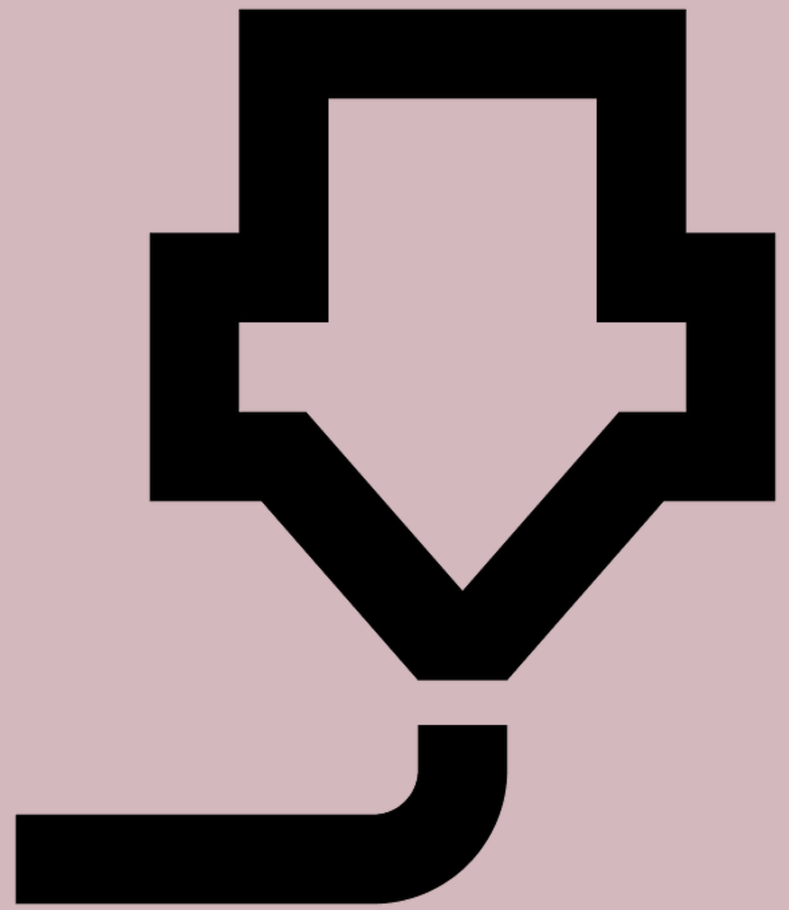
3D Printing for the Radio Amateur



Steve Horejsi KEØVDC. 11 October 2025

3D Printing for the Radio Amateur

Contents

- How does this relate to Ham Radio?
- What kinds of things can I make?
- Exactly what is 3D Printing?
- Some example projects
- What materials can I print with?
- Exotica
- Question and Answer

How does this relate to Ham Radio?

It’s all about fabrication…

- Amateurs have traditionally been builders
  - ‘Homebrew’ rigs, Antennas, Station layouts, Mobile installations, Project packaging…
- These projects have always required fabrication skills
  - General metalworking, woodworking, finishing, drilling, grinding, etc.
  - Sometimes this became an obstacle
- Not all of us are ‘Workshop Superheros’… (self definitely included)
- 3D Printing allows the easy creation of custom parts
  - No cape or tights required…

What Can I Make?

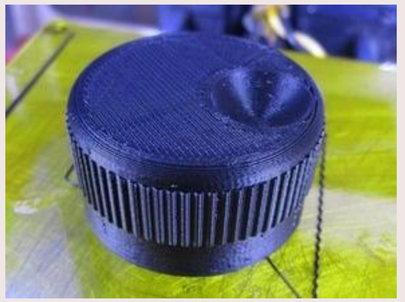
Some quick examples…

- Fabrication: Enclosures
  - Easily customized to any need
  - Very professional-looking results
  - You'll likely never buy another project box

What Can I Make?

Some quick examples…

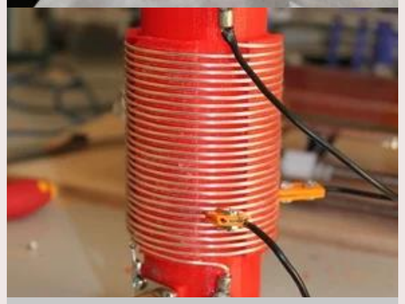
- Parts: Knobs, Buttons, etc.
  - New or Replacement
  - Thousands of available designs
  - Customize color, size, material

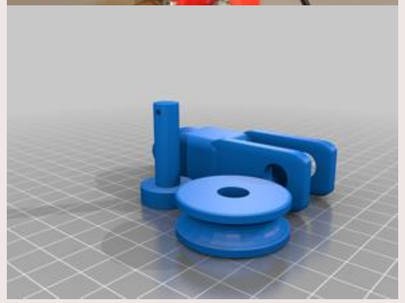


What Can I Make?

Some quick examples…

- Antenna Parts
  - Element Clips
  - Coil Forms
  - Center and End Insulators
  - Choke / Balun / Trap Enclosures

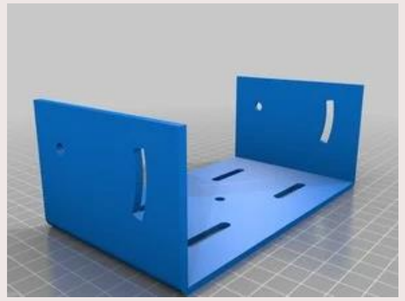




What Can I Make?

Some quick examples…

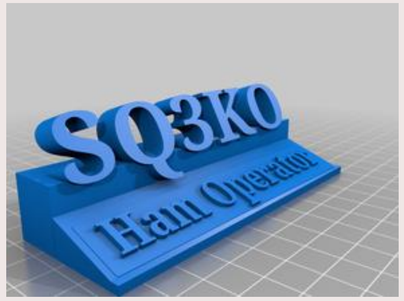
- Brackets
  - Couplings
  - Mounting Brackets
  - Protective Rails
  - ‘Go Box’ Stuff

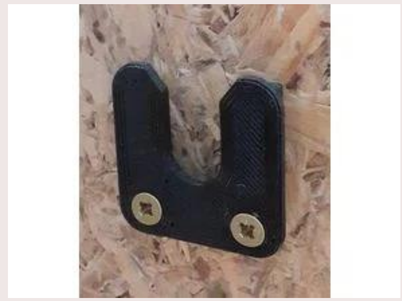


What Can I Make?

Some quick examples…

- Just Stuff
  - Station Accessories
  - Portable Helpers
  - Power Distribution





What Can I Make?

Some quick examples…

- Where Do I Get the Design Files?
  - Public Repositories
    - Thingiverse, Printables, MakerWorld, MyMiniFactory, Cults3D, Yeggi, STLFinder
  - Design Your Own
    - Fusion 360, SolidWorks, FreeCAD, TinkerCAD, SelfCAD, OpenSCAD, Blender
    - It’s not *that* hard…
      - Advice: Take the time to learn the tool before tackling your first design.

Exactly what is 3D Printing?

High Level View

- 3D Printing is part of the ADM (Additive Deposition Manufacturing) process family
  - “Deposition” means material is selectively added to build the part from scratch
  - This is in contrast to typical machining processes where material is removed
    - Examples: Milling, turning, CNC machining, etc.
- Within ADM is a subcategory called FDM, or “Fusion Deposition Manufacturing”
  - Heat is used to “fuse” material to the build object
  - 3D printing is an FDM process

Exactly what is 3D Printing?

High Level View

- DLP (Digital Light Processing) is also a popular method, involving a a photoreactive resin which ‘sets’ upon exposure to (UV) light.
  - Design is projected onto a vat of material and drawn out of the tank
    - Projection may be via LCD shutter or UV laser
  - Very high detail levels, but not typically for structural parts
    - Parts tend to be brittle
- This presentation deals with FDM processes, specifically printing with plastics.

Some 3D Printing Terminology

Definition of Terms - Printer Components

- Filament
  - The plastic feedstock that is melted and formed to create the target object
  - Looks like a reel of spaghetti.. In fact, one popular supplier is named ProtoPasta
  - Various materials melt between ~190°C and over 300°C
  - Most common filament diameter for hobbyist printers is 1.75mm
  - Standard reel size is 1KG which typically contains ~335 meters.
  - (Yes, almost all 3D printing stuff is done in metric…)

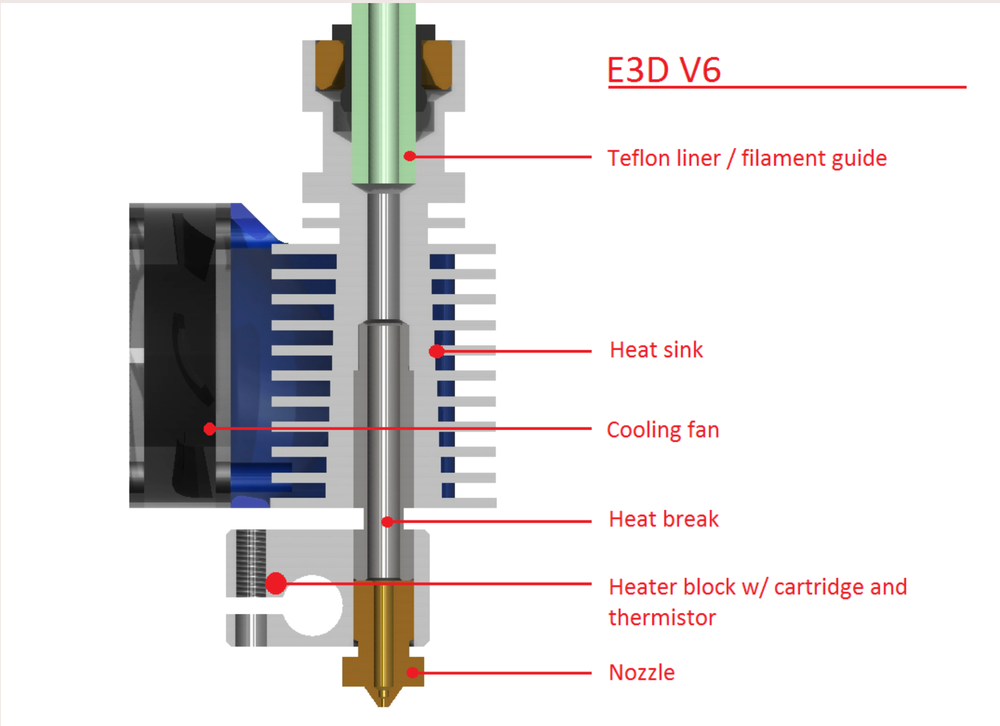
Some 3D Printing Terminology

Definition of Terms - Printer Components

- Hot End
  - This is the ‘Business End’ of the printer, where the filament is melted and extruded
  - Consists of a Heater, Nozzle, Heat Break, Heat Sink, and Fan
    - The goal is to keep the filament below its melting point until it reaches the nozzle
    - Involves a ‘Heat Break’ to prevent heat creep backwards up the feed tube
      - Often Titanium or possibly Stainless Steel

Some 3D Printing Terminology

Printer "Hot End"



Some 3D Printing Terminology

Definition of Terms - Printer Components

- Extruder
  - The feed mechanism which grips and pushes the filament through the Hot End
  - Can be pinch rollers or (most commonly) gears
  - If the Extruder is mechanically part of the Hot End, the arrangement is referred to as ‘Direct Extrusion’
  - If the Extruder is separate, the filament is pushed through a connecting Teflon tube, referred to as a ‘Bowden Tube’

Some 3D Printing Terminology

Definition of Terms - Printer Components

- Print Bed
  - The bed upon which the output object is printed. Motor driven for position. Many beds are magnetic
    - Bed moving in ‘Y’ direction, with hot end moving in ‘X’ and ‘Z’ is the classical design
      - Euphemistically referred to as a ‘Bed Slinger’
    - Bed moving in ‘Z’ only, with hot end moving in ‘X’ and ‘Y’ is a recent change.
      - Referred to as ‘Core XY’
  - Bed is usually heated to promote better part adhesion and reduce part warping
    - 50°C - 120°C is a common range

Some 3D Printing Terminology

Definition of Terms - Printer Components

- Print Surface
  - The actual surface upon which the print lies.
    - May be spring steel to adhere to magnetic bed
      - Coated with specialized surface, commonly polyetheramide (PEI)
        - Aids both part adhesion and subsequent release
    - Borosilicate glass (‘Pyrex’) is also relatively common
      - Clips are used to attach to print bed, adhesives are used for part adhesion / release

Some 3D Printing Terminology

Definition of Terms - Printer Components

- Enclosure
  - This is optional; some printers are open frame, without an enclosed print space
  - Enclosures may be passively or actively heated.
    - Some filaments require a heated space to minimize warping during cooling
  - Enclosures may include exhaust air filtration
    - Some filaments give off noxious / toxic gases

Some 3D Printing Terminology

Definition of Terms - Software

- CAD Package
  - The actual model creation software. Only needed for custom designs or customization
    - Various packages us different techniques to describe the desired object
    - Most are graphical in nature, but some are parametric / programmatic
    - Resulting 3D object is exported as a ‘Mesh’ of interconnected triangles
      - ‘STL’ (Stereo Lithography) is a common output format
        - Files have a ‘.stl’ extension

Some 3D Printing Terminology

Definition of Terms - Software

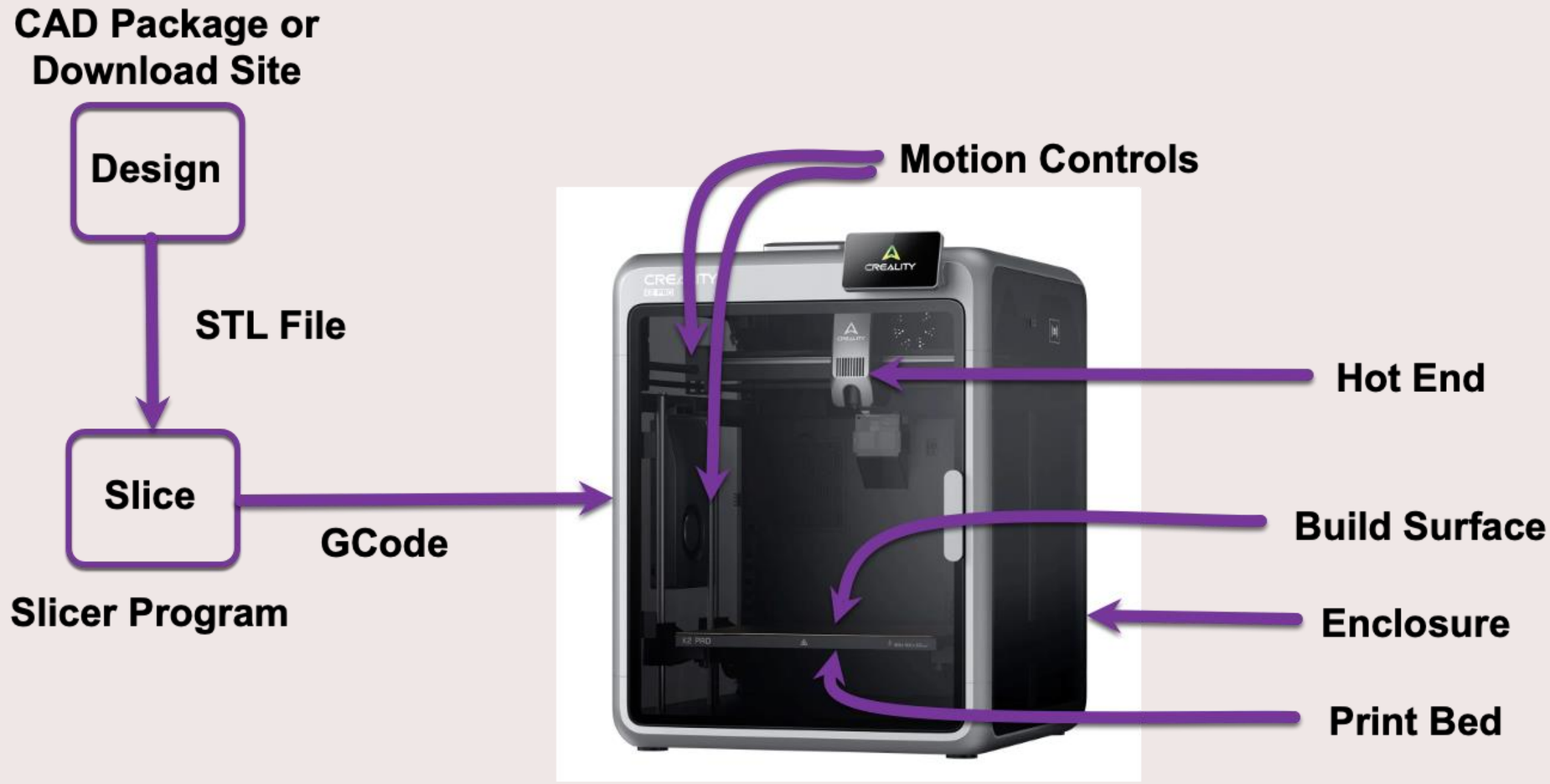
- Slicer
  - Since 3D printed objects are produced in many thin layers, the Slicer does this task
    - A 3D mesh is reduced to a series of thin ‘slices’ which comprise the printed part
  - The Slicer also takes into consideration desired mechanics of the print, such as:
    - Line width
    - Layer thickness
    - ‘Wall’ versus ’Fill’ parameters

Some 3D Printing Terminology

Definition of Terms - Software

- Slicer (Continued)
  - Slicer also manages material settings:
    - Temperatures (Nozzle, Bed, Chamber)
    - Print speeds and extrusion feed rates
  - Output of slicer is a series of elemental movement commands (position, extrusion)
    - Format is referred to as ‘GCode’
    - GCode drives the printer firmware to produce the part.

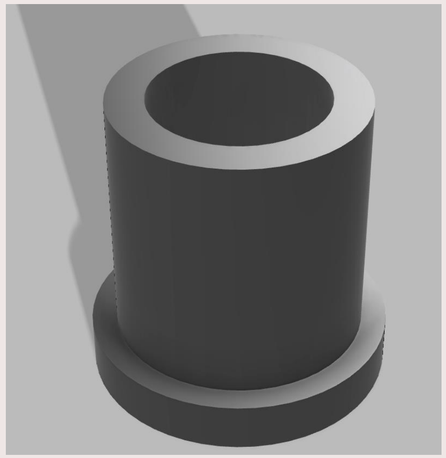
3D Printing Process

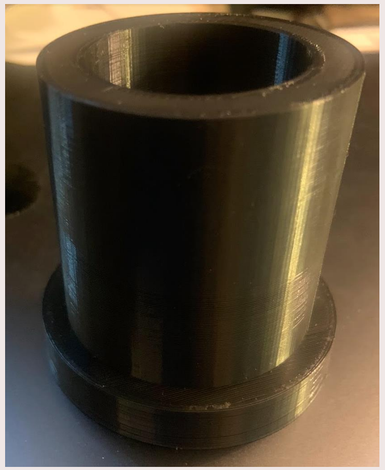


Example Projects

Portable Mast

- Problem: I bought an extensible mast and tripod for portable use but…
  - Outside diameter of the lower mast section is about 35mm
  - Inside diameter of tripod rings is more like 50mm; not a precise fit…

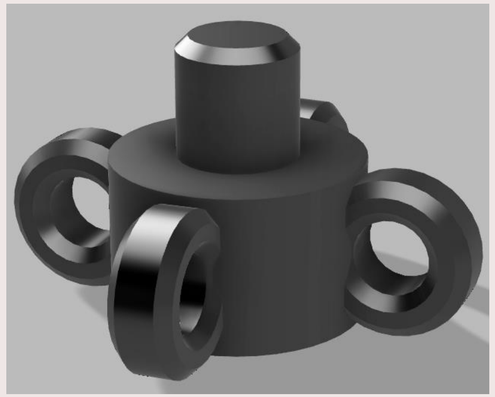


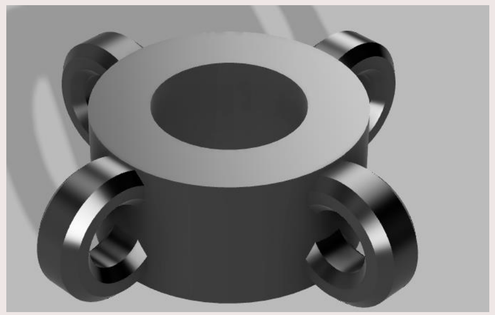


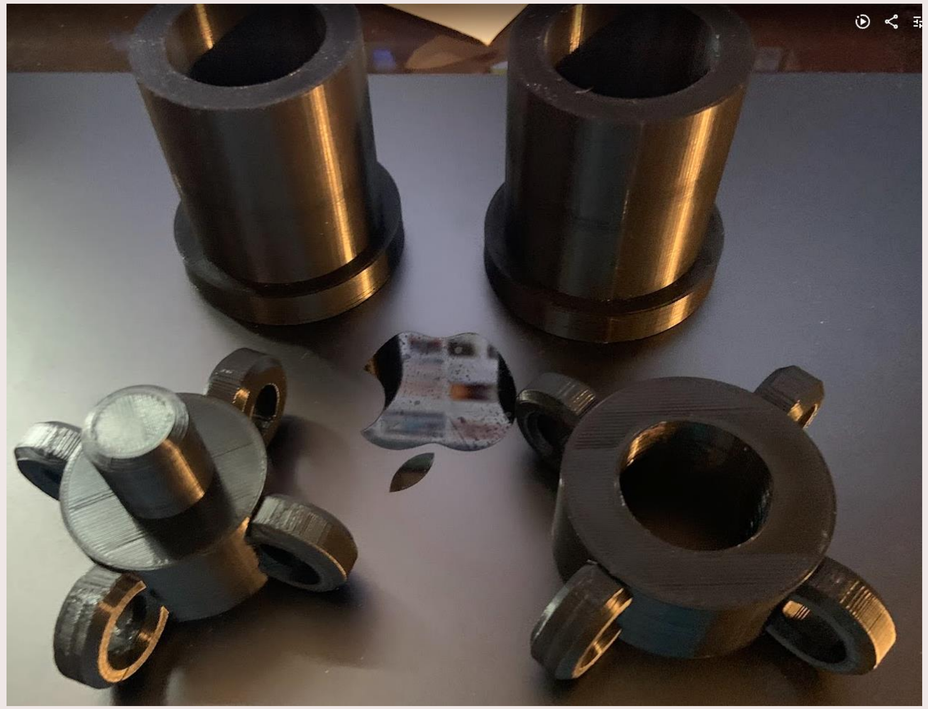
Example Projects

Portable Mast

- Problem: Now the mast was secure, but it had no guy rope attachment points…



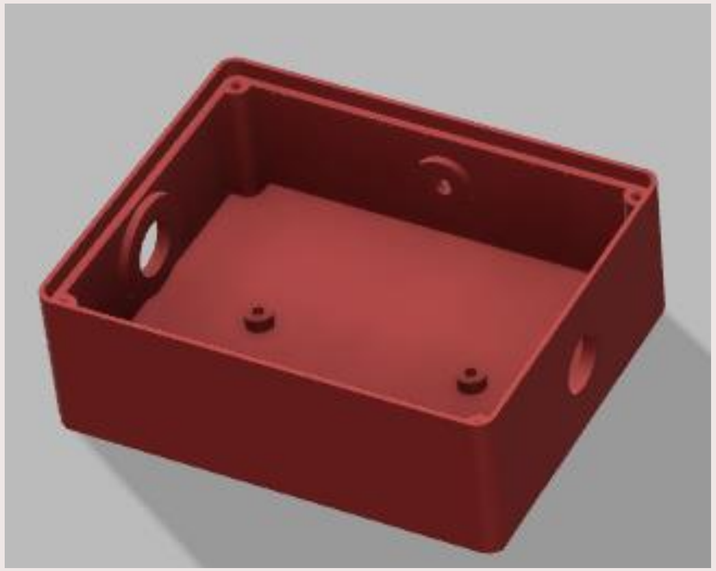




Example Projects

EMI Line FIlter

- Problem: My Inverter / Generator creates some line noise; I need a filter…
  - This is for Field Day use, so it had to be weatherproof…



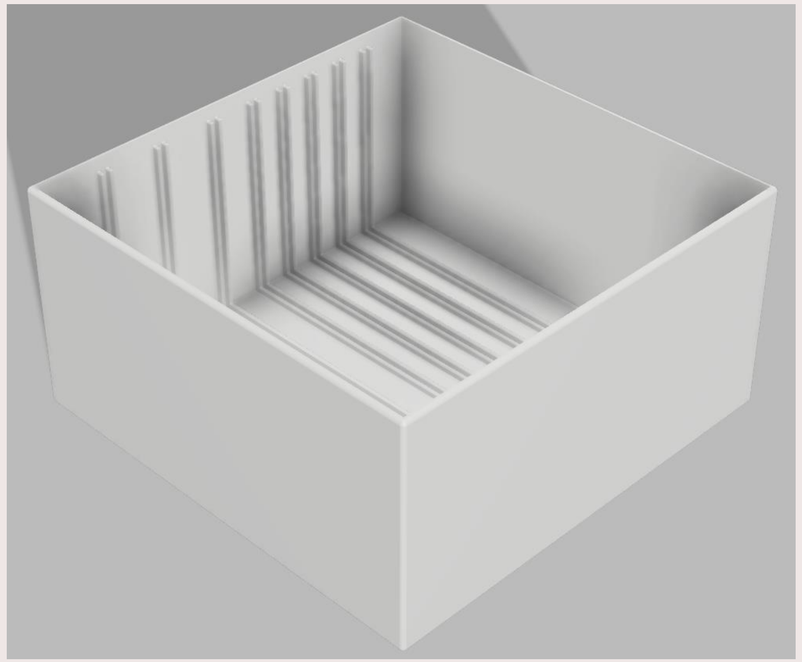
Example Projects

Mini Shelf Unit

- Problem: I had lots of little boxes of parts and components stacked around my work area
  - They were all labeled, but were inconvenient to access as well as easy to tip over.
  - I also had a small stack of 6” x 12” x 1/8” Birch plywood sheets sitting around
  - Gee… those would make neat little shelves…

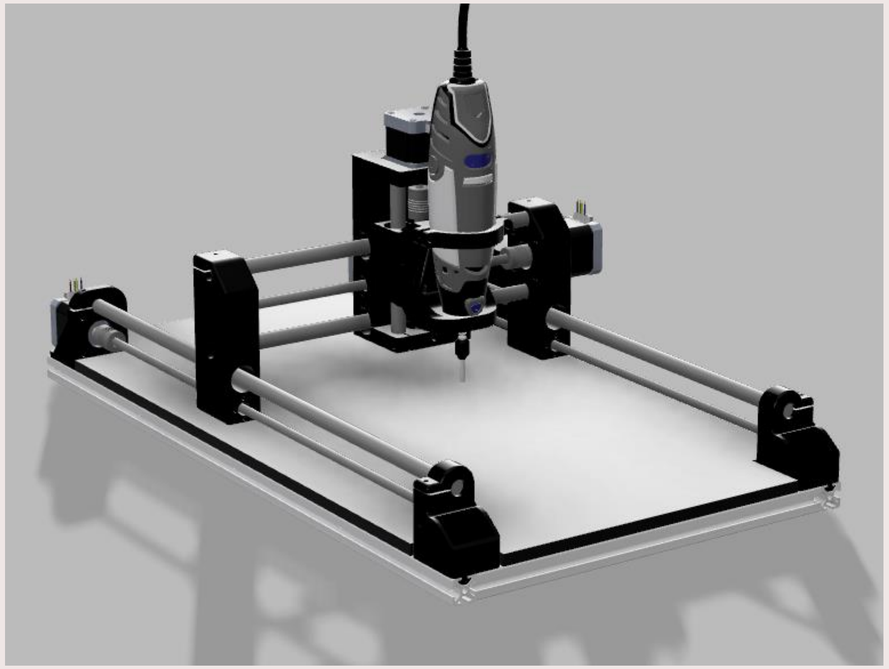
Example Projects

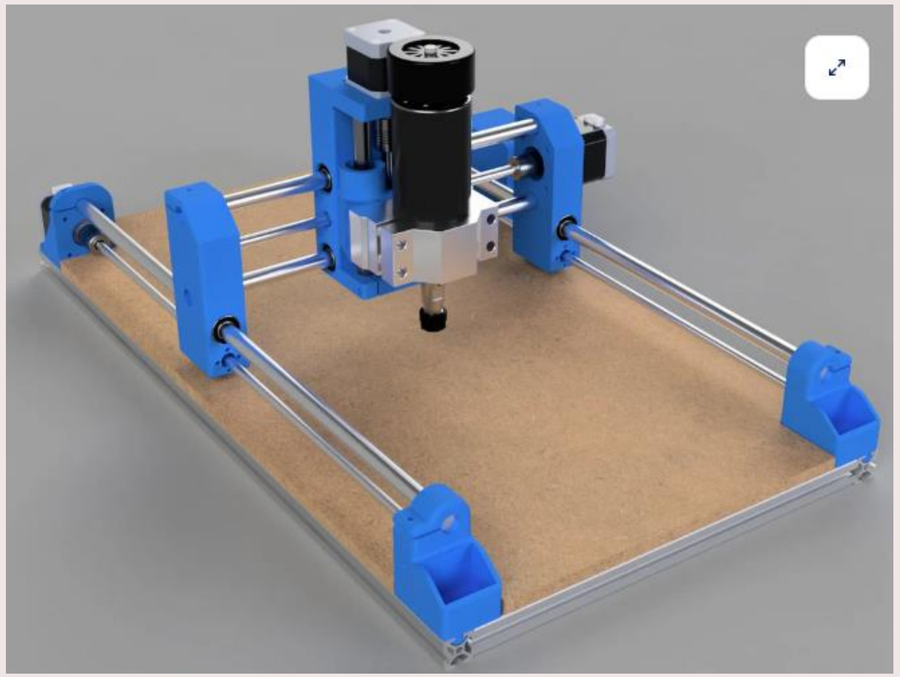
Mini Shelf Unit



Example Projects

Future Project…





Materials

What can I print with?

- Nearly any thermoplastic material can be used for 3D printing
  - But just because you can doesn’t mean you should; some are far superior to others
- I’m going to talk about eight materials because they are the most common
  - There are many dozens more materials for specialized applications

Printing Materials

From Easy to Challenging

Material	Ease of Printing	Print Experience
PLA	Very Easy	Excellent
PETG	Easy	Good
ABS	Moderate	Fair
ASA	Moderate	Fair / Challenging
TPU	Moderate	Fair / Challenging
Nylon	Hard	Challenging
Polypropylene	Hard	Challenging
Polycarbonate	Hard	Difficult

Printing Materials

PLA

- PLA (Polylactic Acid) is by far the most used 3D printing material
- It is inexpensive, easy to print, and quite durable
- PLA is a bioplastic; it’s made from either Corn Starch or Sugar Cane
- Advantages:
  - High tensile strength, high rigidity
- Disadvantages:
  - Poor environmental resistance (Moisture, UV), can be brittle, poor heat resistance

Printing Materials

PET Family (PET, PETG, PCTG)

- PET (Polyethylene Terephthalate) is a very commonly used plastic (Recycle Code ‘1’)
  - Used for water, soda, and juice bottles as well as other food containers
- PETG (Polyethylene Terephthalate - Glycol) is the most common variant for 3D printing
  - Less brittle, easier to print, lower melting point
- Advantages:
  - Flexible (less brittle than PLA), moderate resistance to moisture and UV, more heat resistant
- Disadvantages:
  - A little harder to print, slightly more expensive, less rigid

Printing Materials

ABS

- ABS (Acrylonitrile Butadiene Styrene) is a structurally robust plastic
  - Commonly used in automotive parts, consumer electronics, piping and more
- Good temperature resistance, high impact resistance, inexpensive material
- A bit more challenging to print
  - Generally requires a heated chamber and ventilation or filtration
- Advantages:
  - High strength, Low cost, high resistance to chemicals, moisture and heat
- Disadvantages:
  - Higher printing demands, lower UV resistance, outgassing during printing

Printing Materials

ASA

- ASA (Acrylonitrile Styrene Acrylate) is an engineered plastic developed to address the limitations of ABS
  - Can be a direct substitute for ABS in many applications
- Advantages:
  - Extreme weather resistance (UV and Moisture), Excellent mechanical strength, High thermal resistance, Good chemical resistance, Easier to print than ABS
- Disadvantages:
  - Generally requires an enclosed, heated print chamber; Outgasses Styrene gas

Printing Materials

TPU

- TPU (Thermoplastic Urethane) is a member of a family of flexible filaments
  - Printed objects are flexible, elastic, and abrasion resistant
  - TPU remains flexible at low temperatures
  - Used in phone cases, sports equipment, footwear, hoses/tubing, medical devices
- Advantages:
  - Chemical resistance, tensile strength, natively transparent, biocompatible
- Disadvantages:
  - Some print challenges (stringing, hydroscopic)

Printing Materials

Nylon

- Nylon (Polyamide) is a widely used structural material for brackets and moving parts
  - Resistant to abrasion, temperature, chemicals, and impact.
  - Self lubricating: Ideal for moving parts like gears, bearings, hinges, and sliding surfaces
- Advantages:
  - Tough, durable, reasonably priced
- Disadvantages
  - Hydroscopic, somewhat UV sensitive, challenging to 3D print (Adhesion, Warping)

Printing Materials

Polypropylene

- PP (Polypropylene) is used for food containers, plastic furniture, medical items, automotive bumpers, electrical components, and household storage bins (Recycling code “5”)
  - It is resistant to moisture, chemicals, mold, bacteria, and steam sterilization
  - Like Nylon, it is self-lubricating and often used for gears and ‘live’ hinges (fatigue resistant)
  - Excellent electrical characteristics (High dielectric constant, very high breakdown violtage)
- Advantages:
  - Highly moisture resistant, food safe, abrasion resistant, semi-transparent, lightweight, flexible
- Disadvantages:
  - Quite challenging to print (Heated bed, problems with bed adhesion, warping, slow print speeds)

Printing Materials

Polycarbonate

- PC (Polycarbonate) is known for toughness, durability, transparency
  - Used as a light weight glass replacement (Lexan), safety goggles, recreational vehicle windshields, eyeglass lenses
- Advantages:
  - High temperature resistance, good moisture, chemical and impact resistance
- Disadvantages:
  - Difficult to print (High bed and chamber temperature), Poor bed adhesion (adhesive generally required), high tendency to warp

Printing Materials

Filament Enhancers

- Raw filament materials can be augmented by adding reinforcing fillers
- Carbon Fiber
  - Light weight, adds stiffness and tensile strength. Potential electrical concerns
- Glass Fiber
  - Heavier that CF, similar strengthening properties. Enhances electrical parameters
- Kevlar (Aramid)
  - Heavier than CF, lighter than GF. Does not alter electrical properties. Hard to source

Printing Materials

Exotics (You Probably Don’t Want to Go Here…)

- PEEK, PEKK, PPSU, PEI ($$$$)
  - Aerospace / Industrial materials offering very high durability, high temperature resistance
  - Printing requirements well beyond most hobbyist grade printers (450°C Nozzle, 250°C chamber)
- POM (Polyoxymethylene (“Delrin”)) 
  - Like Nylon, but water resistant. Widely used for gears, bearings, other moving parts
  - Printing process can release formaldehyde gas…. Print bed adhesion issues
- PVC (Polyvinyl Chloride) 
  - High temperature print environment (~400°C), releases chlorine gas during printing

Printing Materials

Conclusions

- There is no single perfect material
  - The choice depends heavily on the application and material availability
  - Experience over time will help you pick what’s best for your situation.

3D Printing

The Future

- Materials Science is pushing the boundaries of what we can print
  - Processes for Ceramic, Glass, and even Metal are in the works
  - Newer polymers are enabling parts with characteristics well beyond traditional plastics
  - AI is invading the printer firmware realm, allowing dynamic autotuning
  - This is gonna be fun….

One Last Thing…

Please Take One

Questions?