# Build your very own desktop 3D printer... and learn how to use it!

A kit containing all materials and software will be provided to build and operate a 3D Printer. The printer is a Graber i3, based on the Prusa i3, with nearly all of the parts being laser cut.

There will be four scheduled class dates, every Saturday from 10:00am until 2:00pm, January 11th through February 1st. More will be added if needed. The first class will focus on assembling the frame. The second will be installing the electronics. The third will cover installing the firmware and host software (Repetier will be provided) and calibration. The last class will cover importing models, slicing, printing, and troubleshooting.

Included with the kit:

* 1/4" MDF laser cut frame and hardware
* Sanguish 1.1 electronics board, with stepper drivers
* 0.35mm J-Head hot end (extruder nozzle)
* 5x stepper motors
* Heated Build Platform with glass cover

What's not included:

* 12 volt power supply. You'll need to provide a minimum 250 watt PC power supply, or purchase one online. I did not include this as it can be a good cost savings if you want to repurpose an old PC power supply. If you request it I can include one for an extra $35.
* A laptop. You will need to bring a laptop to load the firmware, calibrate the movement, and run your print jobs. I've used an old 800MHz netbook with good success, so yours doesn't need to be anything special.

# Agenda

Day 1 - Orientation and Frame assembly.

Day 2 - Electronics and motors.

Day 3 - Installing firmware and software, calibration.

Day 4 - Importing models, slicing, printing, and troubleshooting.

Day 5 (optional)

# Description of Printer

The RepRap - Open Source self-replicating machine. Uses FDM, fused deposition modeling.

The RepStrap - Similar to RepRap except mainly non-printable.

Vitamins - Anything not printed or specifically generated, i.e. nuts and bolts, bearings, rod, and threaded rod.

3 Axis’s of motion - X, Y, and Z.

Stepper Motors

Extruder - Delivers the plastic to the print bed. Consists of a cold and hot end.

* Cold end - Has a stepper and toothed shaft to push plastic to the hot end.
* Hot end - Has an orifice that once the heating element heats the plastic in a reservoir it is then squeezed out of and onto the print bed.

Build platform - The area that the plastic is extruded onto creating your model. Can be heated or not. Heated beds are best used with ABS to prevent the model from lifting or warping.

Types of plastic - PLA (Polylactic acid) and ABS (Acrylonitrile butadiene styrene) are the two most commonly used, but there are many more materials available and more coming to market.

* PLA - Is a biodegradable plastic derived from corn starch. It has a lower melting point, is harder and more brittle. It’s not UV resistant and will warp in warm temperatures. It’s very forgiving for the beginning 3D enthusiast.
* ABS - Is a petroleum based plastic and is very widely used. It has a higher melting point, is more durable as it’s not as brittle. The parts tend to be more resilient.

Models: STL files - any 3D model you create must be exported or converted to an STL file.

CAD/CAM Software

* OpenSCAD - Freeware, is a code based 3D modeling software.
* SketchUp - Freeware, with paid versions available, is a visual 3D modeling software that is widely used and supported.
* Blender - Freeware, used for many 3D applications including animation.
* FreeCAD - Freeware, I don’t know much about this.
* 123D Design - A free Autodesk product, very limited in capabilities compared to thier other products. Is specifically aimed at the maker community, included in a suite of 123D programs.
* AutoCAD - Autodesk product, expensive but very robust modeling software. Does not do organic forms easily.
* 3DS Max - Autodesk product, aimed more at animation and 3D rendering, it’s very complex with many options. Modeling can be difficult at first but results are very good.
* Solidworks - A mechanical engineering software that can be used to build a virtual mechanism to test functionality before exporting individual pieces for printing.

3D Scanning

* 123D Catch - Part of the Autodesk 123D suite. Takes a series of photos and stitches them together to generate a model you can print.
* Xbox Kinect - Uses stereoscopic imaging to scan an object. Other similar tools are on the market.
* Other forms of scanning include some laser and camera based options that can be DIY’d or purchased.

Slicing - Takes your STL file and generates G-code for your control software to send to your printer.

* Slic3r - Open Source, is simplified, but does offer many advanced options.
* Skeinforge - Open Source, lots of variables, some can be obscure.

Printer Control - Includes host software and the firmware that is loaded on your microcontroller. Allows you to manually control your printer as well as sending the G-code commands.

Host software

* Repetier - a package including both firmware, host software, it also has Slic3r and Skeinforge embedded.
* Pronterface - Is host software and can speak to many different firmwares.

Firmware

* Repetier
* Teacup
* Marlin
* Sprinter

Microcontrollers

G-Code

# Tools you will need

Screw Driver

Nut driver or pliers

Heat gun (optional)

Soldering Iron (If building electronics)

Solder

Solder wick (For cleanup of SMT components)

# Bill of Materials

To build a Graber i3 you will need the following hardware, my sources are in parentheses:

* Laser cut Frame - 1/4” or 6mm (MDF from Home Depot, 24x48 panel)
* 5x stepper motors - 40 N-cm (56 oz-in) recommended. (Steven Wilcoxon, TCM member)
* Sanguish Electronics w/ stepper drivers ([bryanandaimee@gmail.com](mailto:bryanandaimee@gmail.com), or any other suitable 3D printer electronics platform)
* 12V Power Supply - 30A recommended if using a heated bed (old PC or Ebay)
* 2x belts - 6mm or smaller width, approx 1 meter each. (Ebay, with pulleys)
* 5x 608zz bearings (Ebay)
* 10x LM8UU linear bearings (Ebay)
* Extruder hot end (hotends.com)
* Extruder body (I printed them , but are available on Ebay)
* Endstops - mechanical or optoelectronic. (Steven Wilcoxon)
* 6x Springs for extruder and bed (AliExpress.com, but Ebay has them too)
* 2x 11.5” Threaded rod - 10-24 or 5mm (Menards)
* 6x 8mm smooth rod. 2x 12.5”, + 2x 13.5”, 2x 15.75” (Use-Enco.com)
* Heated Build Platform -optional for PLA (Ebay)
* 8”x8” glass - HBP cover (Ace Hardware)
* Nuts and bolts - #6-32 (41x ¾”, 6x ½”, 2x 1”, 4x 1¼ ”, 8x 1¾”) , M3 (20x 10mm, 4x 25mm, 4x 20mm) (Menards and McMaster-Carr.com)
* Software and firmware (Repetier.com)

Our kit includes all of the above, excluding the power supply unit, as these can be sourced for free out of old PCs. If you wish to purchase one they are available for about $25 online.

The electronics included in the kit are capable of driving a 3A load, but are configured for 2A to avoid heat issues. The electronics use the MCP2200 USB-to-Serial chip to interpret commands to the microcontroller chip, this requires a hardware driver (included in the kit) to be loaded onto your computer. The Microcontroller chip is essentially an Arduino without the board and any firmware modifications can be done through the Arduino programming environment.

# Assembly Instructions

**Day 1 - Frame construction**

Layout materials by session

Clean your work area

<http://twelvepro.com/news/?page_id=39>

Assemble the main frame:

1. Attach brackets (H) to left and right Z- axis stepper motor mounts (G). Chamfered corner will be the front outside corner.
2. Attach the Z motor mounts to the main upright. (F)
3. Attach the left and right uprights (B) to the base. (A) Orient the base such that the two square holes near the middle are facing the front.
4. Put the Y-axis motor mount (K) into the square hole on the rear of the base, and the Y-axis idler brackets (L) in the front of the base.
5. Attach front (D) and rear (E) faces.
6. Slide the main upright into position and secure to the left and right uprights.
7. Insert 2” threaded rod with 608zz bearing into the idler brackets and secure with nuts.
8. Attach Y-axis rod stops to front and back faces. Use one bolt in the bottom hole.
9. Install Z and Y-axis motors.

Assemble Y-axis and print bed:

1. Attach the two belt brackets (P) to the Y-carriage base (M).
2. Attach three linear bearings using zip ties.
3. Insert Y-axis rods and set in base.
4. Secure Y-axis rods to rod stops using zip ties.
5. Insert thermistor leads into teflon sleeves or wrap in kapton tape.
6. Solder 20-24 Ga wire to leads.
7. Add thermistor to heated build platform, leave plenty of tail to reach the control board later.
8. Solder LED(s) and resistor to board for power indicator.
9. Solder 18-20 Ga wire to contacts, leave enough tail to reach control board later.
10. Attach the heated build platform (HBP) to the Y-carriage base using three or four M3-25 screws with springs inserted between the bed and the carriage. Make firm but not tight.

Assemble X-axis Motor Mount:

1. Place the Y-axis motor mount (Y) on a level surface.
2. Insert two the rod spacers (Q), large tab down, in the two large slots near the middle.
3. Insert X-axis motor bearing plate (X) into the X-motor mount sides (Z).
4. Insert the X-motor mount sides (Z) onto the .motor mount (Y).
5. Insert Z-axis nut into outside facing recess and cover with (AA).
6. Insert two LM8UU bearings in slot.
7. Install X-axis motor mount top (W) and secure with 1¾” bolts.

Assemble X-axis Idler:

1. Place the Y-axis idler base (T) on a level surface.
2. Insert two the rod spacers (Q), large tab down, in the two large slots near the middle.
3. Insert X-axis idler bearing plate (S) into the X-idler sides (U).
4. Insert the X-idler sides (U) onto the Idler mount (T).
5. Insert Z-axis nut into outside facing recess and cover with (V).
6. Insert two LM8UU bearings in slot.
7. Install X-axis idler top (R) and secure with 1¾” bolts.

Assemble the X-carriage:

1. Place X-carriage base (N2) on a level surface.
2. Insert three LM8UU bearings.
3. Install X-carriage top (N1) and secure with 1¼” bolts.

Assemble X and Z-axis:

1. Slide 15.75” smooth rod into X-carriage bearings.
2. Determine correct orientation.
3. Insert X-carriage assembly into X-idler assembly
4. Insert X-carriage assembly into X-motor mount assembly.
5. Slide 12.5” smooth rod into X-axis motor mount bearings and X-axis idler.
6. Insert 11.5” #10-24 threaded rod into the captured nuts on the motor mount and idler assemblies.
7. Insert assembly into the rod holes on Z-motor mounts (G).
8. Attach left and right Z-axis rod holders (I).
9. Using ½” length of tubing attach the threaded rod to Z-axis motors.
10. Mount X-axis motor.

Extruder assembly:

1. Insert two 608zz bearings into recesses on extruder body.
2. Using 20mm (¾”) threaded rod or smooth rod place 608zz bearing into extruder idler.
3. mount idler to extruder body.
4. Mount extruder motor, keep loose.
5. Install small gear
6. Insert hobbed bolt into big gear.
7. Insert hobbed bolt and big gear into body. Use washers to get correct spacing for good gear alignment. Use nylock or jam nuts to secure hobbed bolt in place.
8. Make sure the gears have good contact and tighten motor.
9. Attach extruder assembly to X-carriage.

Attach belts:

1. Make sure Y-motor is loose.
2. Attach one end of the belt to the Y-carriage bolt on (P) by folding over and zip tying in place.
3. Run Y-axis belt through idler, around Y-motor pulley and back to Y-carriage.
4. Attach end of belt as above. Make sure it’s taught.
5. Tighten belt by adjusting Y-motor before tightening motor mount bolts.
6. X-carriage is similar to above.

**Day 2 - Electronics**

Layout materials by session

Clean your work area

<http://reprap.org/wiki/Sanguish>

Assemble the board:

1. Follow instructions on wiki.

Install drivers, software and firmware:

1. Download and install MCP2200 installation utility, or just the driver, your choice.
2. Install Arduino software. The latest versions might compile a little differently and may cause errors. Try it and see, if you get an error install 1.0.x, as it’s known to work without issue.
3. Install Repetier Host. This includes Slic3r and Skeinforge.
4. If your microcontroller doesn’t already have it, or you just don’t know, download the latest firmware update. The online tool works.

Verify you can talk to the microcontroller:

1. Apply 12VDC power to the board.
2. Plug in mini-USB cable.
3. Open Repetier host software.
4. Make sure you’re communicating on the right COM port and at 115200 baud rate.
5. Click the Connect button.
6. From Settings menu check to see if EEPROM parameters are populating.
7. Go to the Manual Control tab and send a command. You could hook up a motor and try sending movement commands.

\*If your status line says “6 Commands waiting” you’re having communications issues and you’re not communicating with the ATMega IC.

Assemble the Hotend and Extruder:

Your hotend should be assembled with the exception of the heating resistor and the thermistor.

1. Using refractory cement or fireplace mortar, spread a little bit on the body of the resistor and insert into the large hole on the brass portion of the hotend.
2. Make sure refractory cement is covering both ends of the hole.
3. Smooth and let set up for a few hours.
4. Insert the thermistor and resistor leads into teflon sleeves or wrap in kapton tape.
5. Solder 18-20 Ga leads to the resistor and 20-24 ga leads to the thermistor. Use heatshrink to protect the leads from being shorted.
6. Buy or make a hobbed bolt.
   1. Mount extruder stepper with small gear to extruder body
   2. Put large gear on bolt with bolt head in gear recess
   3. Insert through 608zz bearings and add washers as needed to line up gears
   4. mark bolt where it lines up with the 3mm hole to the hotend.
   5. mount bolt in drill chuck, a drill press also works well
   6. using a small round file start the drill and file a shallow groove
   7. Mount a #6-32 tap into a drill press
   8. Using 2 608zz bearing on either end of the bolt hold the bolt firmly against the tap with the tap aligned on the groove. The bearings allow it to rotate as teeth are being cut into the groove.
7. Assemble the extruder body, use either a nylock nut or a jam nut to hold the hobbed bolt in place.
8. Insert a 20mm piece of rod through a 608zz bearing and place in idler
9. Tap the idler pivot holes for a 1-1/4” #6-32
10. Use 2x 1-3/4” or 2” #6-32 bolts with springs through the top of the idler assembly to nuts on the main extruder body.
11. Insert hotend into base of extruder body and hold in place with 2x 25mm bolts.

Wire it all up!:

1. Route and plug in all of your motors. Double check all of your motors are plugged in correctly, being one pin off will cause damage to either the stepper driver or the processor.
2. Mount endstops and route wire accordingly. Opto endstops require the addition of a flag in order to trigger the endstop. Mounting the endstops and flags can be a creative challenge, but generally you can mount an endstop holder to the 8mm rods on each axis, the exception being the Y-axis as the bed sits too low and hits the endstop holder.
3. Route and plug in thermistors and heating element leads.

# Upgrades

Cable chain - <http://www.thingiverse.com/thing:57533>

Auto Leveling Bed -

LCD Display -

# Where to order supplies

Laser cut design documents can be downloaded from <https://github.com/sgraber/Graber> or purchased on eBay. Hack Factory members can cut their own once checked out on the cutter.

Plywood/MDF was sourced from Home Depot (Laser cutter settings vary, but The TCM laser is 90 watts. The settings I use are Focus 68mm, Speed 30, Power 100, one pass.)

Also see: <http://reprap.org/wiki/Prusa_i3_Build_Manual#Single_Sheet_Frame_Style>

J-Head <http://www.reprap-usa.com/index.php?route=product/product&path=60&product_id=53> (can be purchased from hotends.com)

Oven wire for connecting hotend: <http://www.mcmaster.com/#8209k11/=qiucup>

Kapton Tape

100k Thermistor B57560G104F or B57540G104F, From [Mouser.com](http://www.mouser.com) or [Digikey.com](http://www.digikey.com)

Teflon (PTFE) sleeving for thermistor lead insulation, McMaster Part No. [5335k11](http://www.mcmaster.com/#5335k11/=dur1vg) (or equivalent)

HeatBed: <http://www.amazon.com/gp/product/B00BLCW1NA/ref=oh_details_o07_s00_i00?ie=UTF8&psc=1> $19.99

Controller: <http://reprap.org/wiki/User:Bryanandaimee> (or direct contact: bryanandaimee@gmail.com)

Belt - Ebay

Pullies - Ebay

Small tiewraps

LM8UU Bearings - Ebay

608 Bearings - Ebay

Stepper motors - Ebay or TCM member Steven Wilcoxon

Threaded Rod, 10/24x36" @$2.18, Home Depot.

Machine Screws,

* 100 pack /w nuts, 3/4" #6-32 @3.99, Menards.
* 1/2 ” #6-32, Menards
* 1” #6-32, Menards
* 1-1/4” #6-32, Mcmaster Carr
* 1-3/4” #6-32, Mcmaster Carr
* 10mm M3, Mcmaster Carr
* 20mm M3, Mcmaster Carr
* 25mm M3, McMaster Carr

1/4" vinyl tubing, 10ft @1.40, Home Depot

or 1/4" poly tubing, 25' @ 3.00, Home Depot

Hobbed Bolt - 5/16”x 2”(?) or 8mm hex bolt with nylock nut or 2 nuts as jam nuts.

PC Power Supply

How to mod the power supply

or <http://www.amazon.com/gp/product/B007KG0ZYI/ref=oh_details_o05_s02_i05?ie=UTF8&psc=1> $29.96