Controllable, User-Friendly 3-Phase Inverter

By

Alex Chirita

Shyam Peden

Johnathan Vogt

Project Proposal for ECE 445, Senior Design, Spring 2026

TA: Frey Zhao

13 February 2026

Project No. 81

Contents

1. Introduction

1.1 Problem

While normal 3-phase AC power systems operate with consistent phase differences of 120 degrees, these systems are not always perfect. There may be occasions (fault conditions) where the power system becomes unbalanced. In order to test small machines under these conditions, one might want to create controllable AC waveforms with adjustable phase angles.

1.2 Solution

We will create 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. This will be achieved using analog control, likely via potentiometers. The PCB will function as a normal 3-phase switching inverter, with switching control handled by the microprocessor, which takes input from analog signals to control the output AC waveforms. There will be 5 main subsystems: input stage with a buck-boost topology, 3 MOSFET H-bridges, Encoder, CONFIRM button, and a small OLED Display as the user interface, and a TI-C2000 microcontroller, as it has enough PWM channels and high resolution timers, whose firmware will include the user input control, and the power control for the bridge.

1.3 Visual Aid

Figure 1 shows a visual representation of our solution.

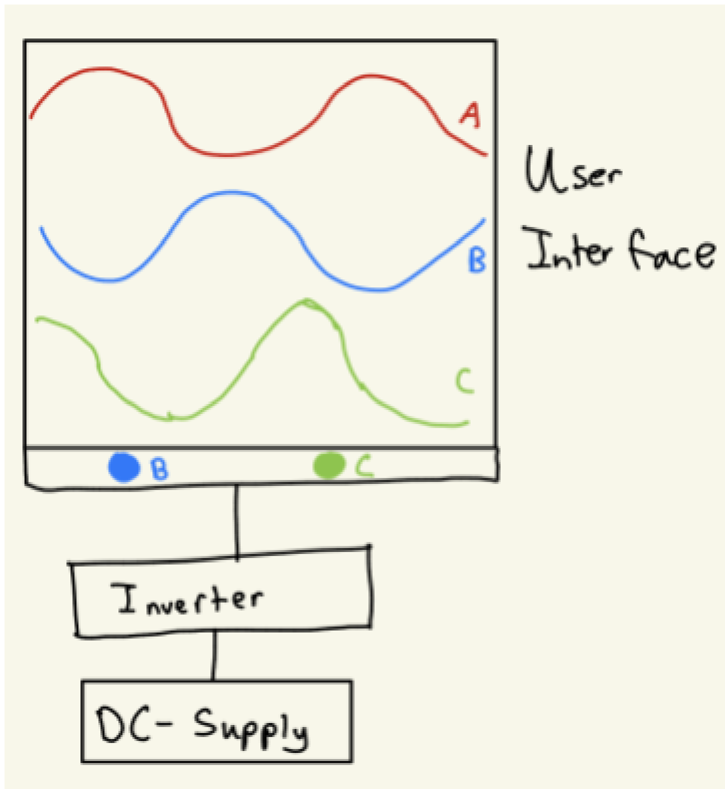


Figure 1: Illustration of our proposed solution with a DC supply, inverter, and user interface, all shown

1.4 High-Level Requirements List

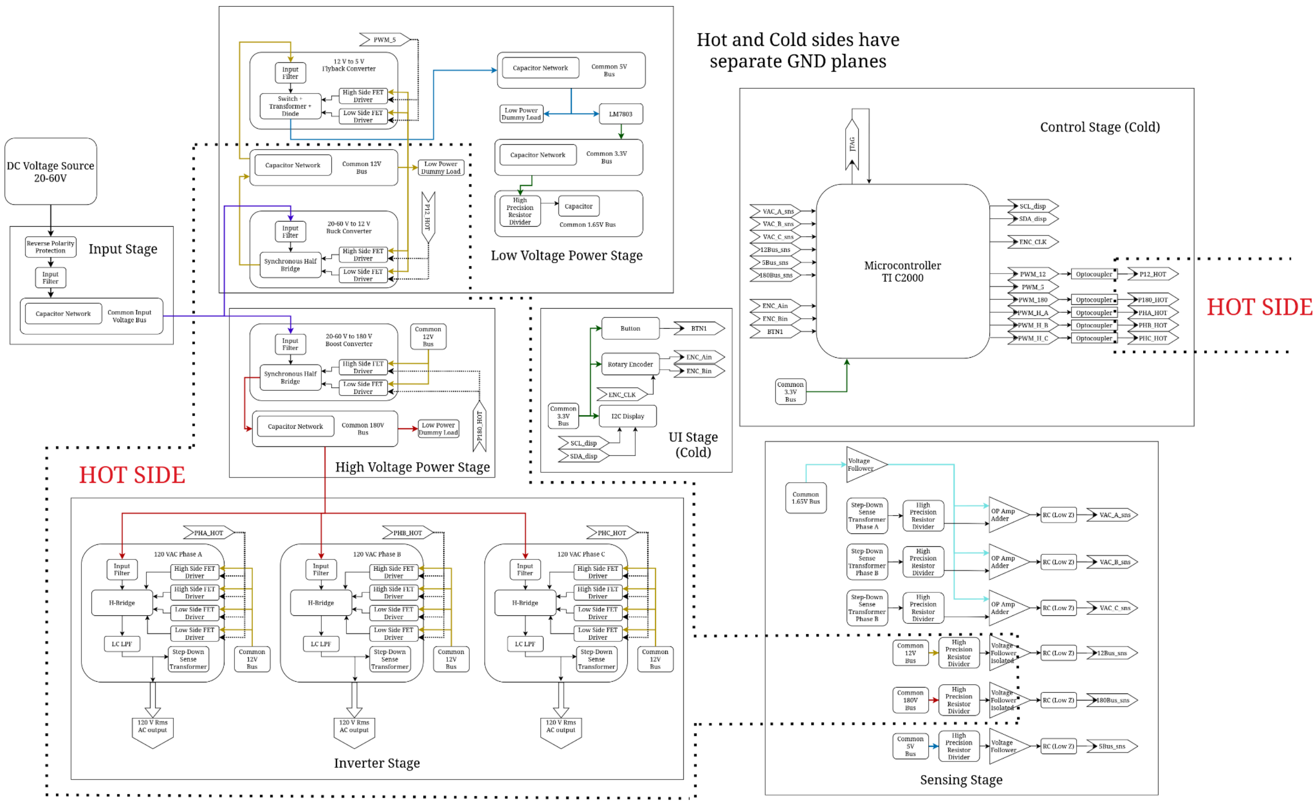
Our high-level requirements in order to consider the problem solved are shown below. In addition, qualitatively, we would like the user interface to be able to properly display all 3 waveforms without fail, with Phase A corresponding to a 0-degree phase and Phases B and C properly updating. The inverter will be tested on a Wye-Connected resistive load.

1. The Output RMS voltage will be 120V ±5%.
2. The inverter will output up to 0.28 A per phase, corresponding to 100 W of 3-phase output power.
3. The microprocessor will respond rapidly to input or phase adjustments, switching the DC-DC converter as necessary to maintain constant amplitude and the inverter to maintain phase.

2 Design

2.1 Block Diagram

Below is the block diagram for our proposed solution.



2.2 Subsystem Overview and Requirements

2.2.1 Buck-Boost Subsystem

The main purpose of this project is the inverter stage, while the input will be any sort of DC power that mimics a solar panel. We will not focus on it being powered from a solar panel during the semester, and leave it as a modification/addition to the inverter part for further development. The input voltage needs to be converted to a setpoint and fed into a common DC bus. This will be done with a half-bridge buck-boost converter. A good quality of this system is the freedom to choose which variables to control. The circuit will be able to respond to quick changes in input voltage, but this semester we will be using a constant DC power supply instead of a solar panel to reduce cost and complexity. Therefore, the buck-boost converter will be run by a switching algorithm with a fixed input voltage. Later, the converter could be used as an MPPT if needed.

2.2.2 Bridge Subsystem

The bridge subsystem will contain three MOSFET H-bridges, each corresponding to one of the phases. Each of the phases will have a similar layout since the control is only achieved by the gate signal, which is fully generated by the microcontroller. We decided to go with an H-bridge because it's a good middle ground between multi-level bridges and a half-bridge. The H-bridge will allow us to generate a good-quality sine wave when averaged out and filtered with series inductors, which will be external to the board. The sine wave will be generated from -Vmax to +Vmax, and the sign will be decided by using a proper pair of MOSFETS from the 4 available. Each MOSFET will have a corresponding low-side or high-side gate driver, which will receive its PWM control signals from the microcontroller. Each phase will have an LC low-pass filter at the end to reduce switching harmonics. Our target output from the bridge system will be 120 Vrms with a tolerance of 2%. This is also one of our high-level requirements.

2.2.3 User Interface Subsystem

The user interface will consist of a display, an encoder, and a confirm button. The user will use the encoder and confirm button to navigate the user interface, where the phase angle will be set for phases B and C in relation to phase A, which is static. Users can also choose to use an autoset, where the microcontroller will default to 120 degrees between each of the phases. We want the user interface to update as the input changes. More specifically, we want the interface to update within around 250 ms of a change in input.

2.2.4 Input Control Subsystem

The microcontroller will run polling input from the button and encoders, run a loop that checks whether the phase is within bounds (-180 to +180 degrees with respect to phase A), and override the proper variables, which will be used by the switching subsystem as the target phase angle. We will need this system to update and override the variables rapidly for one of our high-level requirements.

2.2.5 Switching Control Subsystem

The constant loop will check the phase angle variables and calculate the expected voltage for each phase. It will then generate the PWM for each phase that matches the needed Vrms. The output voltage, which first went into the resistor divider to fit within the maximum operating voltage of the microcontroller, will be collected as samples over the wave period, Vrms calculated and compared to the set Vrms after which the switching signals for each phase will be adjusted.

2.3 Tolerance Analysis

One aspect of our design that could pose an issue to the successful completion of the project is the cutoff frequency of our low-pass filter. We need to use the values of our inductor and capacitor such that our cutoff frequency is much smaller than the switching frequency. We simply have to design our low-pass filters with values that account for this. Below, you can see mathematical equations for this design. We can use a switching frequency of 20 kHz. As you can see, even considering the tolerances of the capacitor and inductor, we will still get a value that is much smaller than 20 kHz.

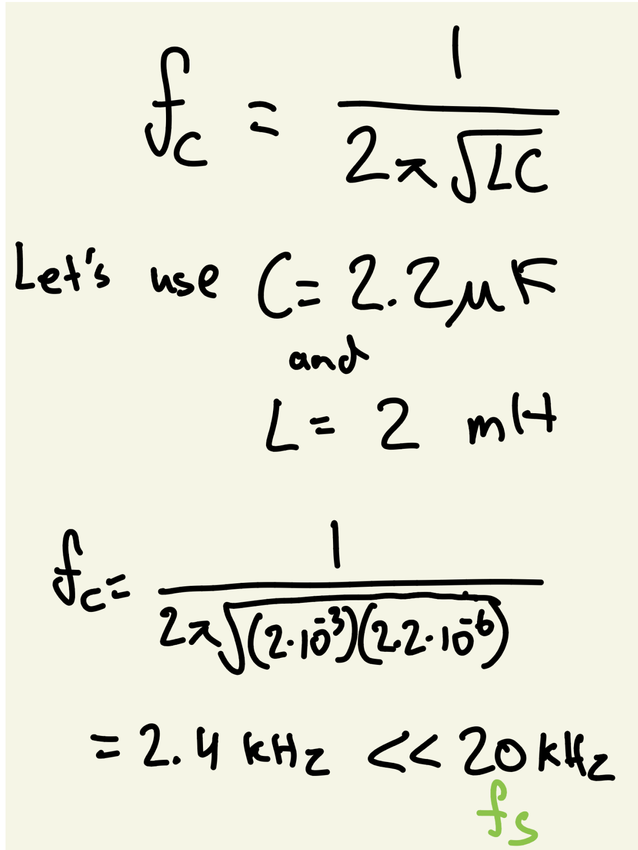


Figure 2: Mathematical Analysis of calculating the cutoff frequency of low-pass filters

3. Ethics, Safety, and Societal Impact

3.1 Ethics

The primary ethical issue we could run into with this project is that we must avoid harm to the user, as mentioned in Article 1.2 in the ACM Code of Ethics. We must prioritize the safety of the user while trying to maintain functionality. If we failed to do this, we would run into an ethical breach. We can do this through electrical isolation. In our situation, electrical isolation would prevent any unwanted transfer of DC voltage from the input and the buck-boost system to the AC currents we are displaying. By doing this, we can avoid a potential ethical issue.

Another ethical issue we could face is upholding integrity during this entire design and implementation process. The first article of the IEEE Code of Ethics and Article 1.3 of the ACM Code of Ethics discuss being honest and trustworthy when reporting measurements. This is incredibly important in a professional environment because failure to report results with integrity could result in a future user getting harmed. This would result in another ethics breach. False results also prevent progress on the project. To avoid this, we will be honest when reporting our results through every stage of our project.

3.2 Safety

The biggest safety issue for this project is dealing with high voltages. Since we are dealing with high voltages, we must take heavy precautions when designing and working with our circuit. By taking proper precautions, we lower the risk of electric shock, electrocution, thermal burns, etc.

3.3 Societal Impact

Our solution could impact testing small machines by preventing fault conditions where they are unbalanced. Being able to account for every type of situation when testing a small machine would be extremely beneficial since testing of these three-phase systems can be more controlled. From an economic standpoint, our project can potentially help lower costs on early-stage research for smaller machines. This is obviously very beneficial since costs are lowered. Finally, from a global context, 3-phase systems are used in a variety of industries. An improvement in testing these systems has a positive impact globally.

Appendix A. Full-Size Block Diagram