

PAPER • OPEN ACCESS

## Control plastic pellet feeding double extruders for 3D printing symmetric bilateral

To cite this article: B Setiawan *et al* 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1073** 012049

View the [article online](#) for updates and enhancements.

You may also like

- [Three-dimensional Porous Alloy Host for Highly Stable and Dendrite-Free Zinc Metal Anode](#)

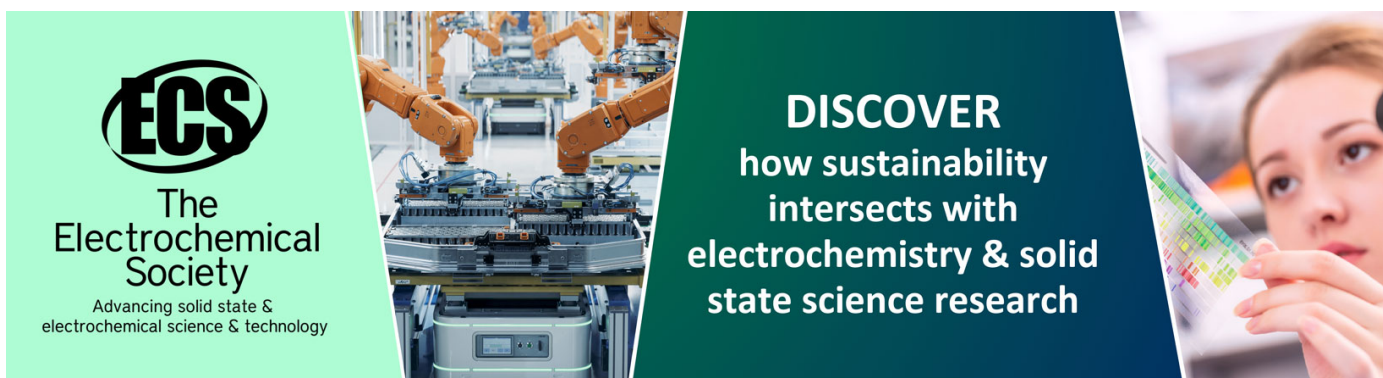
Yu Xiong, Fengyin Zhou, Dongdong Zhu et al.

- [Novel 3D printed single electrode-based portable and miniaturized electrochemiluminescence platform to detect lactate from human serum](#)

Manish Bhaiyya, Prakash Rewatkar, Prasant Kumar Pattnaik et al.

- [3D printing processes in precise drug delivery for personalized medicine](#)

Haisheng Peng, Bo Han, Tianjian Tong et al.



**ECS**  
The  
Electrochemical  
Society  
Advancing solid state &  
electrochemical science & technology

**DISCOVER**  
how sustainability  
intersects with  
electrochemistry & solid  
state science research

# Control plastic pellet feeding double extruders for 3D printing symmetric bilateral

**B Setiawan<sup>1</sup>, A M Damayanti<sup>1,\*</sup>, I Siradjuddin<sup>1</sup>, W Widjanarko<sup>2</sup>, D C Permatasari<sup>1</sup> and V U Audiana<sup>1</sup>**

<sup>1</sup>Electrical Engineering Department, State Polytechnic of Malang, Indonesia

<sup>2</sup>Mechanical Engineering Department, State Polytechnic of Malang, Indonesia

\*annisa\_maulidia@polinema.ac.id

**Abstract.** Three Dimensional Printing (3DP) is one of the technologies that support industry 4.0. One of the common 3DP technology is FFF (fused filament Fabrication), the technology is also known as Fused Deposition Modelling (FDM). In this case, extrusion thermoplastic through a hot nozzle with certain melting temperature. The extrusion machine (extruder) will melt the plastic pellet and push the pellet through a heating zone that has a different temperature and pushed out by a screw to the nozzle to be printed into objects. This research aims, to make a control innovation for plastic pellet feeding double extruders. Those extruders for a bilateral 3DP symmetrically to print an object with a size of 2000x2000x2000mm using FDM method. The research simulation results showed that the extruder melts the plastic pellets with a temperature of melting is 200°C, temperature controlled by PID. In this research using 4mm plastic pellets diameter polyethylene high density (HDPE). The double extruders is controlled by two stepper motors Y- and Y+ axis with speed 70mm/s, on 2mm nozzle diameter. The extruder can be produce 110mm melted plastic filaments in 250 steps.

## 1. Introduction

Three Dimensional Printing (3DP) technology is one of the technologies that revolutionize the design and manufacturing of a new product [1]. The advantage of using 3D printers to create prototyping is that it can create prototypes in a short time and cost-effective comparison of conventional prototypes. This rapid prototyping machine becomes a vital tool in the industrial world. But for industries in Indonesia have not been used because the price of the machine is relatively expensive for developing industries in Indonesia [2].

The most famous and inexpensive 3D Printing technology is FFF (fused filament Fabrication) Technology is also known as Fused Deposition Modelling (FDM), its working principle is thermoplastic extrusion through a hot nozzle at melting the plastic layer by layer [3]. Extruder (extrusion machine) has a function to melt the plastic pellets and then be processed through the heating zone. In the extrusion process occurs transfer event (conveying) resin from one point to another using screw, then melting and pressing. Heat temperature comes from the coil mounted around the screw. Once the movement of the material towards the end, there is a pressure increase through the small holes while the screw is continuously pressing. To produce good Quality 3D Printing products must be set and controlled appropriately [4].



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

## 2. Literature review

### 2.1. 3D printing

Additive manufacturing or 3D Printing is a process in which the material is merged under the control of the computer to create a three-dimensional object, with materials added (such as liquid molecules or powder grains combined), 3DP used in prototype making. Objects can be either form or geometry and are usually generated using the digital data model of the 3D model derived File Manufacture additive (AMF). There are several techniques used, such as stereolithography (STL) or Fused Deposit Modelling (FDM). The printing builds a three-dimensional object of a CAD model or computer-aided AMF file, usually by adding layers by layers in succession [5].

### 2.2. CAD software

Computer-Aided Design is a computer program to draw a part of a product or a total product. The products that want to be depicted can be represented by lines as well as symbols that have certain meanings has become more important for virtual technology for advance [6].

Rapid Prototyping (RP) is a term used to describe a technology that can create three-dimensional objects in a single process directly through CAD. RP simplifies the complexity of the 3D manufacturing process by reproducing it into a series of the limited thickness of 2D shapes or layers and adding both together. RP technology is growing with varied methods [7].

### 2.3. Simplify 3D

Three dimensional (3D) software was used to digitally slice the samples and create the G-Code. G-Code is the basic language used to control CNC machines and it is the ultimate guide for CNC Programming. For 3D printers, G-Code contains the command to set the stepper motor movement. Create G-Code by Slicing 3D design files using the Simplify 3D app and storing them. The saved files will be converted to G-Code files and used by 3D printers as a reference for creating 3d objects [8].

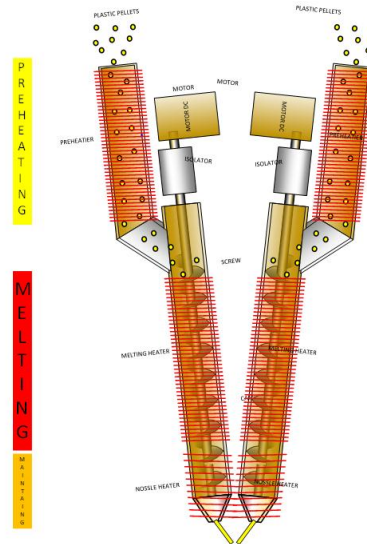
### 2.4. Marlin firmware

Marlin firmware is used by the microcontroller and the test phase for controlling the actuators [9]. Marlin supports many designs of 3D printer platforms [10]. Marlin was made for 3D printer enthusiasts who used to be direct, reliable, and adaptable 3D printer firmware. Marlin is a firmware that can be run directly using an inexpensive 8-bit Atmel AVR microcontroller. Marlin version 2.x can be used on 32-bit microcontrollers. This chip sits at the center of the popular Arduino/Genuino open-source platform. The reference platform for Marlin is the Arduino Mega 2560 with RAMPS 1.4.

### 2.5. Extruders

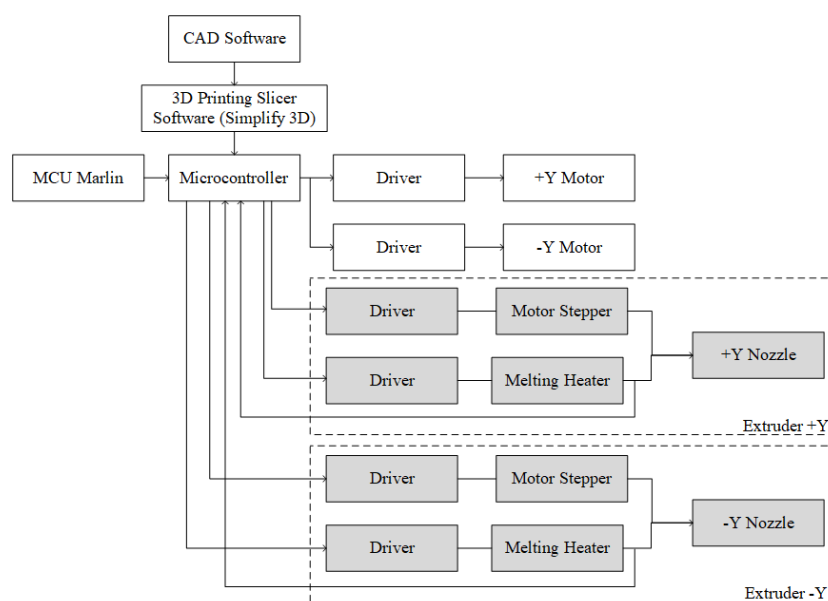
The extruder is a process machine to carry out the extrusion process including mixing materials and printing. Extrusion is a combination treatment of pressure, friction, and temperature processes in a screw that moves at the same time. The extruders are used for the blown film, pipe processes, and blow molding where the discharge temperatures need [11]. Most of the 3D FFF Printers belong to the direct extruder type. In this type of extruder, the moving parts include the nozzle, heater, and motor, which attract and direct the filament from the cold end to the hot-end directly. For the Bowden type extruder, the driving part is hot-end and that is the only difference between the direct extruder and the Bowden [12]. Bowden extruder The FFF printer has a flexible cable connected between the separate sections. This cable is known as Bowden cable and is sometimes also referred to as a Teflon tube (depending on the material name). Thermoplastic filaments in the tube to obtain feedback from the moving material to the hot-end [13].

### 3. Methods



**Figure 1.** Mechanic design of double extruders.

Double extruder mechanical design using a screw with plastics pellets feeding method shown in Figure 1. The extruders process plastic pellet by melting the material applying some heaters. The melted plastic will be press to the nozzle using screw. And then, the melted plastic will be printed to form an object by 3D printing CNC. Figure 1 consists of two extruders. An extruder has an inlet/hopper as input for plastic pallet that will flow the pellet in to heated 200°C chamber of the extruder. Hopper is formed to accommodate plastic pallet for processing; screw to push the plastic pallets to flow into the nozzle; heater consists of a pre-heater, melting heater, and a nozzle heater for melting plastic pallets; and nozzle as output melted plastic whose diameter of melted plastic depends on the nozzle.



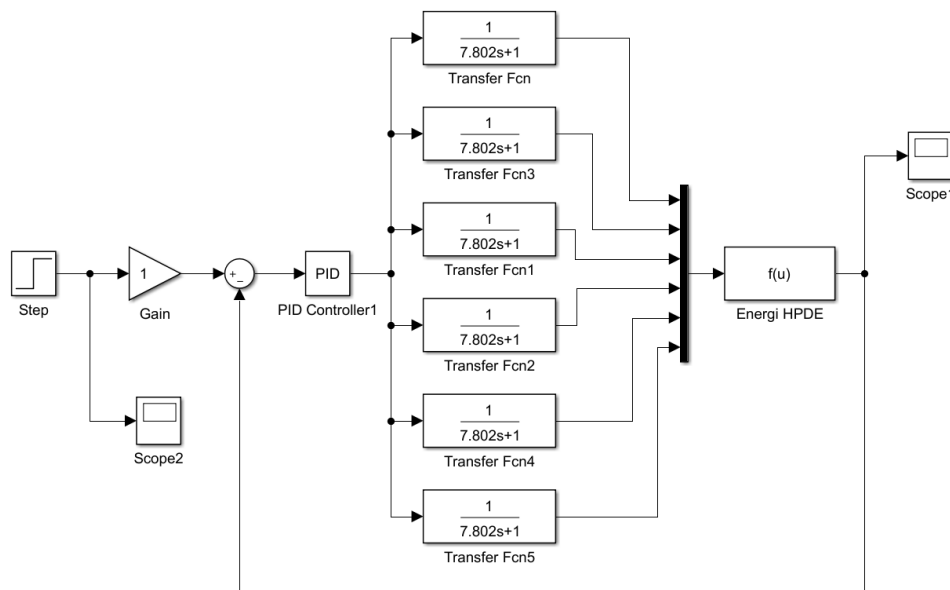
**Figure 2.** Double extruders block diagram.

Figure 2 shows block diagram how to print the 3DP object with double extruders. Create a design on the CAD software and then save and draw in the process of slicing in simplified 3D to generate G-code. Next, it's read by a microcontroller with marlin firmware to drive the +Y & -Y motor and +Y & -Y nozzle through the command in the driver.

#### 4. Simulation and results

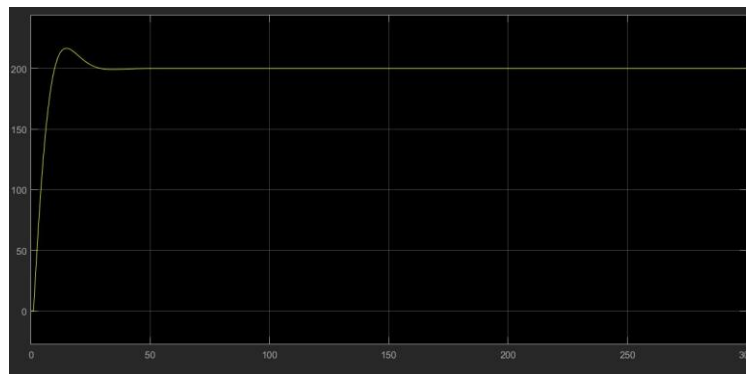
##### 4.1. Temperature Control for each extruder's heaters

Temperature control is used to stabilize the temperature in the melting heater with the set point.



**Figure 3.** Temperature control simulation.

Figure 3 shows the temperature control simulation using PID control. Temperature control melting plastic pellets process using PID controller used to adjust the melting point of the 6 heaters, with a temperature sensor feedback. In the simulation, PID auto-tuning is used to obtain optimal control. From this simulation, temperature control was used to stabilize temperature on the melting plastic pellets process in each extruder. Plastic pellet using High-Density Polyethylene (HDPE), where the required melting temperature is 200°C. For the temperature control to be stable to produce melted plastic.

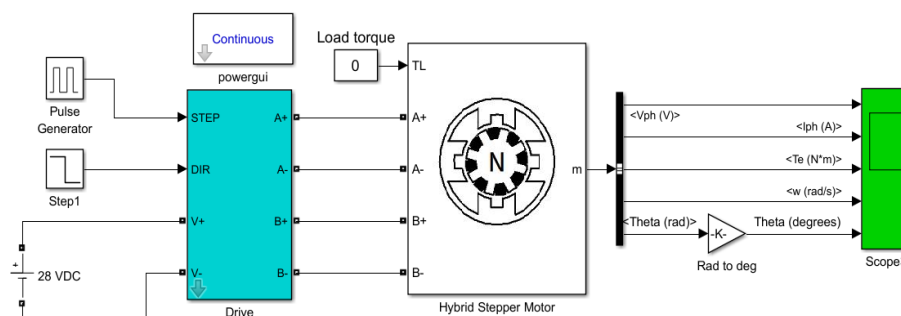


**Figure 4.** Melting temperature response.

From the temperature control simulation with HDPE plastic pellets, the resulting graph is shown in Figure 4, stable temperature control is 200°C and overshoot is 1%. The temperature control results have shown the desired stability.

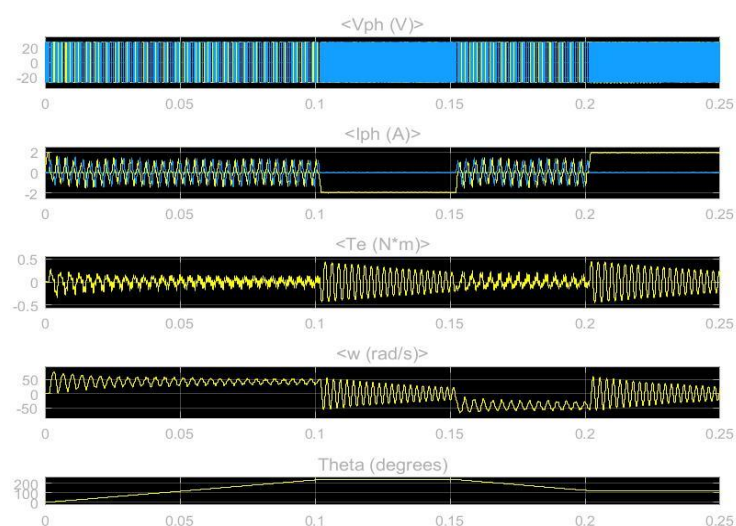
#### 4.2. Stepper Motor Control

Figure 5 shows a stepper motor simulation, a stepper motor speed setting of 70mm/s. In this simulation, the hybrid stepper motor must be adjusted according to the specifications of the motor to be used, motor Nema 23.



**Figure 5.** Stepper motor simulation.

From this simulation, the values of voltage phase, current phase, torque, speed, and angle of movement of the motor position shown in figure 6.



**Figure 6.** Stepper motor response.

From figure 6, it can be seen from the graph above that the system is optimal. Furthermore, it can be seen the simulation results by testing the system directly.

Stepper motor testing through the Pronterface application, by changing the value of "length", step/mm, and stepper motor input pulses. At pronterface, the speed stepper motor is fixed at 70 mm/s and the melted plastic length setting is 100mm, then changing the step/mm to see the actual discharge of the HDPE plastic pellets produced. This is intended to see the relations between motor pulses and the melting of HDPE plastic pellets. Shown in Table 1.

**Table 1.** Pulses of stepper motors with melted plastic pellets.

| Step/mm | Time (s) | Length of Filament (mm) | Pulse | Frequency (Hz) |
|---------|----------|-------------------------|-------|----------------|
| 250     | 85       | 110                     | 25000 | 289            |
| 220     | 94       | 98                      | 22000 | 255.1          |
| 200     | 100      | 80                      | 20000 | 232            |

Table 1 shows the relations between melting length HDPE plastic with motor pulses is directly proportional, the higher the motor pulse, the longer the HDPE plastic melt. And the higher the frequency, the longer the plastic melt.

**Table 2.** Stepper motor speed with filament length.

| Stepper Speed (mm/s) | Time (s) | Length of Filament (mm) | Pulse | Frequency (Hz) |
|----------------------|----------|-------------------------|-------|----------------|
| 100                  | 71       | 81                      | 20000 | 331.1          |
| 90                   | 82       | 83                      | 20000 | 297.6          |
| 80                   | 92       | 80                      | 20000 | 265.2          |
| 70                   | 99       | 84                      | 20000 | 232            |

In table 2, the pulse is fixed at 200 pulses and change the speed of the stepper motor (mm/s) to see the actual length of the filament that comes out. This is to determine the relations between stepper motor speed and HDPE plastic melt length. From the table 2, it can be seen the lower speed of the stepper motor, the shorter the results of the melting filament.

## 5. Conclusion

From the simulation results temperature melting point plastic pellets is stable at 200°C, with an overshoot is 1%. And the higher the motor stepper steps, can produce more length plastic pellet. The extruder can produce 110mm melted plastic filaments in 250 steps.

## References

- [1] Noorani R 2017 *3D printing: technology, applications, and selection* CRC Press
- [2] Dahlan M, Gunawan B and Hilyana F S 2017 Rancang Bangun Printer 3D Menggunakan Kontroller Arduino Mega 2560 *Prosiding SNATIF* 105-110
- [3] Xiaoyong S, Liangcheng C, Honglin M, Peng G, Zhanwei B and Cheng L 2017 Experimental analysis of high temperature PEEK materials on 3D printing test. In *2017 9th International conf. on measuring technology and mechatronics automation (ICMTMA)* 13-16 IEEE
- [4] Samikannu R and Poonamallie B A 2011 Design of synthetic optimizing neuro fuzzy temperature controller for dual screw profile plastic extruder using labview *Journal of Computer Science* 7(5) 671-677
- [5] Share E C Robert Bosch Tool Corp 2019 *Temperature control system for 3D printer extrusion head* U.S Patent 10 500 831
- [6] Maiti C K 2017 *Introducing Technology Computer-Aided Design (TCAD): Fundamentals, Simulations, and Applications* CRC Press
- [7] Cooper K 2001 *Rapid prototyping technology: selection and application* CRC press
- [8] Sahputra B, Hakim R and Saputra I Studi Parameter Temperatur Nozzle Dan Base Plate pada Material ABS sebagai Bahan Baku 3D Printer Terhadap Hasil Kehalusan

## Permukaan

- [9] Quatrano A, De S, Rivera Z B and Guida D, 2017 Development and implementation of a control system for a retrofitted CNC machine by using Arduino. *FME Transactions* **45**(4) 565-571
- [10] Moore S B, Glisson W B and Yampolskiy M 2017 Implications of malicious 3D printer firmware
- [11] Spalding M A and Womer T W, 2017 Mitigating gels in polyethylene products produced using grooved-bore, single-screw extruders *SPE-ANTEC Tech Papers* 63
- [12] Duong T H, Jaksic N I, DePalma J L, Ansaf B, Daniel D M, Armijo J and Galaviz M 2018 G-code Visualization and Editing Program for Inexpensive Metal 3D Printing *Procedia Manufacturing* **17** 22-28
- [13] Abilgazyev A, Kulzhan T, Raissov N, Ali, M H, Match WK and Mir-Nasiri N 2015 Design and development of multi-nozzle extrusion system for 3D printer *International Conference on Informatics, Electronics & Vision (ICIEV)* 1-5 IEEE