OntarioTech
Engineering
& Applied Science

Saravanaa Kesavan
Ahmad Althikri
Ali Al Sulis
Mohammed Alali
Osama Ansari

Off-the-grid Photovoltaic Inverter for Residential Applications

Faculty Advisor: Dr. M. Youssef
Coordinator: Dr. Q. Mahmoud

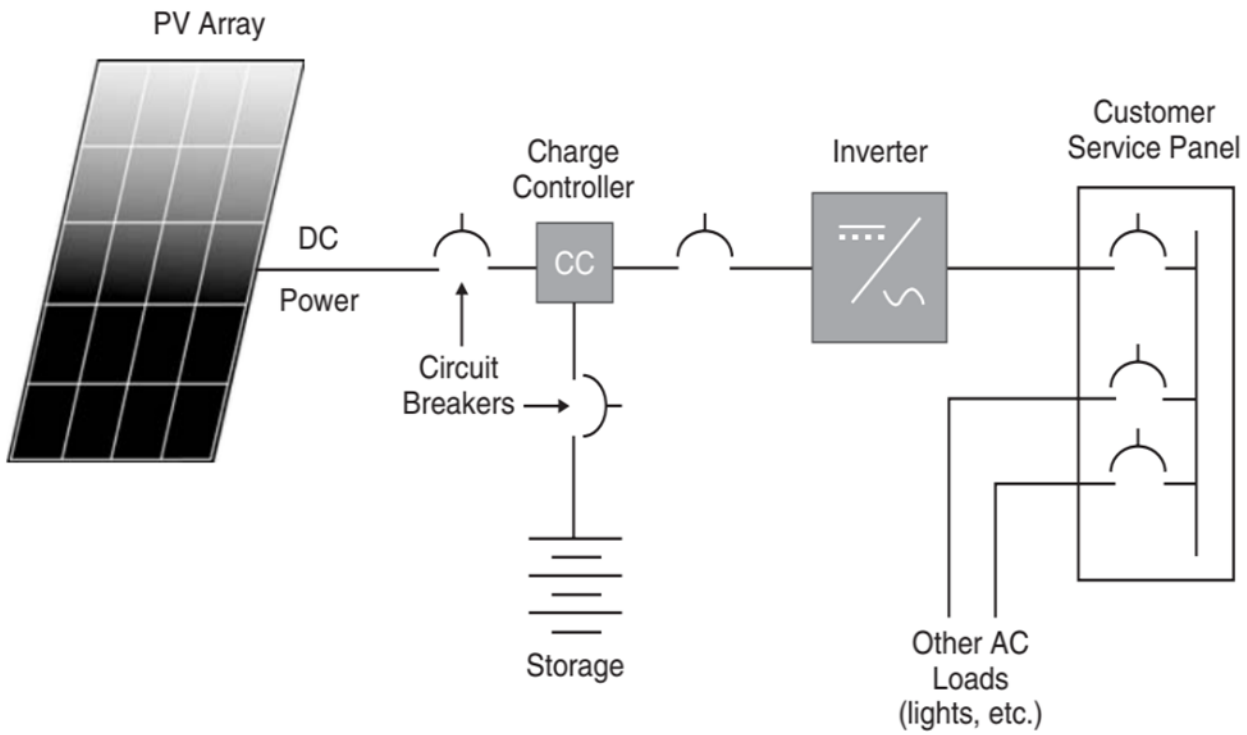
Content

- Introduction and Problem Identification
- Marketing and Engineering Requirement
- Scenarios
- Design Process
- Cost
- Code
- Testing
- Demo Video

Introduction and Problem Identification

Photo-Voltaic Energy

- Relieve energy shortage
- Relieve environmental pollution
- Flexible system size
- Simple installation



Marketing Requirement

Main requirements for the off-the-grid photovoltaic inverters in residential applications:

- Safe to use
- Efficient
- Cost Effective
- Reliable

Engineering Requirement

Main engineering requirements for the off-the-grid photovoltaic inverters in residential applications:

- Maximum Power Generation
- Compatibility with PV system
- Sinewave form with 50 Hz frequency
- Affordable price
- Reliability
- Technologically Implementable

Different aspects of the scenarios

- Final Cost of the produced off-grid inverter
- Compatibility with the other elements in the PV power generation system
- Load and demand
- Produced topologies and technologies in the market

Step 1

- Conceptual design

Step 2

- Software validation by simulation
- PSIM

Step 3

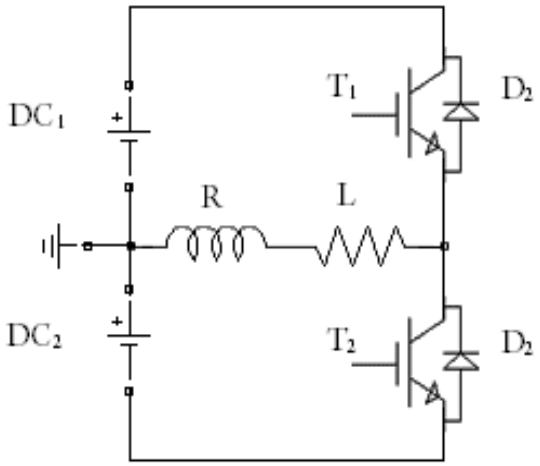
- Functional testing

Step 4

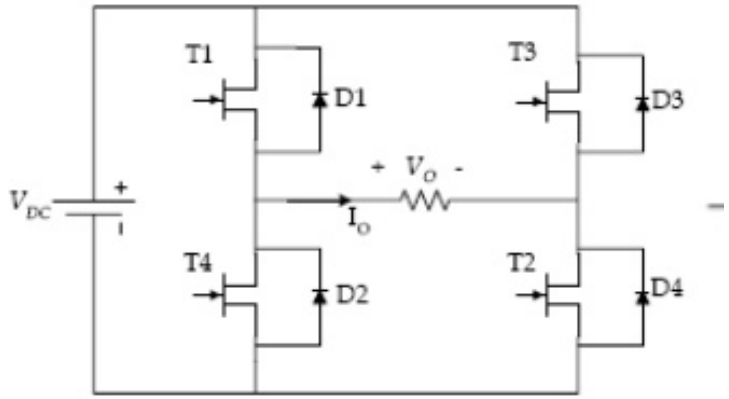
- Final design
  - Schematics (Prototype Board)
  - PCB (Printed Board with components on it)

Design Process for the 1-phase inverter

Single phase Half bridge inverter



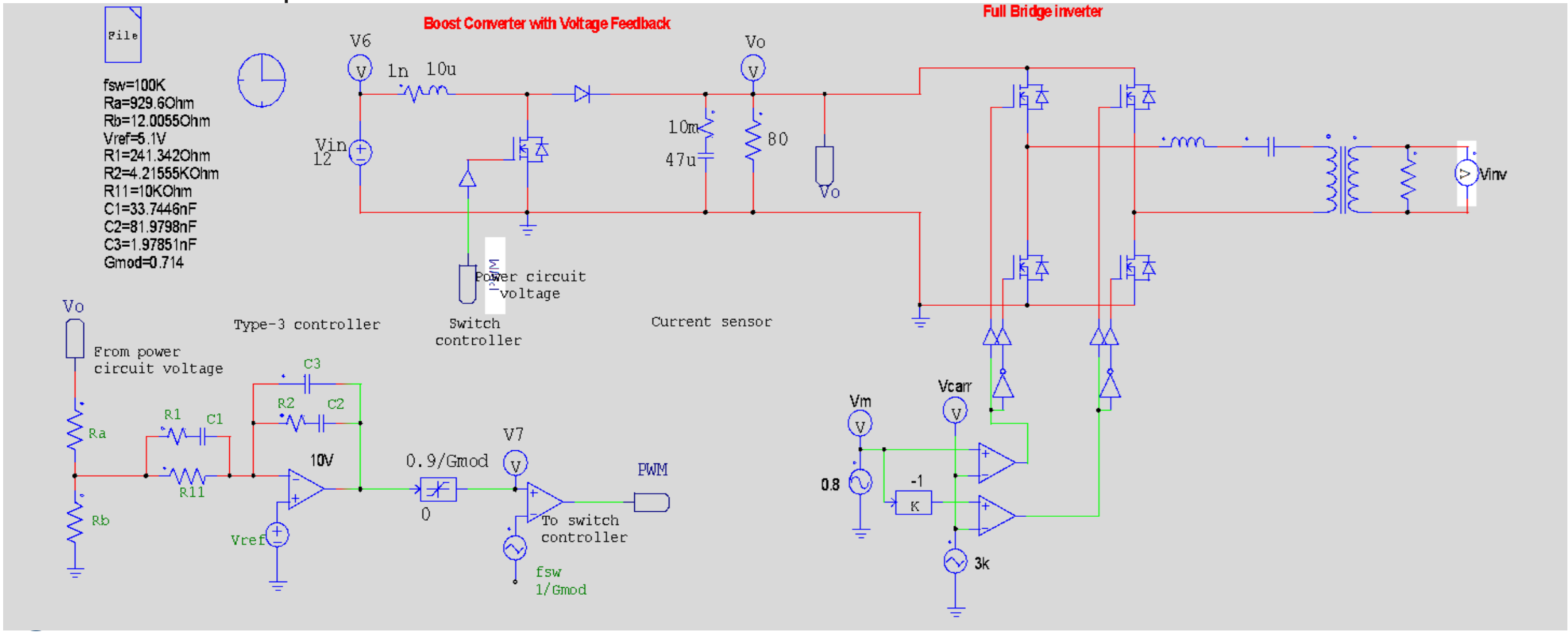
Single phase Full bridge inverter



- For our prototype we chose the Half bridge inverter
- Cheaper and better for home application

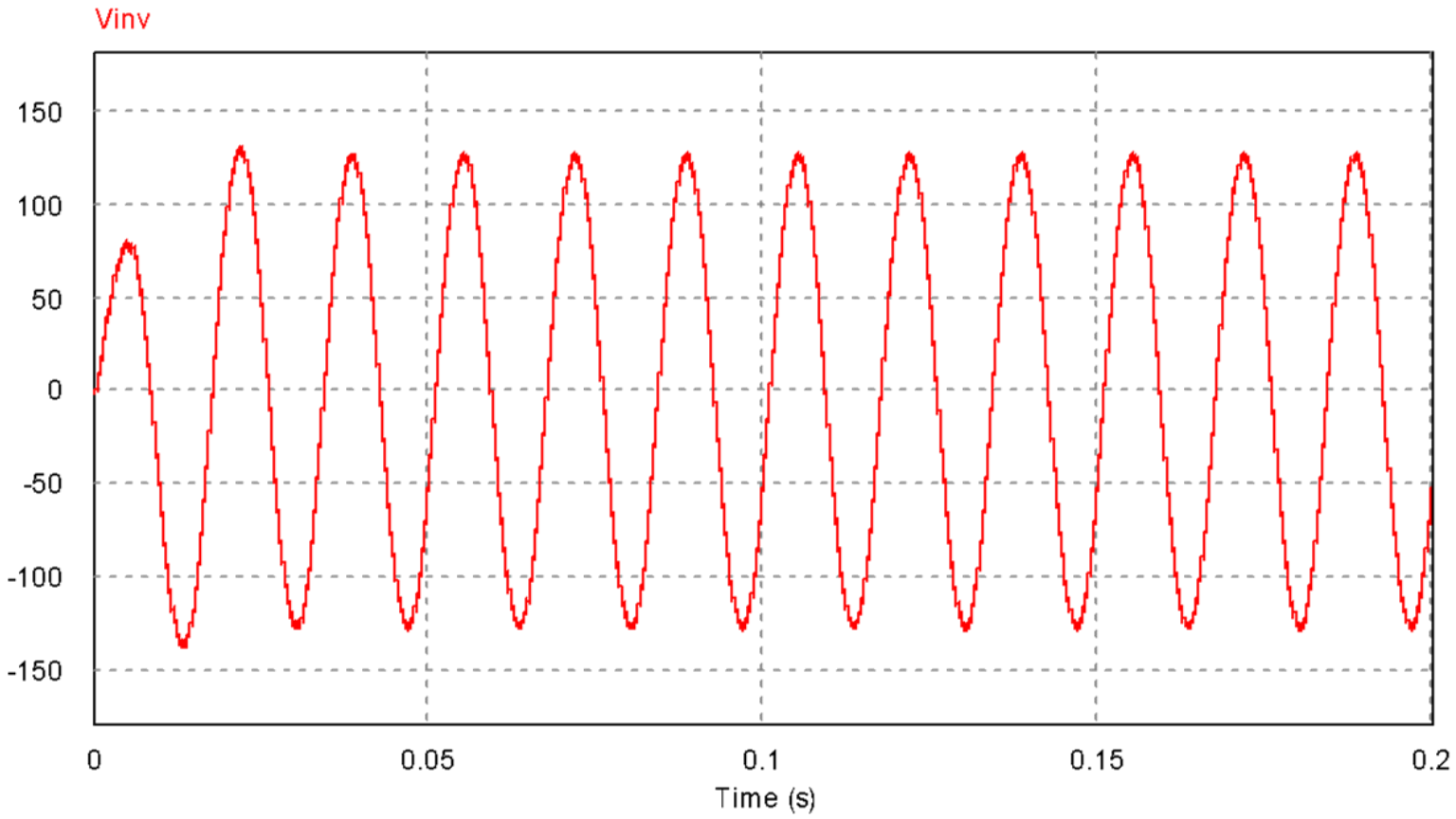
Design Process for the 1-phase inverter

- The 1-phase inverter with DC-DC boost convertor circuit in simulation

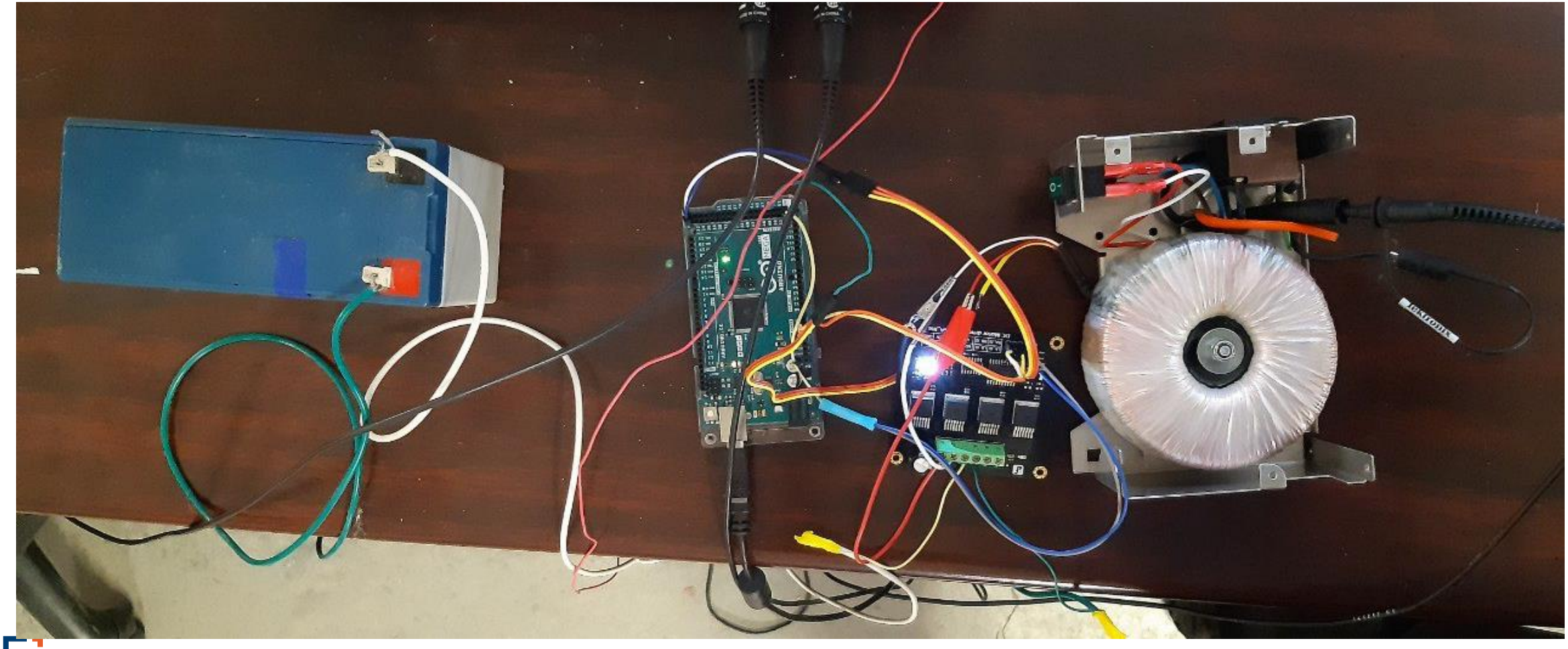


Design Process for the 1-phase inverter

Simulation result for the 1-phase inverter with DC-DC booster



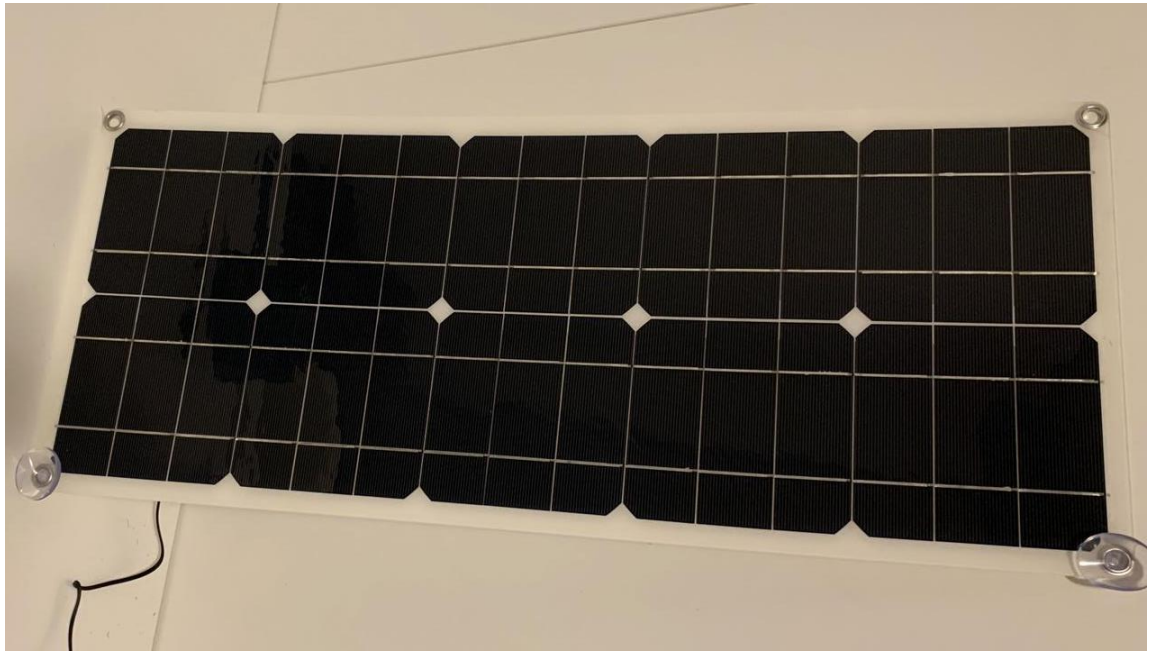
Preliminary Design



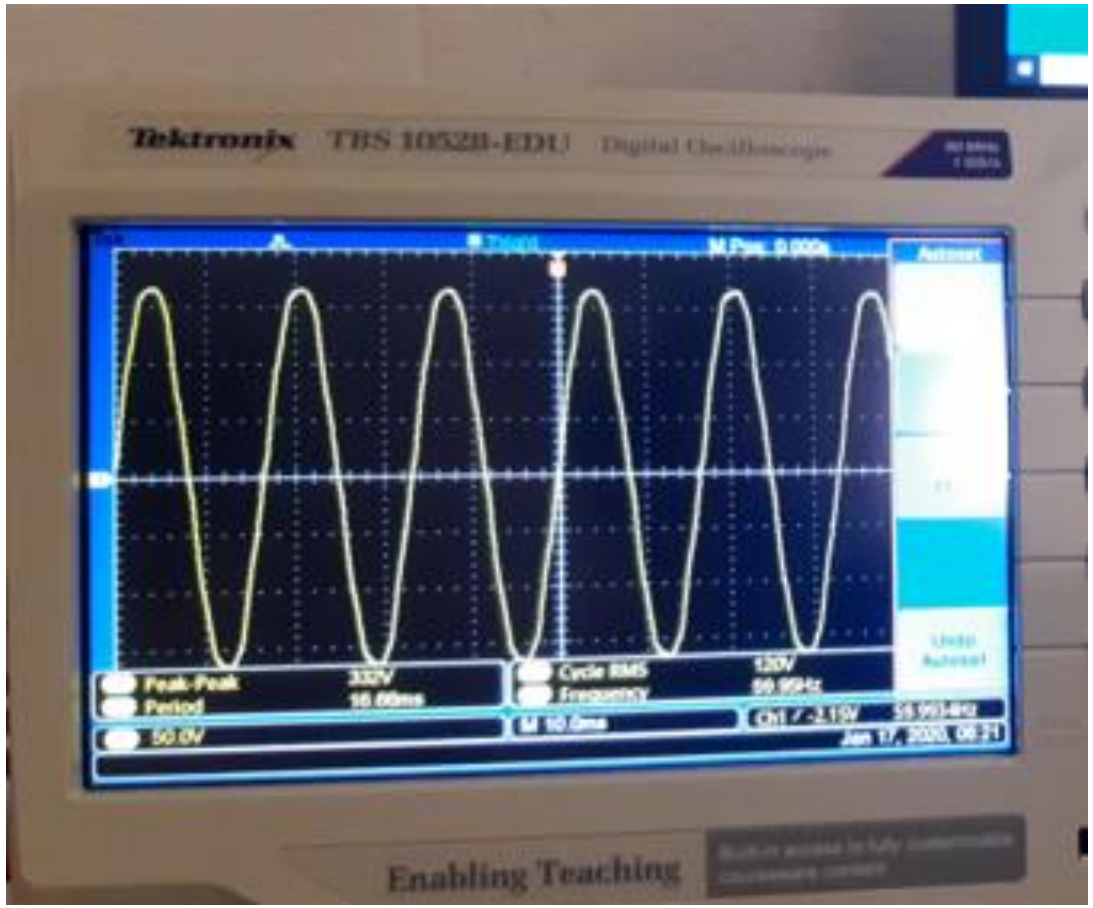
Components

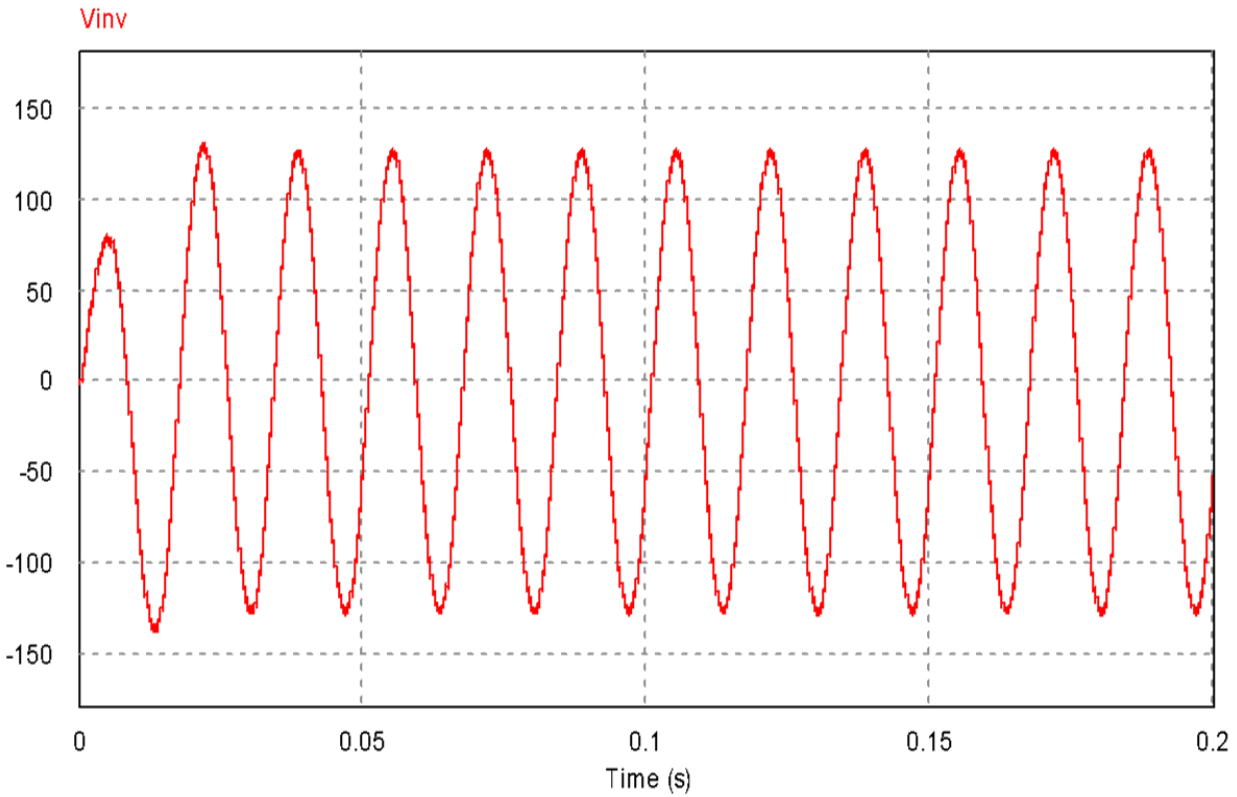
12V Battery

50W Solar panel



Preliminary Design Testing vs. Simulation Result

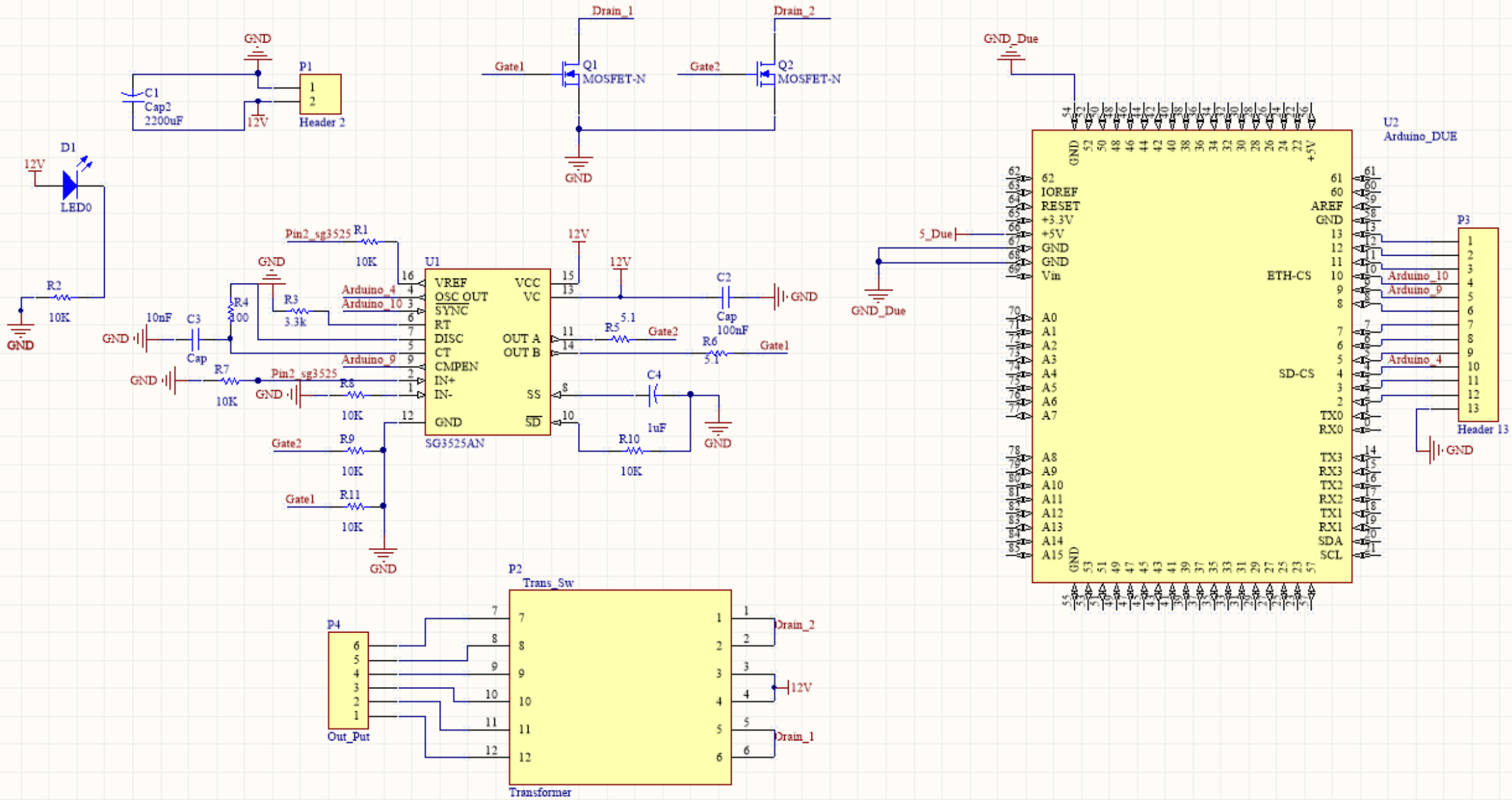




Final PCB Design for 1-Phase Half bridge inverter

Schematics

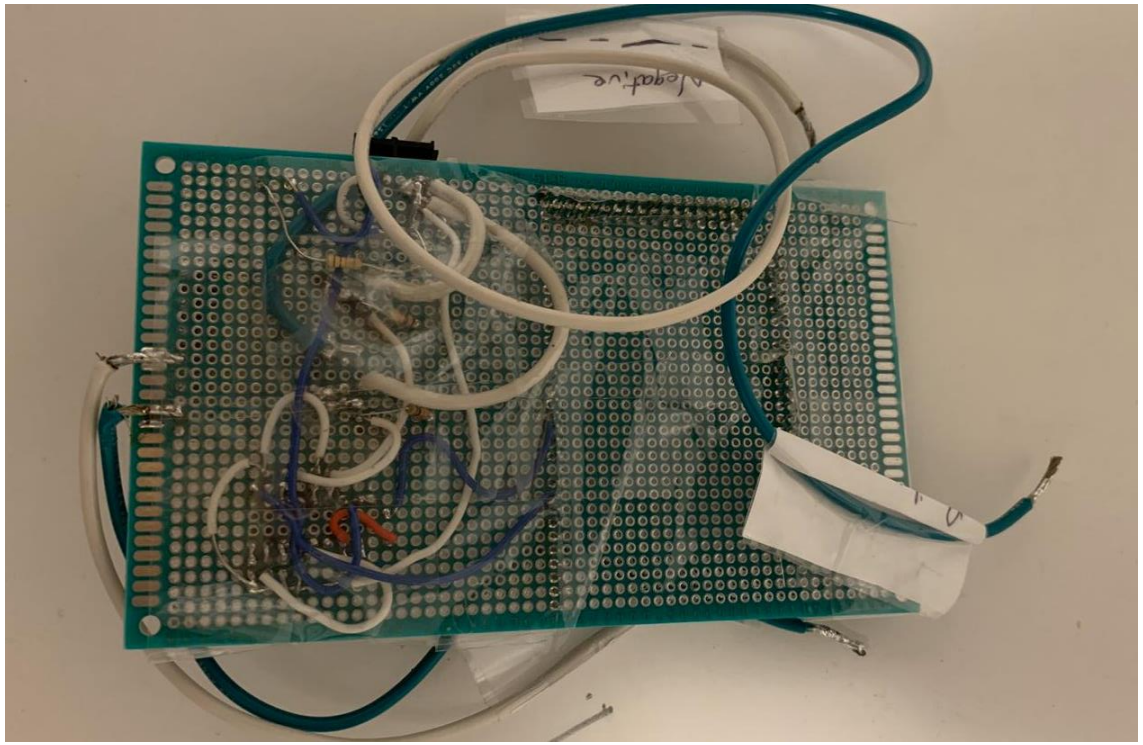
- Create Schematic
  - Arduino Mega with microcontroller ATmega2560
  - MOSFET Driver SG3525A
  - Transformer

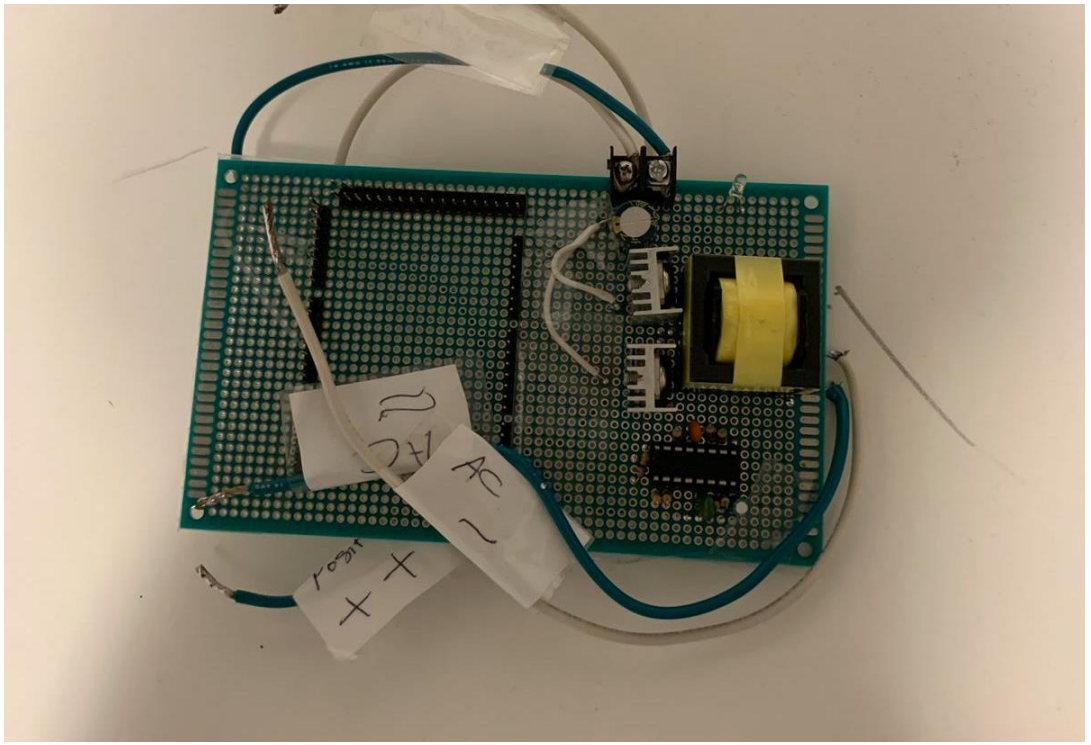

GND
C1
Cap2
2200uF
12V
P1
1
2
Header 2
Drain_1
Drain_2
Gate1
Q1
MOSFET-N
Gate2
Q2
MOSFET-N
GND
GND_Due
U2
Arduino_DUE
5_Due
GND_Due
D1
12V
LED0
R2
10K
GND
Pin2_sg3525
R1
10K
U1
VREF
OSC OUT
SYNC
RT
DISC
CT
CMPEN
IN+
IN-
GND
VCC
VC
OUT A
OUT B
SS
SD
SG3525AN
12V
C2
Cap
100nF
GND
Arduino_4
Arduino_10
Arduino_9
R3
3.3k
R4
100
10nF
C3
Cap
R5
5.1
Gate2
R6
5.1
Gate1
R7
10K
R8
10K
C4
1uF
R9
10K
R10
10K
Gate2
Gate1
R11
10K
P3
Header 13
Arduino_10
Arduino_9
Arduino_4
P2
Trans_Sw
Transformer
P4
Out_Put
Drain_2
12V
Drain_1

Schematic Library for the Arduino transformer, and MOSFET driver

- Arduino controls the MOSFET driver.
- MOSFET driver provides the gate voltage to the two MOSFETS
- The MOSFETS are used in the 1-phase inverter
- The inverter feeds in to step-up transformer

PCB Prototype

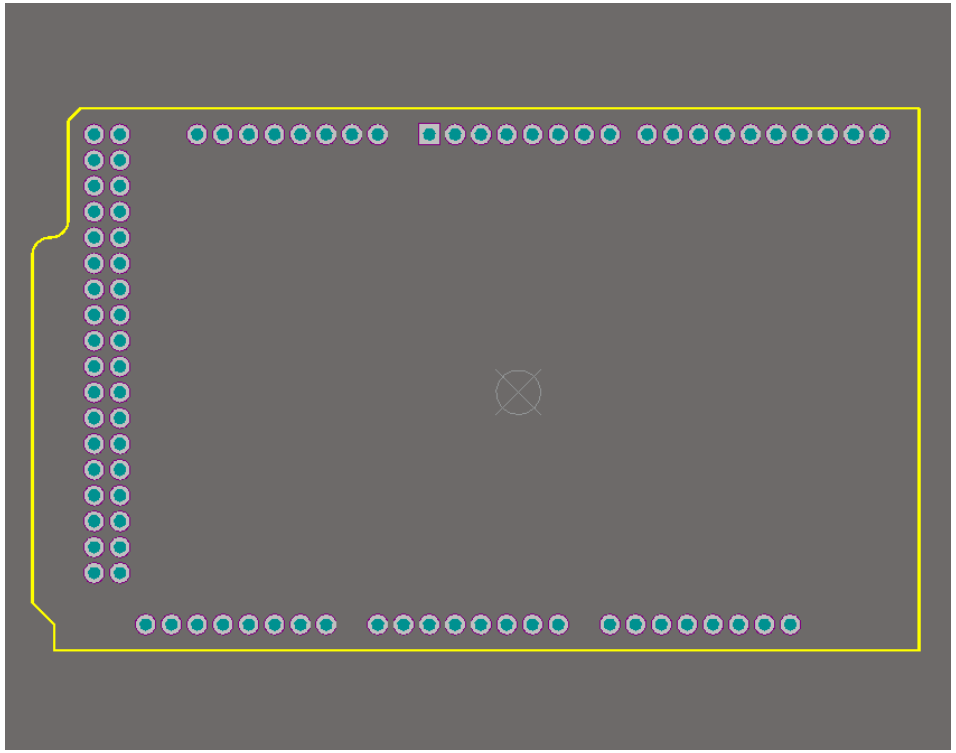




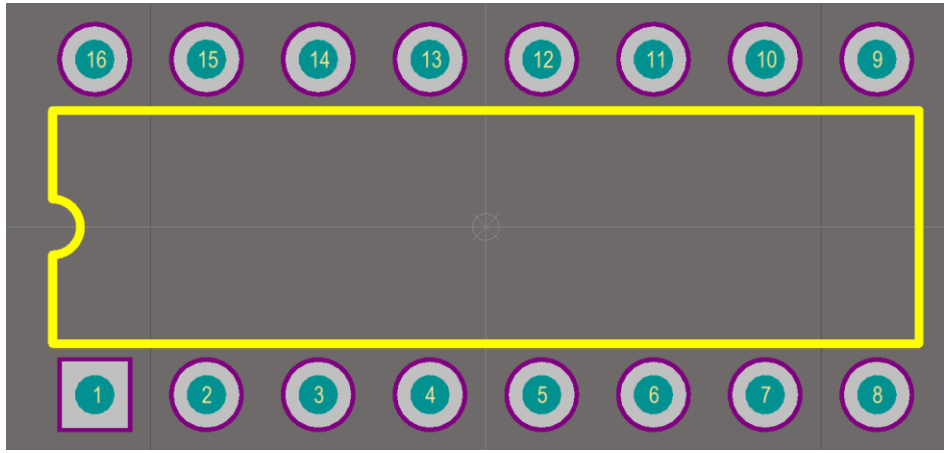
PCB Design

PCB Library for components in schematic

- PCB library obtained from online resources for Adruino Mega



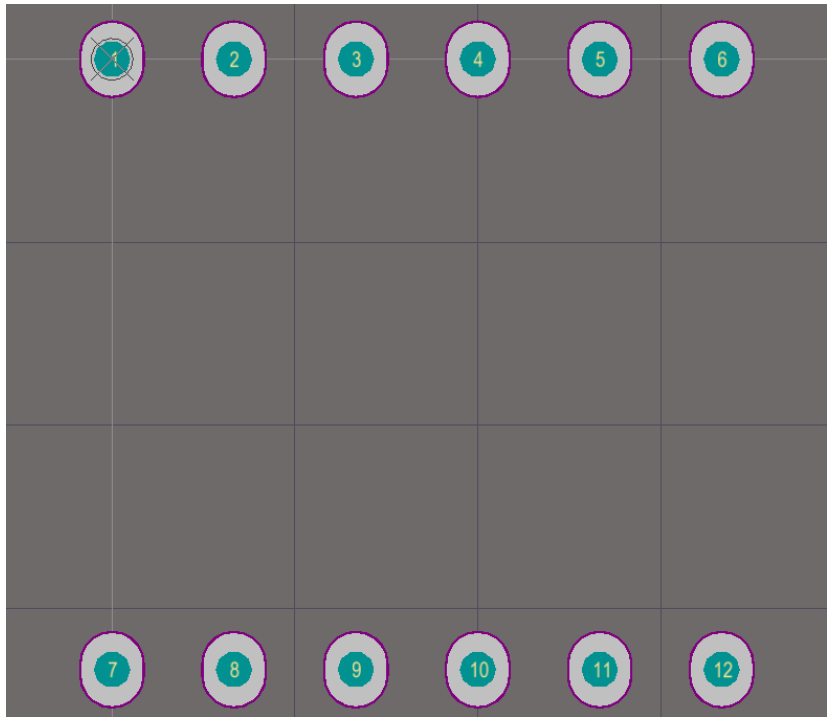
- MOSFET Driver



PCB Design

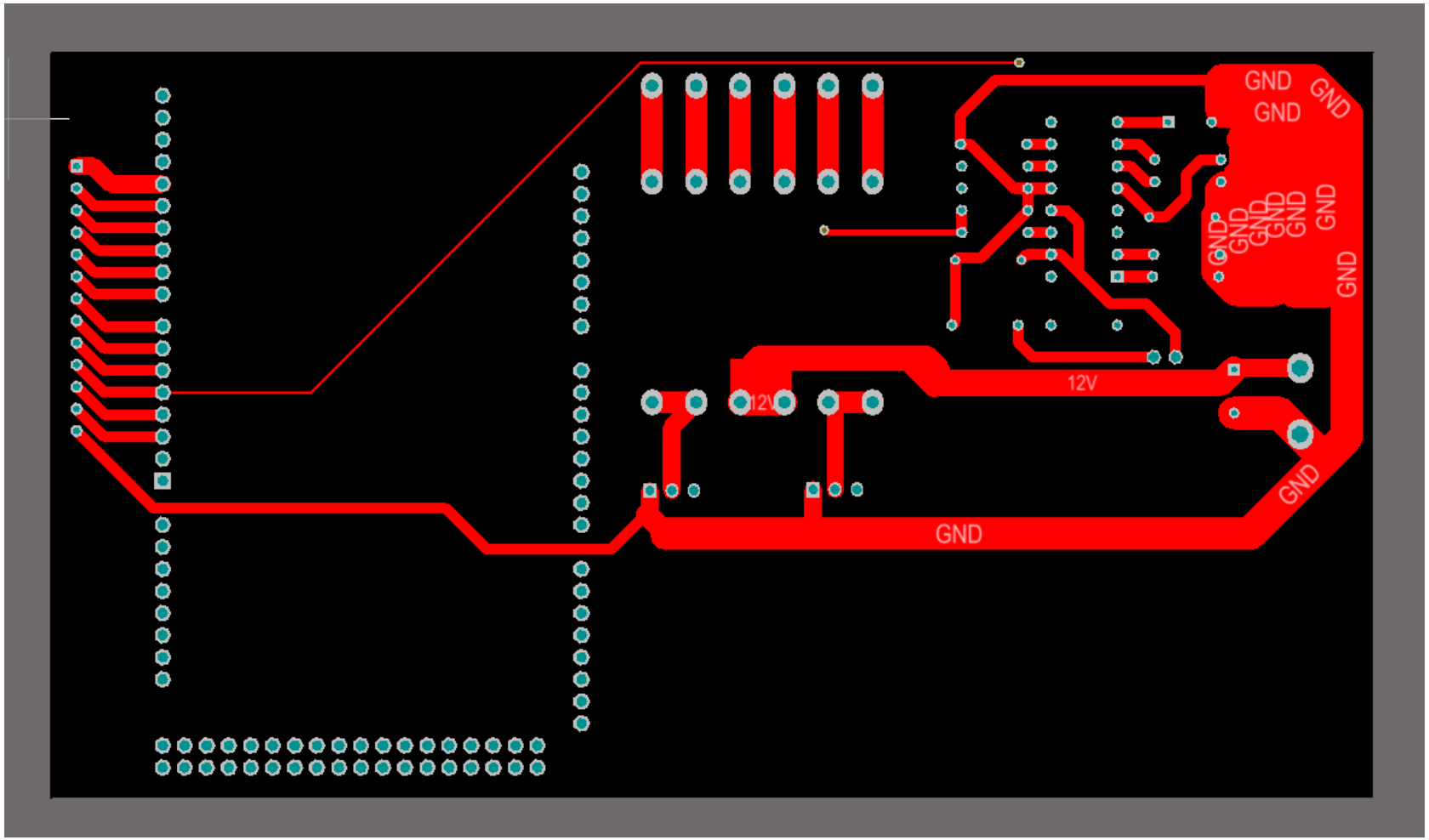
PCB Library for transformer

- Created PCB Library from scratch which is built using exact dimension and specification from the transformer with similar properties.



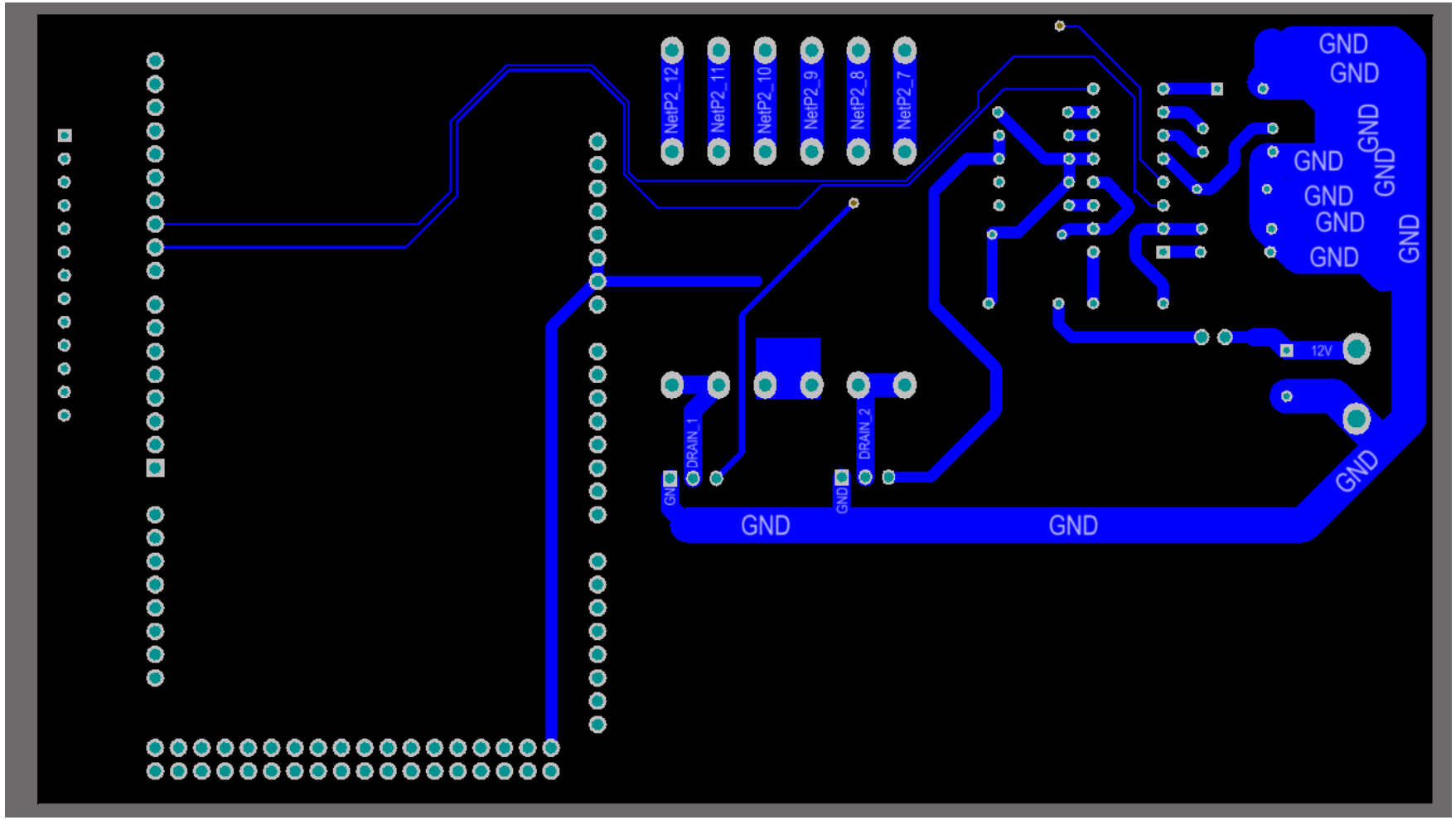
PCB Design

Implementation – Top Layer



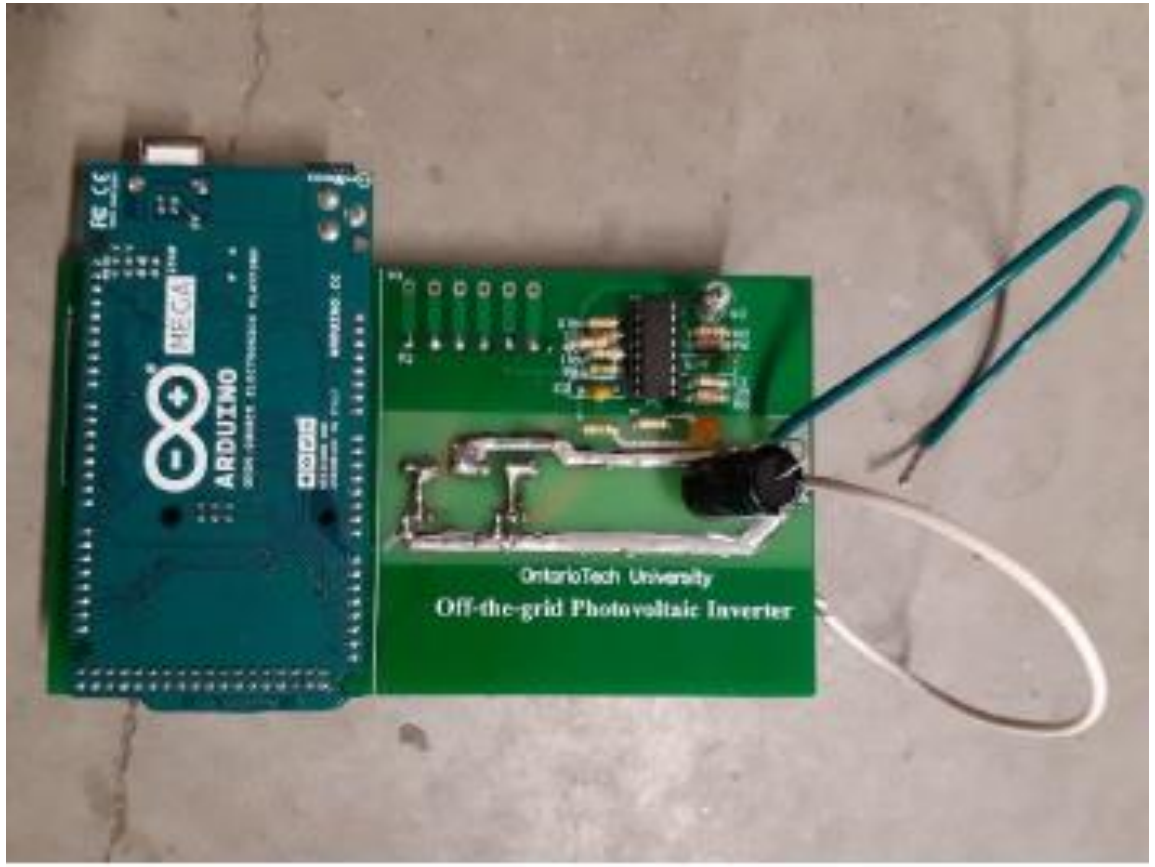
PCB Design

Implementation – Bottom Layer

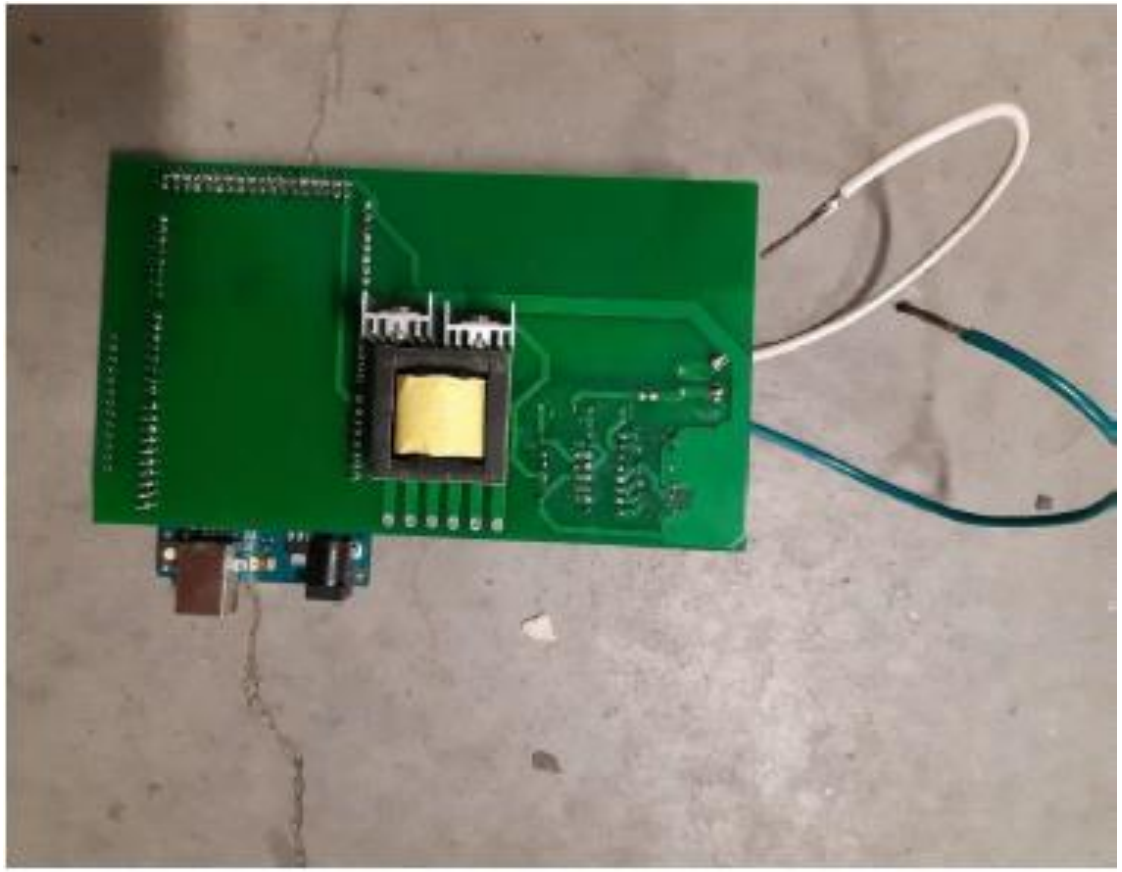


Final Product

Top Side



Bottom Side



PV inverters can be categorized as:

- Module integrated inverters, typically in the 50–400 W
- String inverters, typically in the 0.4–2 kW
- Multistring inverters, typically in the 1.5–6 kW
- Mini central inverters, typically > 6 kW
- Central inverters, typically in the 100–1000 kW

Cost

Vendor and Description of Expense (ie. Bestbuy-HP Scanner)	Subtotal	HST	Total
uxcell 20 sets EE 16 5 with 5 pin Transformer bobbin PC40 ferrite core vertical 40 ferrite	$14.50	$1.08	$15.58
bridgold 10 pcs IRF 3205PBF IRF 3205 N channel power MOSFET transister	$12.63	$0.93	$13.56
3KV/ 100 pF to 10000pF High Voltage DIP ceramic Capacitor assortment Kit 150 pcs	$12.63	$0.93	$13.56
Wingoneer 10nF to 470nF Metallized polyster Film Capacitors assortment kit	$11.48	$0.76	$12.24
IndustrailMaker 10 pcs.lot SG3525AN DIP16 SG3525A DIP SG3525A DIP SG3525 3525 DIP-16	$5.73	$0.36	$6.09
APC Back-UPS ES 550 8 Outlet 550 VA BE550R 12 V 7 Ah UPS Battery	$29.39	$3.82	$33.21
Solar Panel 50w 18V 12 V bendable flexible, waterproof solar car battery charger	$99.99	$7.27	$107.26
Shipping	$66.89	$0.06	$66.95
			$0.00
PCB samples	$264.77	$25.43	$290.20
Fedex international Economy (shipping)	$133.92	$0.00	$133.92
Duty custom for the PCB samples	$40.78	$0.00	$40.78
Philmore power supply Transformer with center tap +2 of uxcell torid core inductor wire	$70.70	$0.00	$70.70
Mega 2560 R3 ATMEGA16U-MU USB Board Development Board for arduinos mega2560	$26.40	$5.82	$32.22
Double BTS7960 43 H-bridge High-power Motor Drive module smart car	$12.00	$16.06	$28.06
Total Cost			**$864.33**

Code

- The core microcontroller in this Arduino is AVR ATmega 2560
- CodeWizardAVR used to program AVR microcontroller
  - Provides more tools to access to the timers
  - Access to other peripherals
- Code contains following functions:
  - Timer1 overflow interrupt
  - Timer3 overflow interrupt
  - Timer 0 and Timer 4 for PWM
- Each interrupt updates duty cycle and gate signal of switches.

CV
AVR

Testing

- Inverter DC performance test:
  - To assess the inverter performance during voltage and power changes in the DC source.
- Inverter AC performance test:
  - Inverter Output Time Delay Test
  - Under-Voltage/ Over-Voltage Transients Tests
  - Voltage/Frequency Oscillation Tests
  - Short Circuit Test

Conclusion & Achievements

- We created a simple yet effective design.
- Our design provides good performance and a stable output.
- It is safe and commercially viable.
- By using wholesalers and PBC fabrication companies we can offer our inverter less than 150 dollars.
- Making our design one of the cheapest on the market.
- We will have some difficulty to certify our product by national and international standard organization
- To improve our inverter we need to add 2 more parallel circuits
  - One problem we need to synchronize all the circuit
  - So we need to create a synchronizer circuit to synchronize all the outputs
  - Current Limiter and voltage limiter

Live demonstration

References

- F. Dincer, "The analysis on photovoltaic electricity generation status, potential and policies of the leading countries in solar energy.," Renewable and Sustainable Energy Reviews, pp. 713--720, 2011.
- R. Adib, "Renewables 2015 global status report," REN21 Secretariat, vol. 83, p. 84, 2015.
- R. A. Messenger and A. Abtahi, Photovoltaic systems engineering, CRC press, 2010.
- Poissant, Yves, Lisa Dignard-Bailey and P. Bateman, "Photovoltaic technology status and prospects:Canadian annual report 2015," 2016.
- P. Selya, et al., "2008 solar technologies market report. No. LBNL-3490E. Lawrence Berkeley National Lab.(LBNL)," Berkeley, CA (United States), 2010.
- A. Luque and S. Hegedus, Handbook of photovoltaic science and engineering, John Wiley & Sons, 2011.
- B. Burger, "Highly Efficient PV-Inverters with Silicon Carbide Transistors," in Proc. 24nd European Photovoltaic Solar Energy Conference, 2009.
- Y. Yang, Advances in Grid-Connected Photovoltaic Power Conversion Systems, Woodhead Publishing, 2018.
- M. Meinhardt, G. Cramer, B. Burger and Zacharias, "Multi-String-Converter with Reduced Specific Costs," Solar Energy, p. 217–227, July–December 2001.
- O. Lopez, R. Teodorescu, F. Freijedo and Doval, "Leakage Current Evaluation of a Single-Phase Transformerless PV Inverter Connected to the Grid," in Applied Power Electronics Conference, APEC 2007.
- Y, Zaohong and S. Paresh, "A novel switch-mode DC-to-AC inverter with nonlinear robust control," IEEE Transactions on Industrial Electronics, vol. 45, pp. 602--608, 1998.
- Fardoun, A. Abbas, Ismail, H. Esam and A. Sabzali, "New efficient bridgeless Cuk rectifiers for PFC applications," IEEE Transactions on Power Electronics, vol. 27, pp. 3292--3301, 2012.
- J. Newmiller, D. Blodgett and S. & Gonzalez, "Performance Test Protocol for Evaluating Inverters Used in Grid-Connected Photovoltaic Systems," DNV KEMA Renewables, Inc. and Sandia National Laboratories, NM, Rep. SAND2015-1817R., 2015.
- "http://shrinkthatfootprint.com/average-household-electricity-consumption#F7wK2pRtd07OhYDr.99," [Online].
- K. Brennan, A Guide to the Business Analysis Body of Knowledger, Iiba, 2009.