TEVO Tarantula 3D printer

Mech-572-01 TF 8:00 -10:05 AM
CAD, CAM, CAE and Additive Manufacturing
Capstone Design Course
Dr. Paul Zang

Team Members
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Carter Childs
Mitchell Drilling
Jackson Harmer
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June 9, 2017

a) The purpose of the executive summary is to provide key information up-front, such that while reading the report, a reader has expectations that are fulfilled on a continuous basis. Key to a good Summary is the first sentence, which must contain the most essential information that you wish to convey.
b) The summary is to be written as if the reader is totally uninformed about your project and is not necessarily going to read the report itself.
c) It must include a short description of the project, the process and the results.
d) The Executive Summary is to be one page or less with one figure maximum.

Executive Summary

In order to test a study that 3D printers can output dangerous levels of nanoparticles, groups were tasked with building, calibrating, testing, and using a TEVO Tarantula. Groups built the Tarantula from a kit, as well as an airtight enclosure to trap in the particles. On top of this, groups added improvements and enhancements, both required and secondary, and made test prints. From these test prints, calibrations and further enhancements could be made to increase print quality. Additional features, such as an auto-leveling bed, and remote printing capability were also required to be added. Once the printer was setup, it could be used to conduct air quality tests where conclusions could be made from the results.

MECH-572 Objectives:

- Assemble the TEVO Tarantula kit

- Design and build a sealed enclosure for the printer
- Implement 4 given modifications to improve the printer
- Implement 4 custom modifications to improve the printer
- Evaluate the particulate output of the 3D printer using a Dylos air quality monitor to determine whether health concerns exist.

Gantt Chart Timeline (11 Weeks)

Item	Sub Item	Lead Responsible	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11
Timeline		ALL											
Group jobs		ALL											
Media History		Ian	■	■	■	■	■	■	■	■	■	■	
Programming software CURA		Harmer/Carr											
Enclosure build		Carter/Mitch	■	■	■								
	CAD Model	Carter/Mitch			■								
	CAD Drawings	Carter/Mitch			■								
	Include air purifier	Carter/Mitch			■								
Complete 3D printer build		Carr/ALL	■	■									
	Temp tower				■								
	Calb Cube				■								
	Anchors				■								
Midterm Design Review Presentation		All				■							
4 Required Modifications		All				■	■	■					
4 Custom Modifications		All				■	■	■					
Final Design Review Presentation		All									■	■	
Final written report		All									■	■	■
	Report Title Page	Mitch									■	■	■
	Enclosure CAD model and drawings	Mitch/Carter			■								

Project Background

The Illinois Institute of Technology published a study which measured the particle output of various desktop 3D Printers and 3D printing materials. Nanoparticles are of particular interest because they can cause health concerns in great enough amounts. The study by IIT found that 3D printing outputs nanoparticles that can accumulate in inadequately filtered environments such as bedrooms or offices where desktop 3D printers are usually used. This may be more of a concern now because 3D printing is increasing in popularity and availability. The study by IIT focused on desktop, non-commercial printers for this reason. The results also showed that ABS releases more particles than PLA. The IIT researchers recommend to conduct more studies because of the limited scope of their initial work. More information is needed to determine if 3D printing actually creates a harmful environment or if the particulate output is within an acceptable level.

Kettering seeks to provide more research on the particulate output of 3D printers and the effectiveness of air filtration systems. Kettering students will be using an air quality meter to measure the particle content within an airtight enclosure around the 3D printer (TEVO Tarantula). The test will also be run with an air filter operating inside the enclosure to evaluate the effectiveness of this prevention method.

Technical Specifications

- Printer Firmware
    - Marlin RC-7
- Power Supply
    - 12V
    - 48A
- Printer Bed Size
    - 200x200x200mm
- Nozzle Diameter
    - 0.4mm
- Printer Dimensional Accuracy
    - X [+/-.1 mm]
    - Y [+/-.1 mm]
    - Z [+/-.1 mm]
- Printer Temperature Capabilities
    - Extruder [0-260C]
    - Bed [0-120C]
- Material Capabilities
    - PLA
    - ABS
- Printer Hardware Additions
    - Second Z-Axis
    - Fan Shroud [Fang Style]
    - Anchors [Center, Right, Left, Top, Bottom]
    - BLTouch
    - Marlin Firmware
    - OctoPrint connection through Raspberry Pi
    - Material spool holder
    - Improved Z-Axis motor mounts
    - X-Axis Belt tensioner
    - Cork insulation to heated bed
    - Filament guide
    - Glass Top on heat bed
- Air Quality Study Results
    - Air Filter OFF w/ closed enclosure:
        - Large Particles
            - Start: 1000 particles/cubic foot
            - End: 450 particles/cubic foot
        - Small Particles
            - Start: 240,000 particles/cubic foot
            - End: 160,000 particles/cubic foot
    - Air Filter ON w/ closed enclosure:
        - Large Particles

                - Start: 1000 particles/cubic foot
                - End: 30 particles/cubic foot
            - Small Particles
                - Start: 3200 particles/cubic foot
                - End: 490 particles/cubic foot

4.Detailed design documentation: Show all elements of your design including an explanation of

a) Assumptions made, making sure to justify your design decisions.
b) Function of the System
c) Ability of meet Engineering Specifications
d) Prototypes developed, their testing and results relative to Engineering Specifications
e) Manufacturing processes used
f) NX11 CAD assembly and components drawings
g) Human factors considered (ie. Air Quality, Smell, …)

<u>Design Modifications and Benefits</u>

1. <u>Second Z-Axis</u>
    a. **Benefit:** Increases Z-Axis stability. With only one Z-Axis, the X Carriage is cantilevered and can flex. This is especially a concern when the print head is farther away from the threaded rod because the leverage effect is magnified.
    b. **Method:** Involves adding a second Z-Axis Stepper Motor, Threaded Rod, and Z-Axis Nut. The Second Z-Axis motor should be wired to the first Z-Axis through a y-splitter. The X-Carriage MUST be leveled by turning the printer off and manually adjusting the left or right Z-Axis Threaded rod to level the X-Carriage. If this is not done correctly or if this parameter is disturbed, prints will become slanted and slightly offset.
2. <u>BL Touch</u>
    a. Benefit: Replaces manual bed levelling with a much faster and automatic process. The Z-Axis switch is replaced by the BL Touch sensor which detects the location of the bed in Z height. A programmed Z-offset lets the printer know exactly where the nozzle is so the Nozzle to Bed Height is repeatable every time to the precision of the Z-Axis and the BL Touch. Additionally, the BL Touch can AutoLevel the Bed by taking measurement points on the bed to calculate the plane of the bed.
    b. Method: In order to add the BL Touch, both hardware and firmware additions must be made. Hardware is simple, the BL Touch must be mounted on the printhead facing down. The BL Touch must be wired into the motherboard into both the servo port for power and into the Z-Axis Limit Switch. The BL Touch will not work by simply plugging it in. The Firmware of the TEVO must be updated with a version that supports the BL Touch. Example code can be found on the Facebook support group or online, but every printer is different, and requires line by line code evaluation. Once the firmware (This printer uses Marlin RC7) is downloaded, it can be opened in Arduino (Open the Marlin.ino file). The

configuration.h file (one of the tabs that should have opened with the Marlin.ino file) has the majority of settings which need to be changed. All code is present in the configuration.h, but some lines must be commented out/in and some values customized to the specific printer. Read the comments in the code to figure out which lines need to be commented in or out. The BL Touch most likely has its own section. Basic Knowledge of arduino (C-derived) code is all that is required to implement this. Once the changes are made, save the file and connect to the printer through a USB cord. Upload the firmware (WARNING, at this point, you are erasing the stock firmware and replacing it with Marlin firmware).

3. Extruder Fan Duct
    a. **Benefit:** Extruder Fan Duct cools the print and allows for significant quality improvements for overhangs. It can also help print quality by cooling the plastic immediately as it exits the nozzle and preventing it from moving out of place. This is probably the most important modification to make to a printer.
    b. **Method:** The Fan style was chosen based off our fan size. The fan .stl was found on Thingiverse and downloaded. The .stl was sliced in CURA and printed.
4. Anchor Supports
    a. **Benefit:** The anchors keep the printer from moving which improves print quality.
    b. **Method:** The printer anchors can be found on Thingiverse, downloaded, and printed.
5. OctoPrint
    a. **Benefit:** Using the Raspberry Pi with OctoPrint allows a user to access the printer remotely, and is able to start a print and monitor the progress from the internet
    b. **Method:** The OS was downloaded to the microSD card and the OctoPrint package was installed. Printer preferences were selected, and the Pi was connected to the internet via KUSTUDENT using PEAP authentication.
6. Z-Axis Frame Braces
    a. **Benefit:** The stock Z-Axis braces are flat acryllic parts that bend. This reduces Z-Axis precision. The Frame Braces improve Z-Axis stability and adds more stability to the top corners.
    b. **Method:** The Frame braces were printed off of Thingiverse and replaced the stock hardware.
7. X-Axis Belt Tensioner
    a. **Benefit:** The belt tensioner provides easy adjustment to the x-axis belt. Tension can be increased or decreased without cutting any zipties.
    b. **Method:** The belt tensioner was printed and slipped onto the x-axis.
8. Filament Guide
    a. **Benefit:** The filament guide keeps the filament entering the bowden tube from the same angle.
    b. **Method:** The filament guide was printed and added into the aluminum extrusion with the extruder stepper motor on it.

Enclosure Design:

The main objective of the design of this enclosure is to work well, but also look nice. A focus was made on being able to have access to the printer within the enclosure, in order to work on it, a very important aspect looking back on the project.

Styling and Design

Initially, the design of the enclosure was to be used with an IKEA lack table, but to spice things up, we went to our northern manufacturing and design facility in Traverse City, MI. The enclosure is constructed with the finest wood Michigan forests' had to offer. Wood such as cedar, ash, and pine were used in the creation of this enclosure. The box is created using a multitude of fasteners including screws, nails, staples, glue, and caulk. After the box was assembled, the whole exterior and interior was sanded to remove all of the splinters and simplify the staining and painting process.

The rear of the enclosure features a see through window made of acrylic allowing additional lighting and visual. The front of the enclosure is a two part door and latch system. The bottom is simply a door and the top is a window with another piece of acrylic, allowing for a visual of the printing process. Using this two door design, the printer can easily be accessed. The top door folds up and stays open. The bottom folds down and allows for access to the bottom of the printer.

The inside is painted flat black, so the printer stands out with the LED light strip illuminating the printer. The outside panels are stained Miniwax Pecan and the trim, which is 2716 Dark Walnut also by Miniwax and is pine and ash. The center of the interior of the enclosure is a piece of plywood stained Pecan, with the logo of the team, our Amish beard.

We deliberately made the enclosure much larger than the printer, so the air filter, power supply, and other miscellaneous devices can fit, with room to spare for servicing on the printer. The design was made for durability, function, and aesthetics not for lightweighting.

Safety

The design was made with safety in consideration. The hinges allowed for the lid to be opened far enough, so the top would not fall on the operator's head when servicing the printer. All sharp edges and splinters were sanded off to allow for handling of the printer safely. The printer is sealed tight to prevent the contamination of the air from the dangerous micro and nano particles.

Air Seal

To establish an air seal for the 3D printer enclosure the group used adhesive foam seals to seal the box, and weatherproof caulk on every joint within the box. The seal was seen to be effective when the air quality study was run. The quality of the air in the room was significantly worse than the air quality with the filter running and the enclosure sealed shut.

Assumptions

The main assumptions for the design of the enclosure would be that the tolerance of the machining is minimal. A good amount of shimming and tuning was needed to make the box fit as needed.

Assembly Drawing and Realization

CAD Drawings

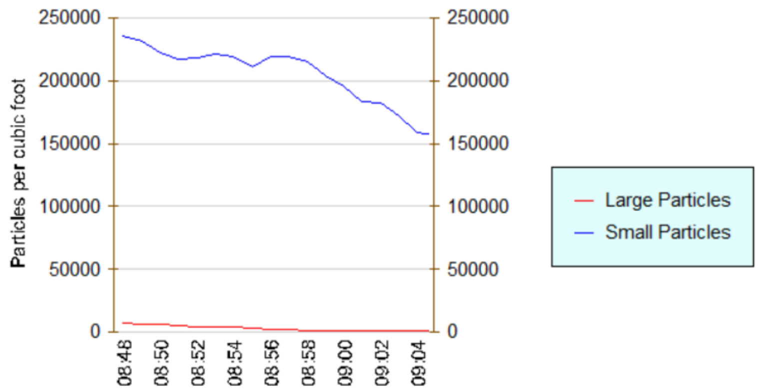
Please see appendix II below CAD drawings for details on each part of the enclosure.

Air Quality Study:

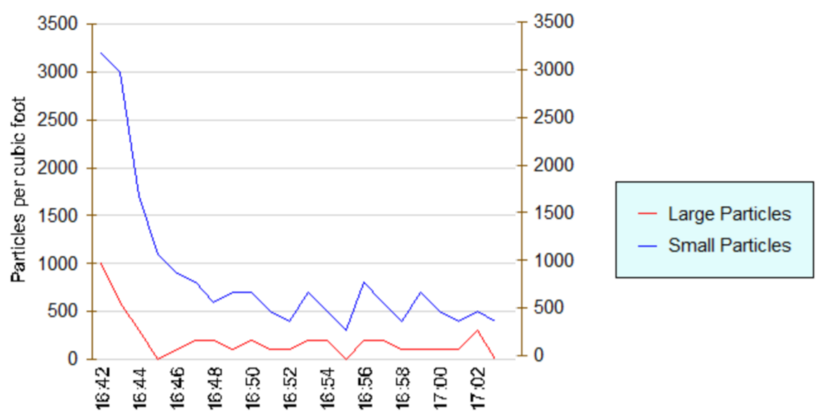
Results

- Air Filter OFF w/ closed enclosure:
  - Large Particles
    - Start: 1000 particles/cubic foot
    - End: 450 particles/cubic foot
  - Small Particles
    - Start: 240,000 particles/cubic foot
    - End: 160,000 particles/cubic foot
- Air Filter ON w/ closed enclosure:
  - Large Particles
    - Start: 1000 particles/cubic foot
    - End: 30 particles/cubic foot
  - Small Particles
    - Start: 3200 particles/cubic foot
    - End: 490 particles/cubic foot

Graphs



Above graph represents 3D printer with air filter turned off



Above graph represents 3D printer with air filter turned on

Assumptions

- To make accurate conclusions we must assume that our data is experimentally accurate
  - Dylos air quality meter is properly calibrated
  - Enclosure is somewhat airtight
  - Each print produces the same amount of particles

Conclusions

- Based on the data, and the air quality guidelines set forth by Dylos:
  - 3D printing can indeed produce a large number of PLA microparticles and macroparticles in the air
  - Printing while using the air filter made a significant difference in the number of particles in the air.Below are tables comparing the referring to the high, low, and average air particle readings for small and low air particles.

Small Particles w/o filter	
Low	24,800
High	235,500
Average	96,430

Large Particles w/ filter	
Low	100
High	7,400
Average	1,183

- Per the air quality guidelines, without operating a filter the concentration of PLA microparticles could have adverse health effects in the long term. Below are tables comparing the referring to the high, low, and average air particle readings for small and low air particles.

Small Particles w/ Filter	
Low	300
High	3,200
Average	882

Large Particles w/ Filter	
Low	0
High	1,000
Average	2,000

- Through data and graphs provided in the laboratory experiment, our team concluded that we support the use of 3D printers in an enclosed environment operating with a air filter capable of eliminate the air particles for the user. Clean air > contaminated air.

Verification Testing

Once the build and design of the printer were completed several tests were completed to verify the functionality of the printer. A calibration cube was printed first to check the tolerance of the printer. A calibration cube is a 20mm cube and after completion the cube is measured to discover the tolerance of the printer. This information allows for tweaks to the stepper motor speed in the gcode to ensure the appropriate distances are being traveled.

Once the tolerance of the cube is confirmed a temperature tower

Ethical Consideration

3D Printers are a great tool for all ages to learn from. But, there are ethical considerations both good and bad for consumers to take note of when purchasing 3D printers.

Medical industry can be a prime benefiter to the increased availability of 3D printers. Once properly calibrated, home 3D printers can achieve very fine prints able to inspire students and teachers with the ability to create new 3D printed hips, shoulder pieces and even full length arms (Springer, 2017). The cost of 3D printing is very affordable and with time if standardized can bring medical costs down for all.

People can print new items that will harm others in the form of weapons. A home 3D printer can be bought and sold anywhere in the world with no license required to print. There was a case where a young man named, Yoshitomo Imura of Japan, printed and created several designs of revolvers to show through the internet video uploading service, Youtube. Imura would soon be arrested for his constant uploading of new revolvers able to fire six .38 bullets without damage (Greenberg, 2017). Japanese agents have said that he was inspired by the Liberator design, the first of widely made 3D printed firearm design. A majority of countries around the world consider the printing and distribution of 3D printer files for weapons illegal and have taken measures to monitor websites to stop illegal spread of firearms.

Problems encountered

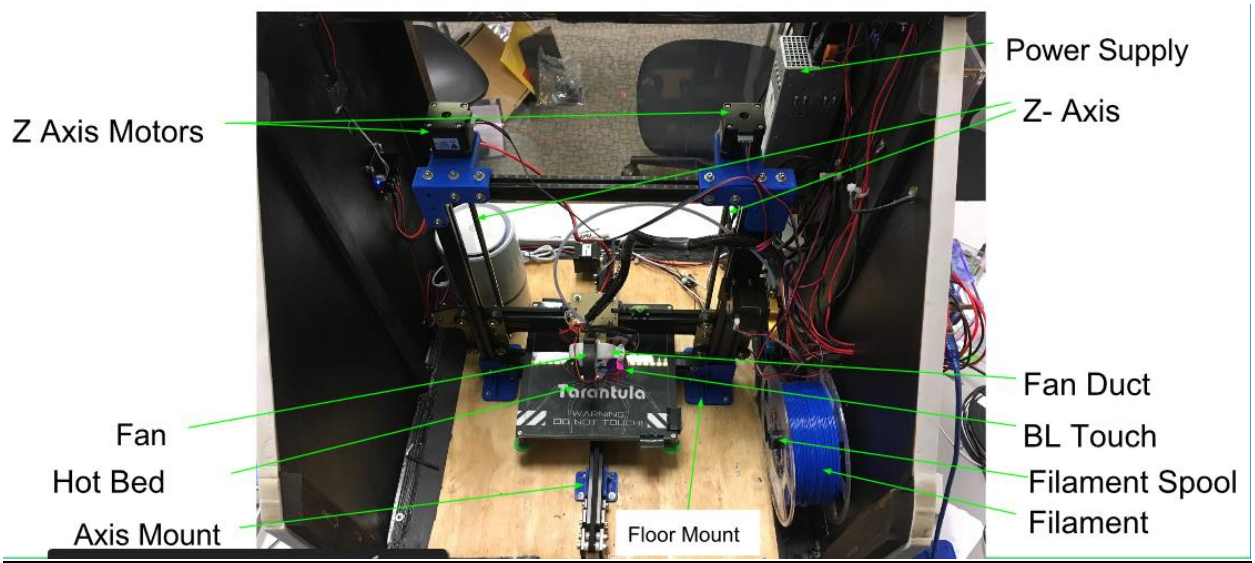
- Air Quality study showed a reduction in both large/small particles
- Clicking Extruder
- Clogged Nozzle
- Bad Firmware
- Bed Adhesion
- Broken Power Supply

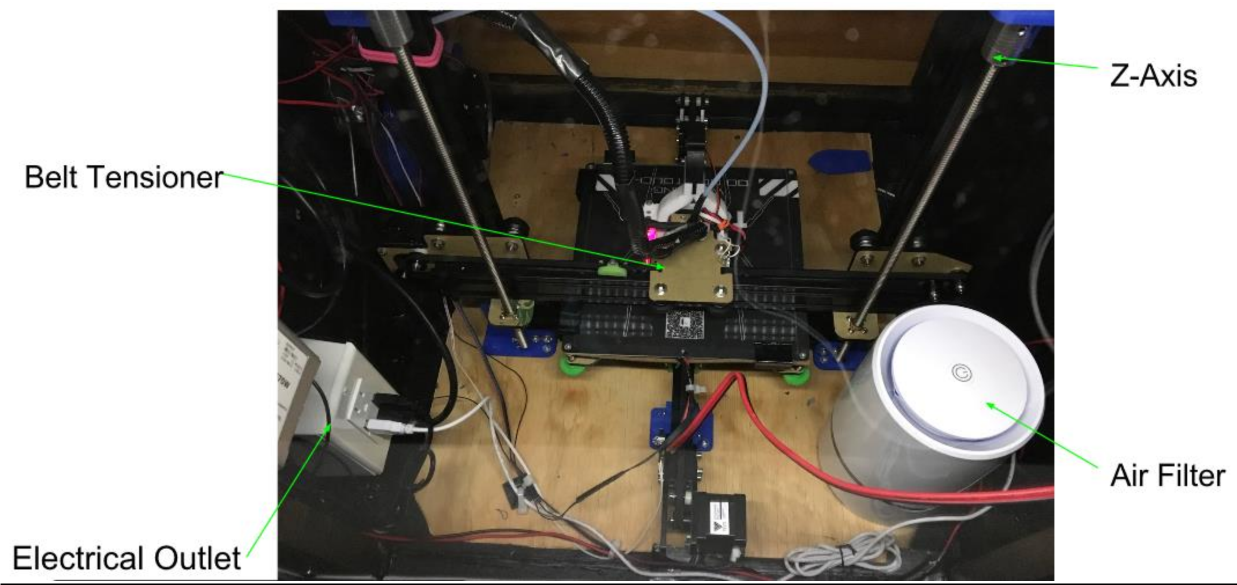
Acknowledgments

Dr. Jonathan Shaft - for insight and materials when building the enclosure at the up north facilities.

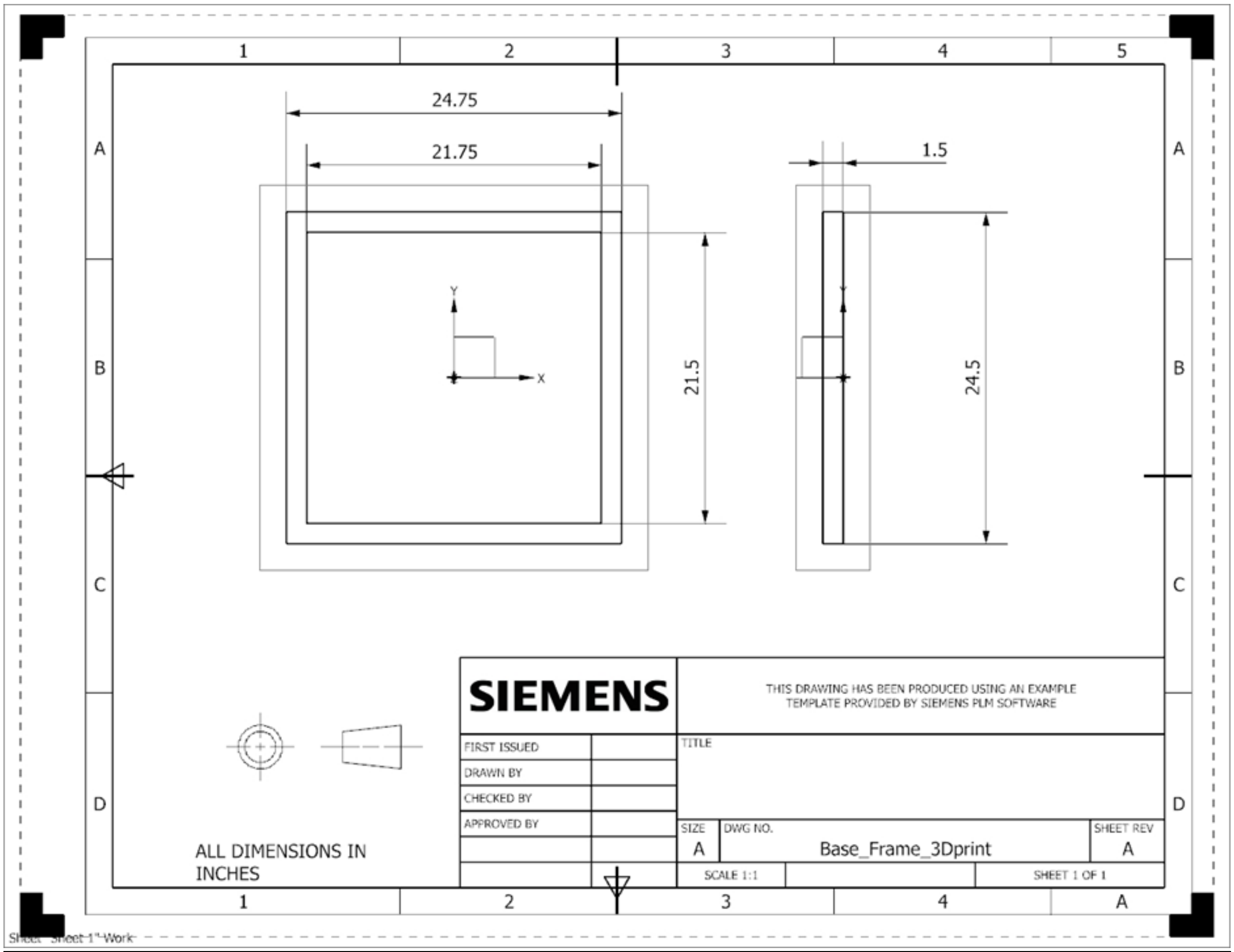
Appendix I: Modifications

Below Images shows modifications installed on the printer and enclosure. Each modification is called out with a pointer in the image.





Appendix II: CAD Drawings



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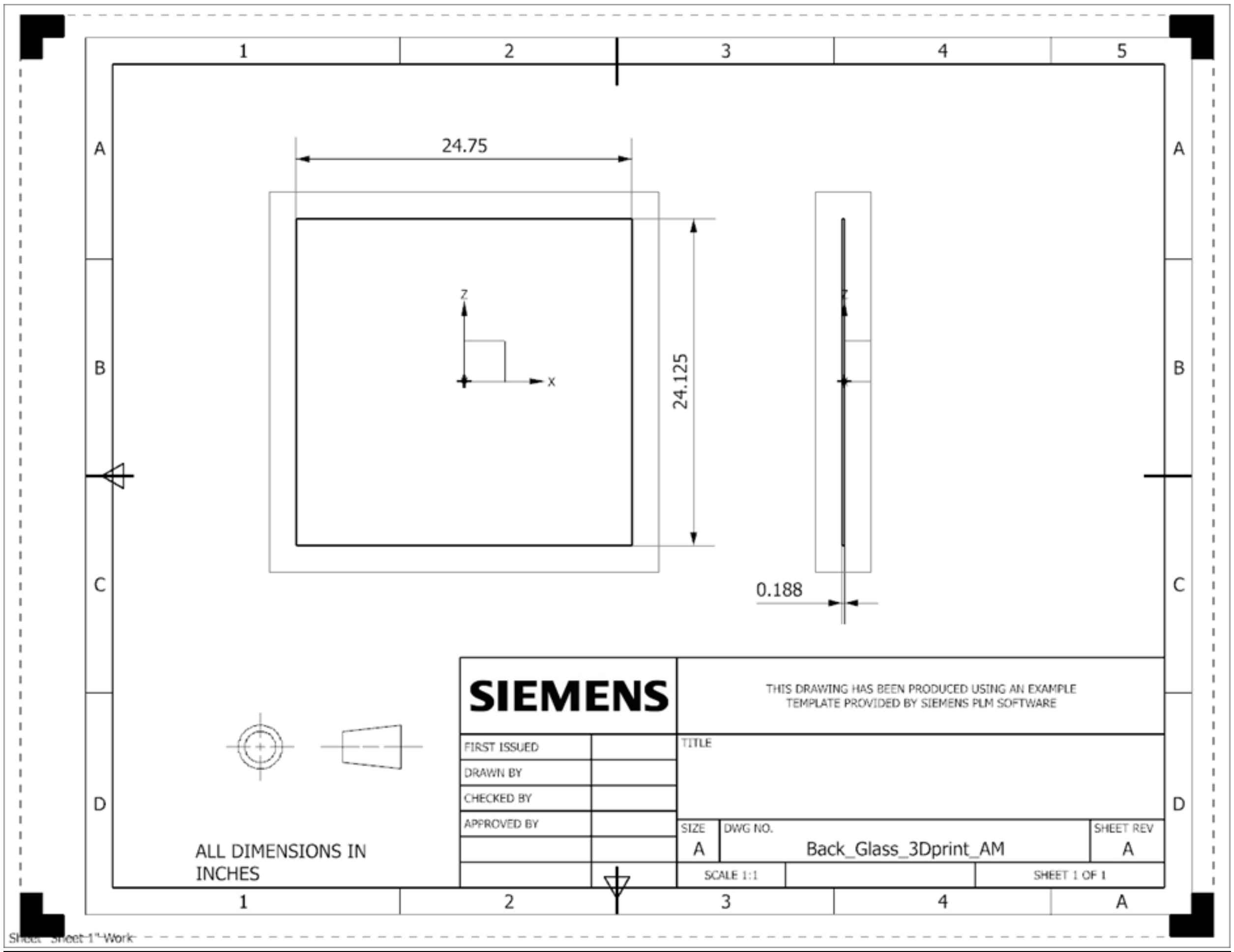

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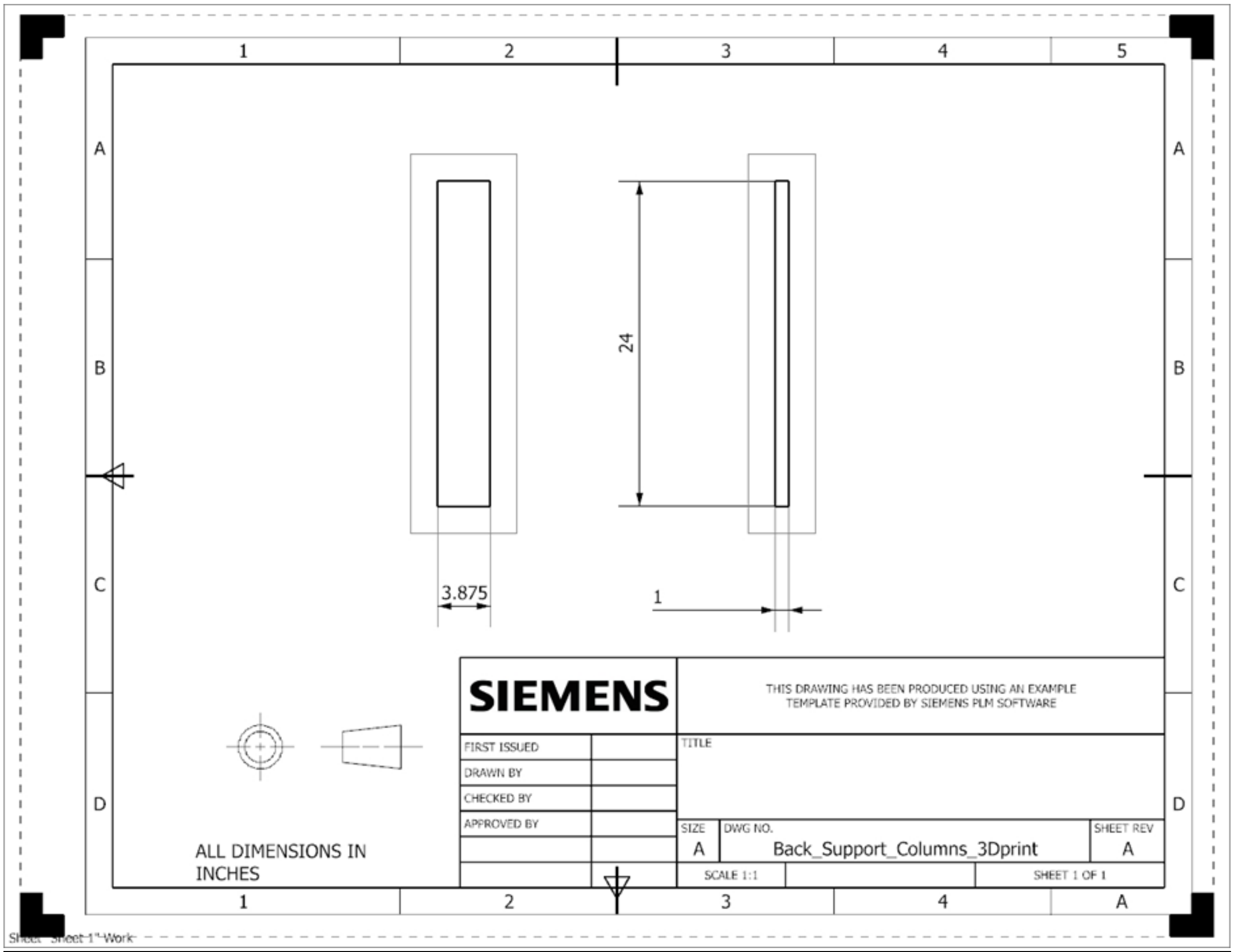
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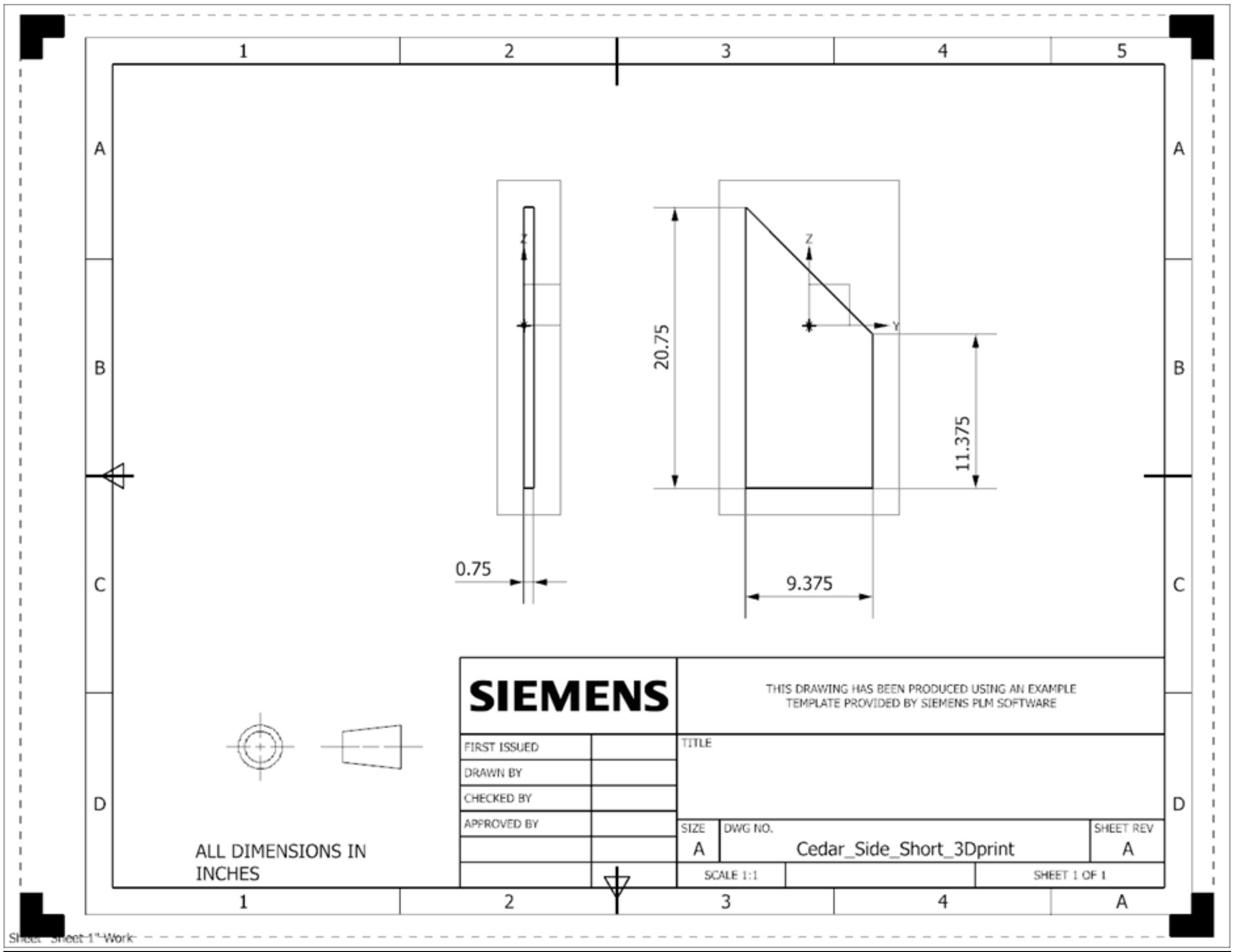
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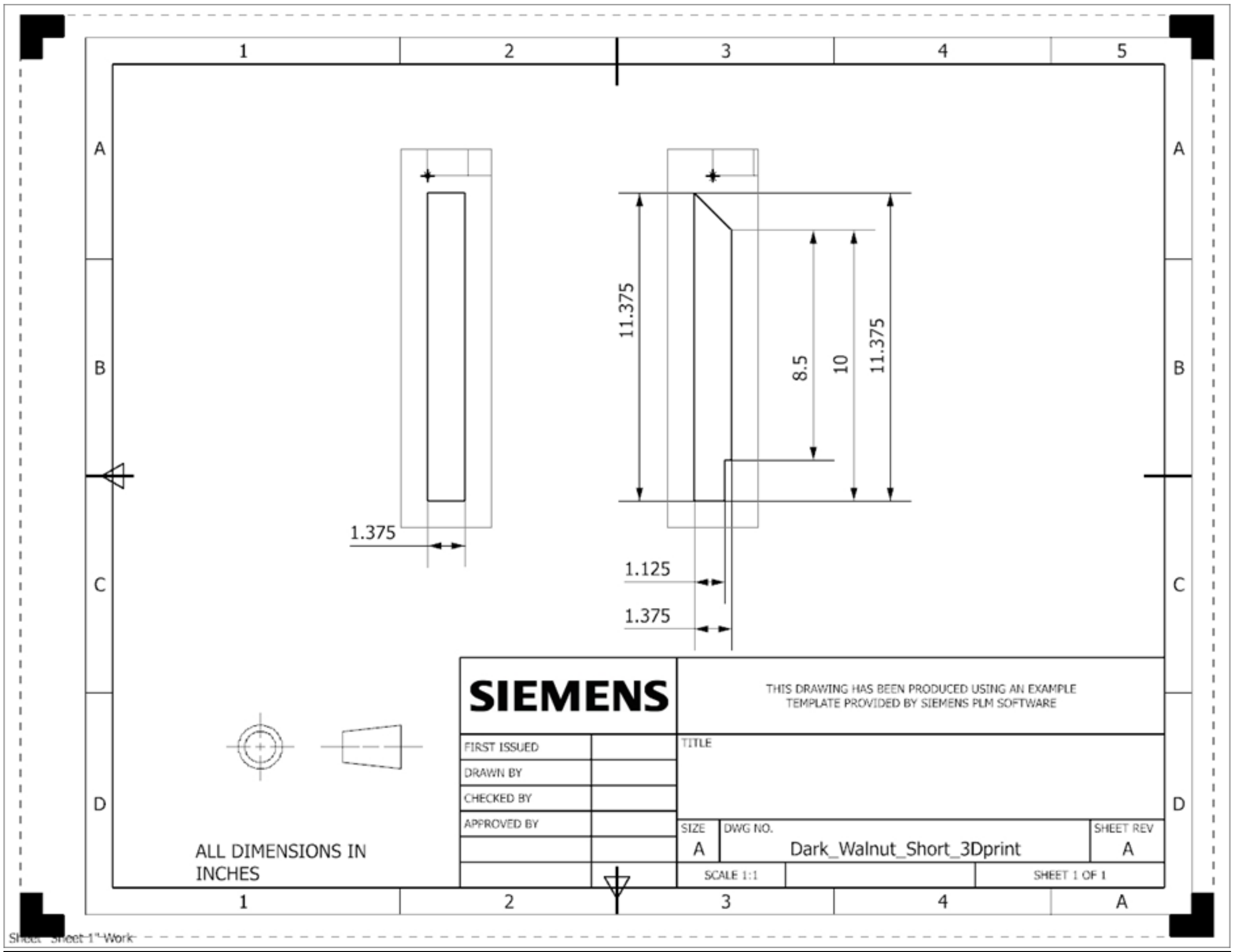
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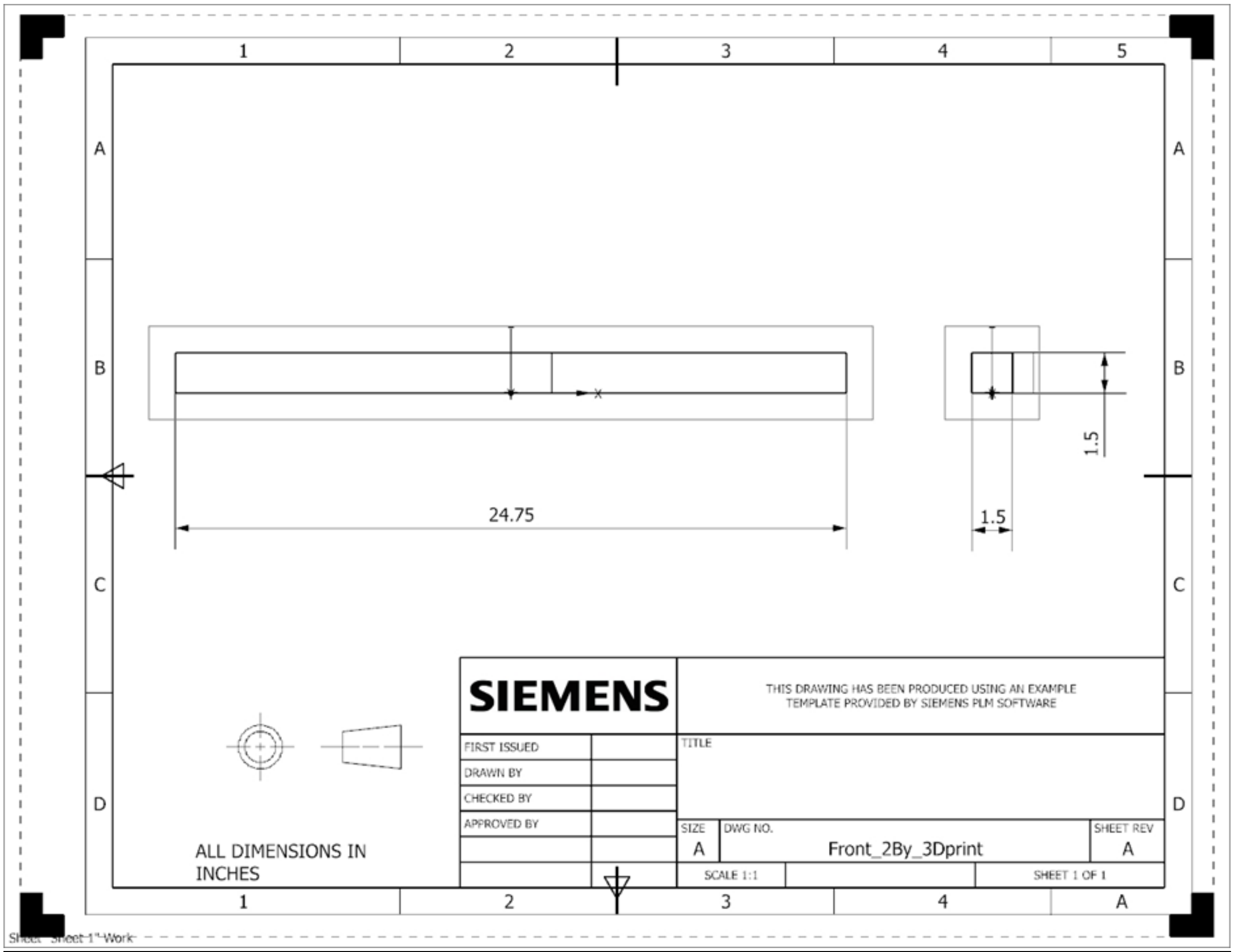
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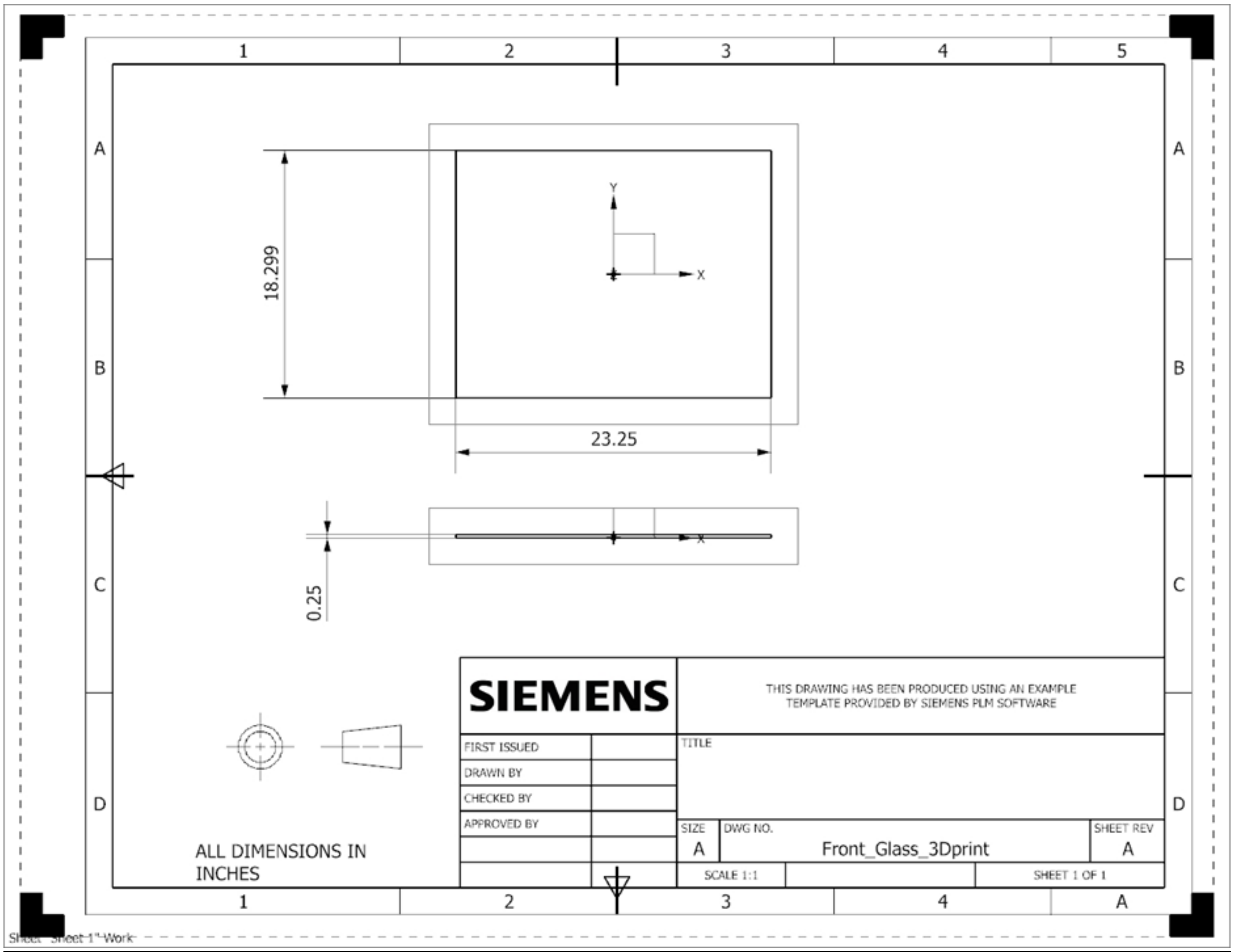
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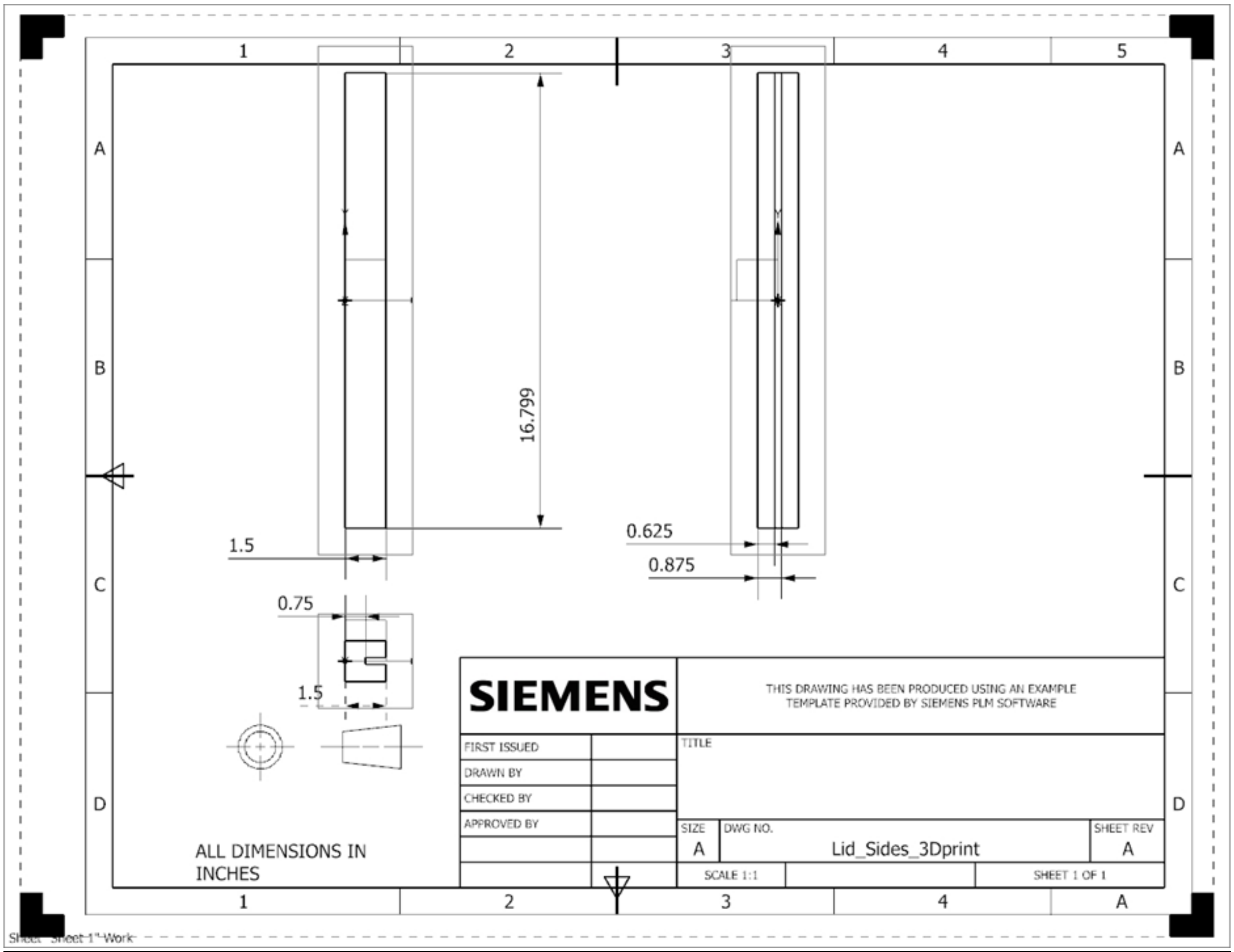

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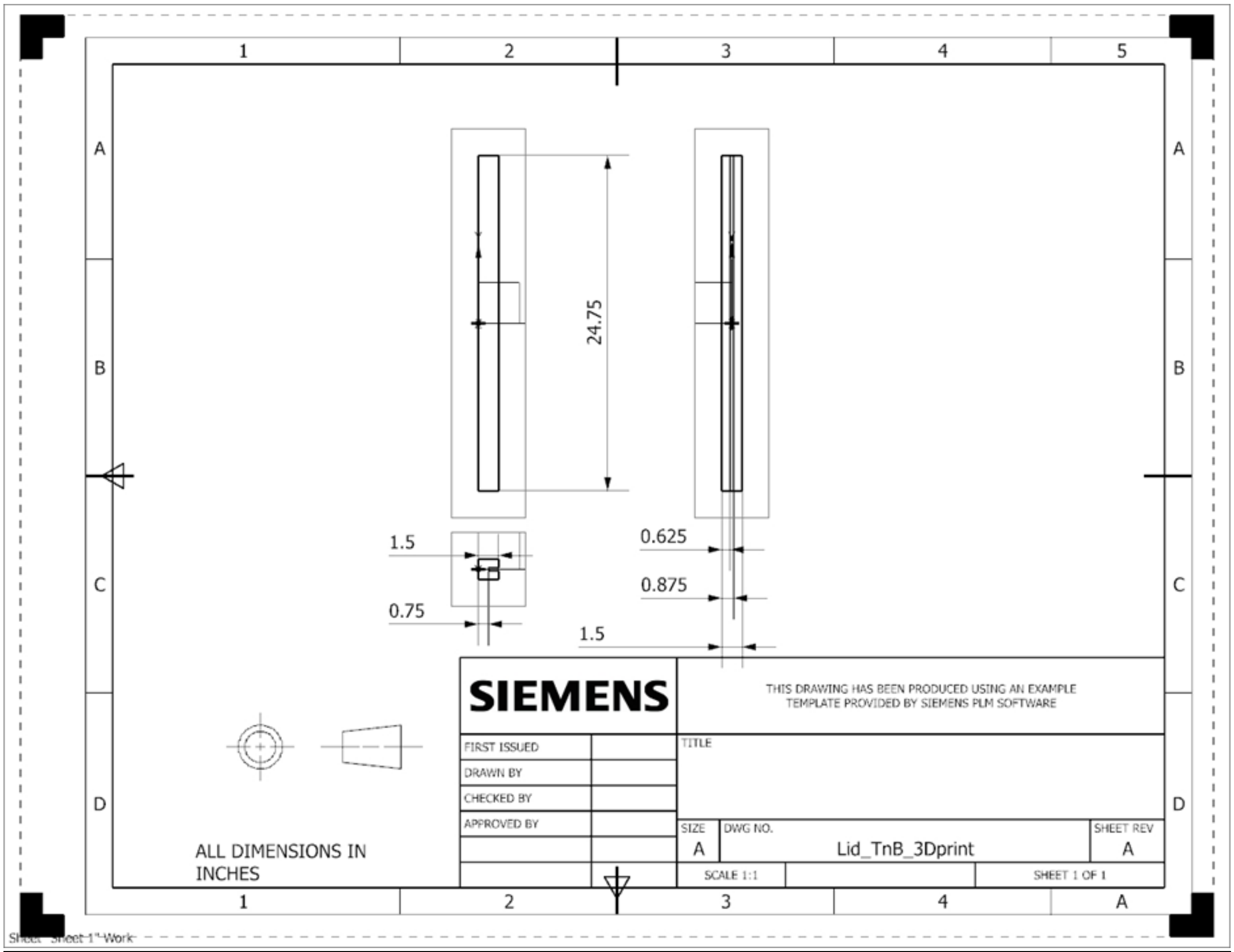

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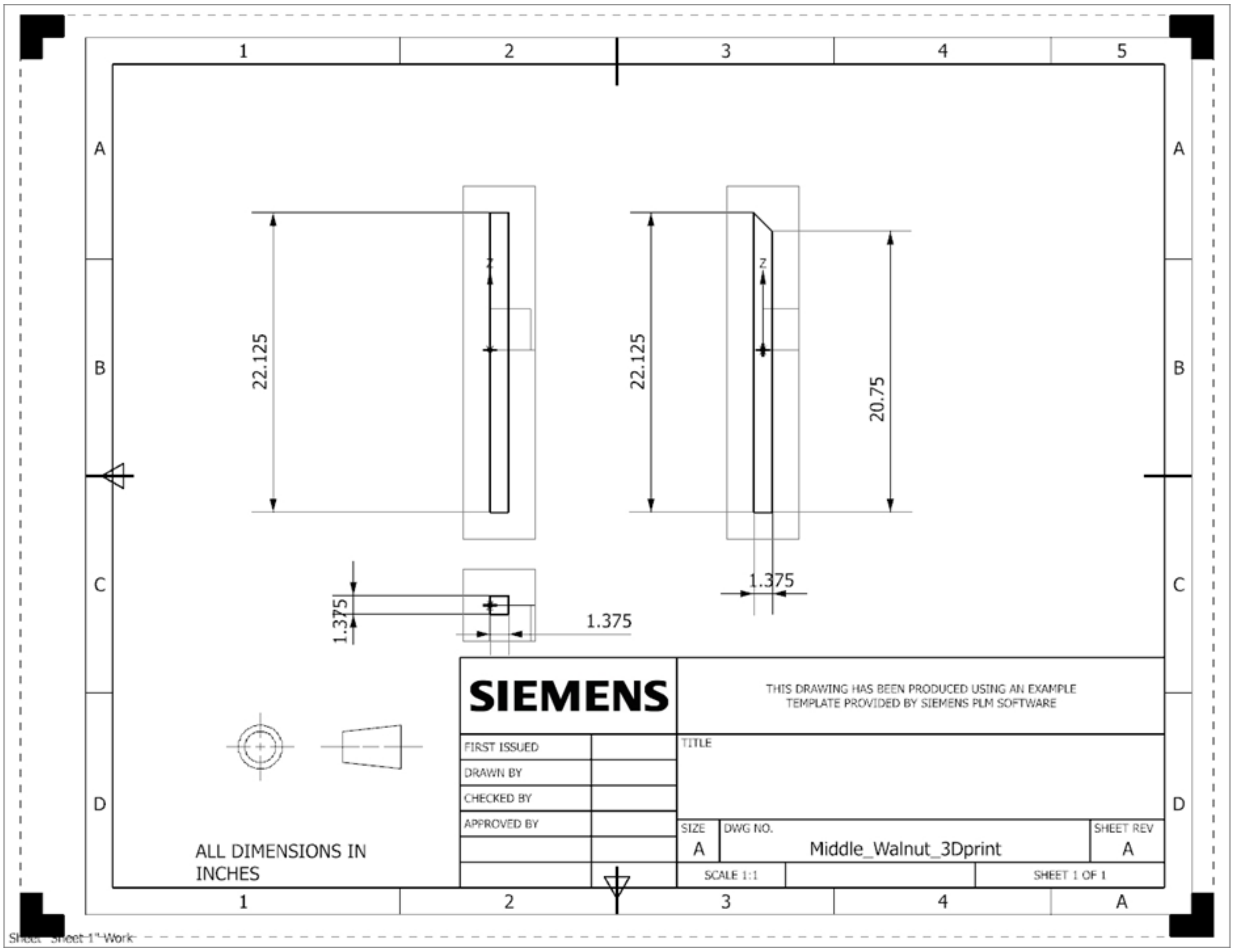
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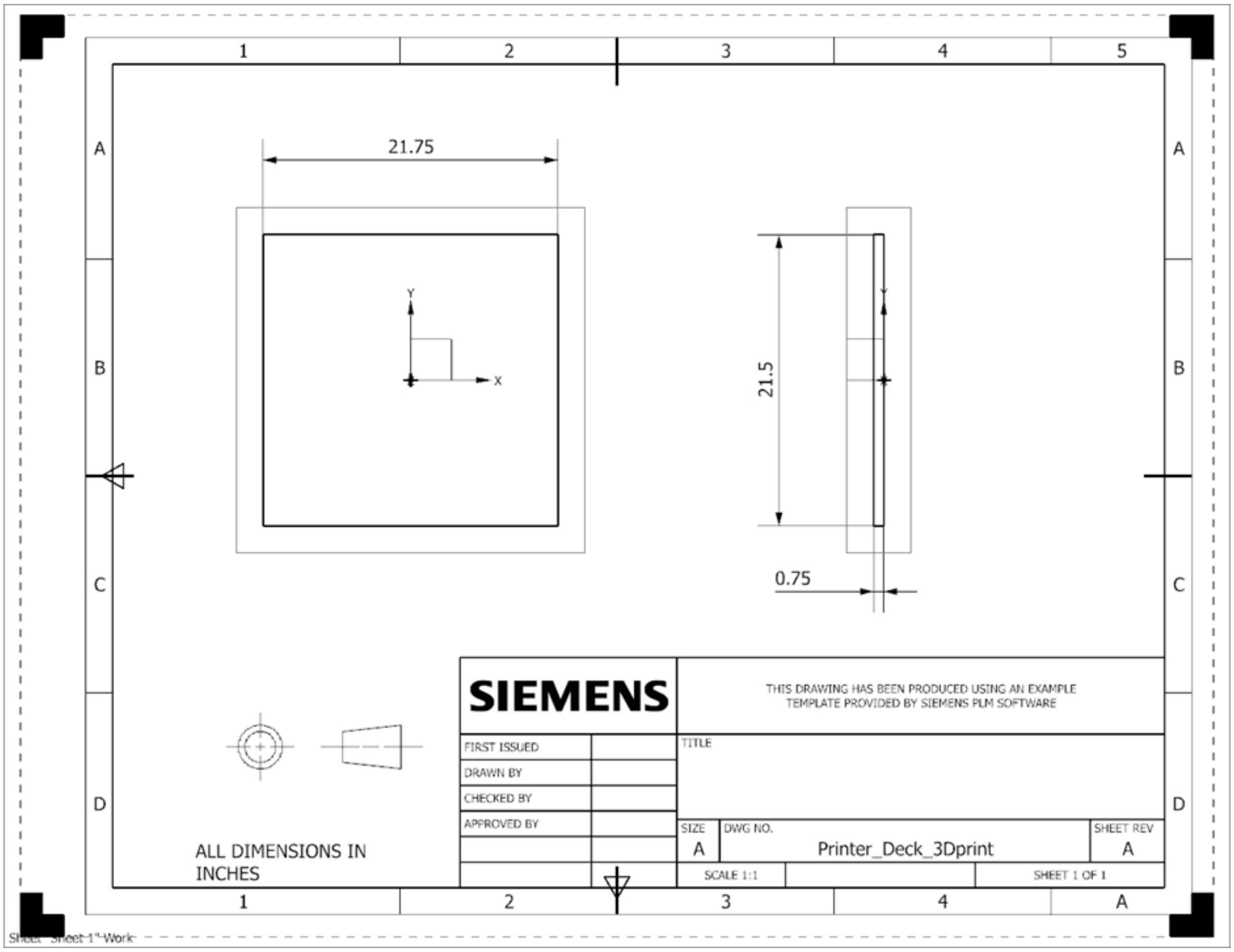

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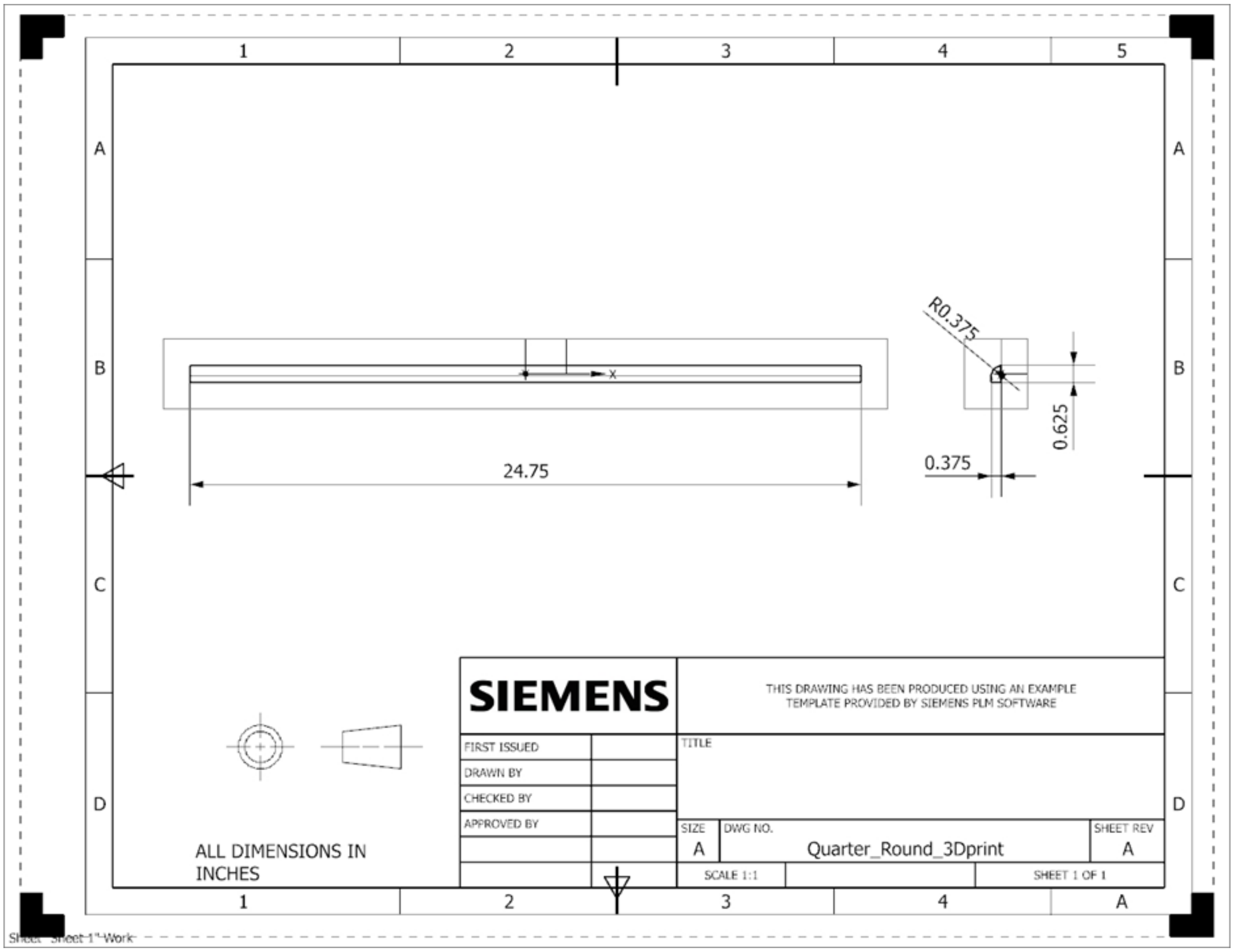
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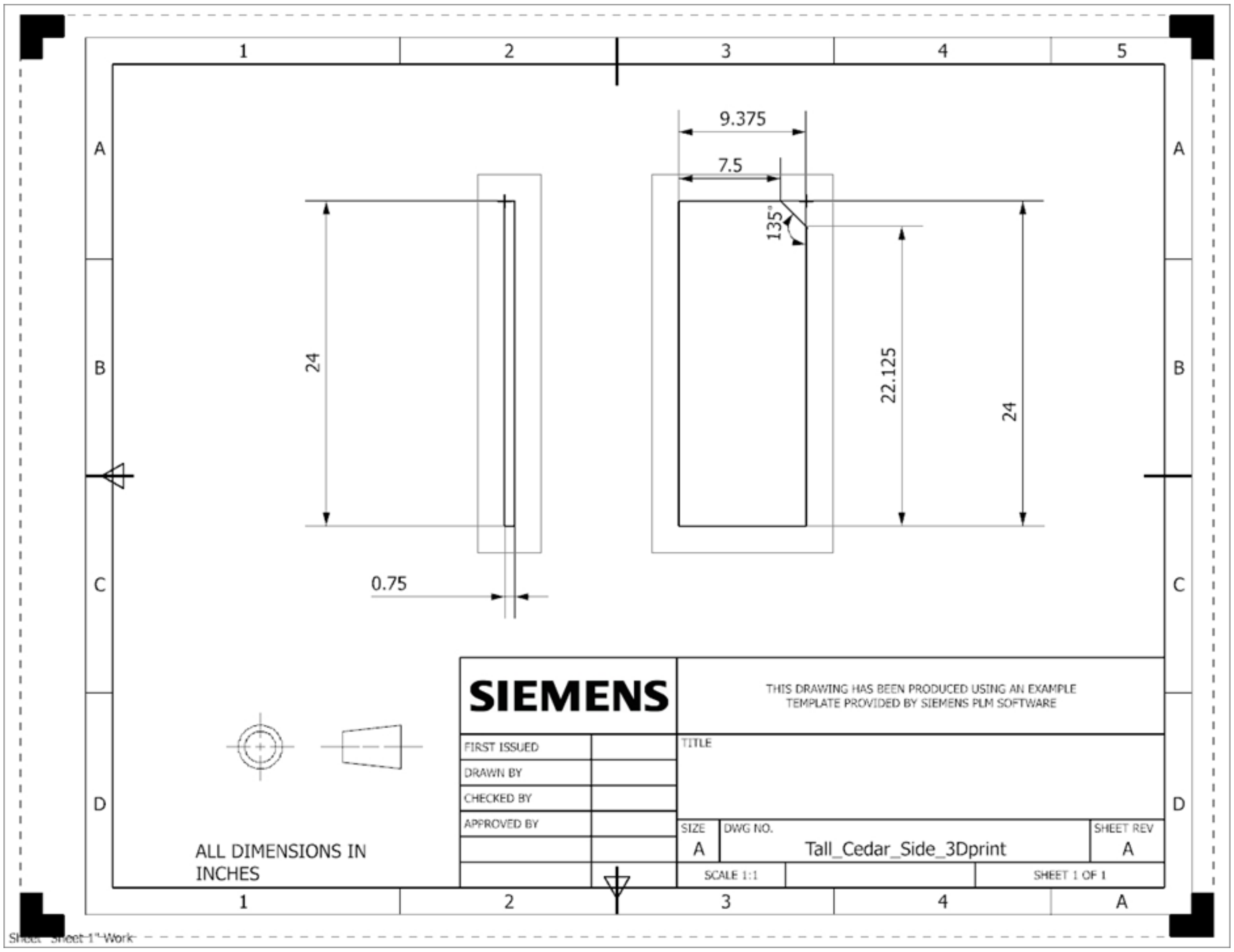

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TITLE
SIZE
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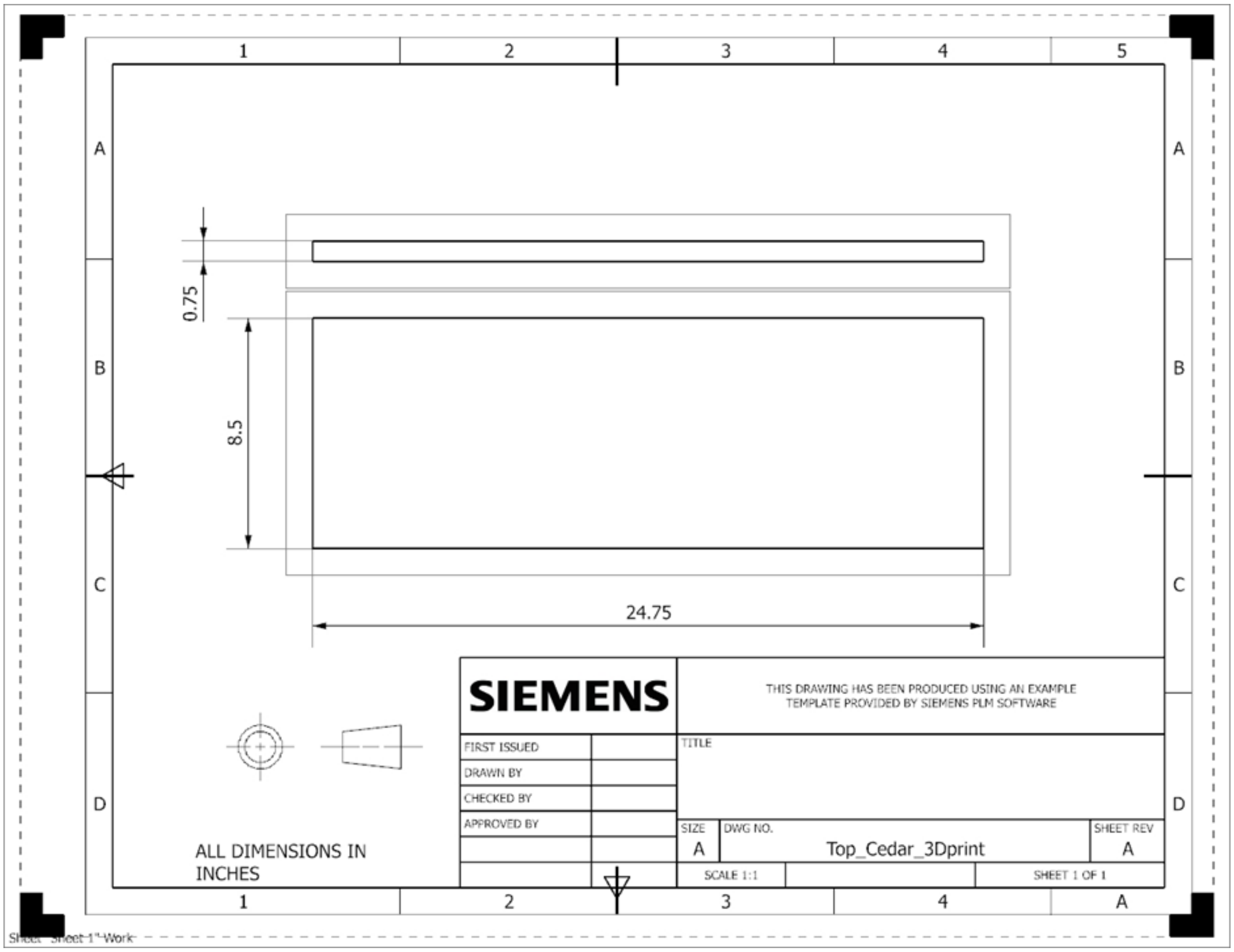
DWG NO.
Tall_Cedar_Side_3Dprint
SHEET REV
A
SCALE 1:1
SHEET 1 OF 1
ALL DIMENSIONS IN INCHES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Top_Cedar_3Dprint
SHEET REV
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SCALE 1:1
SHEET 1 OF 1
ALL DIMENSIONS IN INCHES
Sheet "Sheet 1" Work

Appendix III: Bill of Materials

MECH-572 Spring 2017 Project Kit BOM		
Item	**Price**	**Purchased from**
TEVO Tarantula	$200.00	AliExpress
BL Touch Sensor	$40.00	EBay
Spools of ABS (2)	$0.00	Included w/ Printer
8 GB SD Card	$0.00	Included w/ Printer *** Do NOT use this SD card!!! ***
Z Axis Kits	$40.00	AliExpress
200 x 200 mm Boro Glass Sheet	$10.00	EBay 213mm x 200mm x 3mm
IKEA LACK Tables	$10.00	IKEA
Amazon Car Air Purifier (WSTA)	$36.00	Amazon
RaspberryPi 3	$35.00	Amazon
12v MOSFET	$10.00	Amazon
120v Outlet plug, Switch, Misc. Connectors	$5.00	In Hand
16 GB mini SD Card	$0.00	In Hand
LED Light Strip	$5.00	EBay
23"x23"x0.375" Acrylic Sheet	$0.00	Local Supplier
FoamCore Sheets	$0.00	Home Depot
OSB	$0.00	Home Depot
Masonite Sheets	$0.00	Home Depot
Silicone Caulk	$0.00	Loews
120v USB Power Outlet	$20.00	Home Depot
Carlon 1 Gang Electrical Box	$1.00	Home Depot
2 Port USB Bulkhead Outlet	$13.00	Amazon
TOTAL	$425.00	

References

Greenberg, A. (2017, June 03). How 3-D Printed Guns Evolved Into Serious Weapons in Just One Year. Retrieved June 16, 2017,from https://www.wired.com/2014/05/3d-printed-guns/

Springer, M. (2017). Advantages of 3D Printing in Healthcare. Retrieved June 16, 2017, from https://healthmanagement.org/c/healthmanagement/issuearticle/advantages-of-3d-printing-in-healthcare