AME 554: Additive Manufacturing
Final Project: *DIY Mini CNC Laser Engraver*
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1. Introduction

The objective of this project was to explore how additive manufacturing could enhance low-cost CNC systems by improving their functionality and accessibility. Leveraging 3D-printed components, the project focused on creating a stable, precise, and customizable DIY CNC laser engraver. The working area of 40mm x 40mm was selected for compactness and precision, making it ideal for small-scale engraving tasks. This project exemplifies the potential of integrating 3D printing and CNC technologies to develop affordable, customizable systems for diverse applications.

2. Primary Components and Their Functions

The DIY Mini CNC Laser Engraver integrates a range of electronic, mechanical, and 3D printed components. Each part was selected for its functionality, accessibility and contribution to the overall system design. Below is a detailed overview of the key components and their roles in the system:

1. Arduino Uno REV3 (with USB cable)	The Arduino Uno serves as the central microcontroller. It is programmed to control the laser and motors, sending precise signals to the CNC module board for coordinated motion and engraving tasks.
2. Generic CNC Module Board	This board acts as an interface between the Arduino and the stepper motors. It translates control signals from the Arduino into specific motor movements, ensuring precision and stability.
3. DEVMO 6-15V AC/DC to 5V Converter	The voltage converter ensures a stable 5V power supply to the Arduino and other sensitive electronics, safeguarding them from fluctuations in input power.
4. 2x Stepper Motors	These stepper mechanisms are cost-effective solutions for providing motion in the system. They

	offer the precision needed for small-scale engraving.
5. 2x A4988 Stepper Motor Driver Modules	These modules control the stepper motors, allowing for smooth and accurate motion. They are essential for achieving precise control over the X and Y axes of the engraver.
6. Focusable Laser Module with a power output of 250mW and a wavelength of 650nm.	The module includes: An outer metal housing that acts as a heatsink to dissipate heat generated by the laser diode during operation. A focusable lens that allows for precise adjustments to the laser dot, ensuring accuracy for engraving or cutting.
7. 12V 2A Power Supply	This power supply provides sufficient energy to drive the entire system, including the stepper motors and the laser module.
8. Soldering Iron Kit	Used during assembly, the soldering iron kit was critical for securely connecting electronic components, ensuring durable and reliable wiring.
9. Crimp Tool Connector Kit	This kit enabled the creation of robust and secure wire connections, minimizing the risk of disconnections or faults during operation
10. Jumper Wires	Jumper wires were used extensively to facilitate electrical connections between the Arduino, CNC module board, and motor drivers.
11. Compression Spring	Compression springs were integrated into the moving assemblies to maintain tension and support, reducing backlash and improving motion consistency.

12. M2 Screws (6mm, 8mm, and 10mm)	These screws secured the various structural components, ensuring the stability and durability of the assembled system.
13. Super Glue	Super glue was used for non-mechanical joints, providing additional structural integrity where screws or mechanical fasteners were unnecessary.
14. Laser Safety Glasses	Safety is paramount when working with laser systems. The laser safety glasses protect the user from accidental exposure to the laser beam, ensuring a safe working environment.

3. 3D Printed Parts and Materials

The structure of the DIY Mini Laser Engraver relied heavily on 3D printing. This project utilized two advanced 3D printers: **Bamboo Lab X1C and LuxStar LX-100 Printer.**

All components were printed using PLA, chosen for its eco-friendliness, reliability, and suitability for prototyping. White PLA was printed by LuxStar and used for general structure components. Phosphorescent PLA printed using the Bamboo Lab printer, this material added a unique glow-in-the-dark feature, enhancing the system's aesthetic and functional appeal.

The structural components of the *DIY Mini CNC Laser Engraver* were carefully designed, dimensioned, and fabricated to ensure seamless assembly and functionality. The table below summarizes the 3D-printed parts, including their quantities and dimensions in millimeters (X × Y × Z):

3D Printed Part	**Quantity**	**Dimension (X × Y × Z) in mm**
Frame_Side_L_R	2	7 × 65 × 105
Rail_Frame	2	76 × 35 × 14
Thread_Guide	2	8 × 10 × 5
Slider	2	18 × 35 × 8
Back Plate	1	90 × 53 × 5.40
Base	1	100.87 × 115 × 14.90
Cable_Guide	1	6 × 8 × 4

Laser Holder	1	15.99 × 19.51 × 30
X_Plate	1	60 × 60 × 7.20

The **Frame_Side_L_R** and **Rail_Frame** provided the structural support for the engraver, while smaller components like the **Thread_Guide**, **Cable_Guide**, and **Laser Holder** played key roles in guiding mechanical movement and securing the laser module.

4. Hardware Assembly Processes

The assembly process involved multiple stages, including mechanical assembly, wiring, and integration of electronic components. The first step was to prepare the slider - using super glue to attach the slider and guide into a single integrated part. And adding a compression spring to maintain tension between the guide and the lead screw. These springs are essential to avoid the backslash, which could negatively impact the system's precision and functionality. Next, the Y-axis was assembled by integrating the slider into the base. This required careful alignment to ensure smoothness along the rail without unnecessary friction or misalignment. For the X-axis, the guiding mechanism was attached to the laser housing using a combination of screw and glue. This step was crucial to ensure the guiding mechanism is robust and properly aligned for the laser's movement.

The soldering and wiring process was an important step to ensure the reliability and durability of the electrical connections for the *DIY Mini CNC Laser Engraver*. To establish strong and secure joints, a soldering iron with a tip temperature of **410°C (770°F)** was used. This temperature was carefully selected to efficiently melt the solder wire while preventing damage to the motor's delicate wiring pads. Maintaining this precise temperature was essential—any deviation could result in weak connections, which would compromise performance, or overheating, potentially damaging the electronic components. Following the soldering process, the wiring method was implemented to guarantee the correct functionality of the stepper motors. A standardized **color coding system** was used to ensure proper polarity and prevent errors during operation. The wires were connected as follows: **Yellow (A+), White (A-), Red (B+), and Black (B-)**. By carefully executing the soldering and wiring process, the system achieved durable electrical connections, forming the foundation for precise motor control and reliable system performance.

The final stage of the assembly process involved integrating the electronic components based on the wiring diagram and ensuring their functionality for testing the motors and laser module. Safety was a top priority when working with the laser module. **Laser safety glasses** were used as a precaution to protect against accidental exposure during testing. Proper safety protocols were followed to minimize risks throughout the assembly process. With the electronic components fully integrated, the CNC structure was complete, and the laser module was mounted and ready for testing. This stage marked the successful culmination of the assembly process, ensuring that both mechanical and electrical systems were aligned for reliable performance.

5. Challenges, Solutions and Key Insights

Despite successfully completing the hardware assembly, several challenges emerged throughout the process. One of the most significant challenges was **dimensional inaccuracies in the 3D-printed parts**, particularly the sliders and the base. The holes in these components were undersized, preventing the smooth insertion of the rods and causing excessive friction, which impacted the movement of the sliding axis. To resolve these issues, the holes were **manually widened using a drill** to ensure proper fit, and stabilization holes were manually added to the frame slide to maintain structural integrity. This experience emphasized the critical importance of achieving precise tolerances in the design and printing process to ensure seamless part integration and smooth mechanical operation.

Another notable challenge involved **component compatibility**, specifically with the stepper motors. The motors initially selected were repurposed from Xbox 360 DVD drives and, unfortunately, did not match the required dimensions. The size mismatch created significant gaps between the Rail Frame and the motors, preventing secure mounting and compromising the overall structural stability of the assembly. To address this, correctly sized stepper motors were procured and integrated into the system. The new motors fit seamlessly into the design, restoring proper stability and motion control. This issue underscored the importance of thoroughly verifying part dimensions and specifications before procurement to avoid similar setbacks in future iterations.

Finally, thermal contraction during 3D printing also introduced **surface imperfections** and **uneven material distribution**, particularly on the base. These imperfections created misalignment issues that further impacted the smooth movement of the sliders. While complete elimination of these imperfections was not possible, careful adjustments were made during assembly to minimize their impact. Moving forward, optimizing the 3D printing settings, such as temperature and print speed, and selecting materials with better thermal stability will be essential to reduce shrinkage and improve part quality.

Through overcoming these challenges, several key lessons emerged. First, achieving **precise tolerances** in the design and fabrication phase is critical to ensure seamless assembly and functional performance. Second, verifying the **compatibility of components** prior to procurement is essential to avoid costly errors and assembly delays. Finally, the iterative nature of troubleshooting and hands-on adjustments plays a vital role in addressing unforeseen issues, underscoring the importance of flexibility and problem-solving in the design and fabrication process.

6. Software Setup: Arduino IDE and GRBL Firmware

The software setup was a crucial step in configuring the *DIY Mini CNC Laser Engraver* for operation. The process began with downloading and installing the **Arduino IDE** software from the official website. The **Arduino Uno** board was then connected to the computer via USB, and the appropriate COM port was selected within the IDE to establish communication. Next, the **GRBL firmware**, a widely used motion control software for CNC systems, was downloaded from its official repository. Using **Windows PowerShell**, the GRBL path was copied into the Arduino libraries directory. This allowed the firmware to be uploaded to the Arduino Uno as a sketch within the IDE, effectively enabling the microcontroller to interpret and execute G-Code commands. To send G-Code to the CNC system, the software **LaserGRBL** was used. Recognized as one of the best G-Code streamers for DIY laser engravers, LaserGRBL offers powerful functionality. It can load and stream G-Code paths directly to the Arduino and engrave images using its built-in conversion tools. This software proved essential for controlling the laser module and motors, bridging the gap between the system's hardware and its intended operations. Through this setup, the system could be fully configured to interpret G-Code commands, laying the groundwork for precision engraving and smooth system performance.

7. Results and Future Directions

The project achieved significant milestones in hardware and system integration. The **wiring and hardware setup** were successfully completed, with all critical components—such as the **laser module**, **stepper motors**, and **electronic connections**—fully assembled and functional. This ensured the physical and electrical integrity of the *DIY Mini CNC Laser Engraver* and demonstrated the system's potential for small-scale engraving tasks. However, challenges remain in configuring the **LaserGRBL software**. The current settings require fine-tuning to establish smooth communication between the CNC driver board, stepper motors, and laser module. The software's ability to send coordinated engraving commands is critical for full system functionality, and troubleshooting efforts are ongoing to resolve these technical issues.

The next steps for advancing the *DIY Mini CNC Laser Engraver* focus on two key improvements: optimizing software settings and developing a larger system design. The immediate priority is to **finalize the GRBL configuration** to ensure the laser module and stepper motors operate smoothly in sync with the engraving commands sent through LaserGRBL. This will involve revisiting GRBL documentation and troubleshooting communication errors to improve system precision and reliability.

Looking ahead, the goal is to design a **larger and more robust CNC machine**. A scaled-up version would allow for larger engraving areas and more advanced applications. Key improvements will include **better tolerance control** for precise part dimensions, **modular components** for easier assembly and upgrades, and **reliable assembly methods** to enhance structural stability and performance.By addressing these areas, future iterations of the CNC machine will build upon the current proof-of-concept and enable greater versatility and functionality.