for fun.
2. **Slicing**
   Slicers prepare a solid 3D model by dividing it up into thin slices (layers). In the process it generates the G-code that tells the printer in minute detail how to reproduce the model. There are many slicers to choose from, including:
   - PrůšaSlicer is a very capable, cutting-edge, free, open source slicer based on Slic3r.
   - Bambu Studio is a fork of PrůšaSlicer introduced in 2023 by Bambu Labs.
   - Orca Slicer is a popular fork of Bambu Studio with some refinements.
   - Cura is a popular free slicer that’s included with many printers and often re-branded.
   - Slic3r is one of the first slicers and is the basis for many others.
   - Simplify3D is a solid commercial offering with a simplified interface.
   - Kiri:Moto is a free web-based slicer that is fine for simpler print jobs.
3. **SD Printing**
   Marlin can print a file from an SD Card with no connection to a host device. On a headless printer with an SD card, a standalone SD print can be initiated from the host and then the host can still monitor the print.
   USB Flash drives (and USB-C dongles as on the AnkerMake M5) are also supported, and Marlin 2.x can switch between two media drives. In a future update we’ll be adding support for several arbitrary media types.
   It’s a hassle to carry Micro-SD cards around, so some printer boards have a “target mode” (look for “SDIO”) allowing you to tell the printer to temporarily release the onboard media. Then the SD/FD can be mounted as a USB drive on your PC for quick file transfers and firmware updates.
4. **Host Printing**
   Host software is available for several platforms, including desktop systems, Raspberry Pi, and Android tablets. Any device with a USB port and serial terminal can technically act as a host, but

you'll have a better printing experience using host software specifically designed for 3D printers. Current selections include:

- OctoPrint is a powerful open-source host for Raspberry Pi by Gina Häußge.
- Pronterface is an open-source host by Kliment that runs on desktop.
- Repetier Host is a closed-source host by Repetier Software.
- Cura is an open-source host by Ultimaker. YMMV depending on your printer.
- Simplify3D is a slicer but includes a basic host and console to send a print job.

Many 3D printers ship with a customized version of Repetier or Cura. While this helps to associate the printer brand with a companion piece of software, these versions are usually obsolete and receive few upgrades. We recommend you download the latest generic or open source version instead. The latest innovations can also save time and material, so it pays to stay up to date.

Community Support

The Marlin firmware community offers extensive support through various platforms, including GitHub, online forums, and social media groups. Users can access detailed documentation, report issues, and contribute to development. Active discussions in communities like Discord, Facebook, and Reddit help users troubleshoot and share custom configurations. Many enthusiasts create educational content on YouTube, while tools like the Marlin Firmware Builder simplify customization. The collaborative nature of the community ensures regular updates, bug fixes, and the ongoing addition of new features, making Marlin a robust and well-supported firmware for 3D printing.

Conclusion

Marlin Firmware stands out as a robust and versatile solution for controlling 3D printers, offering a powerful and adaptable platform for a wide range of 3D printers and CNC machines. Its open-source nature, combined with a rich feature set and active community, makes it an ideal choice for both beginners and advanced users, empowering them to customize and optimize their machines to meet specific needs. The firmware's support for a variety of features ensures high-quality prints and efficient operation.

The strength of Marlin lies not only in its comprehensive feature set but also in its active community of developers and users. This community is instrumental in driving the continuous improvement of the firmware, ensuring it evolves alongside technological advancements in the 3D printing industry. Users can access extensive documentation and community support, making it easier to configure and troubleshoot their setups.

As the 3D printing industry continues to evolve, Marlin remains a flexible and reliable choice for both hobbyists and professionals, continuously adapting and improving to meet the needs of a diverse user base. Its ability to integrate new technologies and adapt to different hardware configurations ensures it will remain relevant in the face of emerging trends. Whether for educational purposes, prototyping, or professional manufacturing, Marlin provides the robust foundation necessary for achieving precise, reliable, and high-quality results.

References

https://marlinfw.org/
https://github.com/MarlinFirmware
https://en.wikipedia.org/wiki/Marlin_(firmware)
https://reprap.org/forum/list.php?415

Circuits Boards for DIY-3D printer

In this project RAMP 1.4 circuit is used. Here is an overview of the circuit and comparison with other available circuit boards.
RAMPS 1.4 Assembly:

1. **Components:**
   - RAMPS 1.4 Shield: Sits on top of an Arduino Mega 2560 board, which together controls the motors, heaters, thermistors, and endstops.
   - Pololu Stepper Drivers: Can control up to five stepper motors with precise 1/16 micro-stepping.
   - Supports interfacing with hotend, heatbed, fan, and LCD controller.
   - Operates on 12V or 24V power supplies.
   - It connects up to three thermistors and six endstops.

2. **Assembly Process:**
   - Inserting Jumpers: Configure jumpers on the RAMPS board to control stepper motor precision, generally set to 1/16 micro-stepping for accuracy in 3D printer motion.
   - Stacking the Boards: The RAMPS shield stacks on the Arduino Mega, and the stepper drivers are placed on top of the RAMPS board.
   - Connecting the Power Supply: Ensuring the correct voltage (110V or 220V) is selected. Proper connection of wires to power the RAMPS board.
   - Motor and Sensor Connections: Motors, thermistors, hotends, heatbed, and fans are connected to the appropriate terminals. Endstops and LCD controllers are also attached.

3. **Schematic: The schematic outlines how to connect the motors, sensors, and other components properly to avoid damaging the board. Orientation and polarity are important, especially for motors and endstops.**

Circuit Explanation:

- RAMPS (RepRap Arduino Mega Pololu Shield) is a modular design intended for RepRap 3D printers. It relies on:
  - Arduino Mega 2560 as the main controller board.
  - Pololu Stepper Drivers to drive the stepper motors.
  - The RAMPS shield acts as an interface between the printer hardware (motors, heaters, thermistors) and the Arduino.
- The circuit includes connections for stepper motors, endstops, heaters, and thermistors. Power is supplied from an external 12V or 24V source, distributed to the necessary components through the RAMPS shield.

Pros of RAMPS 1.4 for 3D Printers:

1. Modularity: Separate boards for the controller (Arduino), shield (RAMPS), and motor drivers make it easy to replace or upgrade individual parts.
2. Cost-Effective: One of the cheapest solutions available for 3D printer electronics.
3. Wide Compatibility: Works with many RepRap printers and can control multiple motors, heaters, and sensors.
4. Customizable: Users can add or remove components, such as an LCD controller or second extruder, depending on their printer's needs.
5. Open-Source: Widely supported by the RepRap community with extensive documentation and support.

Cons Compared to Other Types of 3D Printer Circuits:

1. Limited by 8-bit Processing: Since it uses an Arduino Mega (8-bit processor), it's slower compared to more modern 32-bit boards. This can limit the processing speed and print quality at higher resolutions.
2. Wiring Complexity: The modular nature means there are many wires, which can be overwhelming and prone to errors during assembly.
3. Driver Overheating: The Pololu stepper drivers can easily overheat if not properly cooled. Heat sinks and sometimes active cooling are necessary.
4. Lacks Advanced Features: Newer boards like the Duet or SKR 1.4 support advanced features like Wi-Fi connectivity, faster processors, and more powerful motor drivers (TMC drivers), which offer smoother motion control and quieter operation.
5. Power Limitations: While RAMPS can work with 24V systems, this requires some modification. Other boards natively support 24V without additional changes.

When comparing RAMPS 1.4 to other circuit boards used in DIY 3D printers, it’s important to understand that newer boards have advanced features, more processing power, and better efficiency. Here’s a comparison with some popular alternatives:

1. SKR 1.4/1.4 Turbo (32-bit)

Overview:

The SKR 1.4 and SKR 1.4 Turbo from BigTreeTech are modern 32-bit controllers that provide powerful computing capabilities and advanced features.

Pros:

- 32-bit Processor: Faster processing speeds, resulting in smoother and higher-quality prints.
- Integrated Stepper Drivers: Supports TMC stepper drivers, which allow for silent printing and stealthChop mode, offering smoother, quieter motion.
- Flexible Power Options: Works natively with 12V and 24V systems without modification.
- More Features: Offers Wi-Fi support, touch screen integration, and better motor control.

- Compatibility with Marlin Firmware: Widely supported by open-source firmware.

Cons:

- Slightly More Expensive: Costs more than RAMPS, but the feature set justifies the price.
- Less Documentation for Beginners: The community support is growing but not as mature as RAMPS.
- Complex Setup: Advanced features can make initial setup more complicated for beginners.

2. Duet 2 WiFi (32-bit)

Overview:

The Duet 2 WiFi is a high-end 32-bit controller designed for advanced 3D printers. It supports a wide range of features, from multiple extruders to automatic bed leveling.

Pros:

- Wi-Fi Connectivity: Allows remote monitoring and control through a web interface.
- 32-bit Processor: Provides fast and responsive performance for high-precision prints.
- Integrated Stepper Drivers: Built-in Trinamic drivers offer silent operation and advanced motion control.
- Touchscreen Compatibility: Comes with the PanelDue touch screen for an intuitive user interface.
- Extensive Features: Supports features like automatic bed leveling, filament sensors, and multiple extruders.

Cons:

- Expensive: One of the priciest options available, which may not be ideal for DIY enthusiasts on a budget.
- Complex for Beginners: The vast number of features can overwhelm beginners.
- Smaller Community Support: While growing, the community around Duet isn't as large as Marlin or RAMPS.

3. MKS Gen L V1.0/V2.0

Overview:

The MKS Gen L is an affordable 3D printer board that combines the simplicity of RAMPS and the power of an Arduino Mega in one PCB, reducing the number of connections.

Pros:

- All-in-One: Combines RAMPS and Arduino Mega into a single board, reducing wiring complexity.
- Cost-Effective: One of the most affordable all-in-one boards, making it popular among budget DIYers.
- Compatible with Marlin: Easily runs Marlin firmware and has a wide user base.
- Supports TMC Drivers: Works with TMC drivers for smoother, quieter operation (although not natively silent).

Cons:

- 8-bit Processor: Like RAMPS, it is also limited by the 8-bit Atmega processor, leading to slower performance compared to 32-bit boards.
- Limited Expandability: Not as easily upgradable as SKR or Duet boards.
- Thermal Management: Like RAMPS, it has the potential to overheat if not adequately cooled.

4. Smoothieboard (32-bit)

Overview:

The Smoothieboard is a 32-bit board that runs Smoothieware firmware, known for its ease of use and high performance.

Pros:

- 32-bit Processor: Offers high-speed performance, supporting faster and smoother prints.
- Easy Configuration: The configuration file is text-based, making it easier to edit than Marlin's source code.
- Modular Design: Supports a variety of motors and extruders, including dual extrusion.
- Good for CNC and Laser Engraving: Works well for 3D printers, CNC machines, and laser engravers.

Cons:

- Price: More expensive than entry-level 8-bit boards.
- Firmware Lock-In: Smoothieboard works best with Smoothieware, meaning you're limited to using this firmware (unlike other boards which support Marlin, Klipper, etc.).
- Less Community Support: Smaller user base compared to Marlin, making troubleshooting less convenient.

5. Rambo Board

Overview:

The Rambo board is an all-in-one 8-bit solution that's highly regarded for its durability and reliability, often used in Prusa 3D printers.

Pros:

- All-in-One Design: Combines everything into one compact board, reducing wiring and making it easier to install.
- Reliable and Robust: Known for its durability and reliability in industrial settings and personal use.
- Easy Setup: Less complex wiring compared to RAMPS 1.4, reducing setup time and potential issues.

Cons:

- 8-bit Processor: Slower than 32-bit boards and can be a bottleneck for complex prints.
- Less Flexible: While easy to set up, it's less customizable compared to boards like RAMPS or SKR.
- More Expensive than RAMPS: While cheaper than Duet, it costs more than RAMPS 1.4 or MKS Gen L.

Conclusion:

RAMPS 1.4 is a great low-cost solution for beginners and tinkerers, but it falls short in terms of processing power and modern features. SKR 1.4 and Duet 2 offer far better performance, especially with 32-bit processors, quieter drivers, and advanced features like Wi-Fi and touchscreen support, though they come at a higher cost. MKS Gen L offers a middle ground between RAMPS and newer boards, providing better wiring management while still being affordable. Smoothieboard and Rambo provide other options that cater to those needing reliability or better performance for CNC or laser use cases.

Different types of 3D printer with pros & cons.

1. Fused Deposition Modelling (FDM):

- **How it works**: FDM extrudes thermoplastic filament, such as PLA or ABS, through a heated nozzle, layer by layer.
- **Pros**:
  - **Affordable**: One of the most accessible types of 3D printing due to its low cost and ease of use.
  - **Wide Material Range**: Can use various materials like PLA, ABS, and TPU, making it versatile for different applications.
- **Cons**:
  - **Lower Detail**: Limited precision, with visible layer lines that can affect the aesthetics of the print.
  - **Supports Required**: Complex geometries often require support structures, which increase post-processing time.

Reference:

- Turner, B. N., Strong, R., & Gold, S. A. (2014). A review of melt extrusion additive manufacturing processes: I. Process design and modelling. *Rapid Prototyping Journal*, 20(3), 192-204.

2. Stereolithography (SLA):

- **How it works**: SLA uses a laser to cure liquid photopolymer resin, solidifying it layer by layer to form an object.
- **Pros**:
  - **High Resolution**: Offers finer detail and smoother surface finishes than FDM, ideal for intricate models.
  - **Smooth Finish**: Minimal post-processing needed compared to FDM, yielding near-professional quality prints.
- **Cons**:
  - **Resin Cost**: Photopolymer resin is more expensive than FDM filament.
  - **Post-Processing**: Requires additional curing and washing, often with isopropyl alcohol, to finalize the print.

Reference:

- Ngo, T. D., Kashani, A., Imbalzano, G., Nguyen, K. T. Q., & Hui, D. (2018). Additive manufacturing (3D printing): A review of materials, methods, applications and challenges. *Composites Part B: Engineering*, 143, 172-196.

3. Selective Laser Sintering (SLS):

- **How it works**: SLS fuses powdered material, such as nylon, by using a laser to sinter each layer, bonding it together.
- **Pros**:
  - **No Support Structures**: The surrounding unsintered powder supports the object during printing, allowing for more complex geometries.
  - **Durable Parts**: Produces strong, functional parts that are suitable for mechanical use.
- **Cons**:
  - **High Cost**: SLS printers are more expensive, and the powder materials can also be costly.
  - **Post-Processing**: Requires powder removal and surface finishing, which can be time-consuming.

Reference:

- Goodridge, R. D., Tuck, C. J., & Hague, R. J. (2012). Laser sintering of polyamides and other polymers. *Progress in Materials Science*, 57(2), 229-267.

4. Digital Light Processing (DLP):

- **How it works**: DLP uses a digital projector to flash entire layers of a design onto liquid resin, curing them simultaneously.
- **Pros**:
  - **High Accuracy**: Superior to SLA in speed for small, detailed parts.
  - **Fast Layer Curing**: Cures an entire layer at once, allowing for quicker print times compared to SLA.
- **Cons**:
  - **Toxic Resin**: The liquid resin can be harmful, requiring proper ventilation and post-processing.
  - **Limited Materials**: Primarily limited to specific types of photopolymers, which may not have broad applications.

Reference:

- Lim, S. H., Chia, S. M., & Leong, K. F. (2003). Rapid prototyping: principles and applications. *World Scientific Publishing Co. Inc.*

5. Multi Jet Fusion (MJF):

- **How it works**: MJF uses a combination of inkjet heads to apply a binding agent onto a bed of powder, fusing it with heat to create each layer.
- **Pros**:
  - **High Speed**: Faster than SLS, MJF is suitable for high-volume industrial production.
  - **Strong Functional Parts**: Produces durable, fully-functional components with smooth surface finishes.
- **Cons**:
  - **Cost**: MJF printers and materials are typically more expensive and are primarily used in industrial settings.

- **Post-Processing**: Requires cleaning of the excess powder, which can add time to the overall process.

Reference:

- Vasquez, M., Lawal, M., Espalin, D., & Wicker, R. B. (2020). Powder fusion additive manufacturing—The NIST additive manufacturing benchmark test series. *JOM*, 72, 1178-1184.

6. Metal 3D Printing (SLM/DMLS):

- **How it works**: Metal 3D printing, including Selective Laser Melting (SLM) and Direct Metal Laser Sintering (DMLS), uses a laser to fuse metal powder into solid objects.
- **Pros**:
  - **Metal Parts**: Produces strong, heat-resistant parts used in aerospace, automotive, and medical industries.
  - **High Precision**: Offers excellent accuracy and mechanical properties, suitable for high-performance applications.
- **Cons**:
  - **Very Expensive**: The cost of the printer, metal powder, and post-processing equipment is significant.
  - **Complex Post-Processing**: Requires extensive post-processing, including support removal, heat treatment, and surface finishing.

Reference:

- Herzog, D., Seyda, V., Wycisk, E., & Emmelmann, C. (2016). Additive manufacturing of metals. *Acta Materialia*, 117, 371-392.

These references provide a deeper scientific foundation for the various pros and cons of 3D printing technologies. The chosen articles reflect research and development in additive manufacturing, helping to illustrate each technology's strengths and limitations

Printer Type: Cartesian 3D Printer with Back-and-Forth Moving Bed

We chose a conventional Cartesian 3D printer design where the heat bed moves back and forth along the Y-axis. This motion allows the extruder to handle the vertical (Z-axis) and horizontal (X-axis) dimensions while the bed moves in the Y direction. This configuration offers an effective balance of simplicity and accuracy, making it suitable for our application.

1. Advantages of Our Design

Simplified Mechanism:
The movement of the bed along the Y-axis reduces the load on the extruder, which only moves in the X and Z directions. This simplicity leads to fewer parts in motion, reducing wear and potential points of failure.

Improved Print Speed:
With the bed moving on the Y-axis, the overall design can achieve faster print speeds, especially for large objects, without compromising accuracy.

Balanced Load Distribution:
The movement of the bed across one axis distributes the mechanical load more evenly, enhancing the longevity of both the bed and the extruder mechanics.

2. Mechanical Setup

Our printer design follows a Cartesian system where the bed moves back and forth along the Y-axis. This system uses belts and pulleys to drive the bed's movement, while stepper motors and lead screws control the X and Z-axis movements.

2.1 X and Z Movement

The extruder is mounted on a gantry and moves along the X and Z axes. This allows for precise layer placement and ensures uniform layer height for objects of varying sizes.

2.2 Y-axis Bed Movement

The heat bed is mounted on a rail system that allows it to move back and forth along the Y-axis. This motion ensures consistent layer placement as the extruder moves in the X and Z directions.

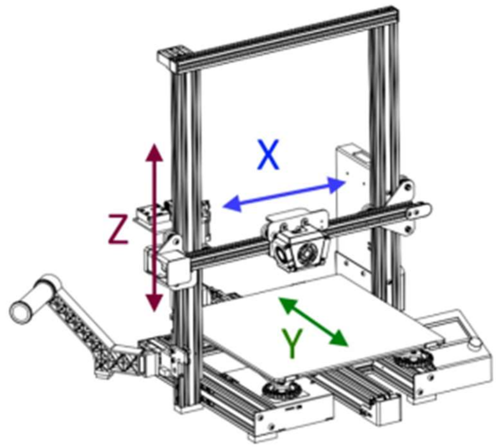

Figure 1: Motor movement in the X, Y, and Z directions. Source: Image Source

3.1 Material Comparison: PLA vs. ABS

The following table outlines key differences between the two filament types used in our 3D printer:

Feature	PLA (Polylactic Acid)	ABS (Acrylonitrile Butadiene Styrene)
Melting Temperature	Low (around 180–220°C)	High (around 210–250°C)
Odor During Printing	Sweet/non-offensive	Unpleasant/Burning plastic
Cost	Generally higher	Lower cost
Strength	Less durable, suitable for aesthetic prints	More durable, ideal for functional parts
Environmental Impact	Biodegradable	Non-biodegradable
Object Hardness	Softer prints, not ideal for high-stress applications	Harder, stronger prints

Table 1: Comparison between PLA and ABS filaments.

3.2 Material Handling

For our initial testing phases, PLA was primarily used due to its ease of use and minimal tendency to warp. The printer is also designed to handle ABS, with the extruder capable of reaching the higher temperatures required for printing ABS.

PLA is advantageous for prototypes or objects that do not require high durability. It has a lower melting temperature and generates less Odor during the printing process. However, ABS is more suitable for functional prints that require greater strength, though it has a stronger, less pleasant Odor and requires higher printing temperatures.

3.3 Extrusion and Layering

The extruder heats the filament and deposits it through a nozzle onto the build platform in thin layers. We optimized the extrusion process to ensure uniform flow and precise placement, which is critical for achieving smooth surface finishes. PLA's lower melting temperature was beneficial during testing, as it reduced energy consumption and prevented clogging in the nozzle.

3.4 Cooling and Solidification

For both PLA and ABS, cooling fans are installed to regulate the solidification process. Proper cooling is critical for PLA to prevent stringing and for ABS to minimize warping, especially for larger prints. Cooling time for ABS requires careful control to avoid cracks and warping, which can negatively affect the structural integrity of the printed object.

4. References

1. CoreXY explained: Comparison + strengths and weaknesses. [Online].
2. PLA vs ABS Filament: Which One to Choose for Your 3D Printer, 3D Insider . [Online].
3. 3D Printing Filament Comparison: PLA vs ABS, All3DP. [Online].

Progress Report: 3D Printer Manufacturing

1. Overview

The 3D printer manufacturing project is progressing as planned with significant advancements in the design, component sourcing, and assembly stages. The project remains on track for the targeted completion date, with minor adjustments made to optimize performance and cost-efficiency.

2. Progress to Date

2.1 Design Phase

Status: Completed

- The final design of the 3D printer, including hardware and firmware, has been finalized. Adjustments have been made to improve print accuracy and reduce overall power consumption.
- CAD models have been sent for review and validation.
- Firmware development is 95% complete, with final testing underway.

2.2 Component Sourcing

Status: 70% Complete

- Key components, such as electronic components (motherboard) and control boards, have been sourced from reliable suppliers.
- There has been a delay in the delivery of specific items, including hot ends, print beds, stepper motors, and nozzles. Alternative suppliers have been identified to avoid further delays.
- Materials for frames and structural components have been received and are undergoing assembly.

2.3 Manufacturing and Assembly

Status: 50% Complete

- Manufacturing of the printer's chassis and key structural parts is progressing on schedule.
- The frame has been successfully produced and inspected.
- Assembly preparation is underway for integrating electronic components once all materials arrive.
- Minor modifications to the assembly process are planned to improve efficiency and reduce production time.

3. Key Accomplishments

- Successful finalization of the 3D printer design.
- Completion of 60% of the structural components manufacturing.
- Early prototype testing has yielded promising results for printing control.

4. Challenges

- Component Delays:

Delays in the delivery of some electronic components have caused minor disruptions in the assembly timeline. Steps have been taken to mitigate the issue by sourcing from alternative suppliers.

- Testing Delays:

More time than expected was required for testing the firmware with multiple material types. The schedule has been adjusted to account for extended testing.

2. Next Steps:

- Finalize the assembly of the remaining components as they arrive.
- Complete firmware testing and make final adjustments.
- Continue stress testing of the prototype to ensure long-term reliability.

3. Timeline:

- Current progress indicates that the project is on track to meet the revised milestone dates.

4. Budget:

- Current expenditure is within the allocated budget, with no major cost overruns. A detailed financial report will be available at the end of the next reporting period.

Report on Materials and Specifications

Materials Used:

1. **PVC Pipe**:
   - **Quantity**: 12 pipes
   - **Diameter**: 0.75 inch
   - **Length**: 37 cm (each pipe)
2. **3-Way Connector**:
   - **Quantity**: 8 connectors
   - **Diameter**: 0.75 inch (to match the PVC pipes)
3. **Glue**:
   - Used to assemble the pipes and connectors for a secure fit.

Structure Overview:
The structure consists of 12 PVC pipes, each having a diameter of 0.75 inches and a length of 37 cm. To join these pipes, 8 three-way connectors with matching diameters are used. The components are bonded using glue, ensuring stability and rigidity in the overall construction.

Notes:

- **Material Strength**: PVC is lightweight and durable, providing a solid foundation for various applications.
- **Connector Compatibility**: The 3-way connectors are designed to fit perfectly with the 0.75-inch diameter pipes, facilitating easy assembly.
- **Glue Type**: A strong adhesive suitable for PVC material is recommended to ensure that the joints are secure and resistant to movement.