Al-Najah National University

FACULTY OF ENGINEERING AND INFORMATION TECHNOLOGY

Computer Engineering Department

Hardware Graduation Project

Economic Filament Maker For 3D Printing

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Disclaimer Statement

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Abstract

3D printing has become an essential tool in engineering, education, and product development, yet its progress is often hindered by the high cost of commercial filament. This project presents the design and implementation of a low-cost, do-it-yourself filament maker machine capable of producing high-quality 3D printer filament from recycled plastic materials. The system integrates an **Arduino Mega 2560** microcontroller with an **ESP8266 Wi-Fi module** to automate the extrusion, cooling, and spooling processes, ensuring stable operation and consistent filament diameter.

The development of the project involved several stages: the mechanical design of the extrusion and feeding system, integration of heating and cooling units, and implementation of motor drivers for puller and spool control. On the software side, custom Arduino firmware was developed to regulate temperature using a PID controller, manage motor speeds, and enable monitoring through a web interface hosted on the ESP8266. Testing and calibration focused on achieving accurate temperature control and producing filament with a stable diameter of 1.75 mm ±0.1 mm.

Unlike traditional methods of filament production, this system emphasizes **sustainability, affordability, and accessibility**, making it a practical solution for local makers, research labs, and small workshops. By reducing dependency on imported filament and promoting plastic recycling, the project supports both economic and environmental goals while opening new opportunities for innovation in additive manufacturing.

Contents

Introduction

Problem Statement

Despite the rapid growth of 3D printing, many users—students, makers, and small labs—face high recurring costs of commercial filament and limited local availability. Traditional recycling methods lack process control, leading to unstable diameter and poor print quality. There is a need for a cost-effective, DIY, and safe filament-making system that delivers consistent 1.75 mm filament with minimal setup, accessible components, and easy monitoring.

Objectives of the Work

Design and build a low-cost filament maker capable of producing consistent 1.75 mm filament.

Implement temperature control (PID) for stable extrusion and quality.

Develop synchronized control for puller and spooler to maintain diameter stability.

Integrate Arduino Mega 2560 with an ESP8266 web interface for monitoring and basic control.

Define a calibration procedure for temperature/speed setpoints and diameter verification.

Evaluate performance (stability, runtime, tolerance) and document safety measures.

Optimize the system for affordability, maintainability, and reuse of local/repurposed parts.

Scope of the Work

The project covers: (1) design of the extrusion, cooling, puller, and spooling subsystems; (2) embedded firmware (Arduino C++) with PID temperature control and PWM motor control; (3) a lightweight ESP8266 web page for setpoints/status; (4) test plans for diameter stability and runtime.

Out of scope: industrial-grade throughput, closed-loop laser diameter sensing (proposed as future work), and mass-production tooling.

Significance of Our Work

The system reduces filament cost, promotes plastic reuse, and improves self-sufficiency for local makers and labs. By emphasizing repeatability and simple calibration, it helps democratize access to 3D-printing materials, aligning with sustainability goals and enabling prototyping and education at lower cost.

Organization of the Report

.1Introduction: Problem, objectives, scope, and significance.

.2Literature Review: Filament extrusion principles, DIY vs. commercial systems, control and cooling methods.

.3Methodology: Mechanical/electrical design, firmware, web interface, calibration and test procedures.

.4Results and Findings: Diameter stability, temperature control performance, runtime observations, challenges and fixes.

.5Discussion: Implications, limitations, and potential applications.

.6Conclusion and Recommendations: Key outcomes and future enhancements.

.7Appendices: BoM (textual), wiring notes, test logs, and procedures.

Constraints, Codes, and Earlier Coursework

Constraints and Limitations

.1Economy: Use widely available/repurposed components (ATX PSU, automotive relays, window motors) to keep costs low.

.2Diameter Precision: Achieve stable 1.75 mm output via coordinated puller/spooler control and steady temperature.

.3Ease of Use: Provide clear menus/LCD and a simple ESP8266 web page for setpoints and status.

.4Safety: Manage hot surfaces and high-current heater with fuses, proper wiring gauge, and emergency cut-off.

.5Manufacturability: Favor simple mechanisms and parts that are locally available and serviceable.

.6Environment: Encourage recycling and minimize waste; consider ventilation for fumes.

.7Reliability: Maintain stable operation over extended runs; document calibration to repeat results.

Codes and Standards (Applied/Referenced)

Electrical safety practices for low-voltage DC systems and high-current heater wiring (fusing, insulation, strain relief).

EMI/Noise mitigation: debouncing inputs, grounding practices, and cable management.

Networking: basic adherence to IEEE 802.11 usage (ESP8266 Wi-Fi).

Documentation style: references formatted in APA as per department guidelines.

) Note: Where formal compliance is required, list exact clauses followed and test evidence(.

Earlier Coursework Supporting the Project

Microcontroller Programming (Arduino/PIC): sensor reading, PWM motor control, serial comms.

Control Systems: PID temperature regulation and tuning for stable extrusion.

Digital/Power Electronics: driver selection (BTS7960/L298N), relay interfacing, and safe power distribution (ATX rails).

Embedded/Networking: UART protocols and lightweight web UI on ESP8266 for monitoring.

Research & Technical Writing: structured testing, analysis, and reporting.

Literature Review (Concise)

Filament Extrusion Basics. DIY filament makers convert thermoplastic pellets or recycled plastic into continuous filament through controlled heating, metering, cooling, and winding. Key variables are temperature profile, feed rate / puller speed, and cooling strategy.

DIY vs. Commercial Systems. Commercial units often include closed-loop diameter sensing and refined thermal profiles at higher cost. DIY builds trade that for affordability and customization, emphasizing careful calibration and component choice.

Control Approaches. PID loops stabilize nozzle temperature; coordinated puller/spooler PWM prevents necking or over-thick filament. Filtering sensor inputs and isolating power domains reduce noise and improve repeatability.

Cooling and Winding. Air (fans) or water cooling affects crystallization and diameter stability; winding tension must track filament speed to avoid stretching or slack.

Sustainability Context. Recycling pathways (pellets or shredded plastic) lower material costs and environmental footprint, supporting local maker communities and education.

Methodology

Hardware Components

Hardware Implementation

seasonic power supply

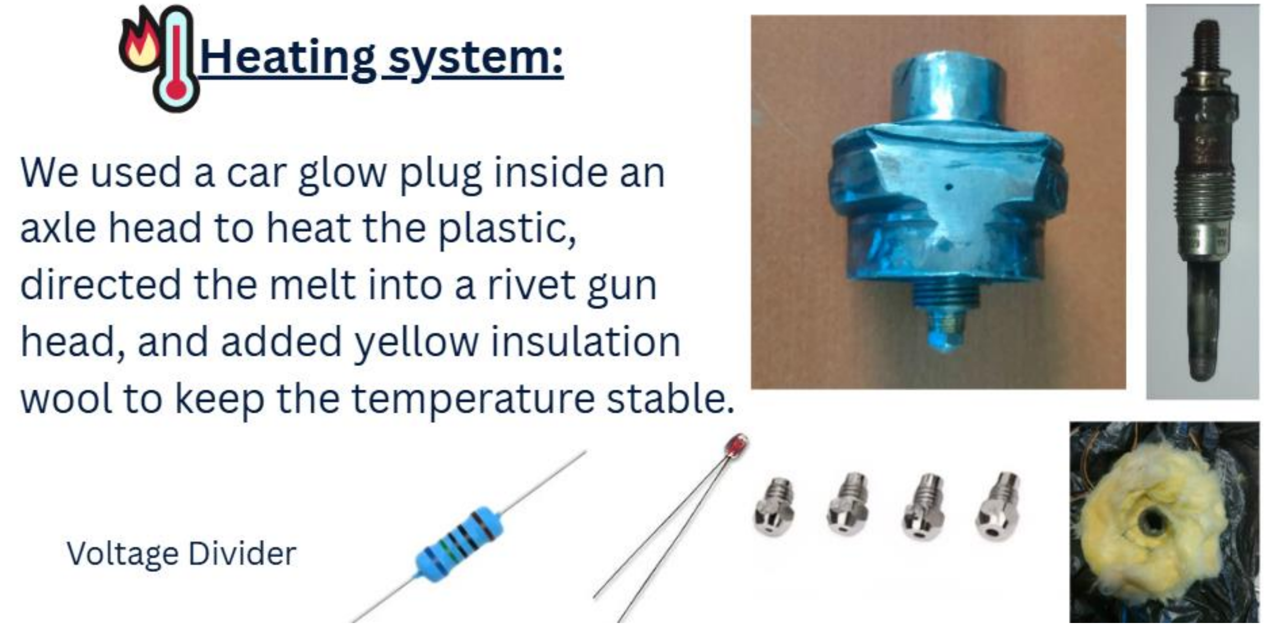
4. Components & Process

Seasonic ATX Power Supply

- Role: Central DC power source for logic (5 V/3.3 V) and power stages (12 V) with strong regulation under dynamic loads (heater PWM, motor start current).
- Rails usage (typical): 12 V → heater relay & DC motors; 5 V → sensors/relays logic; 3.3 V → ESP8266/I²C peripherals (if required).
- Protections: Built-in OCP/OVP/OTP; add an external fuse on the 12 V rail for the heater path.
- Wiring: Use appropriate gauge (AWG14–16 for heater/motors; AWG20–22 for logic). Keep motor/heater returns separated and star-ground near PSU.
- EMI & noise: Twist motor leads; add flyback diodes for relay coils; route sensor/ADC lines away from H-bridge outputs.
- Power budget: Sum steady + surge currents and leave ≥30% headroom to avoid PSU foldback during stalls.

A high-current ATX PSU supplying +3.3 V, +5 V, and +12 V. It powers heaters, motors, and logic. Modular outputs simplify wiring; built-in protections (OCP/OVP/OTP) enhance safety. Using a reputable PSU improves voltage stability during load surges (motor start and heater duty cycles).

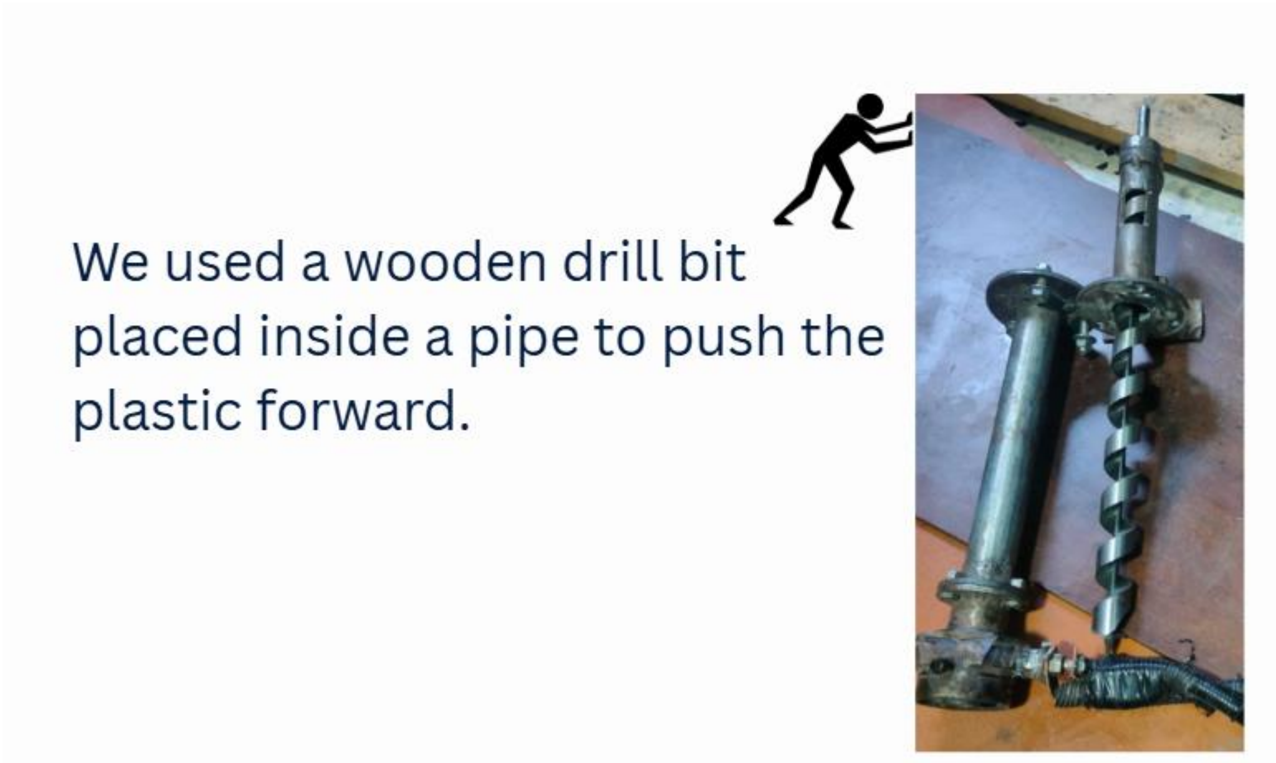
Heating System (Glow Plug + Axle Head + Insulation)



- Heater block: Glow plug embedded in a machined axle head provides thermal mass for smoother temperature.
- Thermal loop: Thermistor near melt zone; PID gains tuned to minimize oscillation; implement anti-windup in firmware.
- Flow path: Keep nozzle concentric and burr-free to reduce shear hotspots/clogs.
- Insulation: Mineral/ceramic wool lowers duty cycle and stabilizes extrusion.
- Safety: High-current path via 40 A automotive relay + inline fuse; high-temp-rated crimp terminals; strain relief on cables.
- Maintenance: Clean nozzle residue; verify thermistor seating and re-torque glow plug threads when cold.

An automotive glow plug is inserted into a machined axle head to form the heater block. Melt is directed through a rivet-gun head. Insulation wool maintains stable temperature and reduces power consumption. A thermistor provides feedback for PID control.

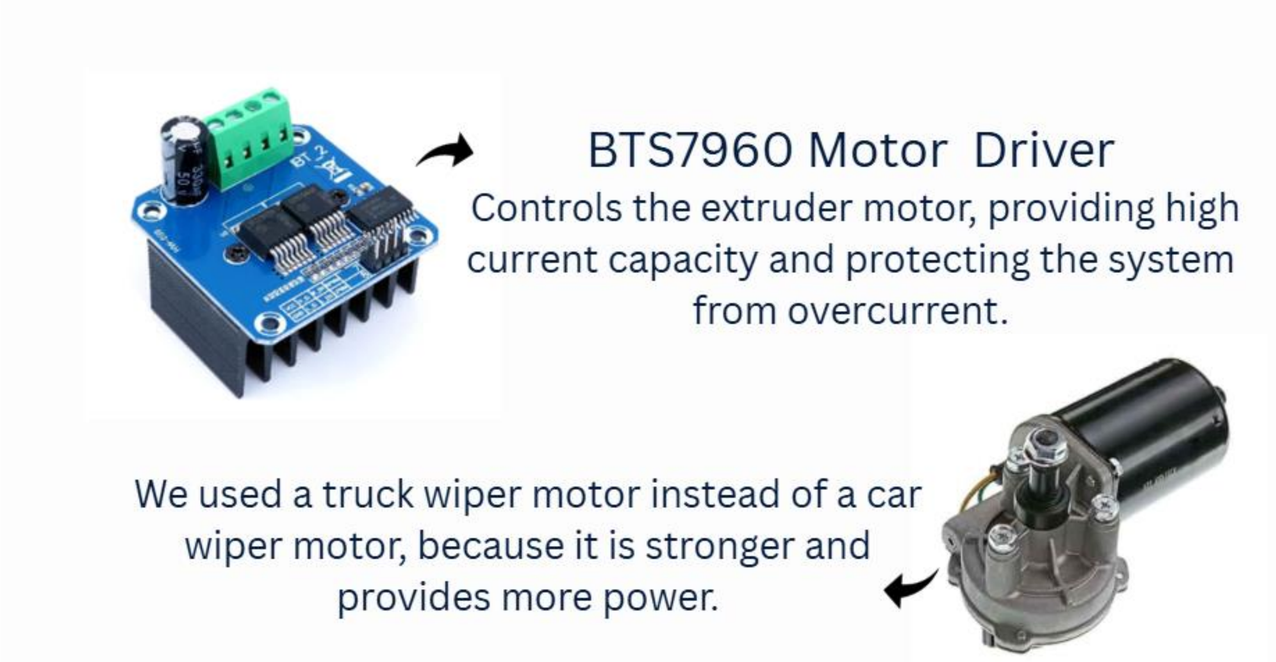
Mechanical Feeder (Wood Drill Screw in Pipe)



- Principle: Auger-like action moves softened plastic forward; pitch and clearance set throughput/pressure.
- Geometry tuning: Smaller pitch → higher pressure but more torque; smooth drill edges to prevent shavings.
- Alignment: Concentricity with heater bore avoids scraping and uneven shear.
- Torque path: Use a rigid coupling with minimal backlash between motor and screw.
- Service: Inspect wear/residue; polish inner pipe lightly to lower friction.
- Clogs: Provide a reverse-jog routine; purge slightly hotter after long idle.

A wooden-drill screw inside a steel pipe acts as a basic extruder screw. The geometry provides forward thrust to push softened plastic. Clearances and speed are tuned to avoid clogging while maintaining throughput.

Extruder Drive (BTS7960 + Truck Wiper Motor)



- Driver choice: BTS7960 tolerates high current; mount with airflow/heatsink.
- Motor: Truck-grade wiper motors offer higher stall torque and better thermal mass for continuous duty.
- Control: Map PWM duty to effective feed rate via a short calibration table saved to EEPROM.
- Protection: Slow-blow fuse on motor feed; star-ground logic/motor returns to reduce ground bounce.
- Wiring: Keep PSU→BTS→motor leads short/thick; separate sensor/logic cables; ferrites on motor leads if needed.
- Monitoring: Log driver temperature (or add an NTC nearby) to avoid thermal shutdowns.

BTS7960 H-bridge drives a high-torque truck wiper motor. PWM duty controls screw speed; current capability helps survive stalls. The motor-to-screw coupling is reinforced for continuous duty.

Cooling System (Fans)

- Goal: Solidify filament before puller to stabilize diameter (avoid necking or brittleness).
- Placement: Aim laminar flow around filament; avoid turbulent spots that cause ovality.
- Speed control: PWM profile vs. line speed; baseline fan % determined during calibration.
- Noise/EMI: Decouple fan supply locally (100 µF + 0.1 µF); return grounds to star point.
- Maintenance: Clean filters; check bearings; replace noisy fans early to reduce vibration.

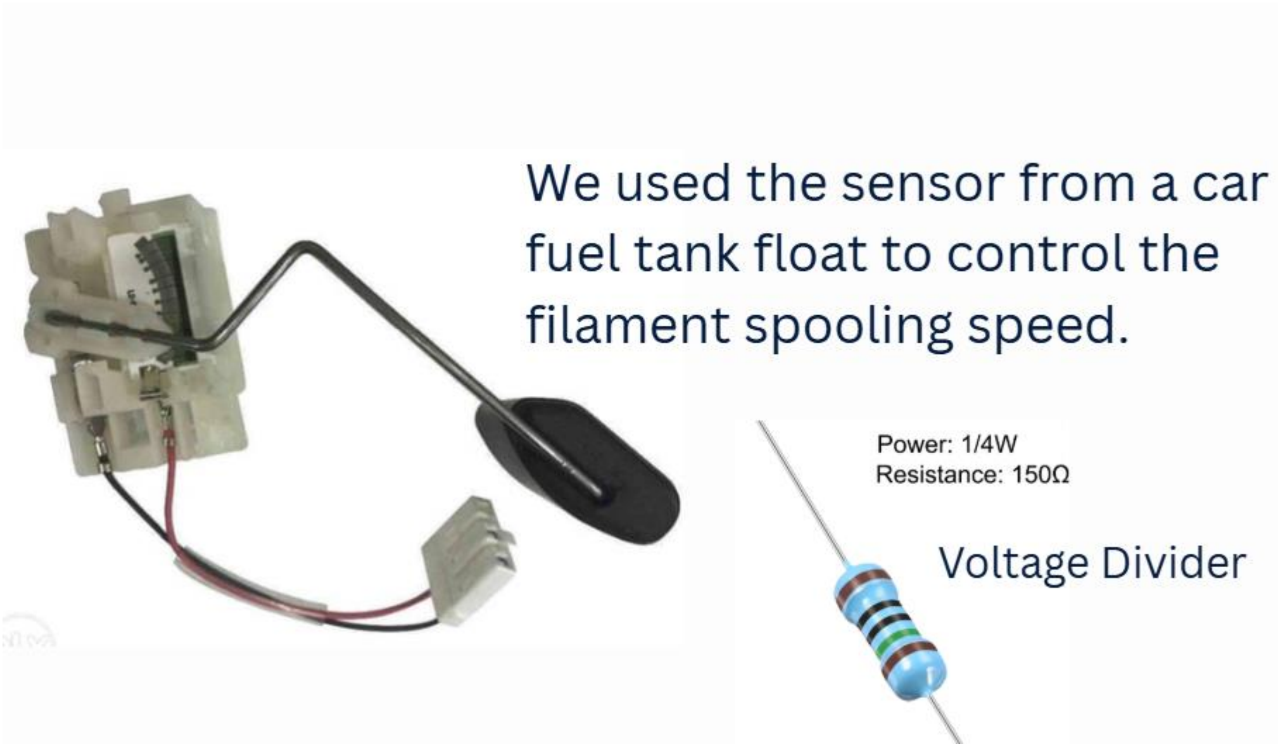
Air cooling shapes the melt and sets crystallization rate. Fan placement and speed help achieve roundness and a stable diameter before pulling.

Puller & Spooler (L298N + Window Motors)

- Roles: Puller sets line speed (critical for diameter); spooler maintains tension only.
- Control strategy: Slightly elastic nip on puller; regulate spooler torque with PWM (optionally use float-sensor feedback).
- Driver & thermal: L298N on a metal plate for heat spread; confirm flyback path for motor inductance.
- Mechanics: Align rollers; keep surfaces clean; spool edges chamfered to protect filament.
- Tuning: Start low tension and raise until layers pack evenly without flattening.
- Safety: Guard pinch points; e-stop cuts motor supply while MCU stays alive to log state.

Two window motors handle line transport: the puller sets filament speed, and the spooler winds with controlled tension. An L298N dual H-bridge provides direction and PWM speed control for these DC motors.

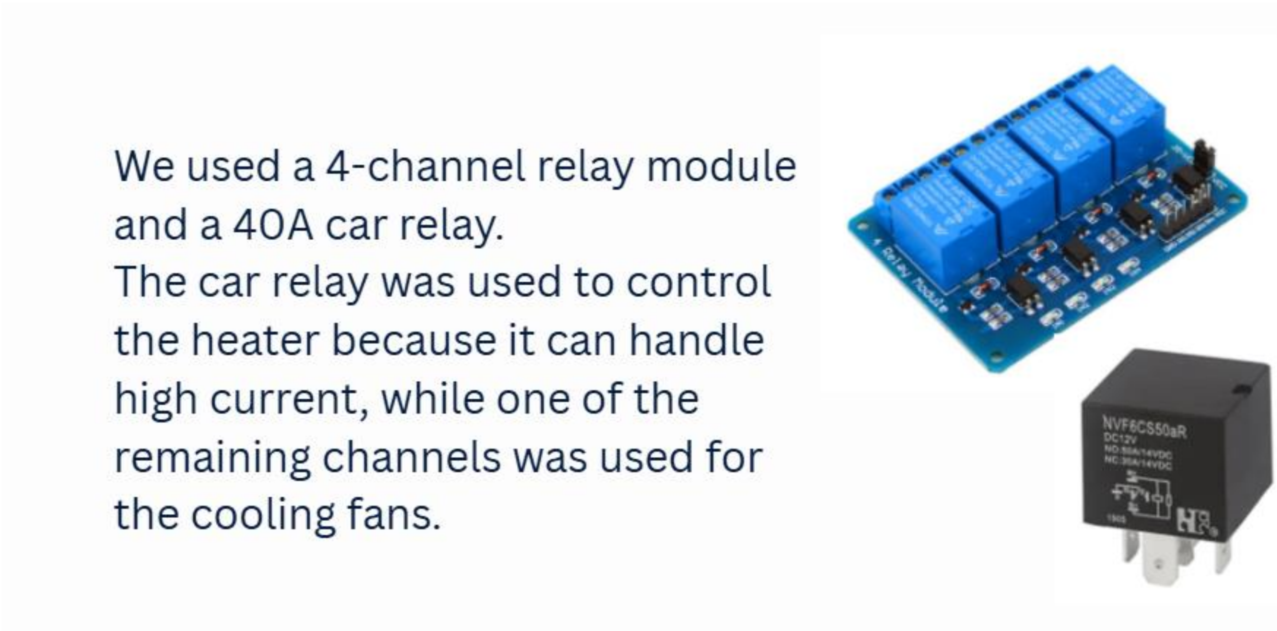
Spool Feedback (Float Sensor + Divider)



- Purpose: Infer spool fill/tension and adjust spooler torque—prevents over-tight winding and slack.
- Scaling: Resistor divider for 0–5 V ADC; add RC filter (≈1 kΩ + 100 nF) to stabilize readings.
- Calibration: Record ADC min/max at empty/full; map to tension setpoint curve; store in EEPROM.
- Mechanics: Smooth linkage without stick-slip; small counterweight can improve repeatability.
- Fallback: If feedback lost, revert to conservative low-tension PWM and raise a UI warning.

An automotive fuel-tank float is repurposed as a position sensor to infer spool fill and tension. Its analog output is scaled using a resistor divider to match the Arduino ADC range.

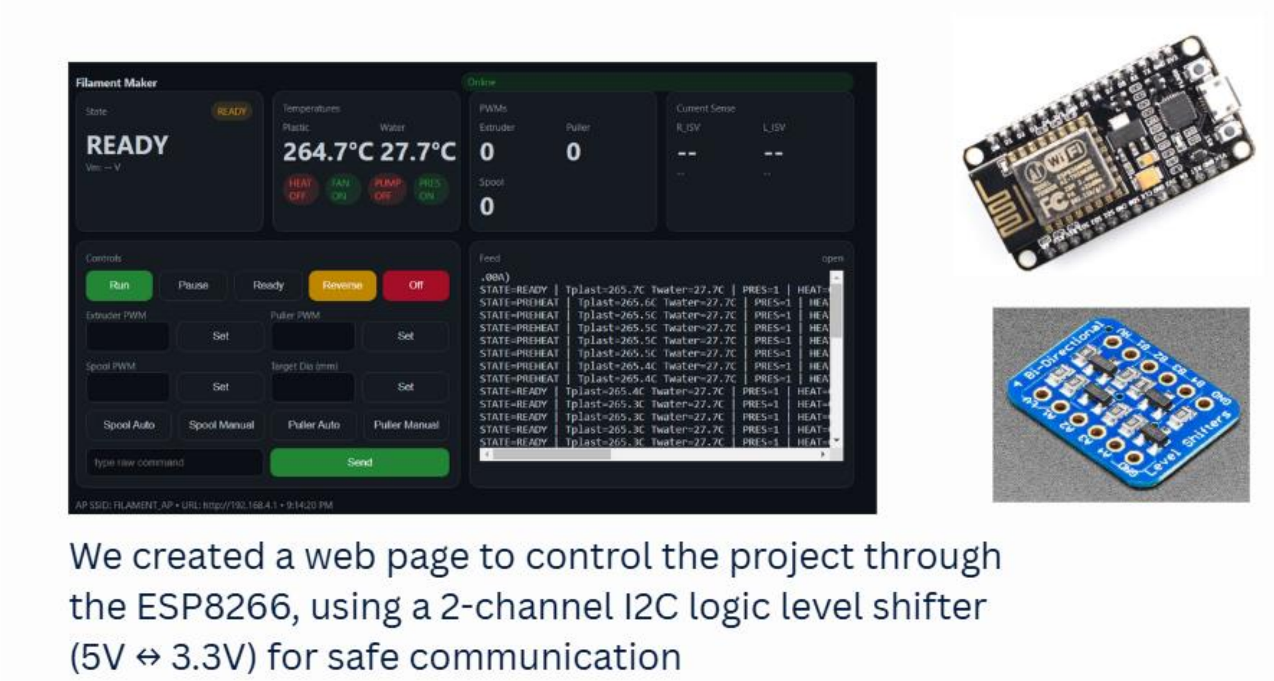
Relays (4- Channel + 40 A Automotive)



- Segregation: 40 A relay dedicated to the heater; 4-channel board for auxiliaries (fans, lamps).
- Snubbers: Flyback diodes across coils; for any AC circuits (if used), RC snubbers reduce arcing.
- Logic: Map active-LOW/HIGH correctly; add startup delays to avoid heater/motor slam on reboot.
- Wiring: Crimped spade terminals for the heater relay; separate high-current paths from logic wiring; mount away from heat.

A 4-channel relay module switches fans and auxiliaries. A 40 A car relay isolates the high-current heater. Using discrete relays simplifies service and improves safety segregation.

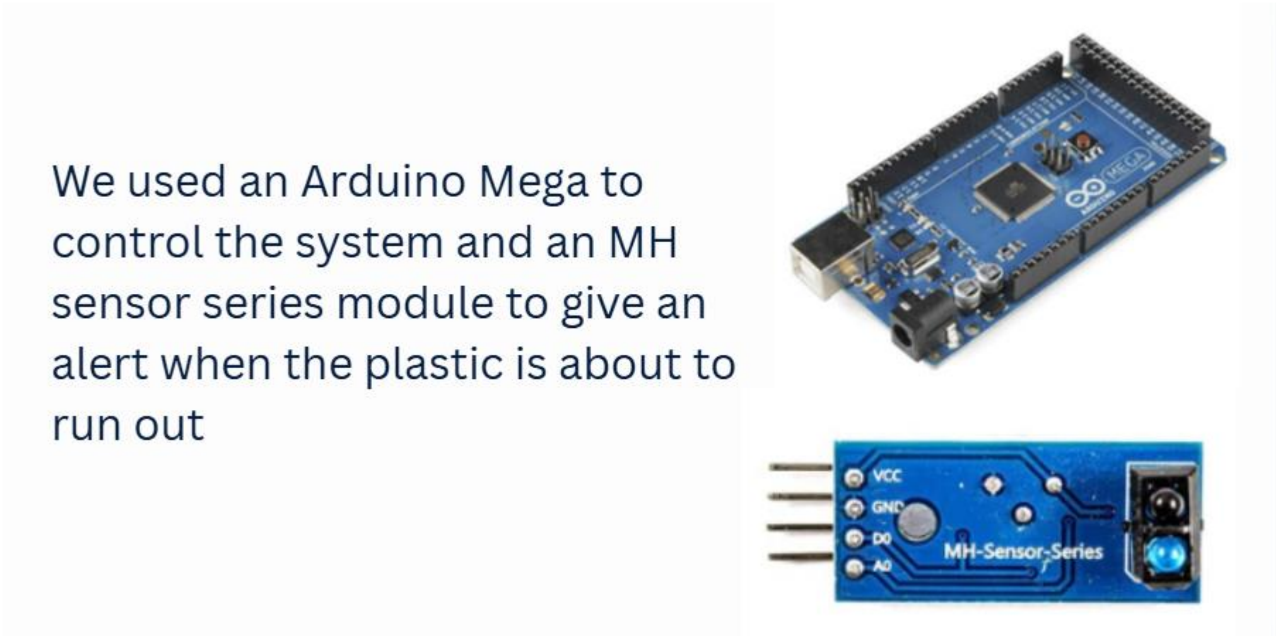
ESP8266 Web Page + Level Shifter



- Functions: Start/stop, temperature target, puller baseline, alarms, and basic telemetry.
- Networking: AP mode for offline use; optional STA to join lab Wi-Fi (avoid internet exposure).
- Level shifting: I²C/UART shifted 5 V↔3.3 V; short cables; 4.7 kΩ pull-ups on SDA/SCL (3.3 V side).
- Resilience: Watchdog enabled; persist last good setpoints in flash; boot with safe defaults.
- UX: Large buttons, °C readout, and presets (e.g., PETG 240 °C) speed up workflow.

The ESP8266 hosts a local dashboard for run/stop, setpoints, and status. A 2-channel I2C level shifter ensures safe 5 V↔3.3 V signaling.

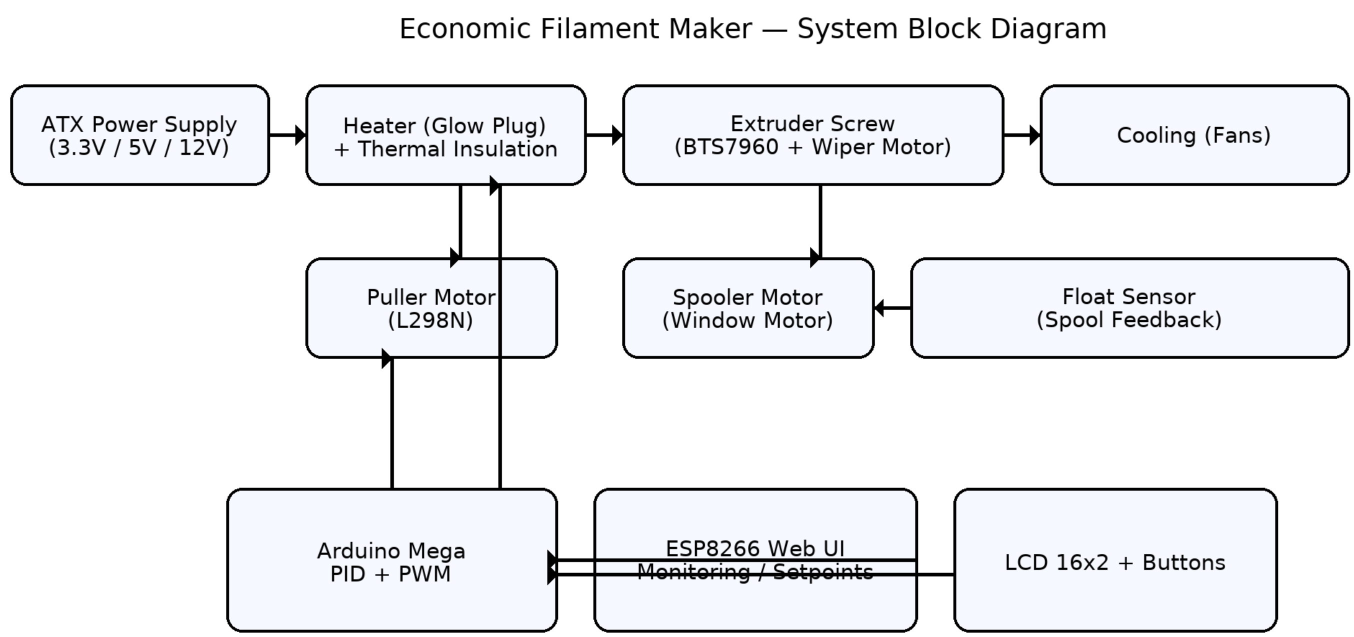
Controller & Sensors (Arduino Mega + MH Sensor)



- MCU duties: PID loop (~10 Hz), PWM updates, ADC sampling (thermistor/float), Serial link to ESP8266.
- Noise immunity: Average multiple ADC reads; stagger PWM edges; maintain a clean analog ground.
- Pin mapping: Reserve Serial3 for ESP; dedicate pins for relay enables; document mapping in Appendix.
- MH sensor: Low-material alert; set threshold and add hysteresis to prevent chatter.
- Firmware hygiene: EEPROM tables for calibration; CRC on config; e-stop input drops motor/heater enables instantly.

Arduino Mega orchestrates control loops and I/O. An MH-sensor-series module is used to alert when plastic feed is nearly empty.

5. Circuits / Block Diagram



System Block Diagram

6. Discussion

The design prioritizes cost, reuse of local parts, and safety. The ATX PSU stabilizes power rails and simplifies wiring. Automotive components provide torque and durability at low cost. PID temperature control combined with coordinated PWM for puller/spooler addresses the key process variables—melt temperature and line speed. Usability is improved via a simple LCD+buttons interface and a web UI. Limitations include lack of closed-loop diameter sensing and manual loading, which are noted as targets for future upgrades.

7. Conclusion

We implemented a practical, modular filament maker capable of producing consistent 1.75 mm filament from recycled materials. The system integrates Arduino-based control, PID temperature regulation, and synchronized transport to achieve stable output at low cost. The architecture supports straightforward enhancements such as laser diameter sensing, automated feeding, and expanded telemetry.

8. References

Datasheets and open-source resources for Arduino Mega, ESP8266, BTS7960, and L298N; community guides on filament extrusion.

9. Appendices

A. Calibration steps (set temperature, tune puller PWM, verify diameter)

B. Safety checklist (PPE, ventilation, fusing, wiring gauge)

C. Bill of Materials (textual)