Controllable, User-Friendly 3-Phase Inverter

Group 81

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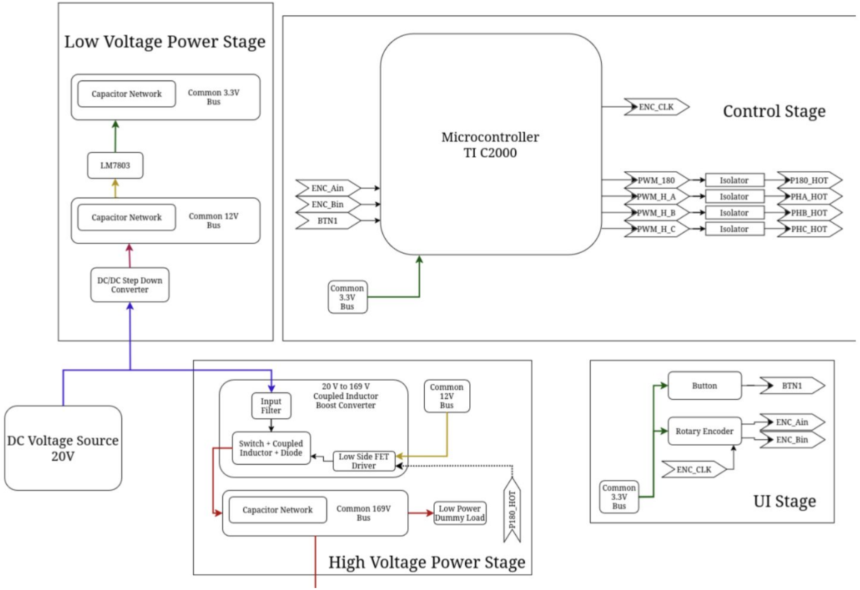
Project Introduction

- Creating an inverter system that is capable of creating three AC waveforms with controllable phase angles
- Phase A will serve as the reference 0-degree phase, while the B and C phases will be controllable with respect to this reference phase
- Adjustments made using encoders for analog input, phases constantly adjust
- Switching control handled by the microntroller board, which responds to analog input changes in real time

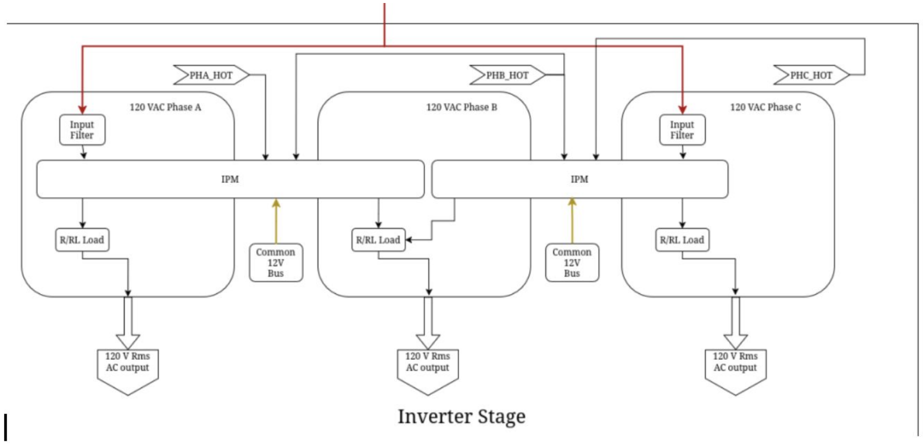
Project Objective

- Use this inverter to test fault conditions of small AC and brushless DC motors, as well as other equipment
- Ideal 3-phase systems have consistent phase angles of 120 between the three phases
- Sometimes a 3-phase system might be slightly out of phase by a few degrees, making the system unbalanced and potentially dangerous to operate
- This project allows testing of unbalanced AC systems, which is useful for many research and product development purposes

Block Diagram



Boost, User Interface, and Microcontroller

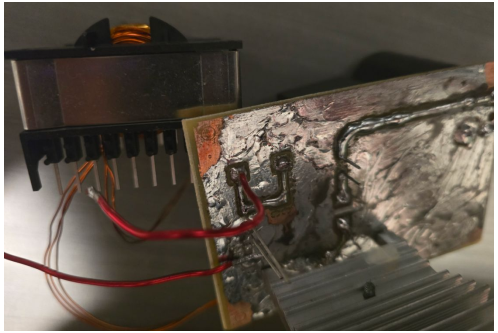


Bridge Subsystem

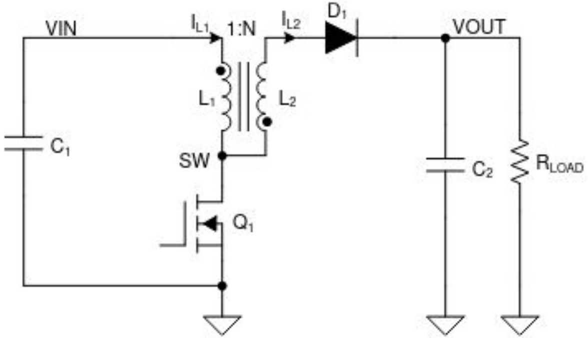
Boost Subsystem

- Trying to boost the input voltage as much as possible
- We will be using a constant DC supply instead of a solar panel (reduced cost and complexity)
- To achieve this, we decided to implement an asynchronous coupled Inductor boost converter, pictured below

Populated PCB Side 2

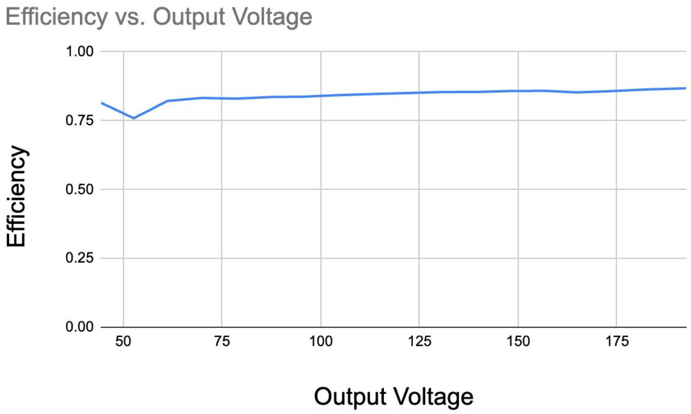


Topology Schematic

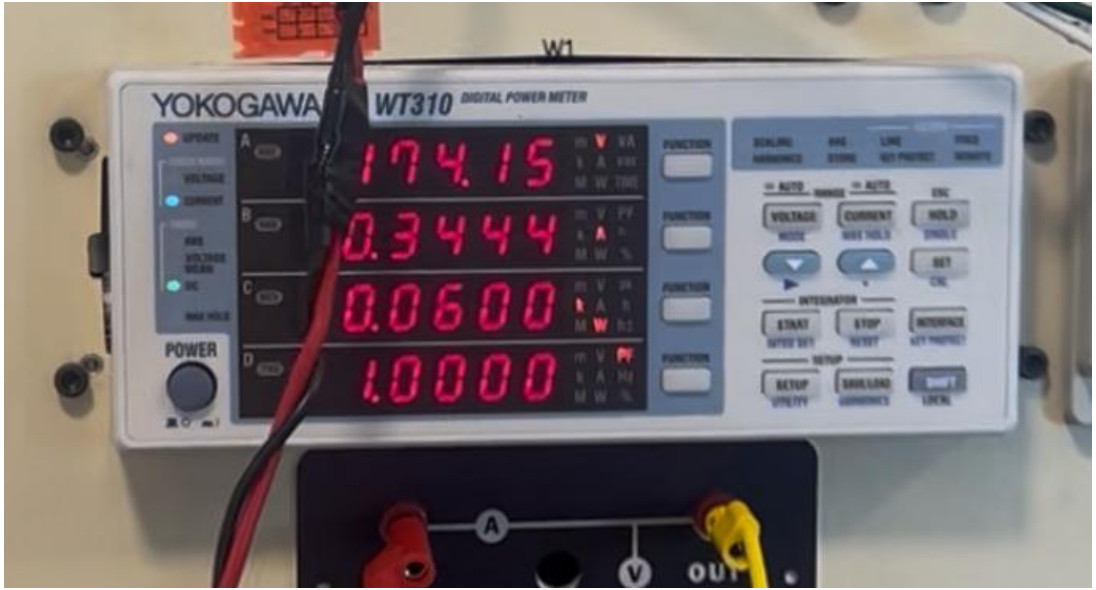


Boost Subsystem

- Results
  - We were able to create a converter that boosts the voltage by a scale of about 9.425 (20V to 188.49V) [8.7 at high load 20 to 174V)
  - 2 Degrees of freedom: Turns Ratio [20:60] and Duty Ratio [67%].
  - Must have load at all times
  - Added Bonus
    - Minimal heat generated
    - 85% efficiency across the board
    - Capable of delivering high power
    - 100W Max before dropping below 100V
    - Extremely low voltage ripple



Boost Converter Results

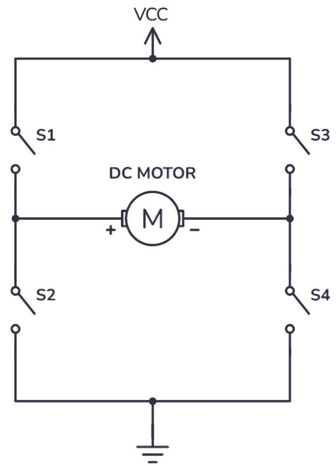


Power Meter Output

- 20V input
- 174V output
- 0.344A output
- 500 Ohm load
- 60W at the output

Bridge Subsystem

- Switching of boosted DC voltage into variable AC waveform
- Receives what the voltage should be and uses a system of h-bridges to achieve the proper voltage
- 3 full H-bridges for three phases (A, B, and C)
- Phase A will not change as we want it to stay 0 degree phase
    - Only phases B and C will change

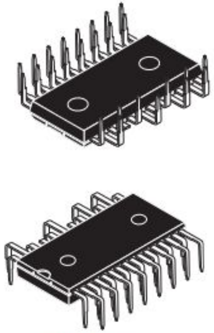


H-Bridge Diagram

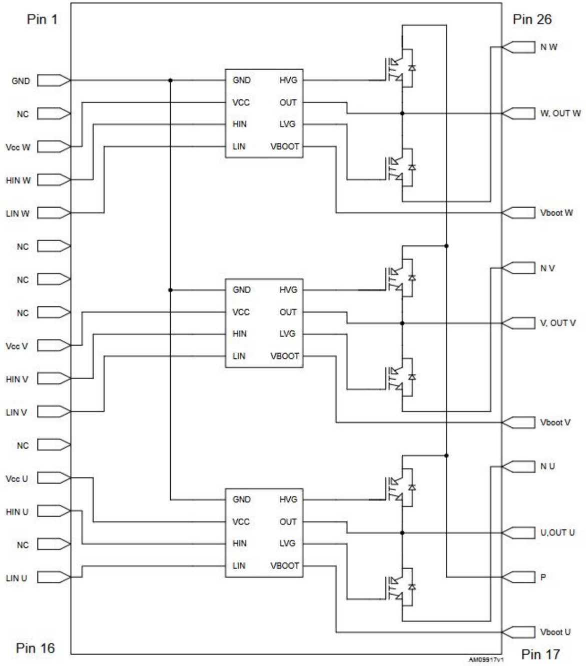
Bridge Subsystem

IPMs

- High voltage rating while being able to be wired as 3 H-bridges
- Integrated



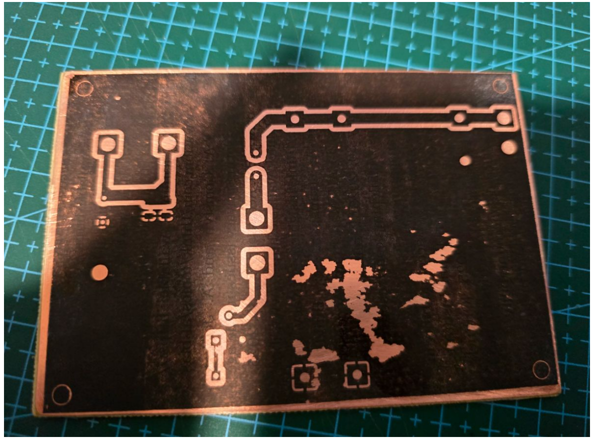
NDIP-26L



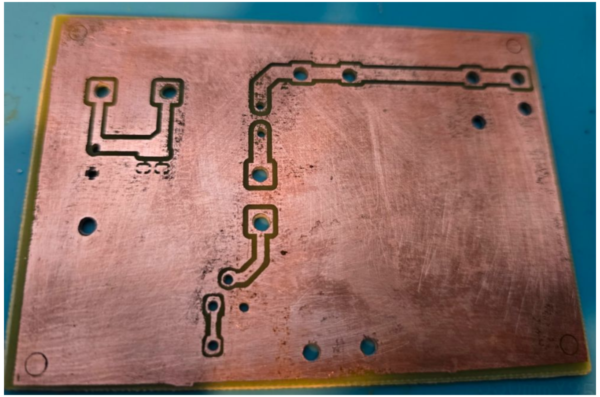
PCB Production

- Flipped image of Kicad schematic is printed on glossy paper using a laser printer
- The toner is transferred to the copper using iron
- The toner protects copper from being dissolved

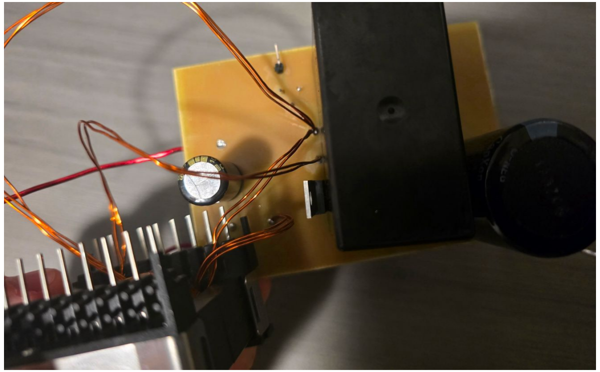
Raw PCB after toner transfer



Raw PCB after solution



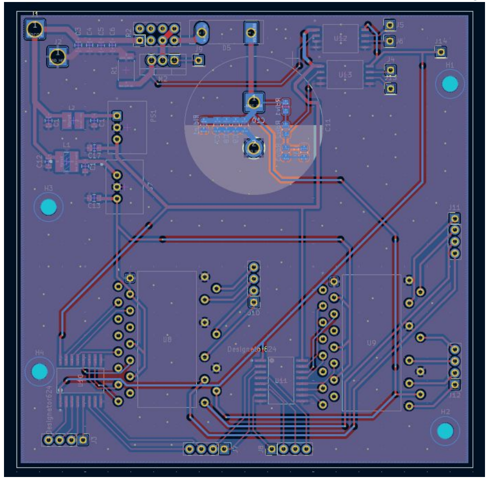
Populated PCB Side 1



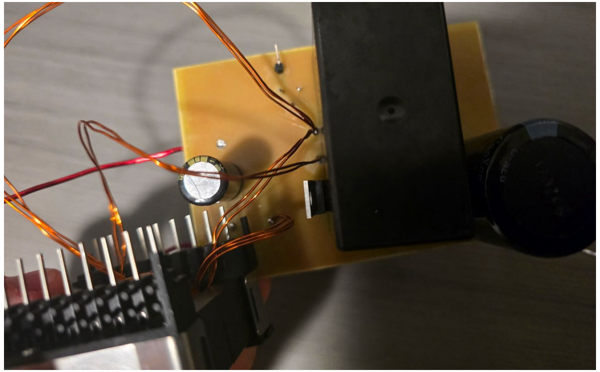
PCB Production

- 3% Hydrogen peroxide, citric acid and table salt solution is used to dissolve unwated copper
- After sultion the toner is sanded off with 300 sandpaper
- The copper is heated up with liquid flux and tinned with 63/37 tin/lead wire
- Components are soldered in at the end

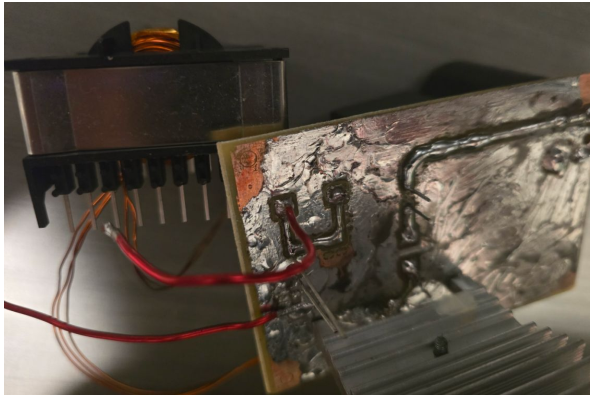
Inverter Board Kicad Layout



Populated PCB Side 1

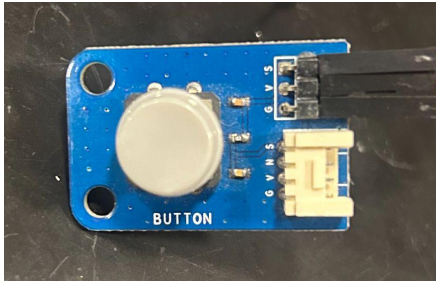


Populated PCB Side 2

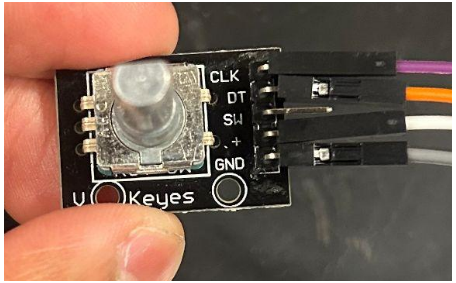


User Interface Subsystem

- 2 encoders and a button.
- Each encoder will correspond to Phase B and C to adjust the desired phase.
- The button confirms that we want to update the display with the new values from the encoder
- Future development would involve the integration of further user control



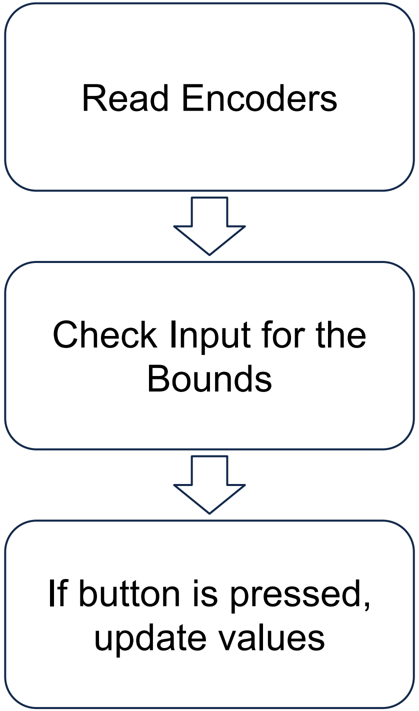
Button Encoder



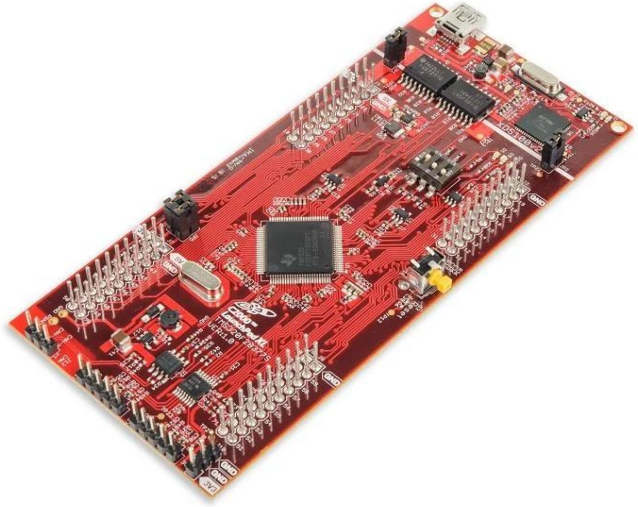
Rotary Encoder

Input Control Subsystem

- Checks whether the input values from the encoders are valid
- If this is the case and the button is being pressed down, it updates the values that will get sent into the switching control subsystem
- Programmed into the microcontroller
- Used quatrature decoding logic to read encoders
  - Uses 2 square waves produced by encoder



TIC2000 Micrcontroller

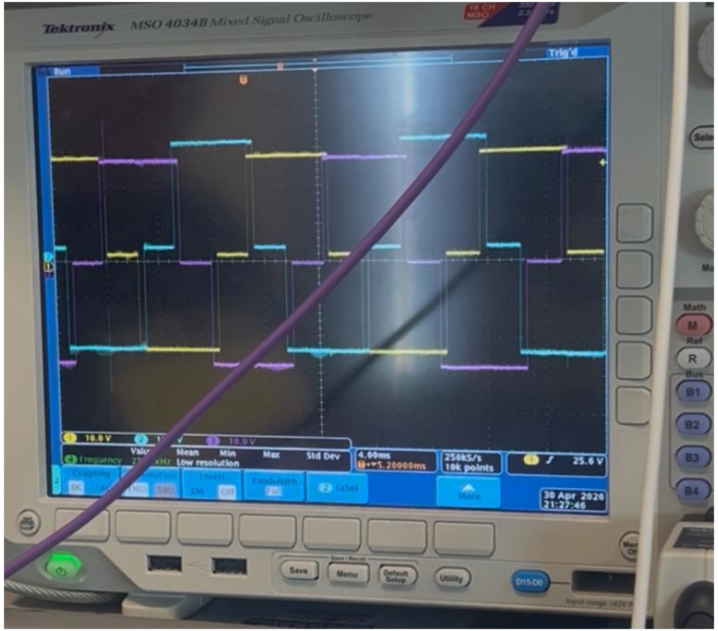


Why?

- The number of input and output channels and familiarity with the TI microcontrollers were appealing
- Integrated firmware development environment as this project is very control-focused
- Integration of microntroller

Switching Control Subsystem

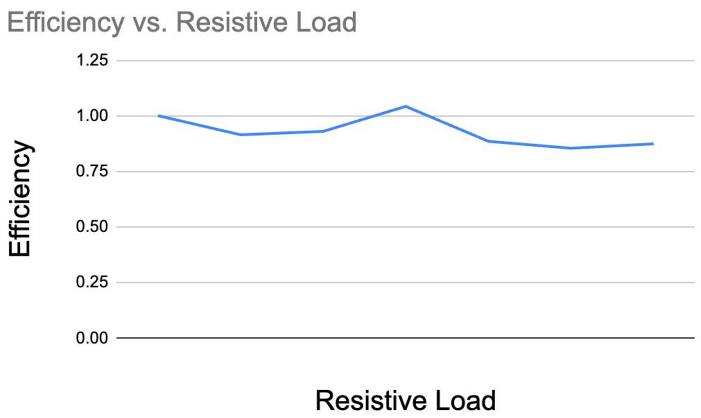
- Also coded in the microcontroller
- Follows timers to control the inverter and DC-DC switching
- Initial phase angles
  - Phase B: 120 degrees
  - Phase C: 240 degrees = -120 degrees
- As the 2 phases change, the timing gets shifted with respect to phase A by the desired phase



Default 3-Phase Output

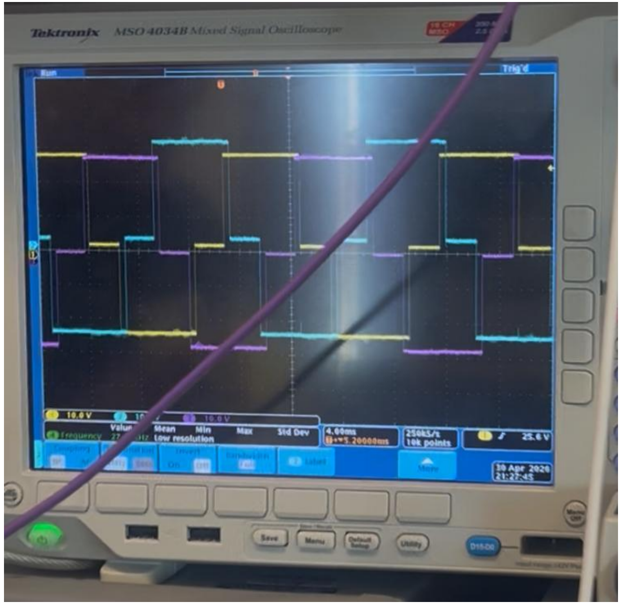
Switching Control Subsystem

- Each phase produces 4 square waves
  - High signal, Low signal, and their complements
- DC-DC switching control is open-loop, will boost any voltage by some given ratio
  - In the future, the microcontroller will read AC output and respond accordingly to produce the needed DC voltage
  - Allows for more stable output that could be tied to a larger power grid as a regular inverter



Successes and Challenges

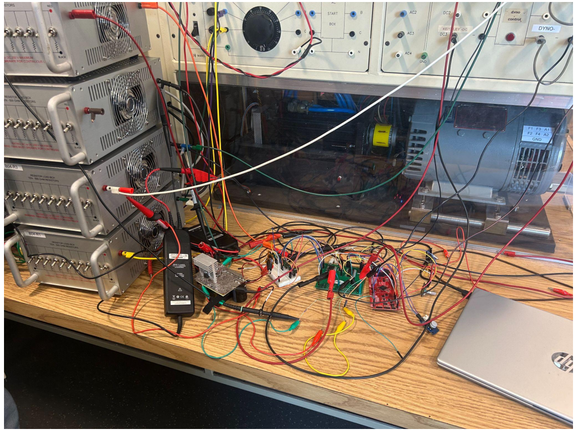
- Successes
  - 3 phases that increase and decrease in amplitude according to the input voltage
  - Boost converter with minimal heat generated
- Challenges
  - ICs fried
  - Navigating TI CCS software
  - Parts placed on backorder
  - Use of lab equipment



Final 3-phase Waveforms

Conclusion

- Generally met our goals at the start of the semester
- Very good experience working with high voltage and microcontrollers
- Potential Redesigns
  - Use of large inductors for smoother sine wave
  - Placing everything onto a single PCB
  - Design around a more enclosed structure
- Future Work
  - Integration of closed-loop boost conversion
  - Allow the user to input a range of DC input voltages



Final Demo Setup


ILLINOIS