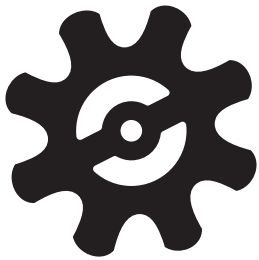


Mini Metal Maker

Instructions for Setup and Use

manual v.160531

Mini Metal Maker

Table of Contents

1. Introduction

The Mini Metal Maker is experimental. This machine is for the experimenter, the technical artist, the inventor, and the scientist. If you do not have any prior experience with 3D printing, you may find this machine challenging to use. It is operated with open-source software, which can be tweaked or even re-written by the user. The software is flexible but not very user-friendly. Ultimately, the machine can be used to extrude virtually any viscus material and is not limited to clay. The Mini Metal Maker is a robust tool and is designed to serve you for many years of use.

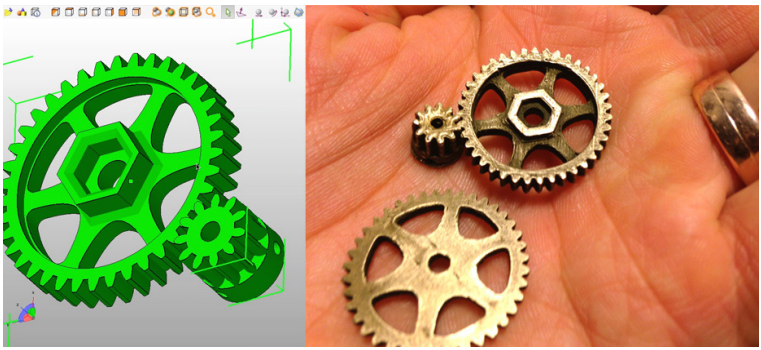
The Mini Metal Maker 3D printer is the first commercially available printer designed to be used with metal clay. It uses a fully-electronic extrusion mechanism (as opposed to pneumatic systems) and is able to deliver 300+ pounds of force to the piston of a pre-loaded cartridge of clay. During the printing process, the clay pressure can be rapidly modulated, allowing for nearly instant start and stop to clay flow. This allows the Mini Metal Maker to produce prints in much the same way as a traditional plastic-extruding FDM machine and at resolutions in the 300 to 100 micron-per-layer range.

Metal clay is generally classed as a material for fabricating hand crafted jewelry. It is composed of microscopic metal particles mixed with a water soluble organic binder. The clay can be extruded as a thick paste, allowed to dry, and then fired in a kiln to produce solid metal objects.

The kiln firing process effectively burns out all of the organic binder and allows the metal particles to fuse into a single contiguous solid of the same shape as the

extruded object. The firing process generally results in a shrinkage of 10% to 15%, depending on the specific clay product. In practice, this shrinkage is compensated for by scaling the digital print file up by the % anticipated shrinkage. With good practices and use of a digital kiln, finished objects can be manufactured within +/- 1% of the intended size. This is similar to the size variability encountered with the traditional wax-casting process.

The Mini Metal Maker differs most notably from all other metal-printing 3D printers in its low cost and its printing at room-temperature. Because the clay is extruded in wet form and allowed to dry, no part of the machine needs to exceed room temperature. This renders the printing process safe and free of fumes or hazardous airborne powders. The use of metal clay provides an additional opportunity for product clean-up during the time between printing and firing. This ‘greenware’ stage is especially useful for jewelers who may wish to incorporate existing metal hardware, stones, or findings into a piece before the final step of rendering it in metal.



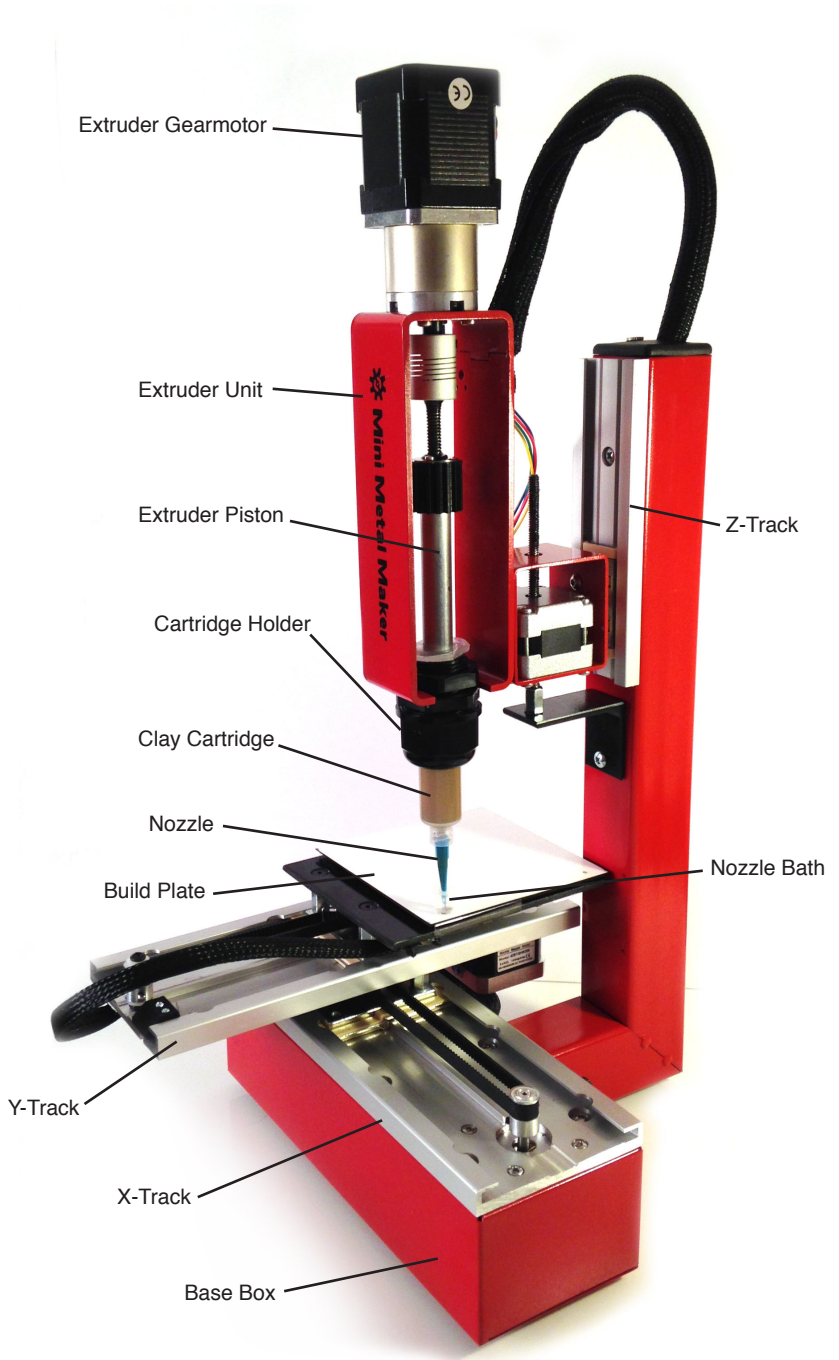
2. Printer Setup

The Mini Metal Maker should be setup on a sturdy level surface within reach of a computer. The process of loading the clay and starting a print requires being able to interact with the machine as well as the computer.

2.1 Build plate & nozzle bath
The Mini Metal Maker prints directly onto the top of vinyl magnetic squares that are placed on the build platform. The squares may be changed after each print. Metal clay clings to the vinyl surface when wet and will automatically release when dry.

The Nozzle Bath is a small plastic cup with a magnet on its base. This bath can be used between prints in order to extend the life of a plastic extrusion nozzle. The nozzles are essentially disposable and become clogged if clay is allowed to dry in the tip for times a short as two minutes. The nozzle bath is filled with water and is placed on the print stage in a specific place. See section 3.5 Configure Printrun for the MMM for details about how to park the nozzle in the nozzle bath.

2.2 Extruder Piston
The extruder piston is a stainless cylinder with a rounded metal plunger at its end. In order to load the Mini Metal Maker, turn it by hand so that it is fully retracted in the upward position. Alternately, the piston can be entirely removed from the extruder screw by turning it the other way in order to clean it.


Extruder Gearmotor
Extruder Unit
Extruder Piston
Cartridge Holder
Clay Cartridge
Nozzle
Build Plate
Y-Track
X-Track
Base Box
Z-Track
Nozzle Bath
Mini Metal Maker

2.3 Cartridge holder

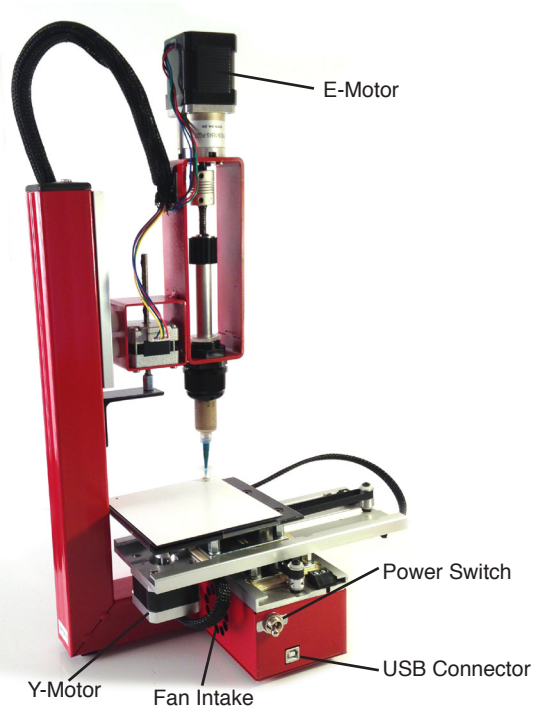
A cartridge of clay is held firmly into place under the extruder piston by the Cartridge Holder. The clay tube is first inserted and the holder is tightened by hand. The entire cartridge and holder unit then slides into the extruder head. See section 4.3 Priming the Printer for details about loading and unloading clay cartridges.

2.4 USB Connector

Connect the Mini Metal Maker to a desktop or laptop computer with a standard printer type (USB A to B) cable. You may use the supplied cable or opt for one of a different length.

2.5 Power supply connector

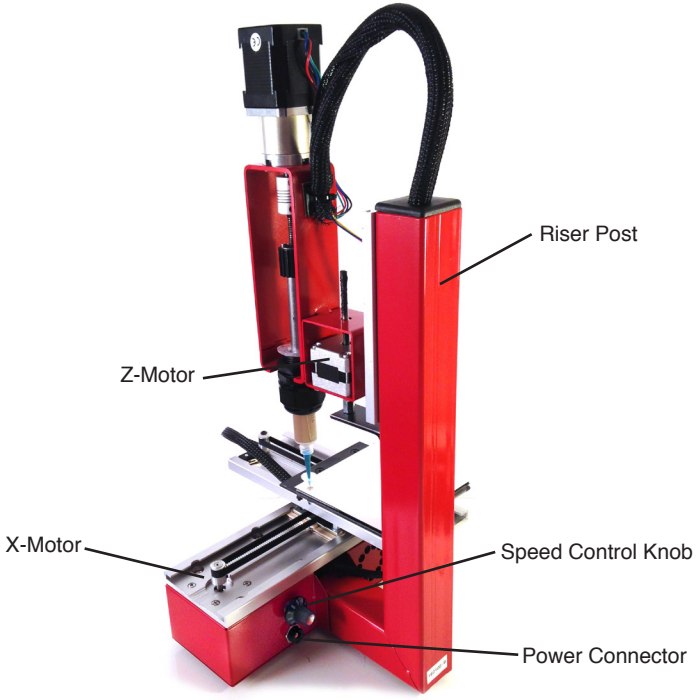
The Mini Metal Maker requires a 12 Volt DC 5 Amp power supply. The provided power supply has been



tested and found to conform to FCC emission standards. The supply is the following: I.T.E. Power Supply Model CENB106A1203F01. Power supplies are not shipped out of the USA.

2.6 Speed control knob

Metal clay consistency changes due to temperature and relative humidity. The best way to compensate for this variation is to make small manual adjustments to the Extrusion Speed Control Knob located on the back right hand side of the Mini Metal Maker. Prints should be started with the knob in the '5' position. Adjustments can then be made by turning the knob up or down one full number at a time. See section 4.4 Printing & tweaking to learn more about use of the speed control knob.



3. Software Setup

The Mini Metal Maker is designed to be used with free open-source software. Many different types of open source 3D printing applications are currently available and are in continuous development. This document outlines the use of one specific set of software applications. You are free to choose the software that you prefer.

3.1 Overview

The specific set of software applications that are used in the process of 3D printing is often referred to as the 'tool chain'. In concept, each program in a tool chain creates a specific file that becomes the input for the next program in the process. The programs are used one after another like links in a chain.

Figure 3.1.1 shows the toolchain recommended for running your Mini Metal Maker. We have tested and fine tuned the settings to work well with the bronze metal clay designed for use with our printer.

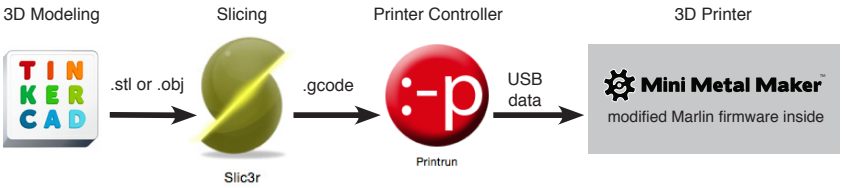


Figure 3.1.1 The toolchain for the Mini Metal Maker.

The major types of software in the process are programs for 1) 3D Modeling, 2) Slicing, 3) Printer Control, and 4) the Printer Firmware. The following explains each in a little more detail:

1) 3D Modeling - The process of creating the actual geometry that you will print. The 3D object should be saved as either a .stl or a .obj formatted file.

2) Slicing - The process of turning a 3D object file into layer-by-layer instructions for manufacturing with a specific 3D printer. The process of slicing takes into account things like printer resolution, print speed, and material thickness. Sliced files are saved as .gcode files.

3) Printer Controller - The print controller program allows you to connect your computer to the printer and to control many its basic functions. The controller lets you start and stop the printing process. The controller essentially feeds the .gcode into the printer through a USB connection.

4) Printer Firmware - The firmware is the software that runs inside the controller board of the 3D printer. The firmware handles the very basic tasks of turning .gcode instructions into movement of the printer's motors. The firmware handles things like understanding when the printer has pressed one of its limit switches, signifying that it has reached the end of its mechanical range. The Mini Metal Maker comes with firmware pre-installed.

The newest versions of all of these applications are available for download online from various different developers. There is a list of quick links on the back cover of the manual to make it easy to find all of the downloads you will need.

3.2 Download Slic3r

Go to the following address and download and install the program Slic3r: *http://slic3r.org/download* When the application starts, it should look much like shown in

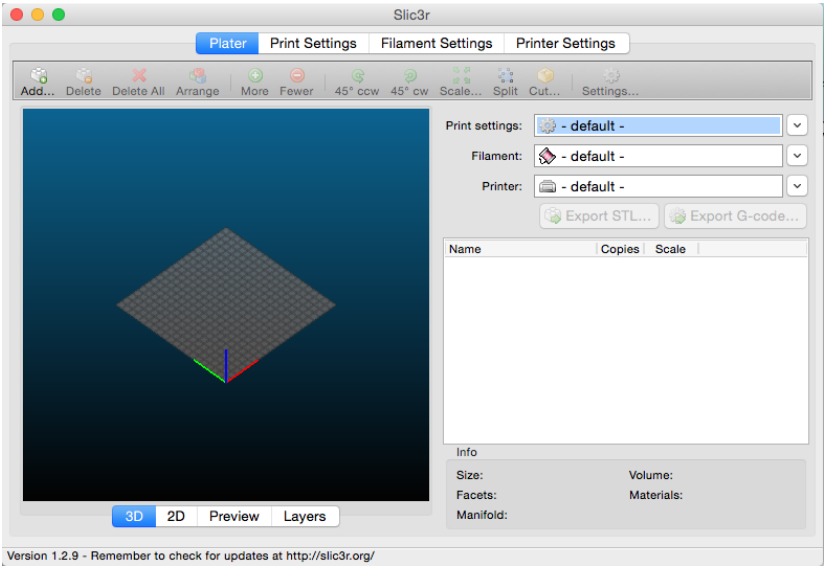


Figure 3.2.1 The Slic3r application when first opened after downloading.

figure 3.2.1 below:

3.3 Download MMM Config for Slicer

The next step is to download a special configuration file that we have created specifically for the Mini Metal Maker. This config file sets up Slic3r to produce .gcode for the Mini Metal Maker. Go to the following address:

http://github.com/MiniMetalMaker/MiniMetalMaker

This is the online repository for all of the software developed specifically for the Mini Metal Maker. Click on “Download Zip” and you will download a folder called “MiniMetalMaker-master” to your computer.

Unzip the file and move the entire folder to your documents directory or somewhere you can find later.

Now, in Slic3r, go to File and choose *Load Config...* You can find the Slic3r config file inside the MiniMetalMaker-master folder as shown in figure 3.3.1.

The configuration file name starts with a date in yymmdd

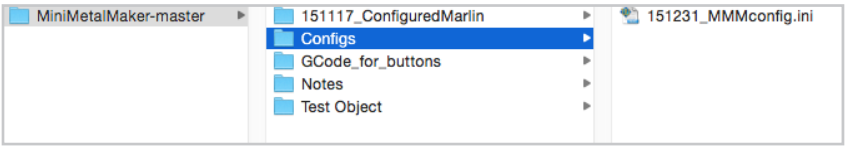


Figure 3.3.1 Locating the MMM configuration file for Slic3r.

format. Choose the newest config file if there are more than one. Once the config file is loaded into Slic3r, it will appear in the settings as shown in figure 3.3.2.

3.4 Download Printrun

Printrun is a powerful free program for controlling 3D

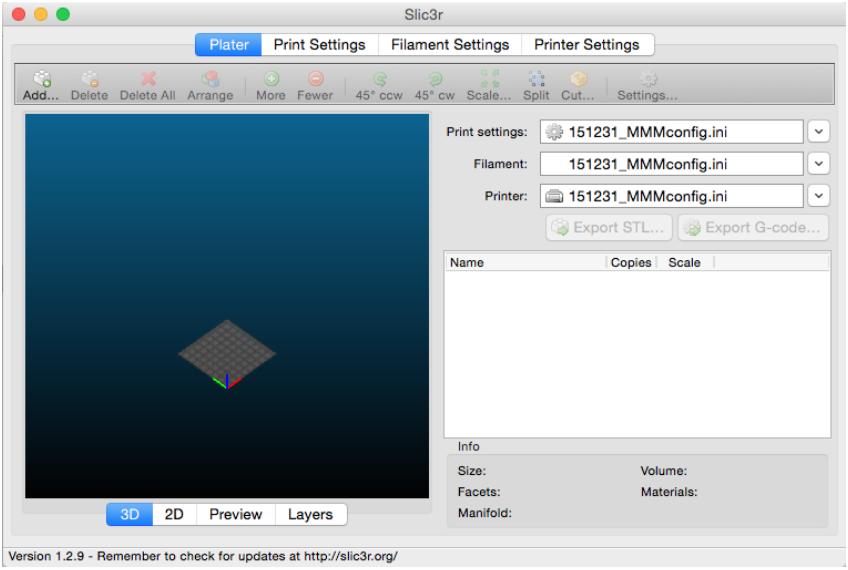


Figure 3.3.2 The MMM config file successfully loaded into Slic3r.

printers. Go to the following site to download and install Printrun aka Pronterface:

https://github.com/kliment/Printrun

Once Printrun is installed on your system, you will need to make a few adjustments to its configurations in order for it to work well with the Mini Metal Maker.

3.5 Configure Printrun for the MMM

Start Printrun (also known as Pronterface). Figure 3.5.1 shows how Printrun should look.

From the menu at the top, click Settings and choose Options. With the 'Printer Settings' tab selected, make

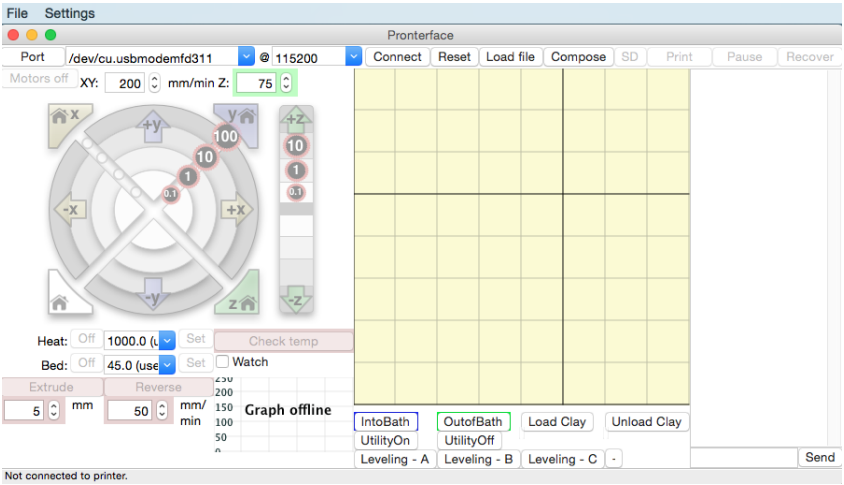


Figure 3.5.1 The Printrun (Pronterface) interface.

your settings match those shown in figure 3.5.2.

Custom Buttons in Printrun

Printrun allows you to add custom buttons that make certain common tasks easier. Figure 3.5.3 shows how a number of custom buttons will appear once they are

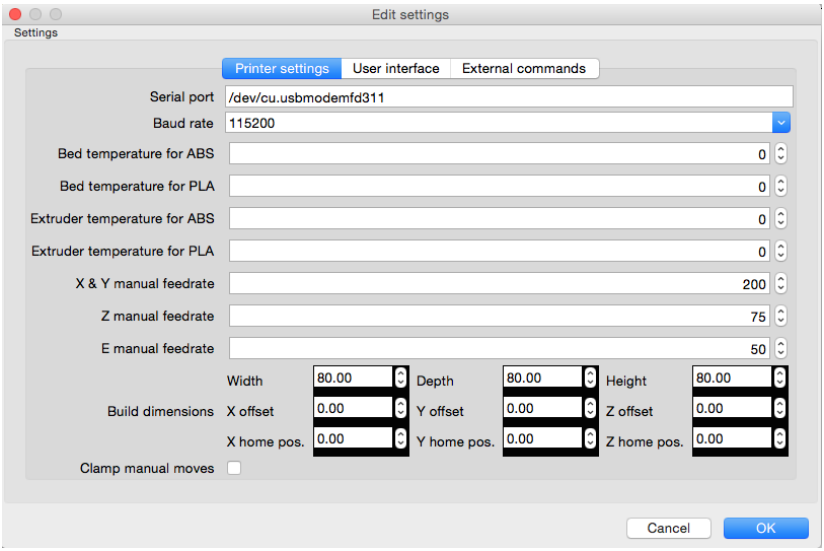


Figure 3.5.2 Manually set your Printrun printer settings to match these.

added to your Printrun controller.

To add a custom button, simply click on the button shown in figure 3.5.3. This will open the *Custom button* panel. Add the name of the button, the G-code commands, and choose a color for the button if you like.

To make things easier, there is a ready-made text file containing snippets of G-Code for each of the buttons shown. You can simply copy and paste the command code when making a button. You can find the code in the MiniMetalMaker-master folder that you downloaded inside the folder labeled GCode_for_buttons.

The buttons that you create will be automatically saved so they will be there the next time you start Printrun. You can right-click on buttons to modify or delete them.
The custom buttons that we created for you to add in Printrun are the following:

- IntoBath - Moves nozzle into nozzle bath
- Outof Bath - Lifts nozzle up out of bath
- Load Clay - extrudes a small volume of clay
- Unload Clay - pulls piston free from clay
- Utility On - turns on utility power port
- Utility Off - turns off utility power port
- Leveling Center - step 1 of leveling process
- Leveling A - moves nozzle to corner A
- Leveling B - moves nozzle to corner B
- Leveling C - moves nozzle to corner C

Figure 3.5.4 shows the G-code commands used to create each button.

If you decide that you need to add your own custom function to Printrun, feel free to play with G-code commands and then create your own custom button. You can find a complete list of G-code commands for the Marlin firmware here: *http://reprap.org/wiki/G-co*

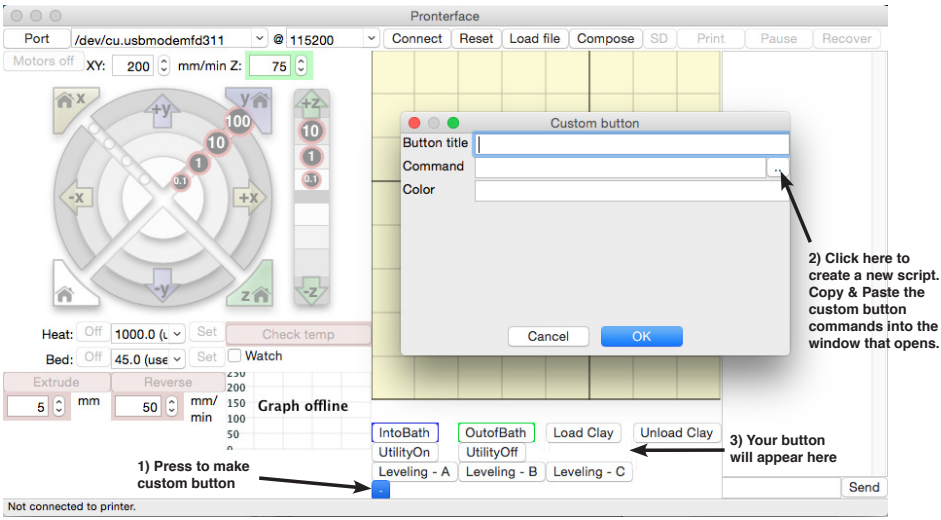


Figure 3.5.3 Adding custom buttons to Printrun, steps 1-3.

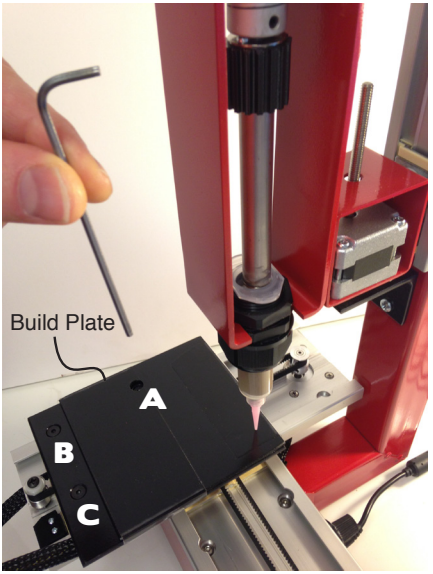
```
Button Title: Into Nozzle Bath

Command:

G28
G90
G0 F1800 Z15
G0 Y80
G0 Z5

_________________

Button Title: Out of Nozzle Bath

Command:

G0 F1800 Z15

_________________

Button Title: Load Clay

Command:

G92 E0
G5 F50 E1


_________________

Button Title: Unload Clay

Command:

G92 E0
G5 F50 E-10

_________________

Button Title: Utility Pwr On

Command:

M35
_________________

Button Title: Utility Pwr Off

Command:

M36
```

```
Button Title: Leveling Center

Command:

G0 F1800 Z2.00
G0 F1800 X40.00 Y40.00
G0 Z0.6
_________________

Button Title: Leveling Position A

Command:

G0 F1800 Z2
G1 X76 Y50
G0 Z0.6
_________________

Button Title: Leveling Position B

Command:

G0 F1800 Z2
G1 X76 Y81
G0 Z0.6
_________________

Button Title: Leveling Position C

Command:

G0 F1800 Z2
G1 X49 Y81
G0 Z0.6
_________________
```

Figure 3.5.4 G-code commands for custom buttons

4. Level the Build Plate

This step gets its own chapter, not because it is complicated, but because it is important.



You only need to level the build plate once every so often. If you don't move your Mini Metal Maker around very much, you may only need to level it once.

You will need:
Cartridge of clay
Extrusion nozzle
Allen wrench, size 2.5mm

1. Load a cartridge of clay. This process does not use any clay, it just holds the nozzle.

2. Put a nozzle on the cartridge. You can use a fresh nozzle or a clogged one. No matter.

3. Remove the magnetic build plate. You have to get to all three adjustment screws.

4. Tighten all 3 build plate screws in the CW direction, until the plate is all-the-way down.

5. Now, loosen each of the 3 screws in the CCW direction by three full rotations. This centers the buld plate in its vertial range.

6. Turn on the printer, start Printrun, connect to printer.

7. Press the ‘Home all Axis’ icon, let the machine go to zero for X, Y, and Z.

8. Press the ‘Leveling-Center’ custom button and let the printer go to the center of the platform.

9. Press the ‘Home Z-Axis’ icon. This zeros out the Z position oncemore, this time in the middle of the build plate.

10. Press the ‘Leveling-A’ custom button. This moves the nozzle near to Screw A.

11. Turn Screw A CCW until you can feel the nozzle beginning to pinch down on the paper, then stop.

12. Press Leveling-B button. This moves the nozzle near to Screw B.

13. Turn Screw B CCW until you can feel the nozzle beginning to pinch down on the paper, then stop.

14. Press Leveling-C button. This moves the nozzle near to Screw C.

15. Turn Screw C until you can feel the nozzle beginning to pinch down on the paper, then stop.

16. Press “OutofBath” button to raise the nozzle.

17. Replace the magnetic build platform.

18. Press the Home button on the manual controls.

✓ The build plate is now level.

5. Making a Print

With the Mini Metal Maker hardware and software set up and the build plate leveled, it is time to make a print. You may wish to start with one of the test objects included in the MiniMetalMaker-master directory that you downloaded. Test objects can be found in the folder named “Test Object.” All of the test objects are in the .stl file format.

5.1 Prepare GCODE in Slic3r
The first step is to slice the .stl file into a .gcode file.

Begin by opening Slic3r. Next, load the .stl file into Slic3r by clicking the ‘ADD’ button in the upper left and choosing a .stl object.

Make sure that each of the preset configurations is set to the latest MMMconfig.ini. See section 3.3 Download MMM Config for Slicer for details on doing this.

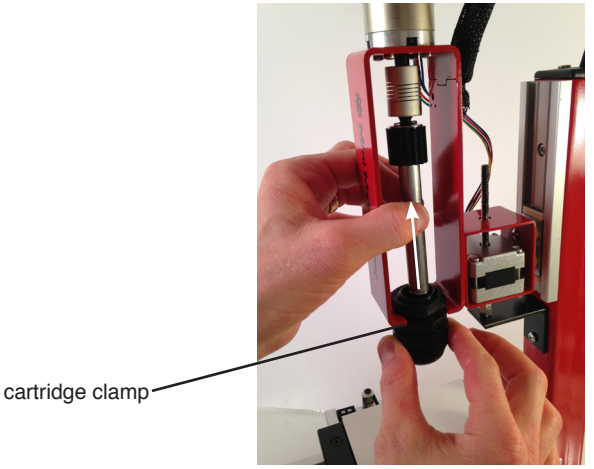
At this point, simply press “Export G-code...” from the right hand side of the Slic3r window, and save the .gcode file anywhere you like. See figure 3.3.2 for an image of the Slic3r interface.

5.2 Opening an object in Printrun
The next step is to load the object into Printrun so that it can be sent to the printer. Open your configured version of Printrun. See section 3.5 *Configure Printrun for the MMM* for details about how to do this if you haven’t already.

5.3 Priming the printer
Now it’s time to put clay in your printer and get it ready for printing.

Turn on the printer and connect to it from Printrun. Printrun will say “Disconnect” instead of “Connect” when the printer is connected. The printer itself will not appear to be doing anything.

First, hand-turn the extrude piston so that it is fully up at the top of its range. Remove the black plastic cartridge clamp.



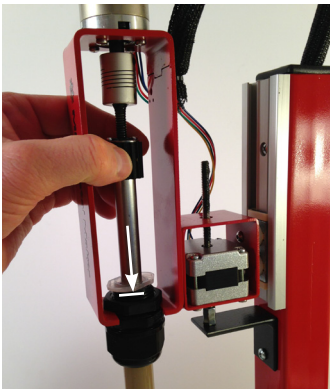
Next, remove the orange clip cap from the open end of the clay cartridge. Tap the cartridge on the surface of a table to remove the wet cotton ball.

Slide the cartridge into the removable cartridge clamp and tighten the clamp so that the cartridge does not slide.

Now, slide the entire cartridge clamp into the base of the extruder head of the Mini Metal Maker. You may have to loosen the top nut of the cartridge clamp.

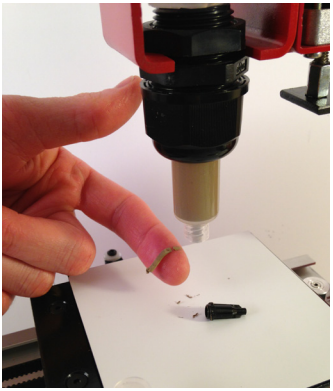
With the cartridge clamp in place, tighten the top nut and give the clamp a final turn to make sure the cartridge is tightly gripped.

Turn the extruder piston by hand to screw it down into the body of the cartridge. You will feel it get hard to turn once the piston is seated against the piston of the cartridge.

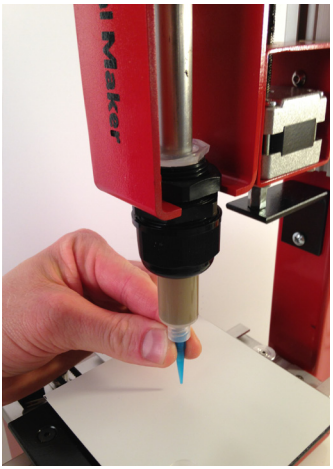


Remove the black end cap from the cartridge by twisting it CCW.

The first amount of clay at the start of a new cartridge is partly dried. Twist the extruder piston a couple turns by hand to manually push it out. Wipe it free with your finger once it pops out.



Once the clay is free to flow, place a fresh extrusion nozzle onto the cartridge. It twists into place finger-tight. You may need to raise the extrude head in order for the new nozzle to fit. Press the +Z 10 button in the manual controls of Printrun.



Press the ‘Load Clay’ custom button a few times until clay has entirely filled the nozzle and is just beginning to extrude from the tip. Once clay is seen to emerge as shown in figure 5.3.8, the printer is primed. Once primed, be sure to use the nozzle bath in order to prevent clay from drying in the tip. This will ruin the nozzle.

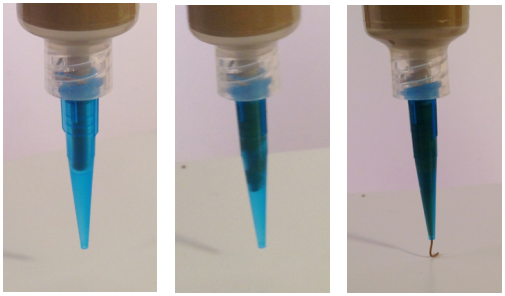


Fig. 5.3.8

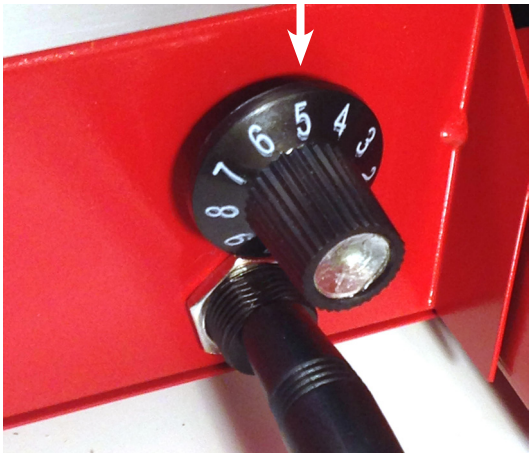
5.4 Printing & tweaking

Set the Speed Adjustment Knob on the back of the machine to the number 5 and click *Print* in Printrun. The machine will begin the print sequence.

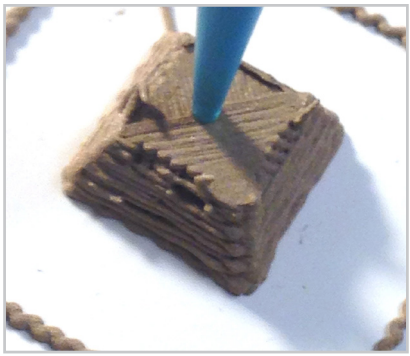
The speed-adjustment knob allows the user to set the extrusion rate over a relative range from 1-10. Under normal circumstances, we recommend starting with the knob set to 5, and then adjusting up or down as the print progresses in order to find the best setting for making prints.

.

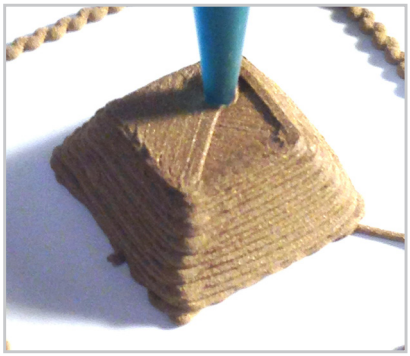
Adjustments can be made during a print. The adjustment will take effect once the current line command is completed, usually within 10-30 seconds. Because of this lag, it is important to make small adjustments and wait to see the effects, otherwise you will find yourself overcompensating out-of-control. Figure 5.4.2 shows the results of four variations of the speed control setting.



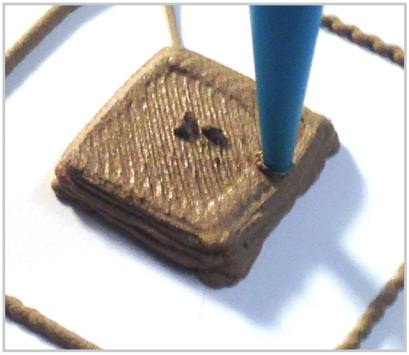
5.4.1 Speed adjustment knob, shown on setting 5.



Under extrusion: Poor layer adhesion, gaps in the perimeters, sides look sunken-in. Lines of clay may appear very thin or may be seen to break during extrusion.



Good extrusion: Layers are even and are not bulged or sunken-in. Perimeters are unbroken. Each layer goes on flat with minimal buildup on the extrusion tip.



Over extrusion: Object appears bulged, corners undefined, layers seem to swell upward during printing, material builds up on extrusion tip. Printing seems muddy or messy.

Figure 5.4.2

Setting 3

Setting 5

Setting 7

Setting 10

5.5 Storing the clay

Cartridges of metal clay manufactured by Metal Adventures are shelf stable and have a life of over six months if kept refrigerated. Remove clay directly from the refrigerator for use, and replace it after with the black and orange caps and the wet cotton ball.

5.6 Finishing & firing

Once an object has been printed, it should be allowed to dry for 8 to 10 hours before firing in a kiln. The removable magnetic build plates allow a piece to be removed from the printer while wet and set aside to dry. Metal clay sticks to the vinyl surface when wet and automatically releases when dry.

Once clay is dry, there is the opportunity for cleanup, surface working, and even joining of parts. If a part is wetted in order to smooth the surface, or two parts are joined with metal clay slip, the part should be allowed to dry for an additional 8 hours before firing.

Different metal clays have different kiln firing schedules depending on the material. Please see the firing schedule that comes with the pre-loaded cartridges of metal clay.

The Kiln

A kiln is essentially a computer controlled electric oven. It is important to use a kiln that has a digital controller that allows for temperature ramping and timed temperature holds. Figure 5.6.1 shows a digital beading kiln by Paragon that is popular in the metal clay community.

Fig. 5.6.1 type of kiln.

If you are using bronze clay, it is recommended that the piece be buried in carbon grains and fired inside a stainless container.

Figure 5.6.2 shows the placement of items into carbon grains within a stainless container for kiln firing. A lid is placed on the container and the container is placed on fire brick risers within the kiln to insure even heating.

Fig. 5.6.2

Metal clay shrinks during the firing process. The amount of shrinkage depends on the specific type of clay, and on the firing profile. Typical shrinkage of bronze clay is 15%. An item can be scaled up during the digital modeling stage by this amount in order to produce prints of a specific size. It should also be noted that the placement of a piece within a kiln can affect the final outcome of a print. By being consistent in the firing program and placement of pieces made from a given type of clay, it is possible to achieve parts with a deviation within +/- 1% of the desired final size. Figure 5.6.3 shows an example of a printed piece before and after firing.

Fig. 5.6.3

6. Maintenance & Troubleshooting

The printer body uses heavy metal construction which reduces vibration and generally holds things together well. The linear motion components use lubricant-free plastic glides, which resist dirt and dust. They will never need to be oiled, simply wipe out the linear rails with a cloth every so often. Likewise, the fan is positioned to provide maximum airflow to the motor drivers, which should allow for a long service life. The drivers are modular and can be easily replaced if necessary.

The motion systems are designed to be easily disassembled and serviced. Nearly all of the screws are metric sizes, but there is some inevitable mixing of units as the Mini Metal Maker was designed and built in the USA.

6.1 Electronics

In many respects, The Mini Metal Maker is very similar to many RepRap style printers that are based on open source hardware and software. The printer itself uses an Arduino Mega 2650 control board with a RAMPS shield to drive a set of four stepper motors. See figure 6.1.1 for a full electrical schematic.

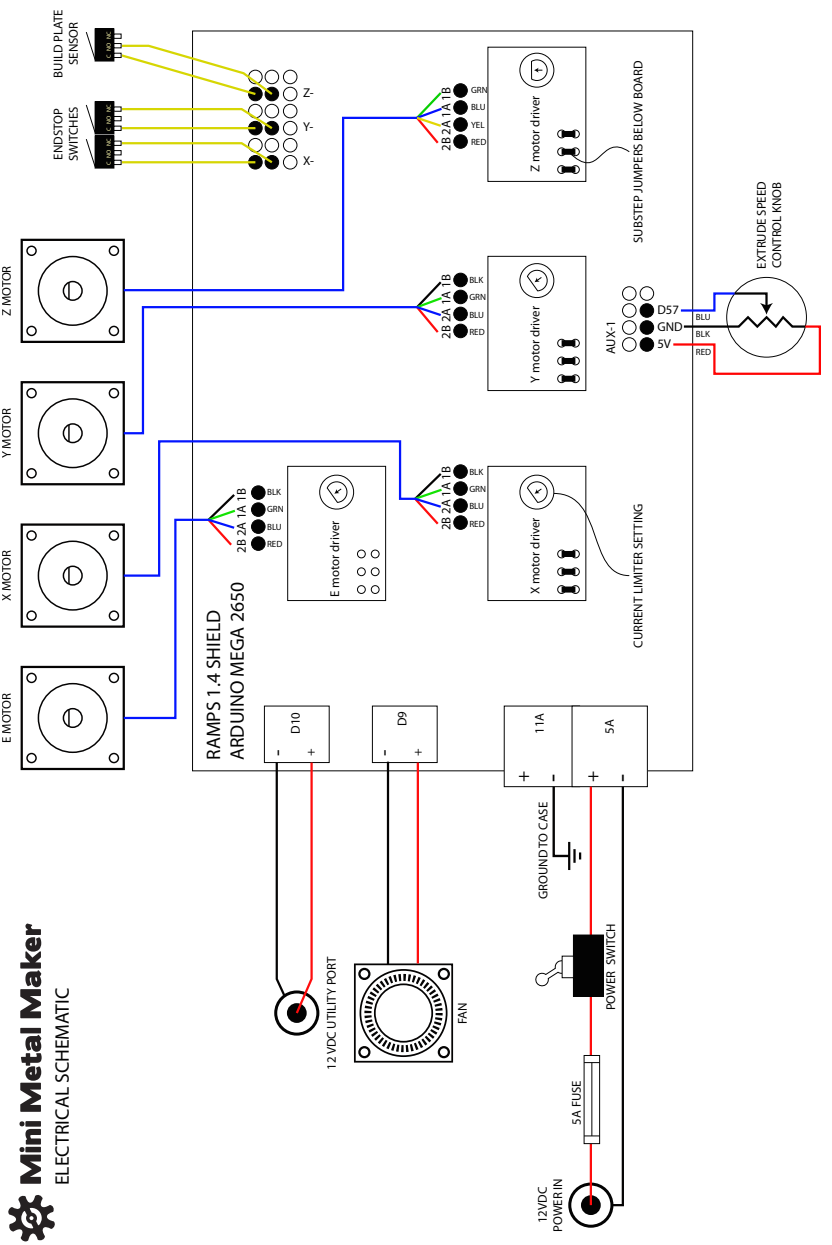

Mini Metal Maker
ELECTRICAL SCHEMATIC
BUILD PLATE SENSOR
ENDSTOP SWITCHES
Z-
Y-
X-
Z MOTOR
Y MOTOR
X MOTOR
E MOTOR
RAMPS 1.4 SHIELD
ARDUINO MEGA 2650
2B 2A 1A 1B
BLK
GRN
BLU
RED
YEL
E motor driver
X motor driver
Y motor driver
Z motor driver
SUBSTEP JUMPERS BELOW BOARD
CURRENT LIMITER SETTING
AUX-1
D57
GND
5V
EXTRUDE SPEED CONTROL KNOB
D10
D9
11A
5A
12 VDC UTILITY PORT
FAN
GROUND TO CASE
POWER SWITCH
5A FUSE
12VDC POWER IN

Fig. 6.1.1

6.2 Software & firmware tweaking

While we have worked hard to configure the Mini Metal Maker to perform well out-of-the-box, you may wish to experiment with some of the more advanced settings in order to optimize it for your own purposes. Table 6.2.1 provides a list of the most relevant controls to adjust through the print process.

In Slic3r:	Location of settings:
Extrusion Multiplier	Slic3er / Filament Settings / Extrusion Multiplier
Print Start Procedure	Slic3r / Printer Settings / Custom G-code / Start G-code
Print Speed Settings	Slic3r / Print Settings / Speed
In Marlin Firmware:	location of settings:
Knob Settings	Marlin / planner.cpp / Line#141-164
Motor Step Increments	Marlin / configuration.h / Line#483, "DEFAULT_AXIS_STEPS_PER_UNIT"

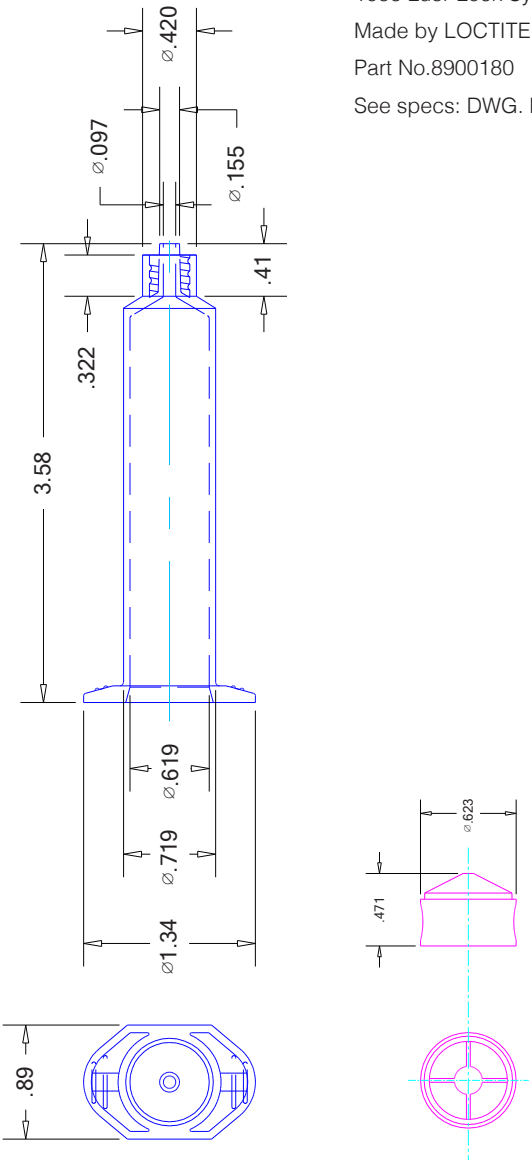
Table 6.2.1

6.3 Use of alternative materials

The Mini Metal Maker is specifically designed to extrude wetted metal clay. If you wish to experiment with mixing your own clays or with extruding other materials, you may need to adjust various internal settings and should do so at your own risk. Of specific interest may be the use of various ceramic materials, polymer clays, and biological substrates. Figure 6.3.1 details the dimensions of one type of 10cc syringe that is known to work well with the Mini Metal Maker's extruder.

Another set of considerations is the choice of extrusion nozzle. The syringe used for extrusion of metal clay uses a luer-lock type collar and so is compatible with a range of industrial glue dispensing tips available in plastic as well as metal. Conical plastic dispensing tips have been found to work best with thicker materials.

Fig. 6.3.1



10cc Luer Lock Syringe Barrel
Made by LOCTITE, Rocky Hill CT
Part No.8900180
See specs: DWG. No. A-98561

Notes

Notes

Quick links to software downloads:

3D Modeling Program: tinkercad.com
http://tinkercad.com

Slicer Program: Slic3r
http://slic3r.org/download

Host Program: Printrun (Pronterface)
https://github.com/kliment/Printrun

Firmware: Marlin, modified for the Mini Metal Maker
http://github.com/MiniMetalMaker/MiniMetalMaker
(optional, since it is already installed in the MMM.)

Development Software: Arduino
http://arduino.cc/en/Main/Software
(optional, only needed to install new firmware into the MMM.)

Mini Metal Maker