Ihsan Salari
Portfolio

Electrohydrodynamic Propulsion

Designed and constructed:

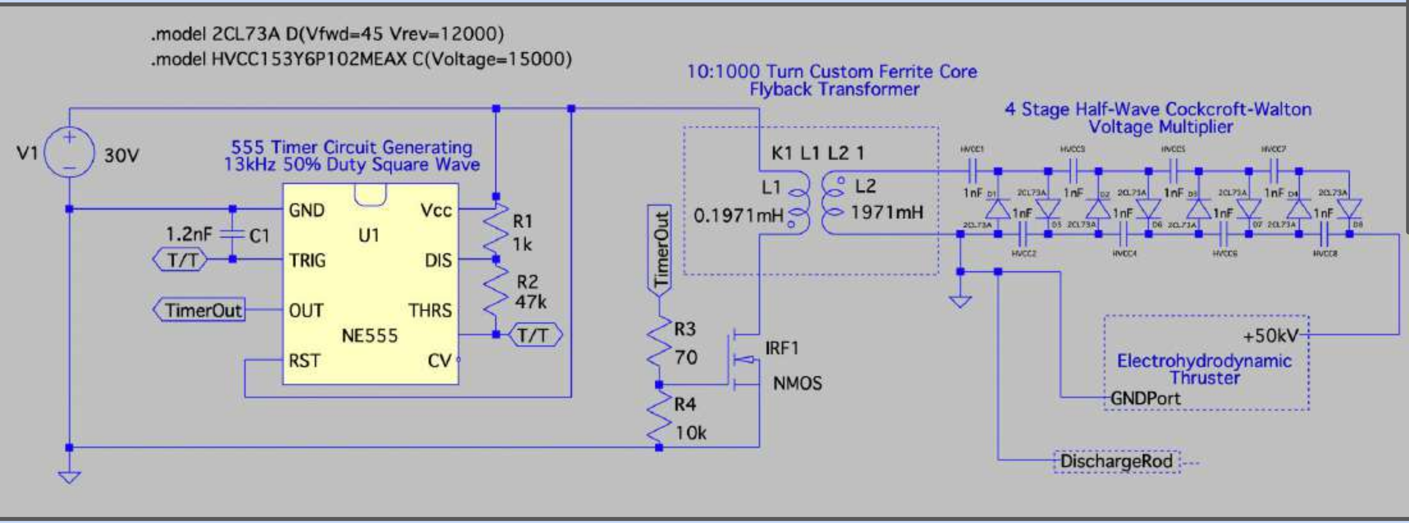
- 50kV 100W high voltage power converter and
- electrohydrodynamic (ionic) thruster which achieved ionic wind speed of 1.5m/s and thrust of 40mN (see image).

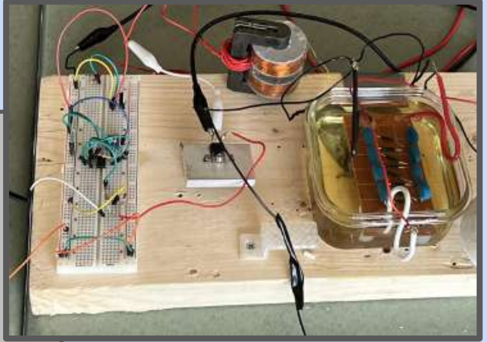
Inspired by MIT, authored paper on the spatial optimization of electrohydrodynamic thrusters.

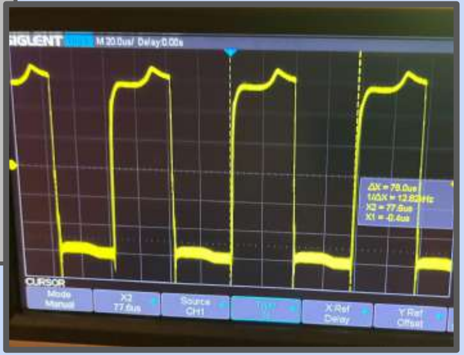
Derived trends mathematically and confirmed them in custom experiment.

YouTube video: https://www.youtube.com/watch?v=MWuXdMzDU_8

50kV 100W High Voltage Power Converter







__Above:__ 13kHz square wave used to drive flyback transformer in a reliable and easy to troubleshoot manner for V1.0 of the power converter.

- Implemented a flyback transformer and half-wave Cockcroft-Walton voltage multiplier topology for increased reliability and low part count.
- Insulated voltage multiplier and transformer in oil in order to prevent arcing and corona discharge losses.

Improvements underway:

- Larger transformer core in order to increase saturation threshold.
- More efficient zero voltage switching (ZVS) transformer driver circuit.
- 100mA high voltage diodes in order to increase maximum output current.

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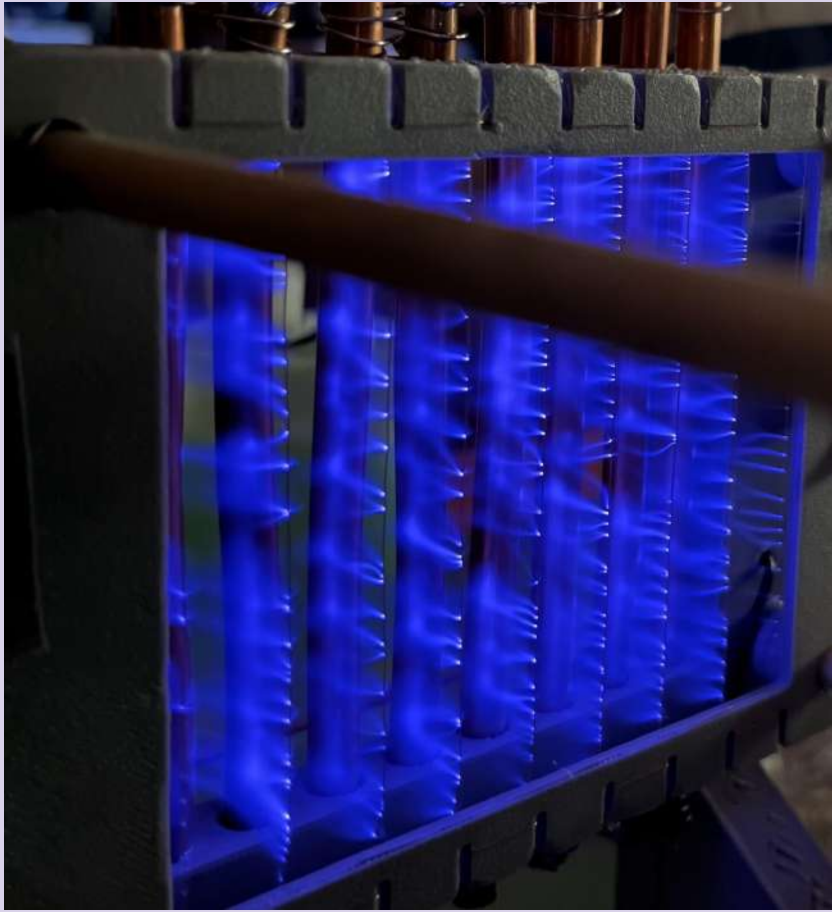
Electrohydrodynamic (EHD) Thruster

- Constructed EHD thruster which generated ionic wind speed of 1.5m/s and 40mN of thrust in experimental two electrode setup.
- Used 34.5 AWG wire as emitter (E) electrode (+50kV) and 6.35mm copper tubes as collector (C) electrode (0V) in order to promote and discourage corona discharge on the E and C electrodes respectively.
- Constructed both desktop eight electrode pair EHD thruster (seen to the right) and two electrode pair experiment EHD thruster (seen in red).
- Designed modular thruster frames in Fusion 360 in order to allow for several thruster modules to be positioned in series with adjustable spacing.



We can observe the purple/blue corona discharge and plasma originating at the emitter and moving toward the collector.

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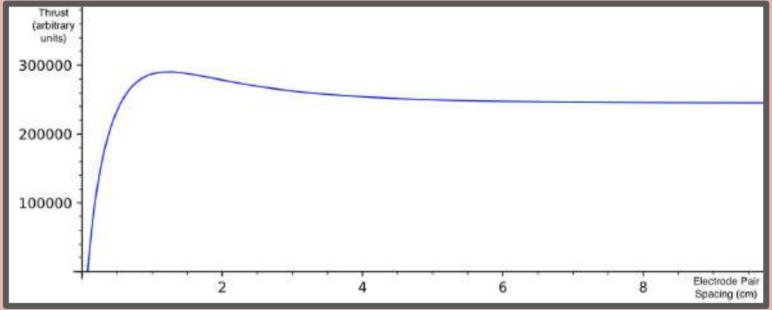
Experimental Research in Electrohydrodynamic Propulsion

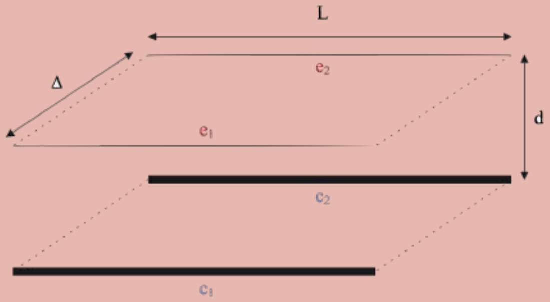


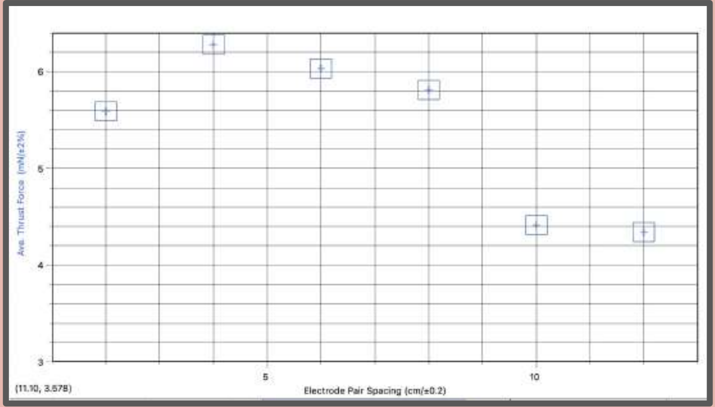
- Inspired by MIT research, derived and experimentally confirmed optimal electrode pair spacing in single-stage electrohydrodynamic thrusters consisting of two wire-to-cylinder electrode pairs in parallel operation.
- Spatial optimization of electrohydrodynamic thrusters is important as this technology is rather spatially inefficient at this point in time.

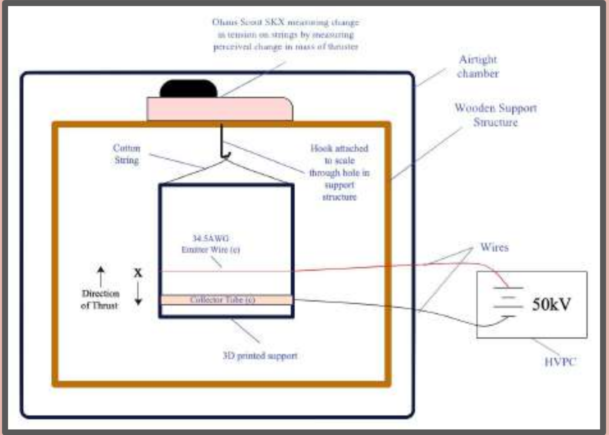
Theoretical derived relationship (above) and experimental relationship (below) both confirm existence of optimal electrode pair spacing.

Diagrams of experimental setup

Varied electrode pair spacing (Δ) and measured resulting thrust in order to determine optimal Δ for given d.





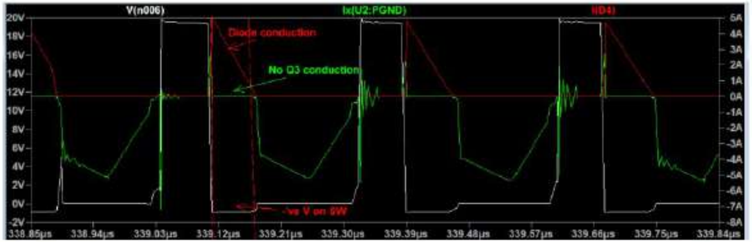


3.5MHz Multi-Stage GaN DC to DC Converter for Advanced Multi-Beam Sonar

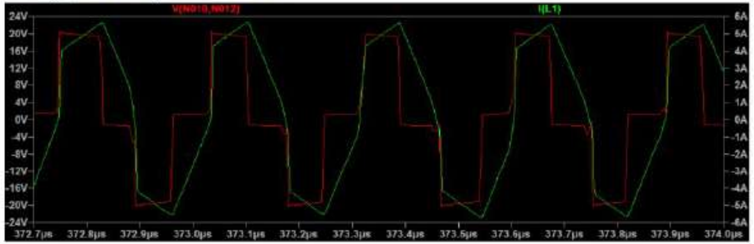
aiRadar

Drove topology selection, design, simulation, mathematical validation, firmware development, part selection, bringup and testing, and tech note documentation of 10 to 50V input, 20V output converter and 10-50V input, 25 to 300V output converter with envelope tracking capability.

Above: Output voltage (yellow), either side of transformer secondary (purple/blue), rectified output (green), voltage across secondary (white).



(a) Graph 1: *green:* current flowing in reverse through bottom FET; *white:* switch node voltage; *red:* body diode current



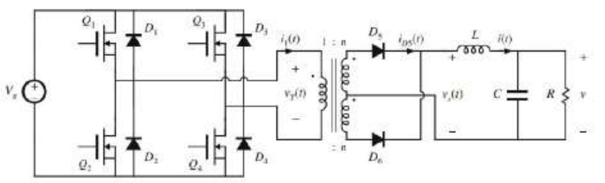
(b) Graph 2: *green:* current through transformer primary; *red:* voltage across primary

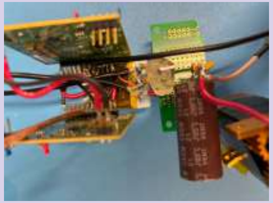
Figure 38: Configuration B: Ideal diode configuration SPICE simulation results.

As we can see from the simulation results in Figure 38, adding an ideal body diode across the bottom FETs completely eliminates third quadrant conduction and the entirety of the current flows through the body diode, as seen in Figure 38a. Figure 38b also shows very clean primary drive current and primary voltage.

Above: Extract of tech note: **SPICE** simulation of the addition of a body diode across **GaN FET**.

Left/below: Converter prototype home lab test setup. **Full-bridge buck-derived isolated converter** (see diagram).





Left: Early protoboard test setup which proved existing design to be flawed and spurred redesign I led.

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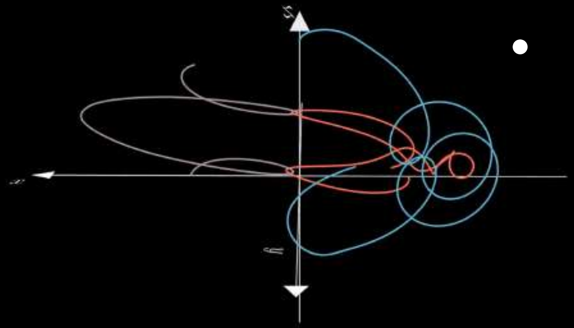
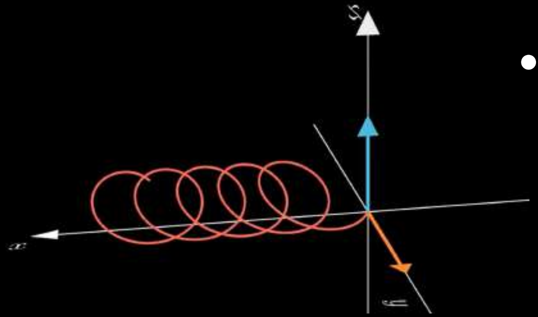
Lorentz Solver E&M Simulation Software - Docs



Above: Simulation of charged particle paths in a complex EM space with other charged particles and magnetic and electric fields.



Above: Simulation of **E cross B drift** (blue arrow: B, orange arrow: E)

- C++ code parses configuration text file, creates electromagnetic objects accordingly and subsequently computes particle paths using a hybrid numerical integration method based on RK4 and Euler methods.
- Python script reads computed trajectories from CSV and animates simulation object descriptions and 3D particle paths using Manim (3b1b library).
- Can simulate spaces with charged particles, static point charges, current carrying wires, uniform E and B fields, and **current carrying coils and magnetic confinement fusion reactors**.
- Can also display simple electric and magnetic vector fields.

```
TITLE
Std sim

SIM
10
Disp obj descp


CONFIG
Lorentz Motion
0.1
0.0001
RK4 Euler


UMF
[0,0,100]

UEF
[0,10,0]


P
[0.1, 0, 0]
[10, 10, 1]
1
0.01


#
```

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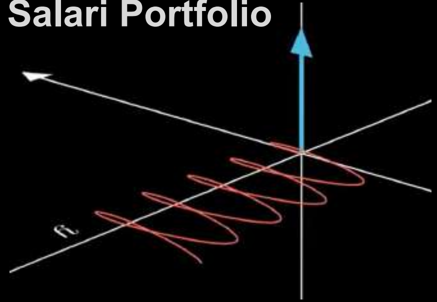
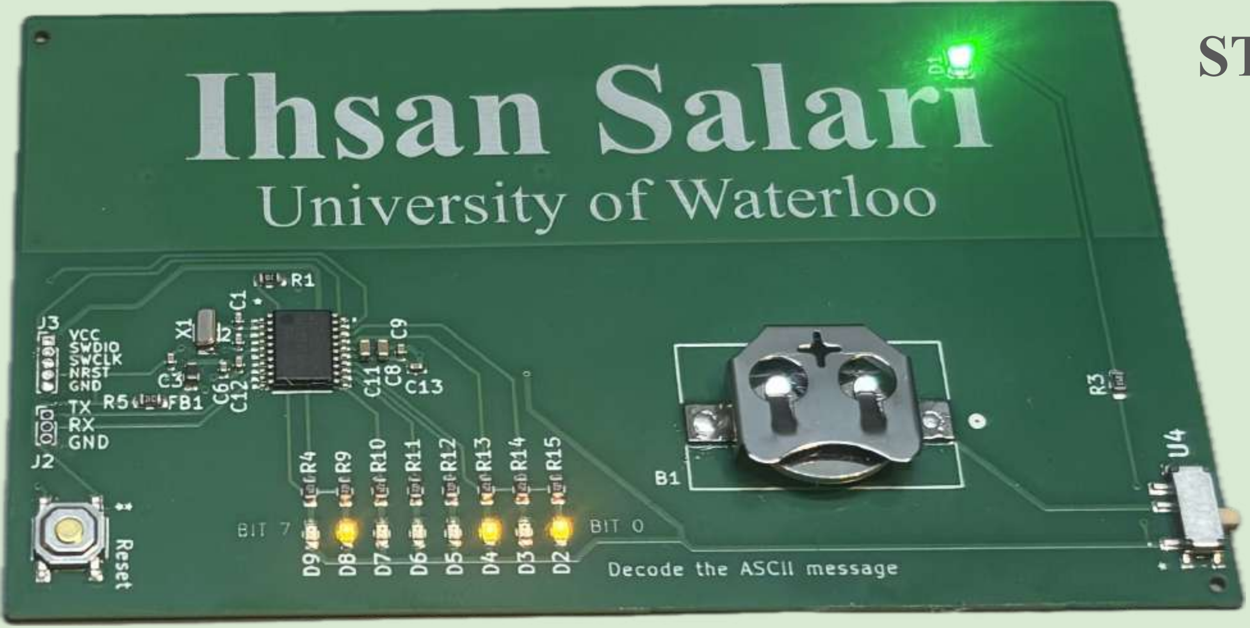


Above: Simulation of **grad B drift**. B fields of different strengths on either side of the y-axis, in direction of blue arrow.

$$F = q(\vec{E} + \vec{v} \times \vec{B})$$

Above: The Lorentz equation, the guiding equation for this project. The fields due to all objects are computed at the particle's position, then added and the force computed.

Left: Example of a configuration file for a basic simulation with B and E fields and a charged particle.



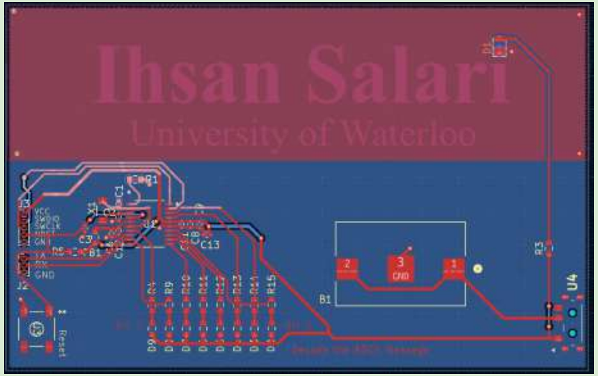
STM32 Business Card

Overview

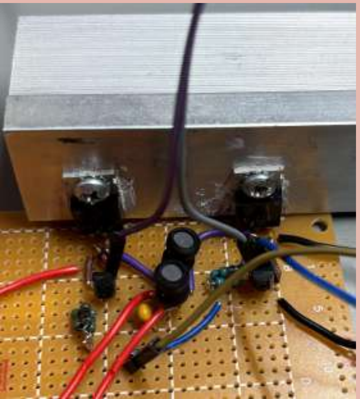
- STM32L0 low power MCU with SW programming and UART configuration interface.
- ASCII message and animation displayed on the 8 LEDs.
- Reflowed and reworked certain components programming wires using solder paste, flux, hot plate and soldering iron.
- Fully custom circuit and PCB using KiCAD and partially manufactured by JLC PCB.

Design decisions

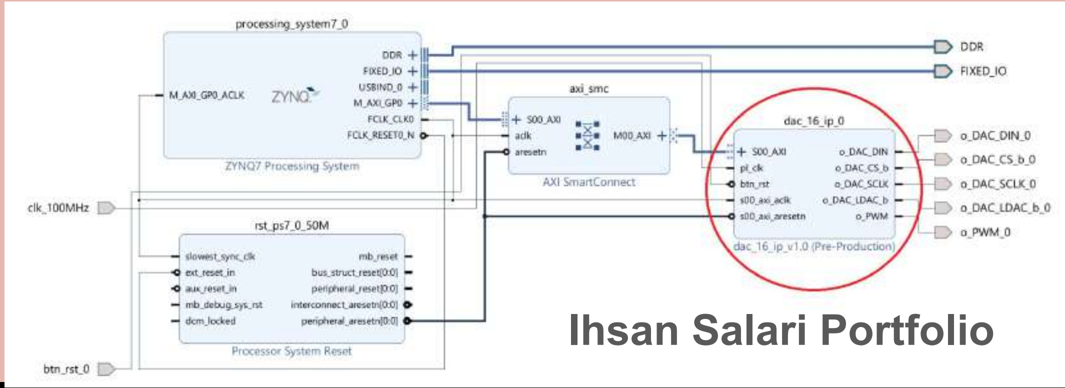
- Part selection made to match manufacturer (JLC PCB) parts library as much as possible.
- STM32L031F6P6 selected for low power consumption, low cost, and small TSSOP-20 size.
- Low profile switch, button and battery selected to fit seamlessly in wallet.
- 2-layer stackup (GND and signal/power) chosen as simple standard layout to simplify grounding of components. Uninterrupted ground return paths prioritized in trace routing.



Digilent Cora Z7 (Xilinx Zynq-7000) based Music Player



- **Verilog** implementation of **SPI** and **UART** interfaces using shift registers and state machines.
- Custom DAC driver and amplifier PWM generation **IP block**.
- Embedded application running on Zynq processor reads music on SD card and sends analog values to IP block over **AXI4 Lite**.
- Constructed class D power amplifier to drive woofer speakers.



Below: Xilinx Vivado simulation of DAC one-way SPI communication. See **o_DAC_DATA** (sent serially over **SPI** on **o_DAC_DIN**) increment by 0xff as example ramp signal increases. **o_DAC_LDAC** held low to load val.

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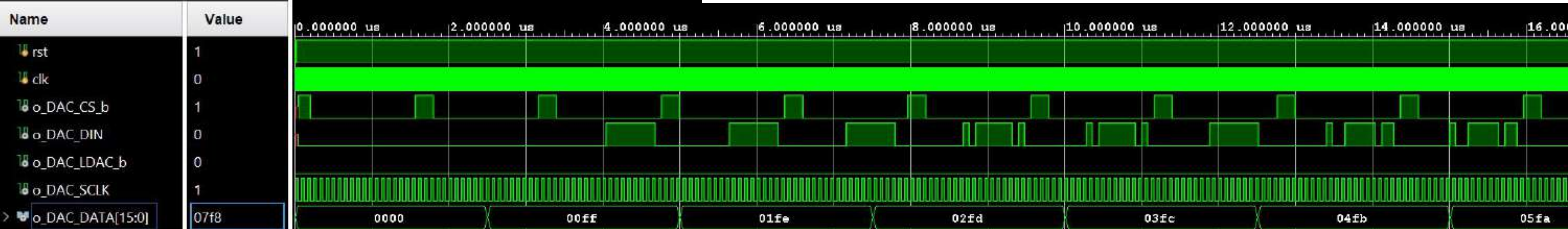
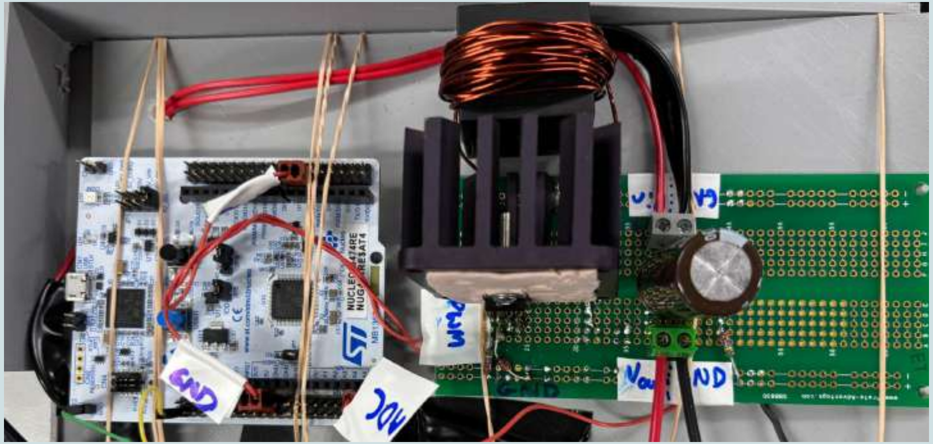
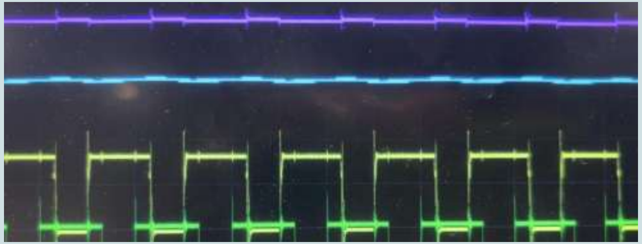


2-day turnaround: Boost Converter for aiRadar 3.5MHz Converter PID Control Development





Oscilloscope

- **Purple**: output voltage (15V @ 1.7A output)
- **Blue**: input current
- **Yellow**: PWM drive waveform

Overview

- Boost converter and 3D printed housing prototyped in two days to facilitate PID controller development for aiRadar 3.5MHz converter.
- 12V input with adjustable 12 to 40V output at a few amps (eg. 15V, 1.7A).
- Stable proportional control with full PID control tuning capabilities via 3MHz high speed UART connection.
- STM32 based control with full debugging capabilities including adjustable switching frequencies, output voltages, and PID constants.

Design decisions

- Due to fast turnaround, circuit was built from components lying around lab, including makeshift inductor wound around ferrite bead.
- 3D printed enclosure designed to house 12V power supply and converter prototype for mobile development due to short development time frame.
- Zener diode to protect MOSFET gate and large heatsink to dissipate heat.

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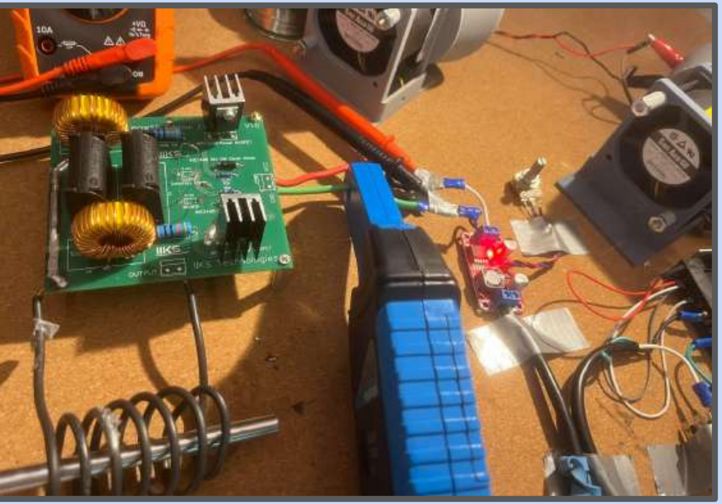
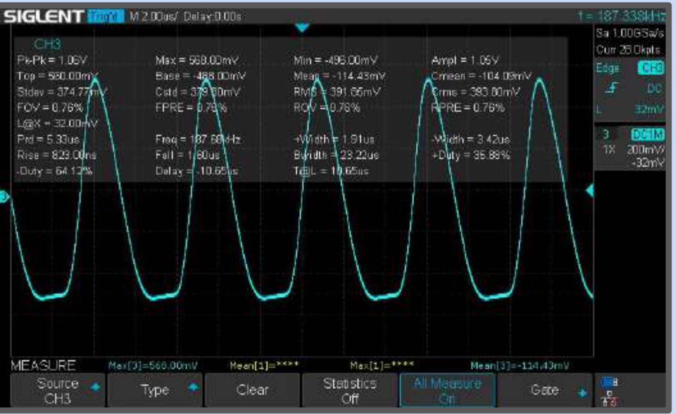
Zero Voltage Switching (ZVS) Driver Circuit

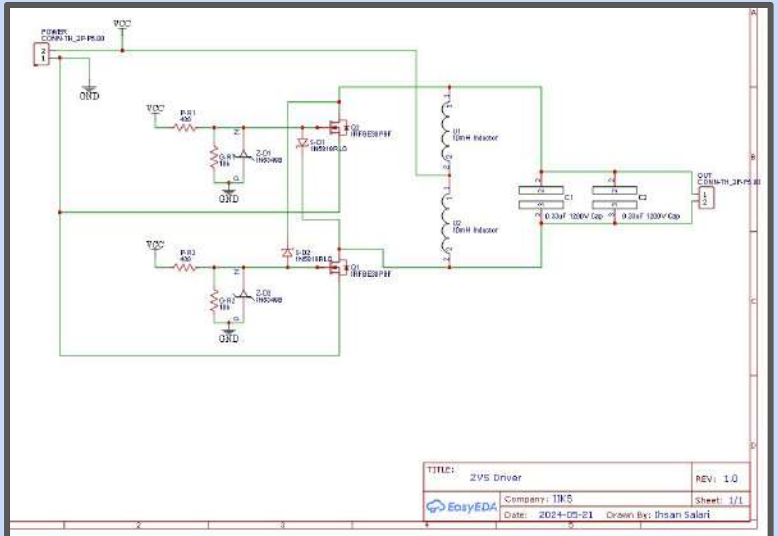


Designed and constructed 100W ZVS circuit for use as induction heater and for driving high voltage power converter.

Power components selected to withstand large currents and dissipate heat. Zener diodes protect MOSFET gates.



Left: *Current waveform in ZVS induction heater coil measured in test setup shown in top left image.*



Above: *Custom ZVS driver PCB. Thick exposed traces were created and covered with solder in order to handle higher current and dissipate heat.*

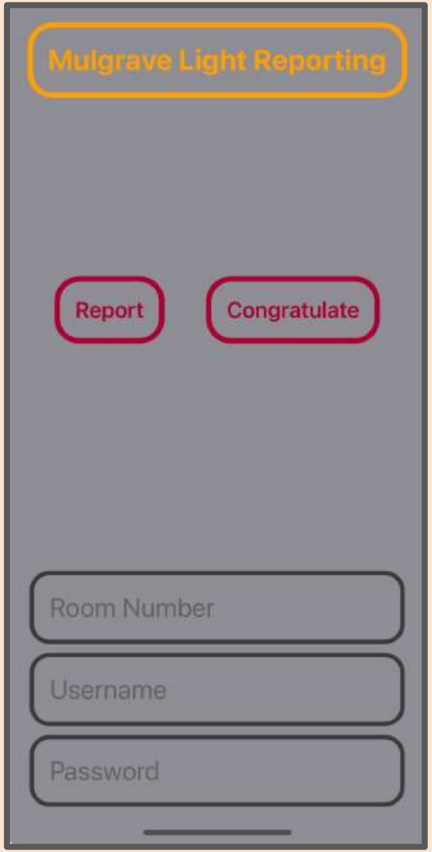
Fusion 360

3D Print Designs Makerworld

OpenScad

>9,000 downloads **>2,000** likes **>30** designs on Bambulab Makerworld - @iiks

Mulgrave Light Reporter Classroom Light Reporting System



Published Mulgrave Light Reporter IOS App

Used React JS, Node JS and Swift UI to create Mulgrave Light Reporter, a system which allows students to report empty lit classrooms and prompt a teacher email reminder.

Used Node JS and React JS due to widespread support on hosting platforms. Created IOS app to make reporting and congratulating classrooms more convenient.

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