

PET Refill: A Low-Cost PET Bottle Filament Maker System for Sustainable 3D Printing

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Abstract

The rapid increase in plastic waste, particularly Polyethylene Terephthalate (PET) bottles, has become a significant environmental concern worldwide. With the growing demand for sustainable and cost-effective manufacturing solutions, additive manufacturing, commonly known as 3D printing, has emerged as a transformative technology. However, the cost and environmental impact of commercially available 3D printing filament remain major challenges. This paper presents the design and development of an IoT-compatible, low-cost, and efficient PET bottle recycling system that converts used PET bottles into usable 3D printer filament. The system integrates embedded electronics, mechanical design, and thermal control to create a compact filament-making unit. It utilizes an Arduino Nano microcontroller, a NEMA 17 stepper motor, an IRFZ44N MOSFET for temperature regulation, and a thermistor for precise heat sensing. Experimental results demonstrate that maintaining a steady temperature range between 240°C to 260°C optimally melts the PET material, which is then extruded into a consistent filament. This project not only promotes sustainability but also encourages the adoption of circular economy practices in engineering applications.

Keywords: PET Recycling, 3D Printing Filament, Embedded Systems, Arduino Nano, Extrusion, Sustainable Manufacturing.

1. INTRODUCTION

Plastic pollution has emerged as one of the most pressing environmental challenges of the 21st century. Among various types of plastic, Polyethylene Terephthalate (PET) is widely used due to its lightweight nature, durability, and cost-effectiveness. However, the improper disposal and accumulation of PET waste have created severe environmental and ecological issues, especially in developing countries like India.

At the same time, the rapid growth of additive manufacturing, commonly known as 3D printing, has created a parallel demand for thermoplastic filament materials. Commercial 3D printing filaments, such as PLA and ABS, are widely used but are often expensive and

not environmentally sustainable. This creates an opportunity to bridge two domains—plastic waste management and 3D printing—by converting waste PET bottles into reusable filament.

This project focuses on designing and developing a PET bottle filament maker system using embedded electronics and mechanical components. The system utilizes commonly available components such as Arduino Nano, NEMA 17 stepper motor, A4988 driver, IRFZ44N MOSFET, thermistor, LCD display, and user input devices to create an efficient and low-cost decentralized recycling solution.

2. LITERATURE SURVEY

The increasing demand for sustainable manufacturing and effective plastic waste management has led researchers to explore innovative recycling techniques.

[1] Joshua M. Pearce et al. (2022): Presented the concept of distributed recycling, where plastic waste is converted into 3D printing filament at a local level. The study focused on reducing environmental impact and cost by using open-source recycling machines, supporting the concept of decentralized recycling adopted in this project.

[2] A. Torrado Perez et al. (2023): Analyzed the mechanical strength and performance of recycled PET filament used in 3D printing. The study concluded that recycled PET can achieve acceptable mechanical properties if processed under controlled conditions, emphasizing the importance of temperature control.

[3] S. Baechler et al. (2022): Discussed the design of a low-cost plastic extruder capable of converting plastic pellets into filament, focusing on affordability and accessibility for small users. The design principles of extrusion and heating control are highly relevant to the development of the PET filament maker.

[4] M. Kreiger and J. M. Pearce (2022): Explored the conversion of waste plastics into filament using open-source hardware, highlighting environmental benefits, cost savings, and the challenges of maintaining filament diameter consistency.

3. METHODS AND MATERIAL

The overall system is designed as an integration of multiple subsystems working together to achieve continuous filament production.

3.1 Material Preparation Process

The process begins with the preparation of raw PET bottles. Used PET bottles are cleaned to remove impurities and cut into uniform strips using a bottle-cutting mechanism. Since PET is hygroscopic, the strips are dried before use to eliminate moisture, preventing defects like air bubbles during extrusion.

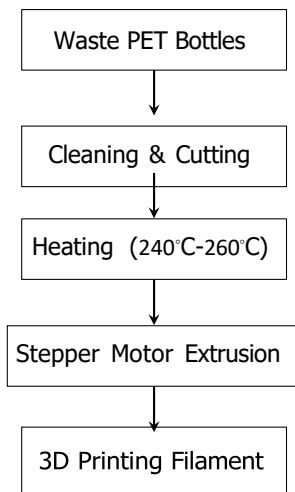


Figure 1: Flowchart of the PET Filament Making Process

3.2 Heating and Temperature Control

An electric heating element is installed inside the heating chamber to melt the PET material. A thermistor is used to measure the temperature continuously, providing corresponding resistance values to the Arduino Nano. The IRFZ44N MOSFET is used as a switching device to control the power supplied to the heating element via Pulse Width Modulation (PWM) signals. A closed-loop control mechanism maintains a stable temperature range of approximately 240°C to 260°C.

3.3 Extrusion and Motor Control

A NEMA 17 stepper motor is used to pull the filament from the nozzle at a controlled speed. The motor is driven by an A4988 driver module, which receives step and direction signals from the Arduino Nano. Synchronization between the heating temperature and motor speed is essential to maintain consistent filament thickness.

3.4 User Interface and Power Supply

The user interface features a 16x2 LCD display showing real-time information such as current tempera-

ture, set temperature, and system status. A rotary encoder and push buttons allow for precise parameter adjustments. A buck converter is used to step down the input voltage (12V/24V) to 5V to safely power the Arduino and logic components.



Figure 2: Hardware setup of the PET heating chamber and extrusion nozzle.

3.5 Mechanical System Design

The mechanical frame is constructed using a combination of 3D-printed components (PLA/ABS) and standard hardware materials. A gear train mechanism, supported by 625ZZ bearings, is implemented to control the pulling speed of the filament, ensuring a smooth and controlled extraction process.

4. RESULTS AND DISCUSSION

The system was tested under controlled conditions using cleaned and dried PET bottle strips. The performance was evaluated based on temperature stability, filament quality, and power efficiency.

1. Temperature Control Performance:

The thermistor and MOSFET-based closed-loop system demonstrated highly stable performance. The Arduino Nano successfully maintained the desired temperature range (240°C to 260°C) with minimal fluctuations. Temperature variation remained within $\pm 5^\circ\text{C}$ of the set value, preventing material overheating or under-extrusion.

2. Filament Extrusion Consistency:

The system successfully converted PET bottle strips into continuous filament. When temperature and motor speed were properly synchronized, the extrusion process was smooth and free from major defects such as breaks or bubbles. The average filament diameter observed ranged between 1.5 mm to 2.0 mm, making it suitable for basic 3D printing applications.

3. Mechanical and Power Performance:

The 3D-printed gear-driven pulling mechanism performed efficiently, maintaining a constant pulling force with low friction due to the 625ZZ bearings.

Power consumption was moderate and highly efficient, with the heating element drawing between 50W to 150W depending on the PWM duty cycle. The use of the MOSFET minimized power switching losses.

4. :Economic and Environmental Impact:

The produced filament, while not perfectly matching industrial standards, is highly suitable for prototyping and educational purposes. The system drastically lowers the cost of 3D printing filament while providing a decentralized, actionable solution to urban plastic waste generation.

5. :CONCLUSION

The PET bottle filament maker project successfully demonstrates a practical and innovative approach to converting plastic waste into usable 3D printing filament. By integrating mechanical design, embedded electronics, and thermal control using accessible components like the Arduino Nano, NEMA 17, and IRFZ44N MOSFET, the system serves as a cost-effective recycling solution. Experimental results confirm stable temperature regulation and consistent filament extraction. This project not only addresses pressing environmental concerns by promoting the reuse of PET bottles but also supports the circular economy, making additive manufacturing more accessible to students, innovators, and small industries.

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