

Development of Arduino Controlled CNC/3D Printer

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Abstract:

The objective of this project is to re-use old computer parts that should be easily accessible to make an affordable CNC/3D printer. 3D printers are commercially available and range from some tens of thousands to lakhs of rupees. In this project, the aim is to make a 3D printer for enthusiasts who are not willing to shell out a fortune for a 3D printer. CNC stands for Computerized Numerical Control and it's a method that allows computers to automate machines. Often used with machines that move along in different axes like X-axis & Y-axis and almost like coordinates that computer will tell it exactly where to go, adding a Z-axis will allow us to control the depth. This is the concept that many 3D printers use to print. The movement in the X, Y & Z directions will be manipulated by making use of a stepper motor available in CD/DVD drives. The Arduino is the device that will be controlling everything. But by itself, it has issues controlling the stepper motors directly. To resolve all Arduino/Stepper motor issues, a "Stepper Motor Driver" is used for each motor. an old pc power supply (SMPS) is used for obtaining power supply. By hacking the 3D pen and making it automated by the use of a bread board and a transistor and connecting it to the Arduino this entire setup can be used as a 3D printer to print various 3D objects.

Key words: 3D printer, CNC machine, Arduino, GBRL controller, Xloader.

I. INTRODUCTION

3D printing can be used to prototype, create replacement parts, and is even versatile enough to print prostheses and medical implants. It will have a growing impact on our world, as more and more people gain access to these amazing machines. 3D printing, also known as additive manufacturing (AM), refers to various processes used to synthesize a three-dimensional object. In 3D printing, successive layers of material are formed under computer control to create an object.

A simple 3D printer has three axes, X, Y, Z, each controlled by a stepper motor, plus the extruder controlled by an additional stepper motor. Each dimension is made with linear actuators of various designs. You may wonder how can we make such a good product is at such a low price. It might even seem incredible to you, as overall the 3D printers on market is a bit expensive. You may once wish you could have a low-cost 3D printer, and so did us. our Arduino controlled CNC 3D printer is really cost-effective and highly extendable. Our design is based on open-source, both in terms of software and firmware. It is our full use of the creativity from all over the world that saves the time and cost during the development.

3D printer:

3D printing, also known as additive manufacturing (AM), refers to various processes used to synthesize a three-dimensional object. In 3D printing, successive layers of material are formed under computer control to create an object. These objects can be of almost any shape or geometry and are produced from a 3D model or other electronic data source. A 3D printer is a type of industrial robot.

Futurologists believe that 3D printing signals the beginning of a third industrial revolution, succeeding the production line assembly that dominated manufacturing starting in the late 19th century. Using the power of the Internet, it may eventually be possible to send a blueprint of any product to any place in the world to be replicated by a 3D printer with "elemental inks" capable of being combined into any material substance of any desired form.

A simple 3D printer has three axes, X, Y, Z, each controlled by a stepper motor, plus the extruder mounted on Z axis. Each dimension is made with linear actuators of various designs.

3D pen:

A 3D printing pen is like a handheld 3D printer. It uses the same kind of heating element and extruder that would find on a desktop 3D printer. But instead of being controlled with computer software and motors, guide the printer head by hand.

Like all 3D printing devices, a 3D printing pen works by heating a plastic filament (ABS) to its melting point and forcing it through an extruder tip. This is very similar to how a hot glue gun works. The melted plastic is very soft and can be fused onto a surface or worked into any shape that you want. Once the melted plastic leaves the tip, it begins to quickly cool down. After a few seconds, the plastic hardens and holds whatever shape you have worked it into.

ABS (Acrylonitrile Butadiene Styrene) Filament has Greater strength, flexibility, malleability and higher temperature resistance. It has a hot plastic smell due to its petroleum-based plastic. Begins to melt at 356 °F and works at 446 °F.

Stepper Motor

A stepper motor is a brushless, synchronous electric motor that converts digital pulses into mechanical shaft rotations. Each rotation of a stepper motor is divided into a set number of steps, sometimes as many as 200 steps. The stepper motor must be sent a separate pulse for each step. The stepper motor can only receive one pulse and take one step at a time and each step must be the same length. Since each pulse results in the motor rotating a precise angle — typically 1.8 degrees — you can precisely control the position of the stepper motor without any feedback mechanism.

Arduino

Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board.

Arduino Uno

The Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. You can tinker with your UNO without worrying too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again.

Stepper motor Driver

These chips keep the power that drives the motors separate from the power that is on the Arduino. The Arduino can't provide enough juice to power the stepper motors directly. This is why you have to use separate chips to sort of act as valves that control how the motor spins.

Another benefit that stepper driver chips provide, is that they provide fractional steps. This helps smooth out the motion of the stepper motor. Without fractional steps, stepper motors can have a tendency to vibrate or resonate at certain RPMs.

II. PROCEDURE

• Gathering The Parts

The intent of this project is to re-use old computer parts that should be easily accessible. Aside from the 3D printing pen, scavenge them from thrift shops, college dumpsters, government or school buildings that are getting rid of them, etc. It shouldn't be too hard to find a free old CD-ROM drive these days.

1. 3 x CD/DVD Rom drives
2. 3 x Stepper Motor drivers
3. PC Power supply
4. Arduino Uno
5. 3D Printing Pen & Filament
6. Various screws, nuts, standoffs
7. 2 x Electrical Box Covers (useful but not required. Use whatever you can scavenge)
8. Soldering Equipment

• Disassembling the Optical Drives

Taking apart Desktop optical drives is really very easy. The first thing to do, that is often overlooked, is to remove the front panel on the drive tray. To do this, force eject the drive tray by sticking a paperclip into the eject hole. Once the tray is pulled out, the front panel should snap off by pulling the bottom of it forward and then pushing it up. When that's done, you can then unscrew the bottom plate of the drive and remove the metal drive casing as well as the plastic front panel.

The metal motor tray with the stepper motor (the one with the spiral rod) and the laser housing is the specific interest. The reason is this specific part of the optical drive is because it offers a motor, track, and housing that can mechanically provide a smooth back and forth movement, which is ideal for a CNC axis. So disconnect any wires leading to the motor tray and separate it from the rest of the optical drive parts. remove the brush-less DC motor from the tray if it is attached. While not used in this project, brush-less motors make great motors for quadcopters. Also remove the laser and any other glass parts, magnets, or stray pieces from the laser sled to make sure that it doesn't have anything that can hinder movement or mounting of other screws. Extend the stepper motor wires, on most stepper motors have a ribbon cable that connects to the main board. It's fine to leave this, but just cut off the extended part of the ribbon cable (see image to the left at the bottom). Solder four new wires to the pin terminals. They should be at least 6" long. colour code the wires so that all through motor wires organized. Repeat this process for all three optical drives so that you have three bare motor trays and are ready for the next step.

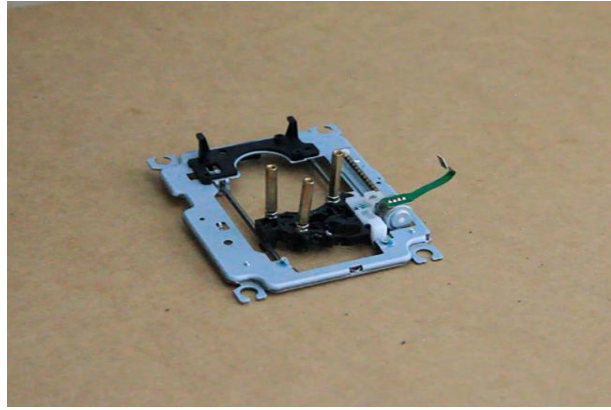


Figure 1-disassembled stepper motor from DVD drive

- **Mounting The Motor Trays**

some type of casing is required to mount the motor trays onto. use the optical drive cases themselves. Start with the Y-Axis. The Y-Axis will go back and forth, so take one of the motor trays and mount it parallel to the length of the casing close to one end. Make sure it's aligned as straight as possible and use some motherboard mounting screws to mount it.

For the X-axis mount it perpendicular to the length of another optical drive case, again making it close to one end and aligning it as straight as possible. Then mount it using motherboard mounting screws as well. As for the Z drive, mount it to the laser housing sled of the X-drive. In order to do this, find some way to extend and create a platform to mount it to. Use more motherboard mounts and an electrical plate cover. Then fasten the final motor tray to the electrical plate cover on the X-Axis. also mount another electrical plate cover to the laser housing sled on the Y-axis to provide it a flat platform as well.

- **Finishing The Stand**

Once all of the drives mounted, the final step is to attach the X & Z axis to the Y axis. mount the X axis perpendicular to the Y axis (looks like an "L" shape) and adjust them so that the Z axis is aligned over the Y axis. Scrub through each axis to make sure none of them are overshooting or running into each other. After you have the alignment set, screw everything together. Better use an L Bracket, but you may be fine just screwing one case directly into the other case.

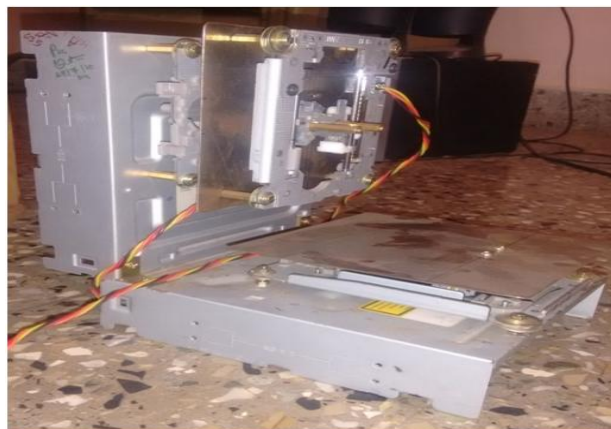


Figure 2- Assembled CNC machine

- **Connecting The Electronics**

Show All Items To get everything wired up so that it works, 5 components are required:

- 1 x Arduino
- 3 x Easy Stepper Motor Driver
- 1 x PC Power Supply

Various wires and maybe some soldering equipment is needed to connect everything together. To see how everything connects, it's best to download this Fritzing schematic (to use with the Fritzing software). It will show the ports and pins that everything runs to. Along with that, I'll try to explain everything here as well. Ok, here we go.

The Arduino Uno is the device that will be controlling everything. It is essentially the "brains" of the device. But by itself, it has issues controlling the stepper motors directly. To resolve all Arduino/Stepper motor issues, we'll need a "Stepper Motor Driver" for each motor (in this case, we'll need 3). Use the reference images above to wire up the stepper motor drivers to the motors, the Arduino, and the power supply (which will cover later in this step).

After the motors connected to the stepper motor drivers, and the stepper motor drivers connected to the Arduino, all we need now is power. Since this project focuses on scavenging most of the parts from old computers, use an old computer Power Supply Unit (PSU). PSU's have a mess of different coloured wires coming out of it and you can use the colour chart to the left to determine what the voltage is for each wire.

On all ATX power supplies, there is a green wire that senses when the PSU is plugged into a motherboard, and if this green wire is not plugged in or connected to anything, the PSU will not turn on. So to bypass this, use a small piece of wire as a jumper to connect the green wire to a black ground wire (use photo above as reference). Then to power the stepper motor drivers, run a wire from a 5v (red) wire and one from a GND (black) wire. These wires are the ones that should be split out and connected to all 3 of the stepper motor driver boards. Again, use the photo below as reference.

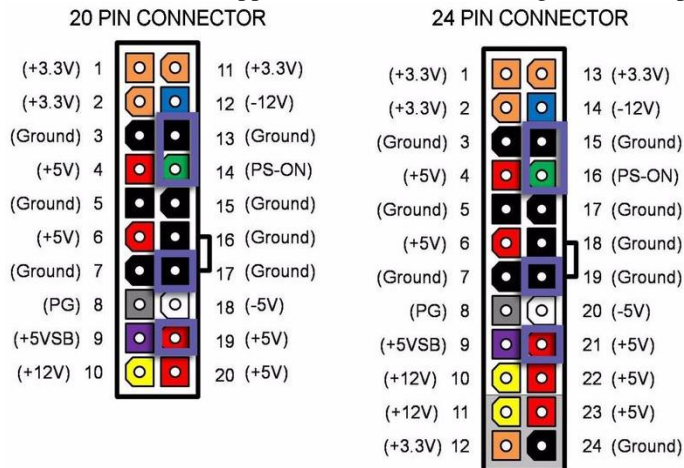


Figure 3-Pin diagram of SMPS pin connector

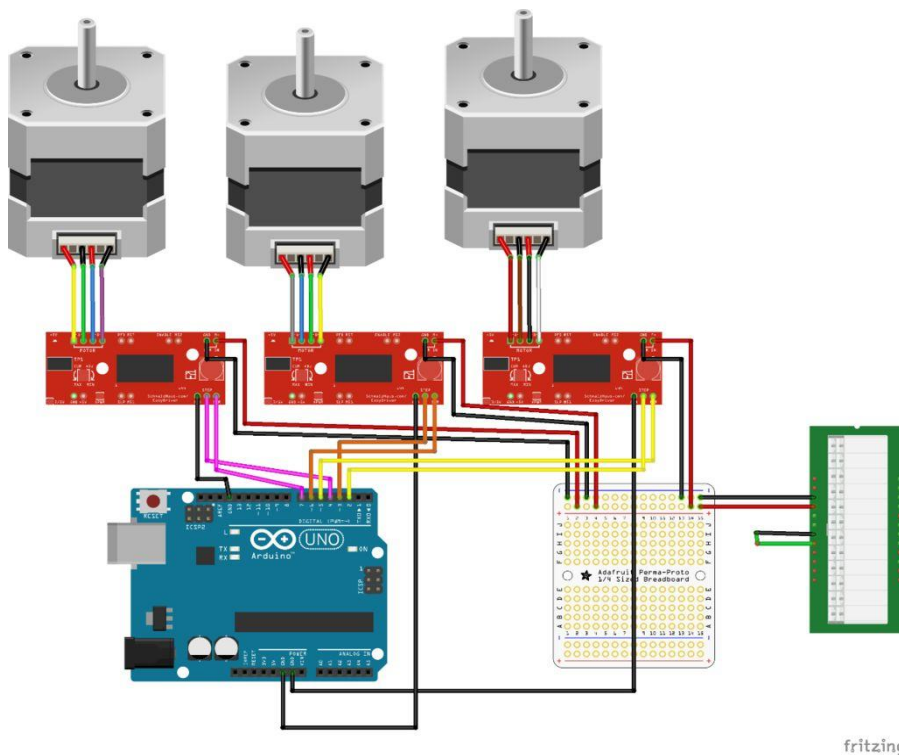


Figure 4-circuit diagram of CNC Machine

• **Hacking The 3D Pen**

The 3D Pen has 3 (or more) controllers. The primary controls are thickness, forward extrusion, and backward extrusion. It would be nice to automatically control all of them, but the one that is almost a necessity to control is the forward extrusion. This button pushes the filament out of the hot-end, an action which is required for 3D printing.

Create a circuit connected to the forward extrusion button that will allow us to use an Arduino to simulate pressing it. So start taking apart the 3D pen to get at the button. Here are the basic steps to disassembling the Pen:

- Unscrew and remove the back plate
- Disconnect the wiring to the top power jack/motor insert.
- Unscrew top section and pry off the power jack/motor insert.
- Remove the slide button by pushing it down away from the pen.

- Remove the metal side button bar.
- Unscrew the filament tube holder.
- Lift up on top end of filament tube and main board and pull out.
- Pry off hot end/nozzle.

Once that's done, see the forward extrusion button. It should have 4 leads coming out of it, one at each corner. test to see which combination of leads trigger the motor. reconnect some parts: the hot end/nozzle and the wiring to the power jack/motor insert. With those two items reconnected, power up the 3D pen. Once the heating element light is green, take a 1k Ohm resistor and touch one end to one of the leads, and the other end to another lead. Test each lead until you hear the extrusion motor start to spin. Once found a correct combination of button leads, the next step is to solder a wire to each lead. The leads are very tiny, so be careful not to use too much solder and end up getting solder all over components

Before re-assembling everything back together, touch the wires together using a 1k Ohm resistor to make sure that everything works and is soldered properly. And to make sure the connections don't come unsoldered, a good trick is to put a dab of hot glue on each connection to hold them into place. And once wires secured, start re-assembling the device. Using a drill or a knife, bore a small hole into the back panel of the device to make a place for the wires to run through.

• **Creating A Switching Circuit**

The next step is to make a circuit that control from an Arduino that simulates switching the forward extrusion button on and off. The secret to make the circuit work is called a transistor. Its purpose is to amplify and switch electronic signals, so it's switching ability will be perfect.

All transistors have 3 pins: a collector, a base, and an emitter. The order of those pins, however, will depend on what type of transistor it is, so be sure to google your "transistor number pin layout" so that know which pin is which. connect one of the button wires to the collector pin on your transistor and one to the emitter pin. At this point, it doesn't really matter which wire goes to each pin. After that, connect the Arduino to the transistor. First connect a ground wire to the collector pin on your transistor, and connect pin 12 on the Arduino to the base pin. This is what will do the switching. connect a resistor between pin 12 and the base pin, but the resistor value depends on the type of 3D printing pen.

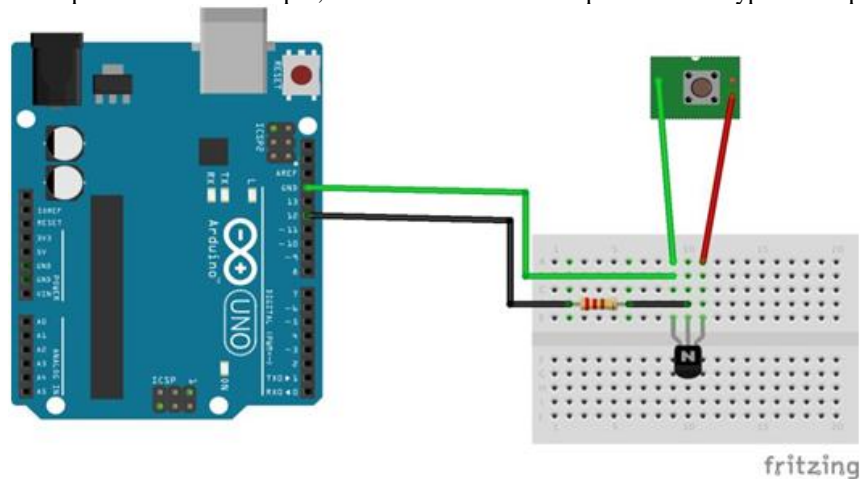


Figure 5-Switching circuit for 3D pen

How to Determine Which Resistor Will Work for Your 3D Pen

To determine what value resistor works best for the 3D pen and transistor, here are a few steps to take. Start by connecting the pen to the emitter and collector pins on the transistor. Connect an Arduino ground pin to the collector pin on the transistor. At this point, go ahead and power up 3D pen to start testing, but leave Arduino powered off completely. Once the 3D pen is powered up and ready to go, take a wire and connect the base pin of the resistor to a ground pin on the Arduino. If this causes the switch on the 3D pen to turn on, that's fine, it just means the resistance is too low. So now start adding resistors. Start with a 1K ohm resistor and connect it from the Arduino ground to the transistor base pin. If the switch still turns on, try a 10k ohm resistor. If it continues to turn on, keep adding higher and higher resistors (ex. a 100k ohm resistor) until the switch no longer turns on.

Now value of resistance is known, it will keep the switch off when it's connected to ground. The next step is to determine what value will turn it back on when current is applied. So take the resistor that is running from the base pin to the Arduino ground wire and connect it to the Arduino 5v pin and power on the Arduino. If the switch does not turn on, that means the resistance is too high, so we need to start stepping down the resistor values. we jumped down at a 47kohm resistor, but it still didn't switch on. After that, try a 22k Ohm resistor and it worked! So 22k ohm is a value that provides enough resistance to prevent ground from switching the transistor on, but will still allow a current to switch it on.

• **Mounting the 3D Pen**

With the switching circuit wired up and functional, start putting everything together. mount the 3D pen to the Z-axis of the CNC machine. simply use clothes pins and hot glue to secure it into place. make sure it doesn't wobble around.



Figure 6-CNC machine with 3Dpen mounted

• The Software

At this point, all the hardware should be completed. The only thing that's left to do now is to install the software that will make it run. The CNC machine runs off of a programming language called G-Code. It essentially tells the X, Y, and Z axis which specific coordinates it needs to go to. By itself, Arduino has a difficult time interpreting G-Code, so install a G-Code interpreter program called Grbl. Here are the steps needed to take to install Grbl on Arduino (Uno).

- Download the Grbl Hex file for specific version of Arduino (we used version 0.8c for my Atmega328 Arduino Uno)
- Download the XLoader software.
- Connect Arduino to your PC.
- Using the Xloader software, select the Grbl Hex file you downloaded, select Arduino from the dropdown menu, and select the COM port that the Arduino is connected to.
- Click "Upload" to upload the Grbl software to Arduino.

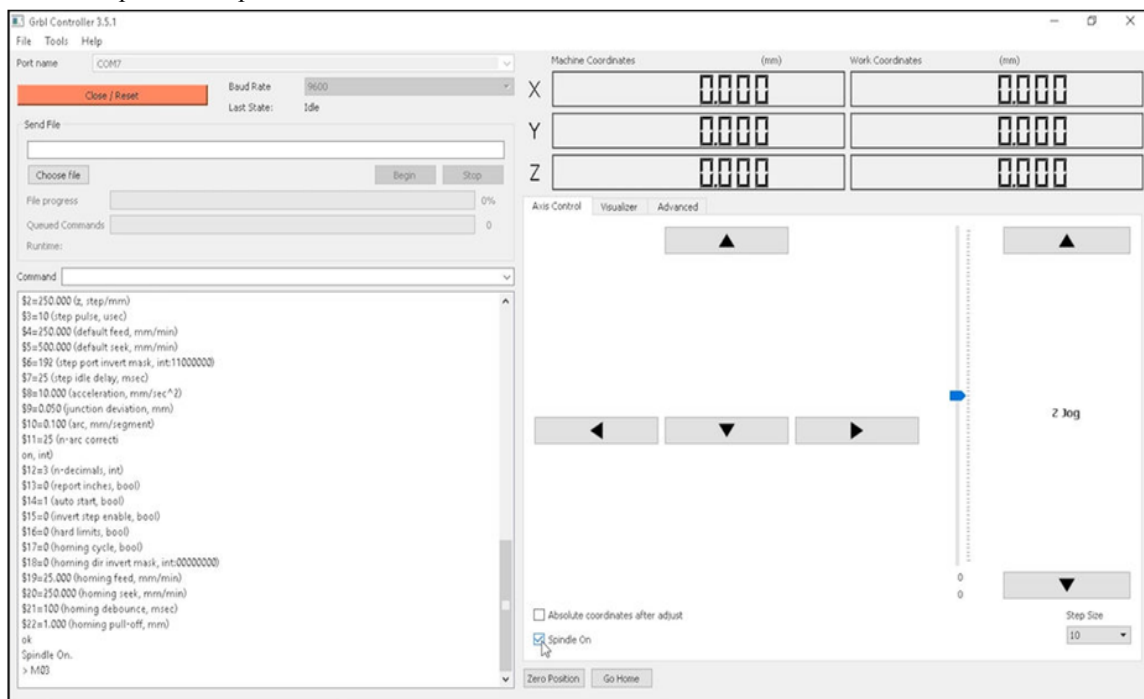


Figure 7-screen shot of the GBRL controller

Now that the Arduino is prepped and ready to go, install some software that controls the CNC machine. A great easy to use program is called Grbl Controller. After downloading and installing it, open it up, select Arduino port and click "Open" to connect.

Make sure power supply and 3D pen are power up and that the Arduino is plugged into the computer. Now use the arrows on the lower right to jog through the motors. Make sure that the dropdown box in the lower right corner is set to 1 instead of 10. If any of the platforms are running backwards, go to Tools > Options and then invert the axis for the backwards motor. To control the 3D pen, toggle the "spindle on" checkbox. Whenever we do that, the 3D Pen motor

should turn on and off. And look at the command screen on the left of the software, it shows that “M3” is the code that turns the switch on, and “M5” is the code that turns it off. remember this for the next step.

- **Creating A Test Image**

Use MakerCam.com to create a test image for the machine. It is a free 3D printing software such as Slic3r, but the code will have to be heavily edited in order to make it work for the machine. In Maker cam, a test image can be created by following these steps:

- Insert a new basic image by going to “Insert” and selecting a shape.
- Using the Arrow tool (from top left toolbar), select your entire image.
- Move it to the bottom left corner of the grid.
- pan around the grid by selecting the Hand tool from the toolbar. Use it to drag the image back to the centre of the screen.
- From the upper right corner of the page, change the measurements to cm.
- Using the scale option from “Edit > Scaled Selected”, scale the object down and move it so that it fits within the single square that is in the corner of the grid (use the picture to the left as reference).
- With the image still selected, go to “Cam > Follow Path Operations” and use these values as a test basis:
 - The “target depth” will be the height of your object. I used -1.
 - “Safety Height” and “Stock Surface” are set to 0.
 - “Step Down” will be the height each layer of filament will be. For starters, I set mine to 0.2, but if you want thinner layering, you can make it lower.
 - “Feed Rate” is the speed at which the print goes. Setting it to 50 worked will with my 3D pen at its lowest extrusion speed.
 - The “Plunge Rate” is the speed at which the nozzle moves up and down. This doesn’t really matter, but I set mine to 50.
- Then go to “Cam > Calculate Selected” to calculate the path.
- Lastly, go to “Cam > Export Gcode” to save the G-Code of image

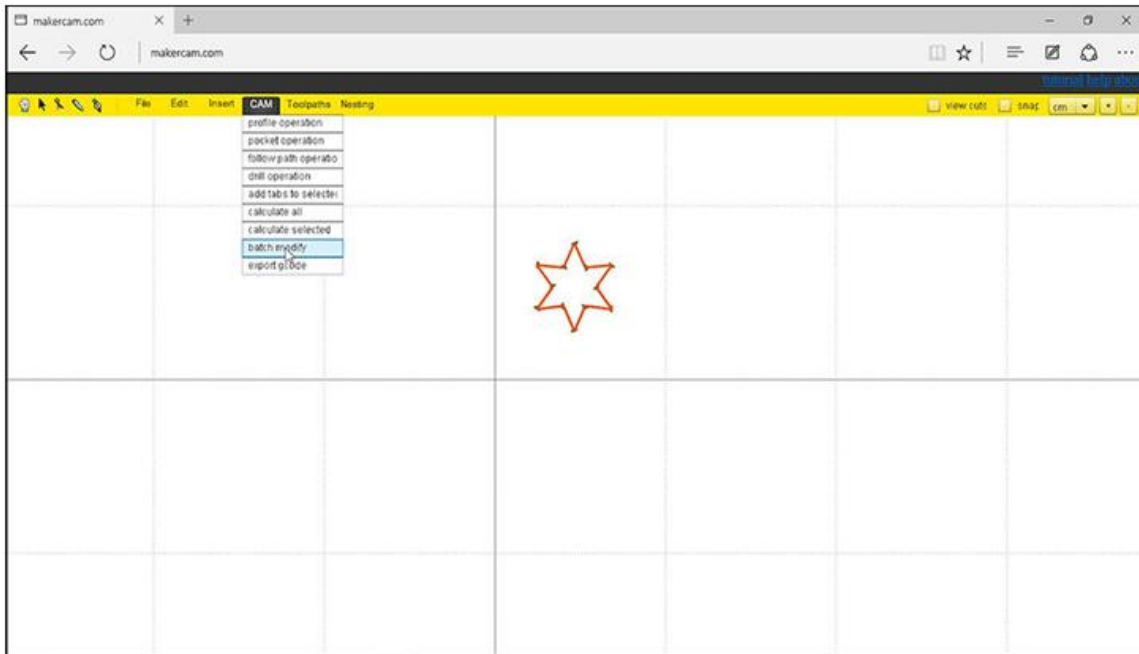


Figure 8-screenshot of makercam software

Before this Gcode runs through GRBL Controller make a few edits to ensure that it works with 3D printer. So open up the file that had been saved from makercam.com in a text editor such as Notepad. Check for a bunch of different lines of letters and numbers. These are the GCode coordinates that are sent to the machine that tells it what to do. Add “M3” and “M5” commands to tell the filament extruder when to extrude and when to stop extruding. Here’s what is needed to do:

- Below “G17” is the first “M3” command. Since this starts the extruder way too early (at the beginning of the script), move it until after the nozzle has moved to its starting position, which is immediate after the first “F50” (feedrate 50) command on the next line.
- Throughout the rest of the code, every time an “F50” command appears, place an “M3” command immediately after it on the next line.
- Next, look for the first Z0 command. Z0, moves the nozzle to 0mm, which is not needed. That would push it down to the base platform and ruin the print. Instead of moving the Z axis at this point, we want to just stop the extrusion motor. So every time Z0 command is been replaced it with an M5 command.

- At the very end of the script, after the final M5 command, we want to move the Z axis so that it is above our final print. Since after setting up the print height to be -1, set the final Z axis height to be -2 (G0 Z-2)
- After setting the final Z height, a helpful thing to do would be to move the X and Y axis back to their original starting positions. So right below the Z axis movement, put “G0 X0 Y0” to move them.

Save your code and then you're ready to print

M3 & M5 Example

```
G1 X5.058375634517766 Y6.964467005076143
M3
G0 X5.059390862944163 Y6.965228426395939
G1 Z-1 F50
M3
G1 Y5.84010152284264 Y5.102893101015228 F5 M20
```

Ending Code Example

```
G1 X5.058375634517766 Y6.964
M5
G0 Z-2
G0 X0 Y0
```

Figure 9-example of G-codes for an image

• Making Your First Print

This last part is easy. Take the 3D Pen on the Z-axis and move it all the way down so that it barely touches the Y-axis platform. Make sure everything is turned on and heated up, and make sure the Arduino is connected to the computer. Open up the GRBL Controller

Software and open up the link to your Arduino. Click “Choose File” and choose the file that is just edited. check the image of that file show up on the right. Then just click “Begin”. If everything works well, the axis should start moving, and the 3D pen should begin to print

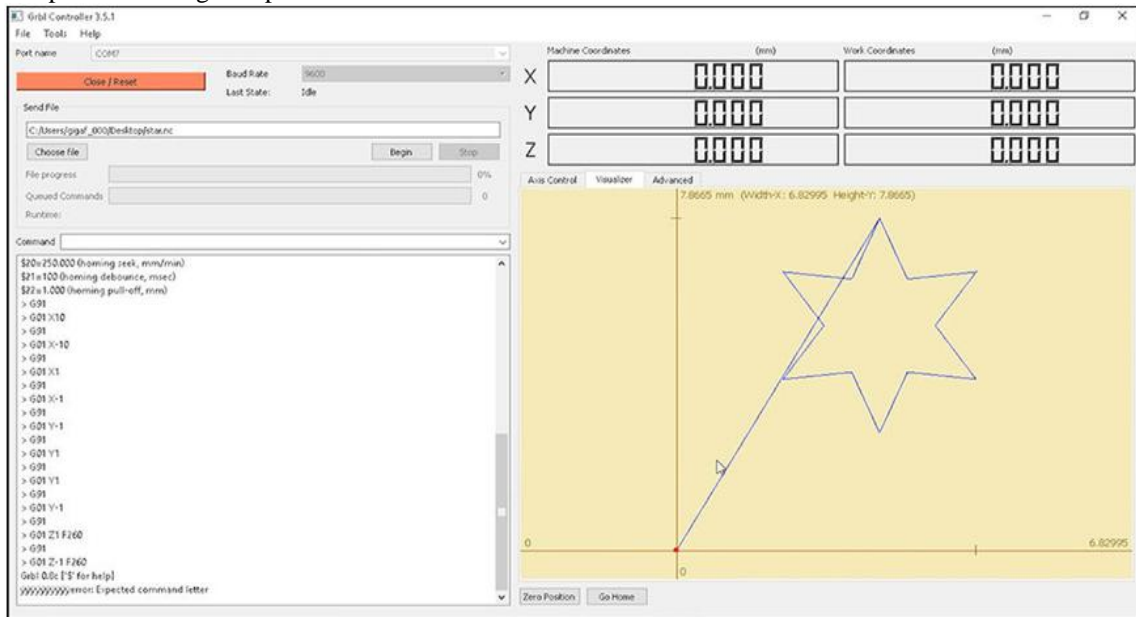


Figure 10-screen shot of GBRL software while performing test image



Figure11-3D printed star

COST

1. 3 x Stepper Motor drivers	(750/-)
2. PC Power supply (Scavenged/Free)	
3. Arduino Uno	(650/-)
4. 3D Printing Pen & Filament	(3500/-)
5. Various screws, nuts, standoffs, wires	(300/-)
Total	5200/-

III. CONCLUSION

The 3-D printer can produce multiple copies just like a photocopy machine. All sorts of goods, from jewellery to mobile phones, auto and aircraft parts, medical implants, and batteries are being “printed out”. As the new 3-D technology becomes more widespread, on site, just in time customized manufacturing of products will also reduce logistics costs with the possibility of huge energy savings.

There are so many 3D printers on the market that it is really hard for users to make a decision, So the main problem is cost. That is why we decided to develop a new printer integrated with stable structure, friendly interface, easy operation and affordable price. We believe that 3D printers should be common items just like household laser printers, rather than high-tech products.

This project describes the design of a very low budget 3D Printer that is mainly built out of recycled electronic components. The result is a small format printer for less than ₹5500, this 3D Printer is built with about an 70% of recycled components, which gives it a great potential and helps to reduce the cost significantly.

IV. ADVANTAGES OF 3D PRINTING

1. Time-to-Market:

3D printing allows ideas to develop faster than ever. Being able to 3D print a concept the same day it was designed shrinks a development process from what might have been months to a matter of days, helping companies stay one step ahead of the competition.

2. Save Money:

Prototyping injection mold tools and production runs are expensive investments. The 3D printing process allows the creation of parts and/or tools through additive manufacturing at rates much lower than traditional machining.

3. Mitigate Risk:

Being able to verify a design before investing in an expensive molding tool is worth its weight in 3D printed plastic, and then some. Printing a production-ready prototype builds confidence before making these large investments. It is far cheaper to 3D print a test prototype then to redesign or alter an existing mold.

4. Clear Communication:

Describing the product, you are going to deliver is often misinterpreted since it leaves construction up to the imagination. A conceptual picture of the product is better than the description since it is worth 1,000 words, but getting to hold the tangible product-to-be, in hand, clears all lines of communication. There is no ambiguity when holding the exact, or at least a very close, representation of the product.

5. Feedback:

With a prototype you can test the market by unveiling it at a trade-show, showing it to potential buyers or investors, or raising capital by pre-selling on Indiegogo or Kickstarter. Getting buyers response to the product before it actually goes into production is a valuable way to verify the product has market potential.

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