3D Printing Safety & Basic Use Class

Concept of 3D Printing

Additive Process

Unlike CNC routing or laser cutting, which do their job by removing material, this type of 3D printer, called a Fusable Flexible Filament [FFF] printer does it's job by depositing a small amount of plastic at a time.

Imagine a very small hot glue gun controlled by a computer. The gun is always pointed down, but you can move the gun in any of 3 axis, X, Y, or Z. You can also control how fast or whether the hot glue is coming out of the nozzle.

By drawing each layer on top of the last, we build up an object out of slices. Each slice is created by drawing with the nozzle in the gun and depositing glue where it is needed. This is mostly done in a continuous flow of glue (hereafter referred to as plastic or filament). But the plastic can stop and the gun (hereafter referred to as the hot-end) can be moved before starting to extrude more plastic. This allows us to create disconnected pieces in any single layer.

The initial layer of filament has to stick to something, so we have a platform on the Z axis which is what we print on. The platform is made of a material that most filament types will not stick to or will stick too well, so we need something to cover the platform with that will stick to the plastic. For many plastics we can print on blue painter's tape. (I have found that Duck brand "Clean Release", as wide as we can get, is the best tape for all plastics that use painter's tape). *See section on preparing the build platform for how to replace painters tape.*

The Hot End

So, let's talk about the hot end. The hot-end consists of a heater element, a heat block, a temperature sensor, and a nozzle. This is what the heated filament comes out of. It gets HOT; hence the name *hot*-end. It gets very hot, usually over 220° C which is 428° F. Do not touch the hot-end with your fingers or any other parts of your body that you don't want melted.

Here is how the hot-end works. We put power through the heating element, it heats up the heat block which is a small mass that can hold the thermal energy. We measure the temperature of the heat block and when it gets to the temp we want we turn off the heating element. The heat block is there to give the system some inertia so that we keep at the proper temperature even with small changes to the external temp and the heat the that filament takes away when we extrude it.

All of the above is being done to get the filament to the proper temperature to have it be extrudable but not molten. It needs to keep it's shape after it is extruded or we would just have a puddle of plastic. We are taking a 3mm filament and we are going to melt it and push it through a .4mm hole in the nozzle. We want the plastic just above the heat block to be solid and the just before it hits the nozzle it should be the correct temperature. This actually happens over a distance and we want it to be a short distance. So, when we push some filament through the top of the hot-end it comes out as a much thinner filament of plastic, but a much longer amount. This is because the ratio of "filament diameter", [*] the length you move the filament is equal to the "diameter of the nozzle" * the length of the extruded filament and the nozzle diameter is about 6 times smaller than the filament so the distance of the extruded filament is about 6 times a long as the input distance.

Here is the reason you needed to know this. The nozzle size is a fixed value and the length of extruded filament is a known value. So if we know the actual diameter of the filament we can figure out how much 3.00 mm filament we need to input into the hot-end to get the length of filament extruded that we want. We live in an imperfect world. Filament that has a label with the value 3.00 mm ~~may not be~~ *is never actually* 3.00 mm. More likely it is 2.85 or some other value, and we need to know what the actual diameter is. Also, filament may be oval and not round, so if you have to measure a filament, measure both sides and multiple places on the spool since filament diameter can vary even within the spool. Then take an average.

Having said that most spools of filament will be labeled with what we found to be the diameter and temperature to print at.

Terms

- **Skirt** is an extrusion around the object, it is used to get the head printing with plastic. To build up the pressure and get the plastic flowing.
- **Brim** is a layer of plastic around the object that is connected to the object and helps to hold the print down to the print platform, this is used in difficult to print objects. See bicube.
- **Raft** is a loosely printed layer of plastic that is put down on the print platform to help hard to print objects. The raft will stick to the bottom of your object and have to be removed, leaving some surface marring.
- **Support** is plastic laid down so that when you go to print an overhang, there is something to hold the plastic up. (need photos).

Basic Tools

Filament

- **PLA**
  Made from corn starch or sugar, biodegradable, strong but brittle. Good thermal stability (won't change shape much when it cools).
- **ABS**
  Not biodegradable, strong, needs a heated bed to print on. Can warp if not cooled evenly so a heated bed will help. also sticks to heated glass or kapton tape.
- **Laywood**
  Wood in a plastic substrate. Prints like PLA. The hotter you print it the darker it gets. Can be used to create a wood grain-like effect.
- **LayBrick**
  Chalk in a plastic substrate. Prints like PLA, the hotter you print the rougher it prints, so you can make things look like sandstone or more marble depending on the temp you print at.
- **EcoFlex**
  Soft material, will be soft when done printing. can print gaskets or wheels
- **ThermoChrome**
  This plastic will change colors at 24 C (about 84 degrees) it gets clear.

- **Nylon**
  has some very nice physical properties. won't stick to painter's tape. I have only gotten it to print on Garulite. print temps at about 230 C

Diameter

Not round.

Measure multiple angles
Measure multiple locations on the spool
Average the measurement. For filaments that measure very differently along the length, just don't print with them

Compound and Temperature

Even filament from the same vendor can be made with different chemicals. This can cause the filaments to print better at different temps. Color can affect this. Find a good temp for each different roll of filament.

Loading & Feeding

Don't try to extrude or retract filament while the hot-end is cold. This will be difficult and probably damage something.

Bed / Surface

Preparing the Surface

For most of our printing we will print on blue painter's tape.
Place the tape on the printing platform, with no overlap and as little space between the strips of tape as possible. What you want is a single layer of tape covering the entire platform. It is better to have a little space between the strips then overlap. The filament can bridge the gaps. the overlay will not let the first layer be a flat as possible.

Leveling

There are 2 issues here. One is that the entire platform needs to be level to the hot-end as it moves X and Y. Second, the platform needs to be ever-so-slightly below the hot-end so that when we print we do not push the first layer of filament into the tape so hard we cannot get the printed object to release from the tape. I use a standard piece of printing paper folded over to give me a double layer and I try to get the hot-end to just drag on the paper when I slide it between the platform and the hot-end. Then I change the position of the hot-end and set that corner.

You will need to set the Z height in all 4 corners.

Loading the Filament

Remove the Current Roll

The filament is loaded at the back of the Ultimaker. Lower the Z axis enough so you can see the hot-end and there is some space to extrude filament. Once the hot-end is at about 210 degrees, you can start to extrude or retract the filament. This can be done by first making sure the hot end is hot enough for the plastic to be melted at the nozzle. Turn the gear in the extrude direction (direction of arrow) a little and you should see some filament extruded from the nozzle. You can now turn the gear backward to retract the filament out of the hot-end and up the bowden tube.
Now you can release the pressure wheel on the extruder at the back of the Ultimaker and then pull the filament out of the tube and extruder.

Add the New Roll

Clip the end of the filament you are going to load. You now want to get the filament up from the bottom of the extruder, right next to the knurled bolt and into the bowden tube. I have found that a way that has worked for me is to put the pressure wheel back into place with a little pressure and insert the filament into the bottom hole where it is between the knurled bolt and the pressure wheel and use the gear to engage the extruder feed

mechanism and let the filament go into the bowden tube. If this doesn't work for you then try releasing the pressure wheel and fiddling around with the filament trying to find the entry to the tube.

Once the filament is going through the tube release the pressure wheel and push the filament up and into the hot-end. I usually have trouble here, sometimes moving the filament around will get it past this. If you get it past this, there is another place where the filament sticks. At this point I usually GENTLY remove the bowden tube (press down on the little ring around the teflon tube and pull up on the tube GENTLY) watch the wiring. Once you have done this you can get about 2 to 3 inches of filament sticking out of the tube and insert it into the connector and into the hot-end. You should be able to get the filament to where it is coming out of the nozzle with a little pressure. Then reinsert the teflon tube into the connector as far as it will go.

Now put pressure on the pressure wheel and latch it into place. You should now be able to get filament to come out of the nozzle by rotating the large gear in the direction of the arrow.

Extruder / Hot End

Stepper Motors

Software / Cura / Repetier Host

Cura Software
http://software.ultimaker.com/

Cura manual
https://www.ultimaker.com/spree/uploads/38/original/Cura_User-Manual_v1.0.pdf

Loading an Object
Thingiverse

Don't set the machine as an Ultimaker 2 you will not be able to set the diameter of the filament.

Setting Temp
You set the temp for the filament in Cura, you can change the temp from the control panel.

Setting Diameter
You set the diameter in Cura. Once the gcode is generated. If you change filament, you will need to change these setting and regenerate the gcode file.

Each filament will have a temp and diameter that it prints out best at. These should be printed on each spool of filament and be available on the wiki.

currently black PLA at IFL 2.82mm 240c print speed at 30mm/s
amber PLA (printbl) 2.83 240C 38mm/s

Slicing an Object
Settings speed versus quality, talk about quality, talk about infill %, nothing should be 100% filled with plastic

USB vs SD Card
USB gives better manual control, but you must have a computer connected the whole time you are printing, SD allows you to print without a computer.

Using the built in controller
Go over the menu on the controller and how to auto-home and preheat hot end.

Cleaning up the Area

Resources
Ultimaker Website

Buying Filament
$1 / per hour

If using USB, make sure the power is still on.
Mentioning the Calipers and other tools

Preheating