

ECE 480 Pre-Proposal
Little Box Challenge, Group 7
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Introduction

The Electrical and Computer Engineering 480 team 7 project is a precursor to the IEEE/Google Little Box Challenge. Inverters which take direct current and convert to alternating current for everyday use are currently about the size of small coolers. If made even smaller, inverters would be able to be used in more applications and by more people.^[1]

The challenge is to make a small, high power inverter. The guidelines that IEEE/Google have laid out for this project are to have a power density of 50 W/in^3 and a physical size of less than 40 in^3 . The challenge is to have a 450 V DC input and invert this to 240 V 60 Hz AC. The inverter must perform the aforementioned with an efficiency of 95%, maintaining a temperature of less than 60 degrees celsius, and complying with FCC Part 15 B.

Unlike other groups, team 7 does not have a corporate sponsor. However, the team is coordinating with Professor Timothy Grotjohn and has a faculty advisor, Professor Selin Aviyente.

Objectives

Due to a 15 week semester time requirement, the IEEE/Google guidelines have been modified. Changing the voltage requirements to a 24 V DC input and 120 V 60 Hz AC output will allow for an appropriate time table. The group will have a power requirement of 1 KVA, but the physical size and temperature specifications will remain the same as the IEEE/Google guidelines. Throughout the design process the group will be pushing different component types to their limits to identify baseline best practices.

Conceptual Designs and Ranking

The team decided that splitting the design process into a number of phases would be the most practical way to achieve the final goal. This is largely due to the fact that smaller voltages are simpler to work with in regards to efficiency and heat considerations.

Phase One: The group will model four initial designs using PSpice. Special attention will be paid to the efficiency of these designs, which is amongst the most important design parameters. The initial design ideas are as follows:

- H-bridge using IGBTs (Figure 1): A set of four insulated-gate bipolar transistors configured in H-formation, using pulse width modulation from a TI MSP430 to

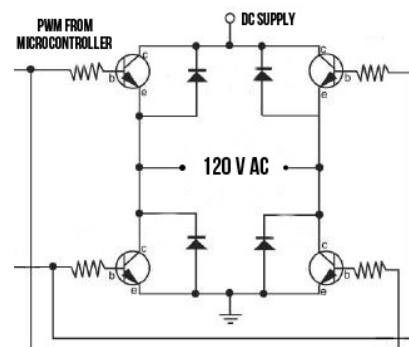
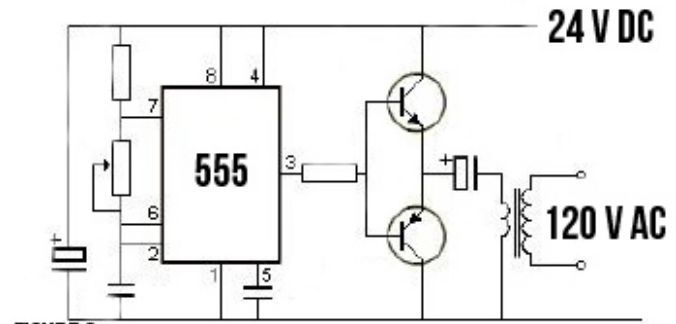


FIGURE 1

achieve as high-resolution 60 Hz sine wave.

- Quantized-step MOSFET with output transformer: Metal-oxide semiconductor field-effect transistors configured to deliver $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, and full voltage of positive and negative peaks, triggered with a TI MSP430 to create a “virtual” sine wave. An output transformer is included to achieve the correct voltage level.

- 555 bridge design (Figure 2): One NPN transistor with a matched PNP transistor, both silicon based, triggered with a 555-timer configured to create a 60 Hz square wave.



- Car inverter: The group will buy a commercial inverter (designed for 12 V DC use), reverse engineer the layout, and model; special attention paid to board layout.

Phase Two: The group will analyze the PSpice models from phase one and select the best with regards to efficiency and practicability. This design will be prototyped and the current will be increased to find the power limits of the material being worked with, beginning with Silicon transistors. Heat dissipation solutions will begin being formed.

Phase Three: Proposed design from phase one is prototyped using updated materials (Gallium Nitride and/or Silicon Carbide). Power is stepped up to test new materials for their limit. Heat sink solutions are expanded to include the use of aluminum, synthetic diamond, and thermo-electric coolers. Power is stepped up a final time.

Phase Four: Chosen design is built with the use of printed circuit boards and custom enclosure. 100+ hours of testing is performed at objective specifications while design issues are troubleshooted and solved.

Proposed Design Solution

The team will solidify the appropriate solution by following the proposed four phase process. It is expected that the preferred design will be the IGBT H-Bridge because of the rate at which the IGBTs are able to switch on and off. The final design is expected to require some level of filtering to comply with FCC regulations.

Risk Analysis

The two main design challenges that the group faces are heat and physical size, both which are as a direct result of increasing the power through the components. Components will be spaced closer together, but this will make heat dissipation evermore crucial.

Containing the circuitry inside a 40 in³ box will limit air flow around the electronics and cause internal temperatures to rise quickly. To combat rising temperatures, four main areas will be researched and developed for the deliverable: materials, conduction of heat removed from the electronics, the convection of air inside the enclosure, and the design of heat dissipation systems.

In designing these power electronic systems, the group will look at the effective upper temperature limits for different components. The group plans on testing different components under like conditions. From the results it will be determined what components, Gallium Nitride and/or Silicon Carbide, would fit best within the constraints of the design. Copper, aluminum, and synthetic diamond will be tested for dissipation effectiveness. Effective surface area and materials in contact with the circuitry will be the primary conduction focus. Increasing fluid flow inside the enclosure is critical to increase convection for dissipation. Three methods are currently being considered: heatsinks, fans, and vents.

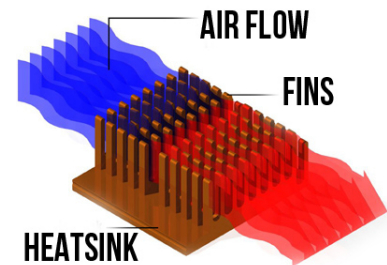


FIGURE 3^[2]

The group is looking towards using silicon carbide for circuit materials, diamond and thermal grease for conduction, and copper - perhaps with fans or thermo-electric coolers - for the convection design. The final dissipation design will be a heat sink given the limited space inside the enclosure.

Project Management

Team 7 consists of five members:

Philip Beard - Webmaster, Design Modeling
Jacob Brettrager - Document Preparation, Programming
Jack Grundemann - Presentation Preparation, Heat Analysis
Stanley Karas - Management, Design Modeling
Travis Meade - Lab Coordinator, Programming

The included roles are assigned for the initial two phases. Responsibilities are likely to expand and change as the project progresses. The group plans to develop an effective timeline to prohibit rushing during the first week of December before design day.

Budget

A cost analysis will begin once the preferred design is chosen following completion of phase one.

References

[1] IEEE/Google Little Box Challenge Official Website <https://www.littleboxchallenge.com/>

[2] ECNMag Official Website <http://www.ecnmag.com/sites/ecnmag.com/files/legacyimages>