Fabrication of 3D Printer with Wireless Module and Dual Extruder

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Abstract - *3D printing is a form of additive manufacturing technology where a three dimensional object is created by laying down successive layers of material. It is also known as rapid prototyping, is a mechanized method whereby 3D objects are quickly made on a reasonably sized machine connected to a computer containing blueprints for the object. The 3D printing concept of custom manufacturing is exciting to nearly everyone. This revolutionary method for creating 3D models with the use of inkjet technology saves time and cost by eliminating the need to design; print and glue together separate model parts. Now, you can create a complete model in a single process using 3D printing. The basic principles include materials cartridges, flexibility of output, and translation of code into a visible pattern. 3D Printers are machines that produce physical 3D models from digital data by printing layer by layer. It can make physical models of objects either designed with a CAD program or scanned with a 3D Scanner. It is used in a variety of industries including jewelry, footwear, industrial design, architecture, engineering and construction, automotive, aerospace, dental and medical industries, education and consumer products.*

Key Words: 3D Printer, Dual Extruder, Filament, Bluetooth, Arduino

1. INTRODUCTION

A 3d printer is an additive manufacturing technique where 3D objects and parts are made by the addition of multiple layers of material. It can also be called as rapid prototyping. It is a mechanized method where 3D objects are quickly made as per the required size machine connected to a computer containing blueprints of any object. The additive method may differ with the subtractive process, where the material is removed from a block by sculpting or drilling. The main reason to use 3d printer is for 90% of material utilization, increase product life, lighter and stronger. 3D printing is efficiently utilized in various fields such as aerospace, automobile, medical, construction and in manufacturing of many household products.

There are several 3D printing methodologies such as stereolithography apparatus (SLA), selective laser sintering (SLS), fused filament fabrication (FFF), and laminated object manufacturing (LOM).

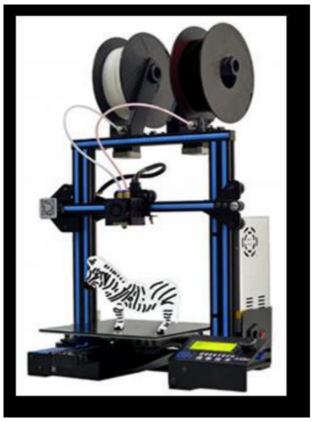

Figure 1: 3D printer with Dual Extruder

2. CONFIGURATION OVERVIEW

This section provides information on the mechanics and limitations of the conventional single extruders and the possible improvements by the proposed Dual extruders.

2.1 Working Principle of Extruder and its Limitations

The fundamental working principles of an extruder have been described in the introduction section. The extruder is composed of cold-end and hot-end. The function of cold-end is to drive the filament into the hot-end. The cold-end generally consists of a stepper motor which rotates a toothed gear against a bearing. The filament (usually 1.75 mm and 3 mm in diameter) located between the gear and bearing is driven towards the hot-end when the motor is activated. Different types of gear combinations (e.g. worm wheel and gear, pinion and gear, or complex gearbox) can be used to increase the torque and improve the extrusion control. Some of the cold-end parts can be 3D printed with plastic filaments. The cold-end cannot be heated as it may close to the hot-end location. Therefore, heat sinks, fans, water cooling, or Peltier effect cooling are normally used to address this issue.

Nowadays, two types of extruders are commonly used, which are direct extruder and Bowden extruder. Most of the FFF 3D printers belong to the direct extruder type.

In this type of extruder, moving parts include a nozzle, a heater and a motor, which pull and drive filament from the cold-end to the hot-end directly. For Bowden extruder type, the driving parts are separated from the hot-end and it is the only difference between the direct and Bowden extruder. Bowden extruder FFF printer has a flexible cable connected between two separate parts. The cable is known as Bowden cable, and sometimes it is also called as Teflon tube (depended on the material name). Thermoplastic filament is driven inside the tube in order to get a permanent feed of the material to the moving hot-end.

There is a thermal insulator or break between the cold-end and hot-end, which joins these two ends and prevents heat Conduction between the two ends. The thermal insulator is normally made of PEEK plastic with PTFE liners. Groove mounts are also used to connect the cold-end to the hot-end.

The function of the hot-end is to melt the filament. It is normally made of brass, but in some case, aluminum and glass are used in order to reduce the weight of the hot-end. The hot end consists of a heating chamber with two holes, one hole for filament feed in, and the other hole for the extrusion of molten plastic. The diameter of the extrusion (tip) hole of the nozzle varies from 0.3 mm to 1 mm. The typical working temperature for the hot-end ranged from 150 ºC to 250 ºC, which includes the melting temperature of the most popular filaments likes ABS and PLA. Thermistor or thermocouple are normally used in the feedback loop to measure and monitor the temperature.

The extruder is mounted to the frame of 3D printer by different means and standards. The material inside the chamber should be in its molten state, but the temperature has to be kept as low as possible, because the quality of some polymers will deteriorate at high temperatures. Furthermore, the application of high temperatures inside a nozzle requires cooling after extrusion. The stability of constant pressure for extrusion is depended on the constant supply of material from the cold-end fed into the chamber. The simple schematic diagram of a conventional FFF extruder is shown in Figure 2.

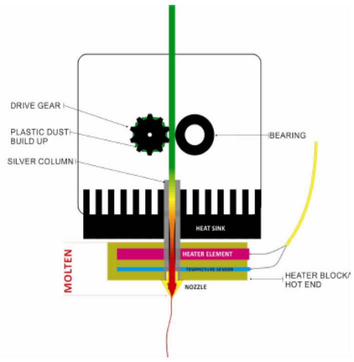

Figure 2 : Schematic diagram of 3D Printer extruder.

The use of only one extruder limits the 3D printing capabilities. Only one single filament can be set into an Extruder at a time and therefore only one color/material filament can be used. Changing of filament would require a noticeable time break as the printing process is paused. The procedures include pull out the used filament, clean the extruder chamber, and feed in the next filament.

2.2 Dual Extrusion Challenges

It is possible to feed several filaments in one goal with the implementation of Dual extruder with one nozzle. It can facilitate printing with two-colors and/or two-materials.

Dual extruder is one of the successful implementation of the concept. There are one nozzle on the dual extruder head. One of the primary reasons for using a multiple extruder is to increase the speed of printing process. The printing time can be reduced by continuous operation of extruders as it is no need to spend extra time on changing filaments. In most cases, the second extruder of the dual extruders is used to print supporting material to hold the object's suspended volume part for complex 3D structural.

The major constraints of the Dual extruders are the bulkiness and the weight since it contains several hot-end and motor systems. It would reduce the print volume and would also lower the printing speed considerably.

2.3 MECHANISM OF THE PROPOSED DESIGN

In the proposed extruder model, there are two main parts,

(1) hot-end and (2) filament driving cold-end. The designed hot-end has one nozzle that are designed to print up to two different colors/materials without any manual interruption to switch/change the filaments. In dual extruder for changing the filament we use servo motor. As we programme it will change the filament. The hot-end is same as simple 3D printer means here is also single nozzle as shown in Figure 3.

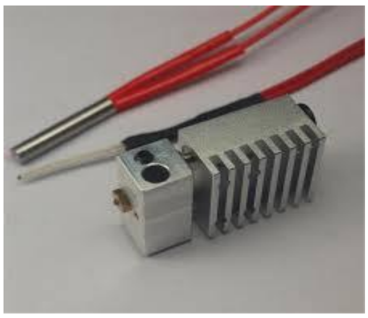

Figure 3: Hot-end

Single nozzle is responsible for only one type of filament. This means that two spools of filament would be attached at the same time. The printing time as well as the frequency of maintenance and cleaning can be reduced.

The whole setup is installed at the X-axis carriage, which is controlled by a stepper motor and a belt. The hot-end can move only along x-axis.

In dual extruder single nozzle 3D printer we made some parts by 3D printing. Parts as washer, idler, body and head.

Basic design of Extruder here as shown in figure 4.

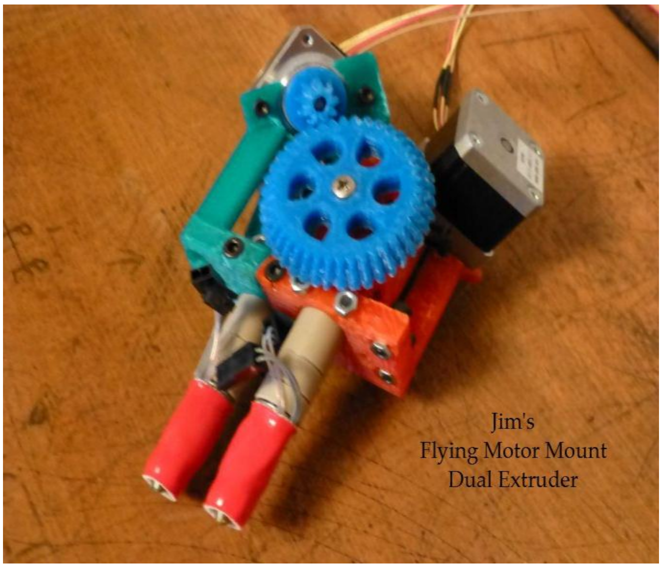

Figure 4: cold end in Dual extruder

Bowden-type extruder is chosen for the connection of cold end and hot-end. The main reason for this selection is to reduce the weight of the moving components. Since the heavy stepper motors are off in a fixed position, the moving hot-end can then be moved with less force and with a faster speed. Bowden cable showed in Figure 5 provides a stable supply of the filament from the cold-end to the hot-end. Moreover, it also decreases the load exerted on the X-axis carriage and improves the mobility of the hot-end.

Figure 5: Bowden cable.

3. Build of Dual Extruder

This Dual Extruder is designed to be used as a part of an existing or new 3D printer. Some adaption is need to make it fit any particular printer. This adaption is up to user.

3.1 Printed Parts:

Print two each of the Extruder Body, Washer, idler, body, Tensioner, Large Gear, and Small Gear from ***Thingiverse.*** I used 40% fill. Note the support material used with the Extruder Body.

3.2 **metal parts :**

- Four M4x35mm socket head bolts with nuts. (nozzles)
- Four M4x16mm socket head bolts with nuts. (leveling)
- Two M4x?? socket head bolts with nuts. (X Carriage mounting) Actual length needed depends on your X carriage.
- Two M3x25mm socket head bolts with nuts and washers. (tensioner hinge)
- Two M4x25mm socket head bolts with nuts (tensioner bearing axles)
- Six M3x10mm socket head bolts
- Two M3x8mm or 10mm set screws with nuts. (small gear mount).
- Two nozzles using 16mm groove mount of the same type, or at least the same length. Use Ubis nozzles or the J-nozzle should work also. Others using 16mm groove mount may work, but are untested. A different nozzle mounting method would require modifications to the scad files.
- Two NEMA14 bipolar stepper motors. The ones I use have 3.2 Ohm coil resistance. Six 624 Bearings.
- One piece of 4mmID, 5mmOD brass tubing (McMaster-Carr) long enough to be cut into two pieces the same length as filament drive gears. Details follow.
- Two filament driver gears (Makerbot MK7 (SKU2394) – 5mm hole)
- M3x5mm set screw (filament drive gear)

Step 1: Clean Up Plastic Parts

Carefully trim away all the support material on the bodies. Clean up flashing and any blobs, etc. from the parts – especially the gears! Clean the nozzle mounting holes so the nozzles fit properly and extend the same distance.

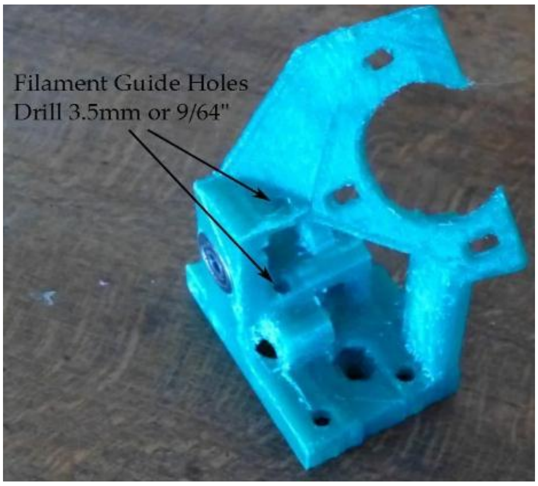

Figure 6: Drilled Plastic Part

Clean out the space for the filament drive gear. Drill holes for M3 bolts to 3.2mm or 1/8 inch. Drill M4 bolt holes to 4.2mm or 5/32 or 11/64 inch. Check each step for the hole sizes. Drill the filament holes to 3.5mm or 9/64 inch as show in figure 6.

Step 2: Build and Join Extruder Bodies

Press one 624 bearing into the "closed" bearing pocket. The "closed" pocket is the one in which the bearing is completely surrounded by plastic (see picture). Clean the hole with an Xacto or Dremel until the bearing seats completely but tightly. The pictures all show these bearings in place.

Press M3 nuts into each tensioning bolt nut pocket. Be sure they seat correctly and tightly so you don't have to keep messing with them during assembly. As show in figure 7.

Back off one of the bolts so you can fit a nozzle in one base. Run the bolt back into the base to hold the nozzle. Put the outer bolt for that extruder body in to secure the nozzle. Repeat for the other nozzle. Make sure the nozzles fit properly and stick out of the bodies very nearly the same distance. Refer to the picture titled *"Nozzles Mounted"*. Again, Kep nuts are shown, but use standard M4 nuts instead.

Figure 7: Nozzle Mounted

Step 3: Build Tensioners

Put bearing into tensioner body and slide the bolt through. Secure with nut as show in figure 8.

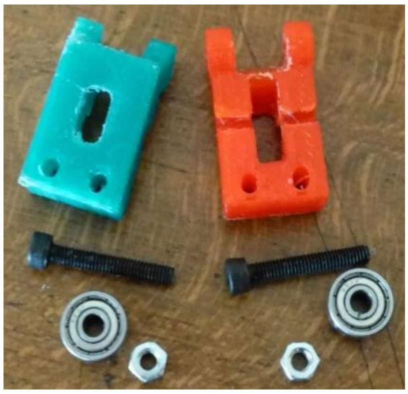

Figure 8: Parts to build Tensioners

Step 4: Install Tensioners

Position Tensioner on the pivot. Put bolt through hole in the pivot and secure with a nut as show in figure 9.

Figure 9: Tensioners Installed

Step 5: Prepare Filament Drive Gears

The MK7 filament drive gear is perfect for the dual extruder except for one problem The ID is 5mm and the axle shaft OD is 4mm. To fix this, make an adapter using the brass tubing.

Insert a 5mm OD x 4mm ID brass tube into the bore of the gear. It will be very tight. Sand it lightly to make if fit if necessary. You should be able to push it all the way into the gear, but it should be tight. I find it most accurate to insert the tube into the gear, then cut it. Cut it to length using an Xacto knife with a sharp, straight blade. Place the gear with the tube in it on a flat surface, hold the blade at a slight angle so the edge is right against the gear, press down firmly, and roll the gear back and forth until the blade cuts through the tube. A good technique is 10 to 20 strokes back and forth, lift the knife, rotate the gear and tube ¼ turn, then repeat until you cut through the tube. File the edge smooth as show in figure 10.

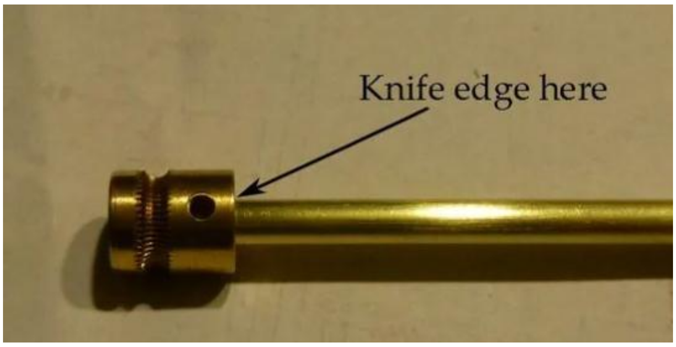

Figure 10: Filament Gear

Step 6: Assemble Axles and Large Gears

Run one nut all the way onto the bolt and seat it firmly against the head. Put the axle through the gear and seat the nut into the nut pocket on the large gear. Put a washer on next to the gear, then thread a nut on and tighten firmly. Be sure that the gear is perpendicular to the bolt

Measure from the side of the nut, not the side of the gear. Grind a flat for the Filament Drive Gear setscrew onto the axle from 13mm to 18mm as shown. A Dremel with a small grinding wheel works great for this. Extend the grinding lightly to 25mm as shown in figure 11. This allows easy location of the flat when the filament drive gear is installed.

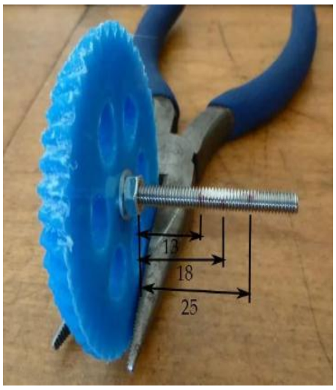

Figure 11: Ground Flat Dimensions

Step 7: Install Bearings, Large Gears, and Filament Drive Gears

Press one ball bearing into the pocket on the "open" end of each extruder body.
Slide an axle through the bearing on the "closed" end of one extruder body, through the filament drive gear, and through the other bearing. Put the a Nylock on to hold everything in place.

Center the filament drive gear on the filament hole, line the set screw up with the flat you ground on the axle, and tighten the set screw. Use a drop of Loctite on the set screw for additional security as show in figure 12.

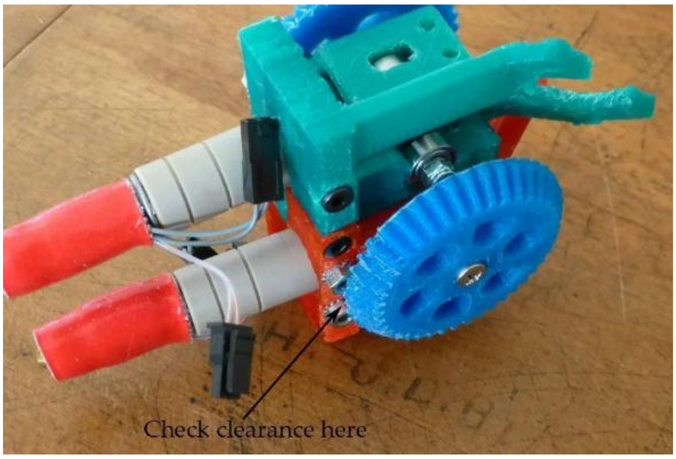

Figure 12: Gear Installation

Step 8: Install Motors

Use three M3x10 bolts to mount the motor. The lower bolt is accessible through the holes in the large gear.

Adjust the small gear and the motor position to obtain a good mesh of the gears, then tighten the setscrews. The gears should turn smoothly.

If your motors run warm, check that your gears mesh smoothly. However, you may find that the motors run warm even with smoothly meshing gears. If so make a couple of the fan mounts found here and add cooling fans.

Step 9: Mount the Dual Extruder

Mounting the Dual Extruder requires some ingenuity on your part since there is no standard design for an X Carriage to carry this extruder. That said, it should only take minor changes to modify any given X Carriage. A Dremel could do it, or a small revision to an existing carriage design on Thingiverse. If you create a modified carriage design yourself, consider posting it to Thingiverse.

For the standard Prusa X Carriage, the dual extruder mounting hole spacing is designed to fit with only slight adjustment and needs only a small amount of grinding to make the nozzles fit. Note that the dual extruder sits at an angle on the carriage so that the nozzles are nearly parallel to the X axis as show in figure 13.

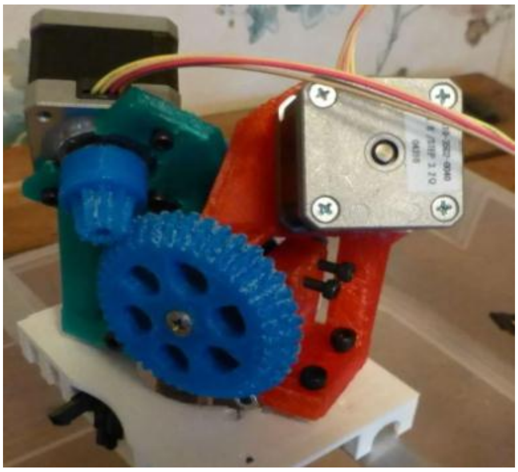

Figure 13: Extruder Mounted

Step 10: Hardware Connection to Printrboard

Connecting the second extruder nozzle and second temperature sensor to the Printrboard is quite easy. Simply use the connections for the Bed Heater and bed temperature sensor. Necessary firmware changes are detailed in the next section. If you want to use a heated bed as well as a Dual Extruder, then you will need to duplicate the interfaces on the Printrboard. Just follow the Printrboard schematics.

The Printrboard has extra pins available on the expansion headers which can be used to control the new driver. Pins from Port D on the ATMEGA90USB1286 processor are available and will be used. Specifically, Port D, Pin 4 connects to Step; Port D, Pin 5 connects to Direction; and Port D, Pin 6 connects to enable. These are accessible on JP11 pins 5, 6, and 7 respectively. JP11 is shown on the schematic, but is labeled EXP2 on the Printrboard.

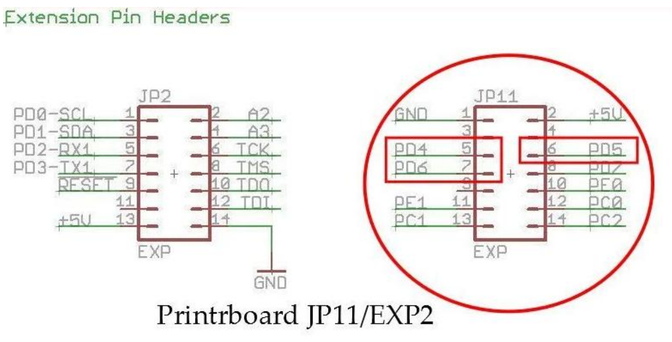

Figure 14: Printerboard

Step 13: Firmware Modifications

The firmware for the controller must be modified to control the new stepper driver, sense the temperature of the second nozzle and drive the second nozzle heater. Exact details of the changes you need to make will depend on the controller and firmware you are using. Here I provide the details for modifying the Printrboard version of the Repetier firmware. Since the extruders are identical, this seems to work fine. Here are the changes I made to Repetier for the Dual Extruder.

In *Configuration.h:*
Change the line
#define TEMP_SENSOR_1 0
to
#define TEMP_SENSOR_1 1
This change enables the second extruder.

Change the line
#define TEMP_SENSOR_BED 1
to
#define TEMP_SENSOR_BED 0
This disables the bed.

In *Configuration_adv.h*
Change the line
#define EXTRUDERS 1
to
#define EXTRUDERS 2

In *pins.h*:
Find the section for the Printrboard. It begins
#if MOTHERBOARD == 81

Now find the line
#define E0_ENABLE_PIN 13

and add the following lines for the second extruder motor driver
#define E1_STEP_PIN 4
#define E1_DIR_PIN 5
#define E1_ENABLE_PIN 6

Change the line
#define HEATER_1_PIN -1
to
#define HEATER_1_PIN 14

Change the line
#define HEATER_BED_PIN 14 // Bed
to
#define HEATER_BED_PIN -1 // Bed

Change the line
#define TEMP_1_PIN -1
to
#define TEMP_1_PIN 0

Change the line
#define TEMP_BED_PIN 0 // Bed
to
#define TEMP_BED_PIN -1 // Bed

Save your changes and reload the Repetier firmware onto your Printrboard.

4. CONCLUSION

The current simple 3D printer has limited its application due to its intrinsic deficiency. It resulted in the relatively low printing speed and limitation of only single color/material printing. Multi color/material printing using extruder requires extra time for filament replacement and nozzle cleaning, which is complicated and time-consuming.

The proposed dual extruder design consists two extruder enables printing with two different colors and materials simultaneously without stopping the operational process while switching the filaments.

Bowden-type extruder is selected so that the driving parts are separated from the hot-end.

Practically, you'll realize that a 3D printing machine with two extruders tends to be relatively faster than any other with a single extruder.

Ideally, what makes this kind of printer to be somehow faster is the fact that it prevents you from exchanging Filaments from time to time since the extruders move independently.

Multi-color printing improves the overall appearance of a 3D image. So when you can find an easy way of attaining it like using a 3D printer with dual extrusion, it even becomes more advantageous.

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