॥ सा विद्या या विमुक्तये ॥

भारतीय प्रौद्योगिकी संस्थान धारवाड़

Indian Institute of Technology Dharwad

B. Tech Project

3-Phase Converter Control Interface

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Contents

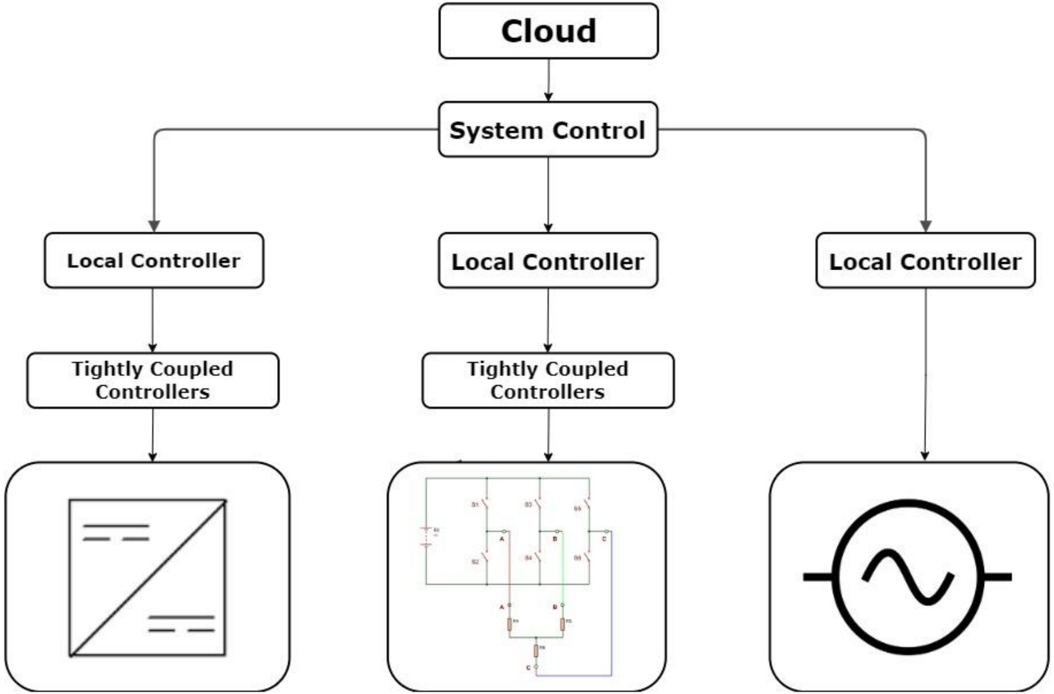
Aim of this BTP

- Exploring current EV Chargers and charging standards to understand the current technology gap.
- Understanding Communication Protocols (in context of automotive and EV chargers) to build a secure controller interface.

- To generate sine PWM signals with variable frequency and amplitude modulation.
- To generate 3-phase signals which will be used to operate DC-AC Inverter.

Why this Problem statement?

Overall System Configuration



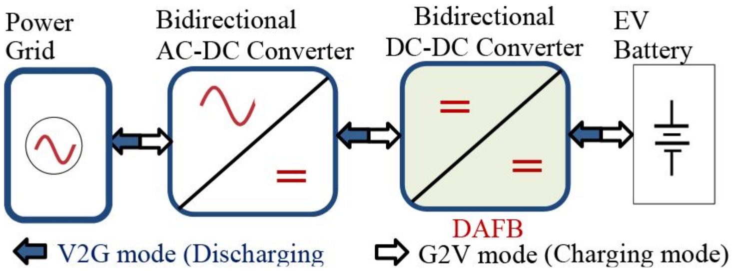


Figure 1: Control diagram for bidirectional EV Charging Equipment

EV Charging Infrastructure

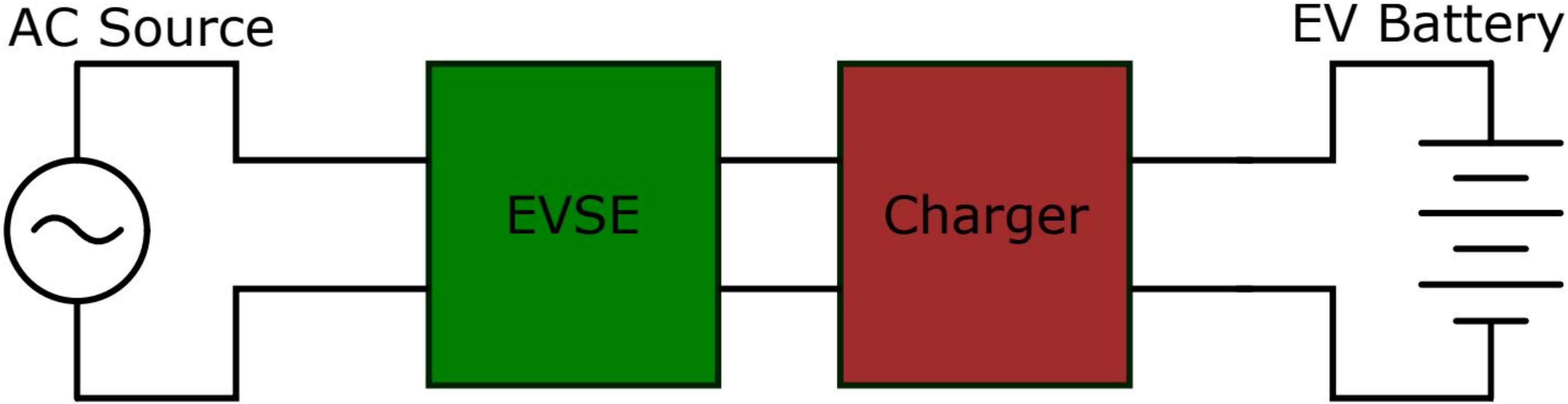
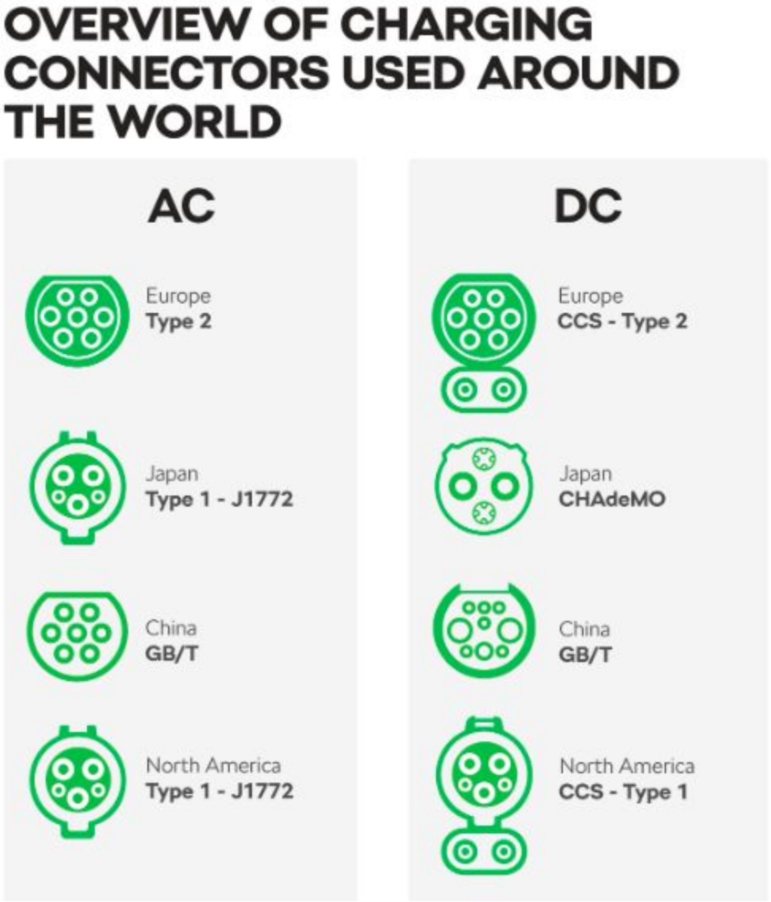


Figure 2: EV Charging Infrastructure from the AC source to the Battery

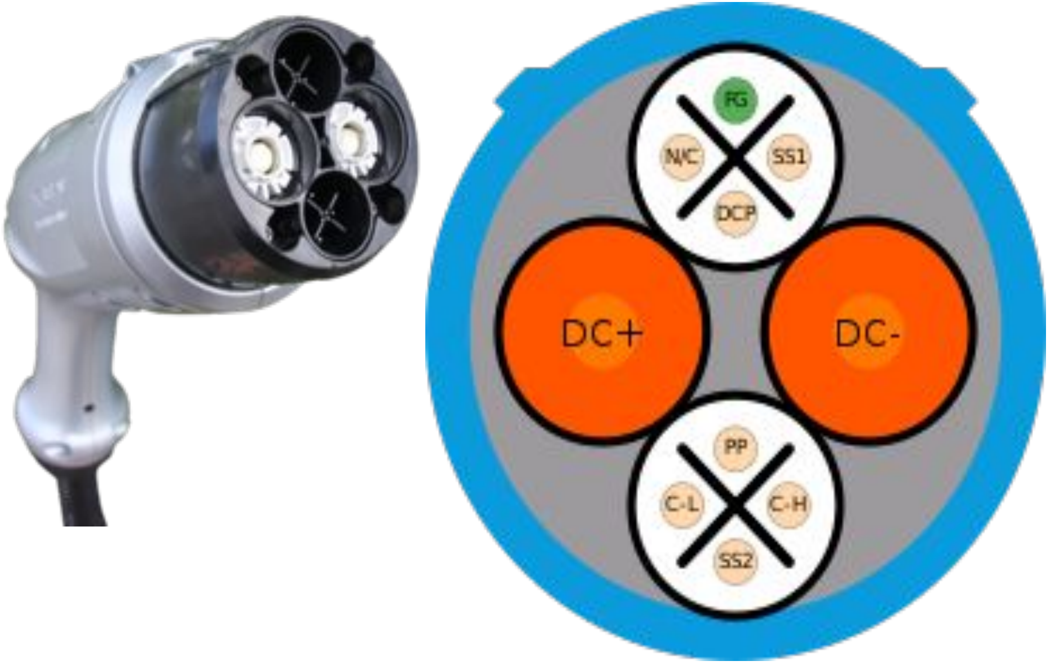
EV Chargers


OVERVIEW OF CHARGING CONNECTORS USED AROUND THE WORLD
AC
Europe
Type 2
Japan
Type 1 - J1772
China
GB/T
North America
Type 1 - J1772
DC
Europe
CCS - Type 2
Japan
CHAdeMO
China
GB/T
North America
CCS - Type 1

Types of EV Chargers

- AC vs DC Charging: Conversion happens outside in case of DC Charging. DC Charging is more expensive, but fast.
- CHADeMo is among the earlier ones of EV Chargers. It stands for **Charge-de-Move**.
- Given the rise in usage of EV Vehicles across the world, there is a need for a global standard for EVSE(EV Supply equipment), and CCS looks like the solution for it. CCS stands for **Combined Charging System**.

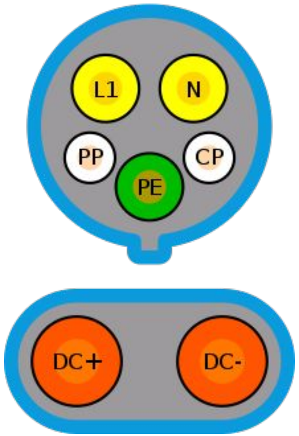
CHADeMo



CHADeMo Connector: Just 2 DC Charging Pins

EVSE Pinouts (terminology)

- The **proximity pilot (PP)** pin tells the charging equipment the type of cable connected to the socket – different cable thicknesses can cope with different amounts of electrical current
- The **control pilot (CP)** pin provides bi-directional communications between the electric vehicle and charging system. This checks the maximum amount of current that the EV is able to take at any one time.
- **DC+ and DC-** are responsible for the actual power supply in the case of DC-Charging.
- **Lx/N** pins act as Single phase wires/ Neutral Line in the case of AC-Charging.
- **PE:** Protective earth: Responsible for grounding.



J1-772

- Developed in **North America**, primarily for **AC charging**.
- Connector consists of power, ground, communication and safety interlocking.
- AC power is supplied to the vehicle's on-board charger, which is then converted to DC to recharge the battery.
- Working: after connection, communication using a pilot signal, after which charging starts.
- Backward and forward compatibility.

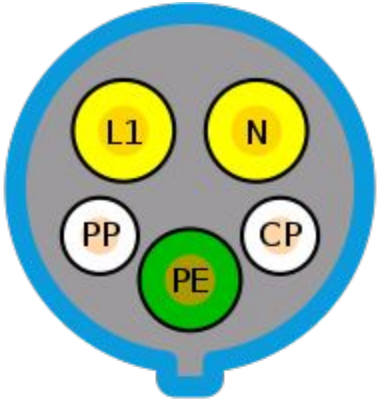
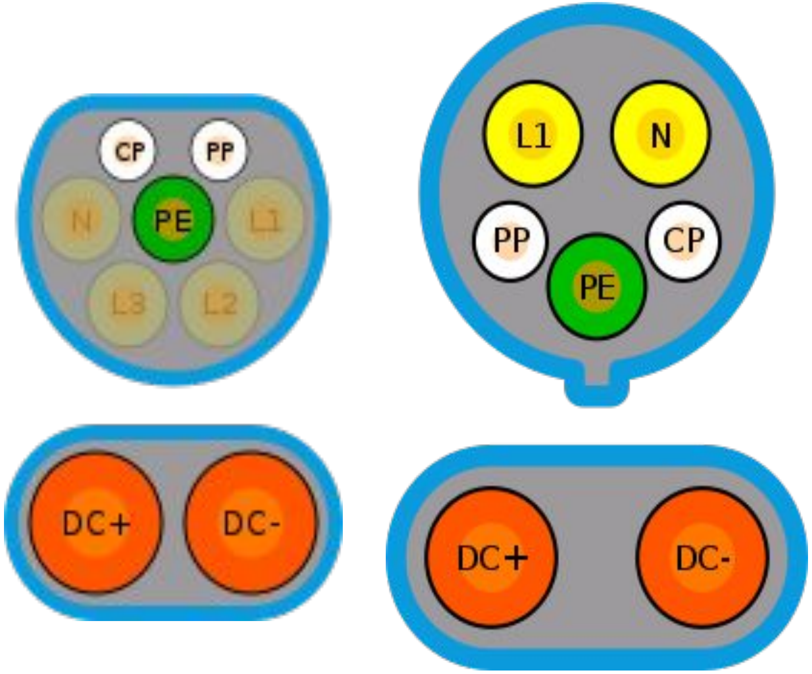


Fig: J1772 Connector

CCS Type-1 and Type-2

- Type-1: North America Standard (only single phase AC charging available)
- Type-2: European Standard (contains extra pins for 3 phase AC Charging)

- It is an extension of the J1-772 AC connector.
- It combines the AC Charging pins of J1-772
  - with DC Charging pins,
  - and hence the name- Combined Charging System



Type-1 Type-2

Communication Protocols

EV Chargers are smart, and what makes them smart is the communication between the vehicle and the EVSE. Our aim was to explore a secure communication protocol and we started with **RS, CAN and ModBus.**

RS-232 and RS-485 are common industry standards for serial communication.

<u>RS232</u>:

- Connection possible with **1 device only**. **Single-ended** and point-to-point communication
- Max speed is just 20 kbps and max length of 50 feet possible. Being replaced by USB and Ethernet

<u>RS485</u>:

- Can handle upto **32 devices at once**, using a single communication bus. Hence useful for industrial applications
- RS-485 applications benefit from **differential signaling** over twisted-pair cable.
- Max speed is about 35 mbps and max length of 4000 feet posible.

CAN

- Developed by Bosch for communication between ECUs.
- Uses differential signalling to reduce EMI and noise.
- Identifier value is inversely proportional to priority.
- Multi master
- Bit stuffing
- CRC for error checking

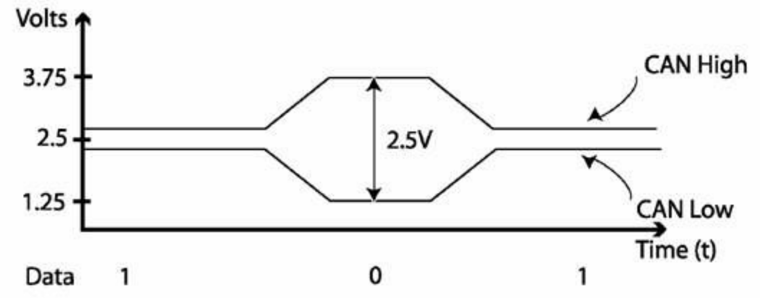


Figure: Differential signalling in CAN

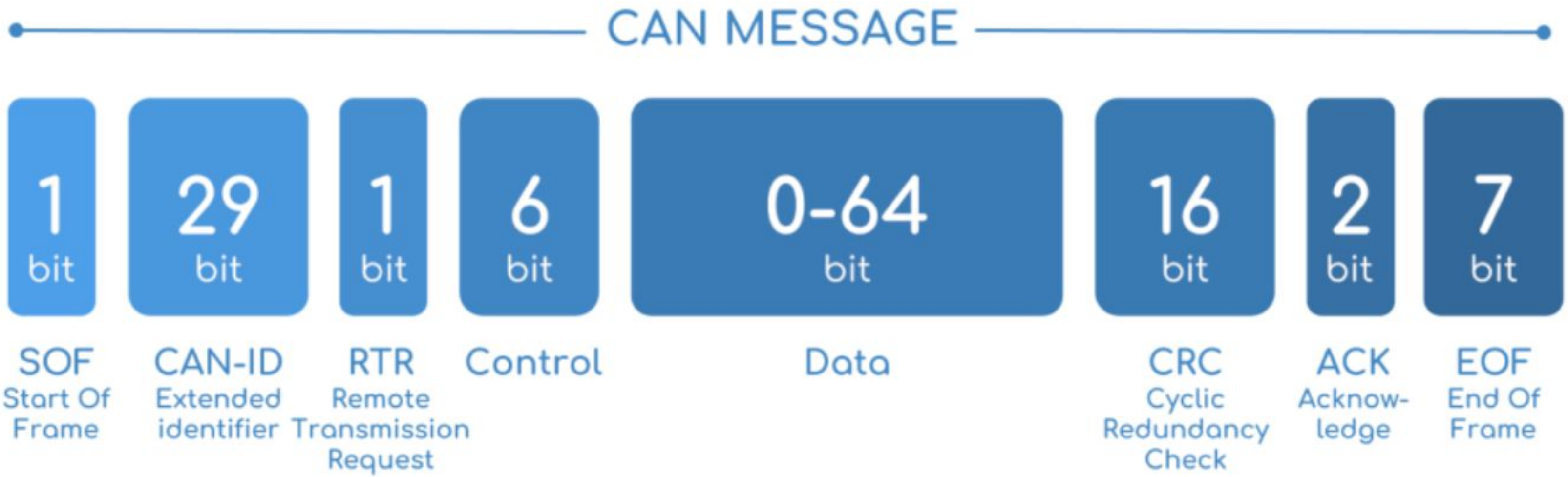


Figure: Format of a CAN message

ModBus

- ModBus is supported by multiple companies and hence new products from multiple companies can be integrated rather quite easily.
- There are broadly 2 versions: Modbus over **Ethernet/TCP/IP** and Modbus over **RS232/RS485.**

Working:

- It follows a **Master-Slave Configuration,** where the Master initiates transactions(requests) called **queries** and the slaves respond to these requests by executing actions supplied by the master.
- There are 2 types of queries from the master: one is a request to an individual slave, where the slave is obliged to respond to the master, and the other is a broadcast message to all slaves, where the slaves may not send any response

ModBus Data Frame

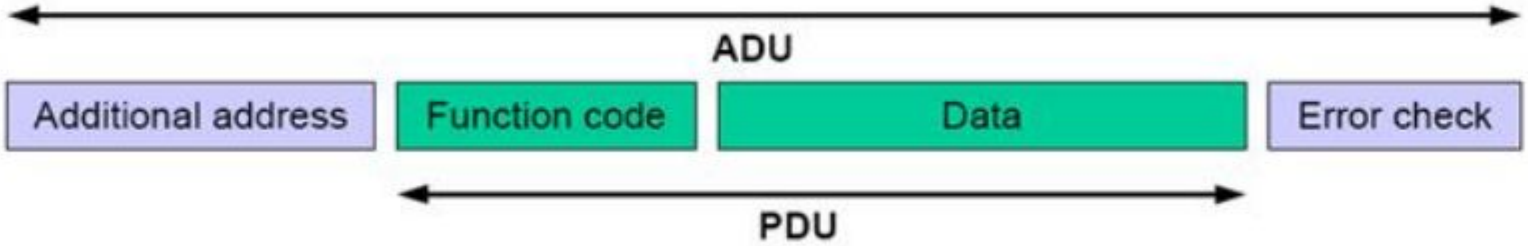


Figure: MODBUS data frame

ModBus Implementation

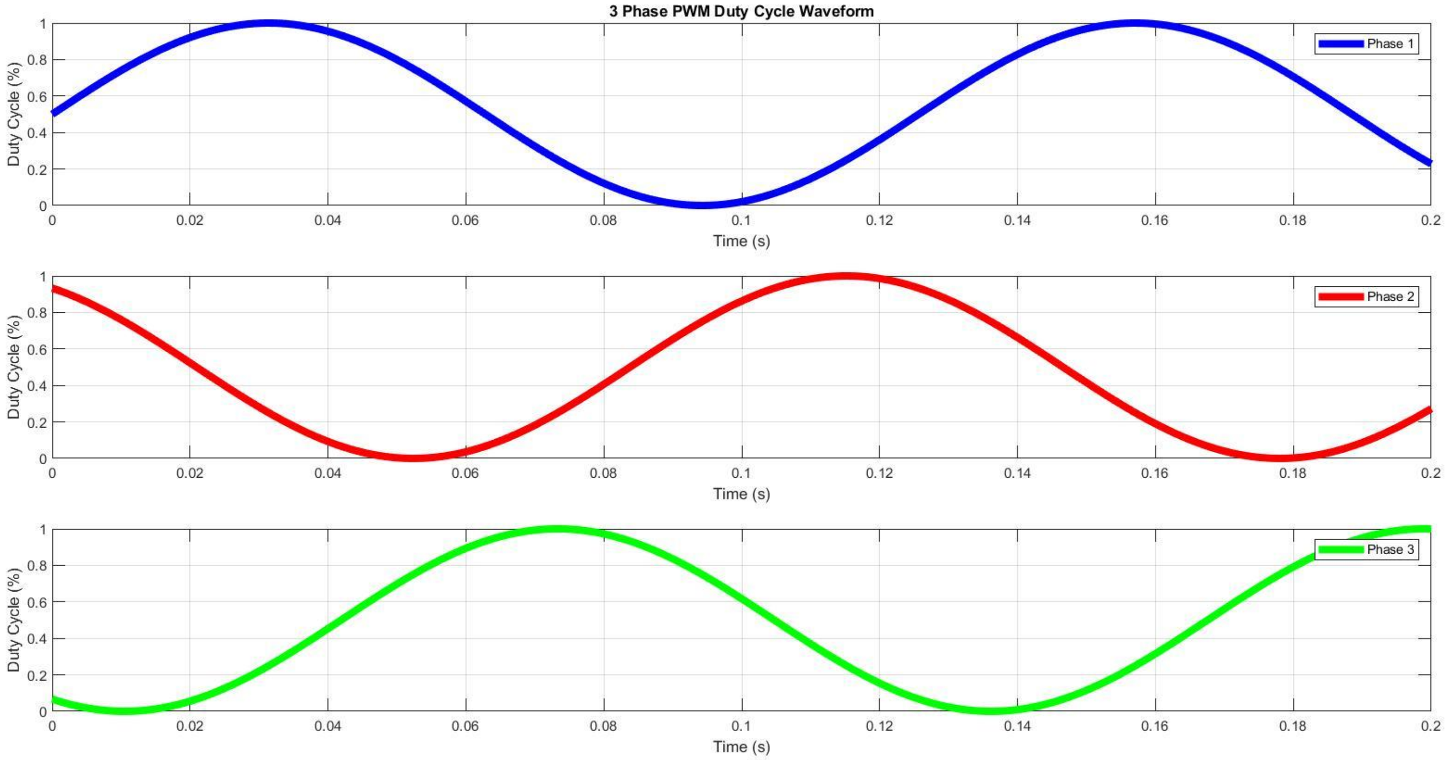
- **Assign IP address** to all Modbus connected devices.
- Connect all devices to ethernet.
- **Initialization**: configure Modbus settings - parity, baud rate, stop bit, etc.
- **Establish a connection**: Master must enable connection with slave using slave's IP address and port number.
- Each message consists of unit identifier, function code, data and error checking fields.
- Example function code:
  - Function code 3: Read Holding register
  - Function code 16: Write multiple register

Mechanism of PWM generation

- Parameters like sampling frequency, modulating frequency, etc are set.
- Using a PWM channel of a microcontroller, a pwm signal of frequency equal to the sampling frequency is generated which takes variables duty cycles based on a lookup table.
- The above method generates a sine pwm of fixed phase and amplitude, to vary the frequency the incrementing index of duty cycles is changed.
- For amplitude modulation, the duty cycle values are scaled by a scaling factor (between 0 and 1).

3 Phase Sine Wave

Duty cycle variation for the 3 PWM signals



Results

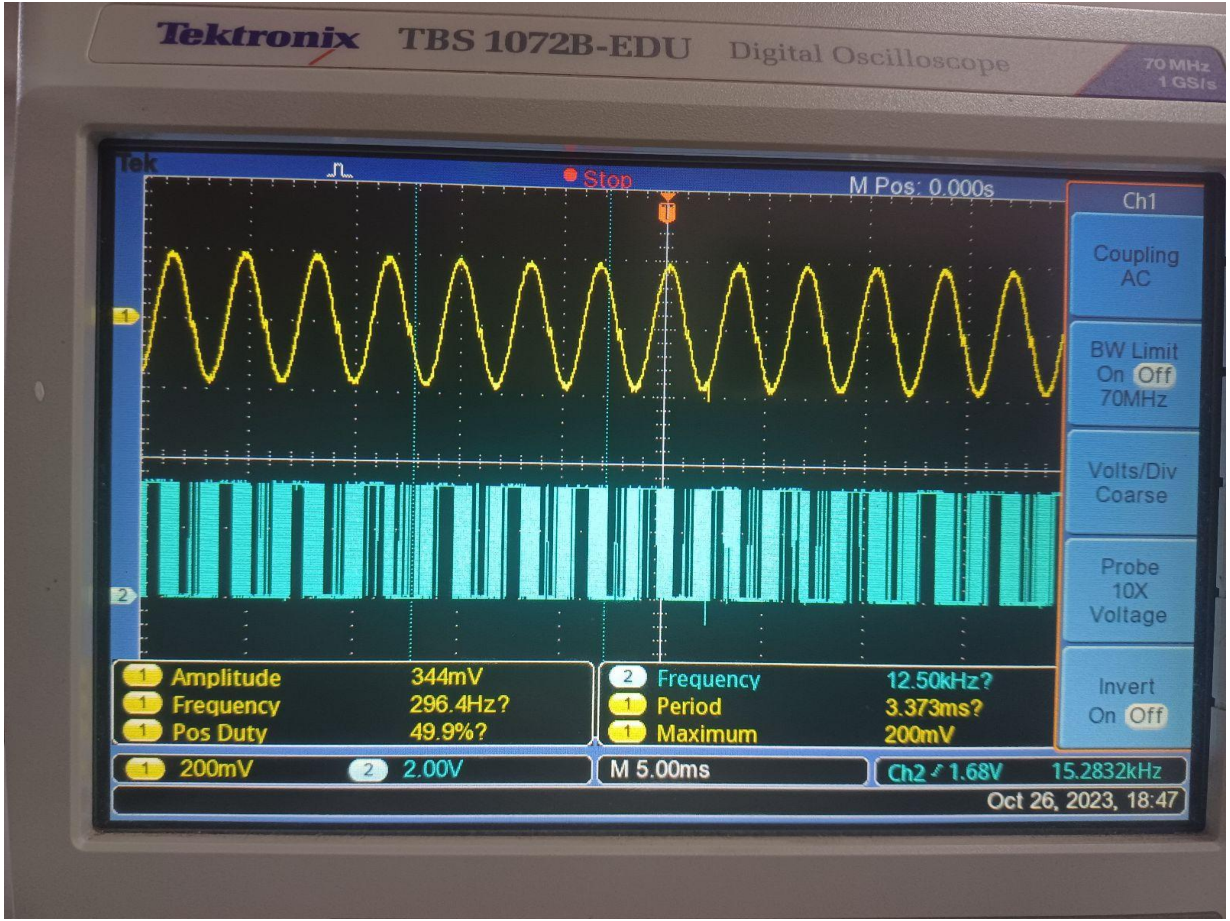


Figure: Results of the sine pwm generation on TM4C123GH6PM, top: filtered pwm signal; below: pwm signal generated by the microcontroller

Results

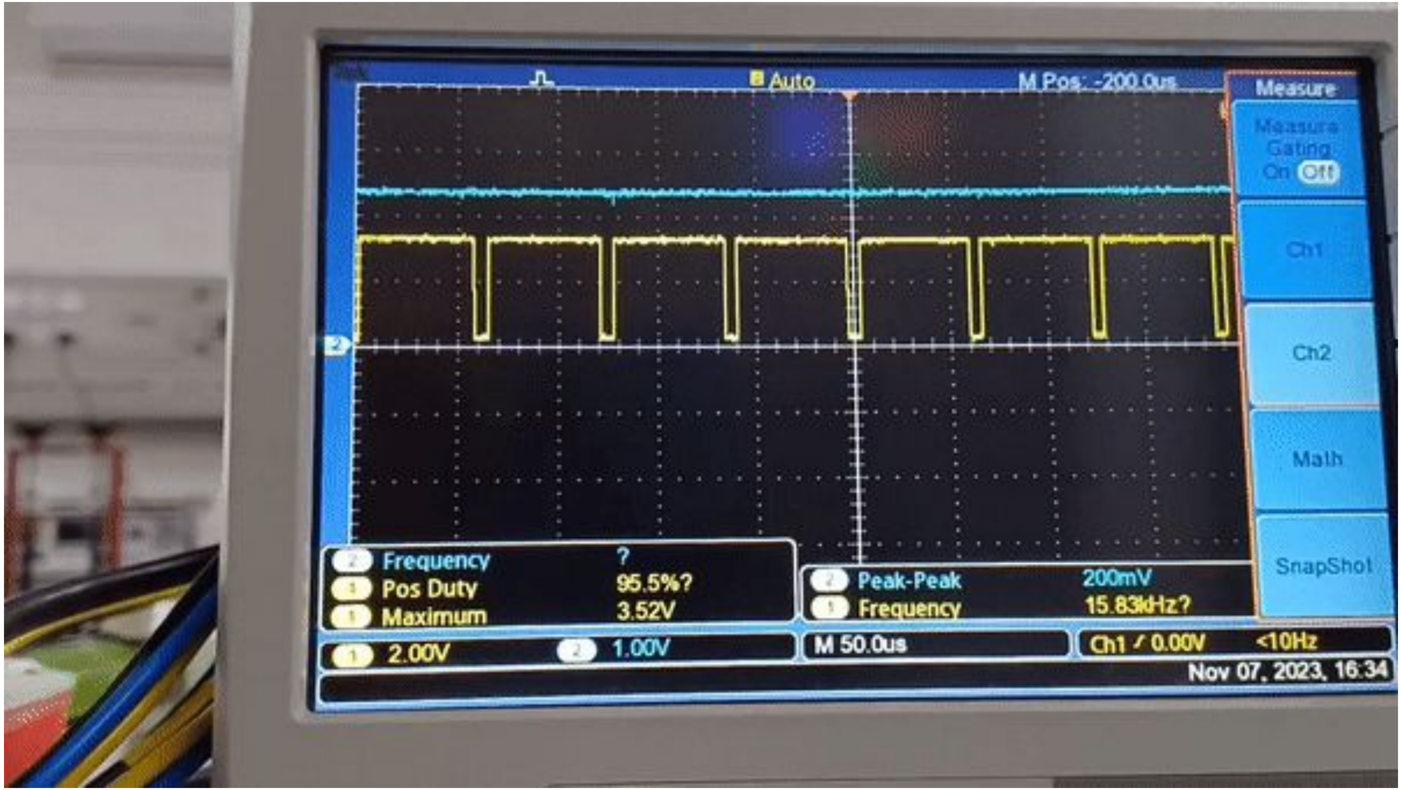


Figure: Results of the sine pwm generation on TM4C123GH6PM, blue: filtered pwm signal; yellow: pwm signal generated by the microcontroller

Results

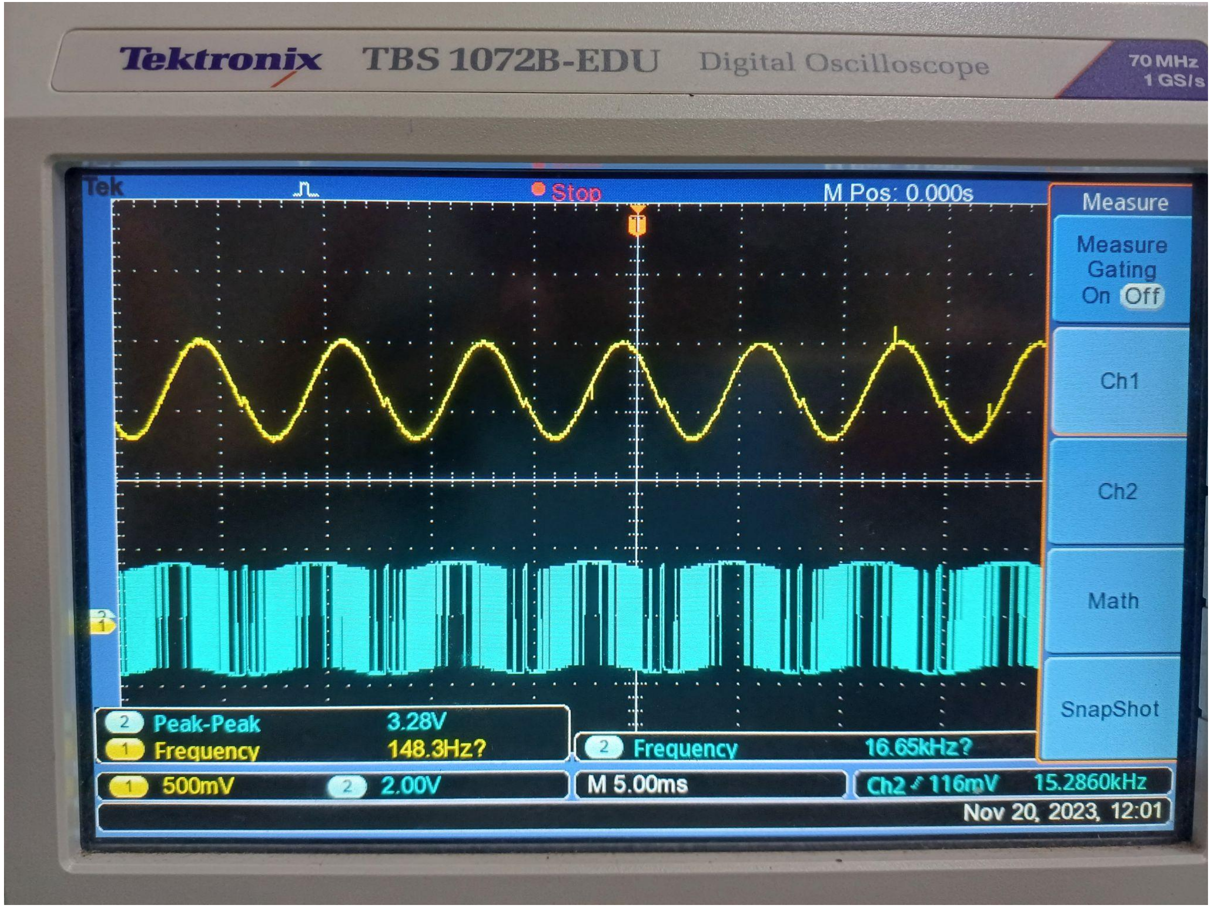


Figure: Results of the frequency modulation of the PWM waveform blue: filtered pwm signal; yellow: pwm signal generated by the microcontroller

Results

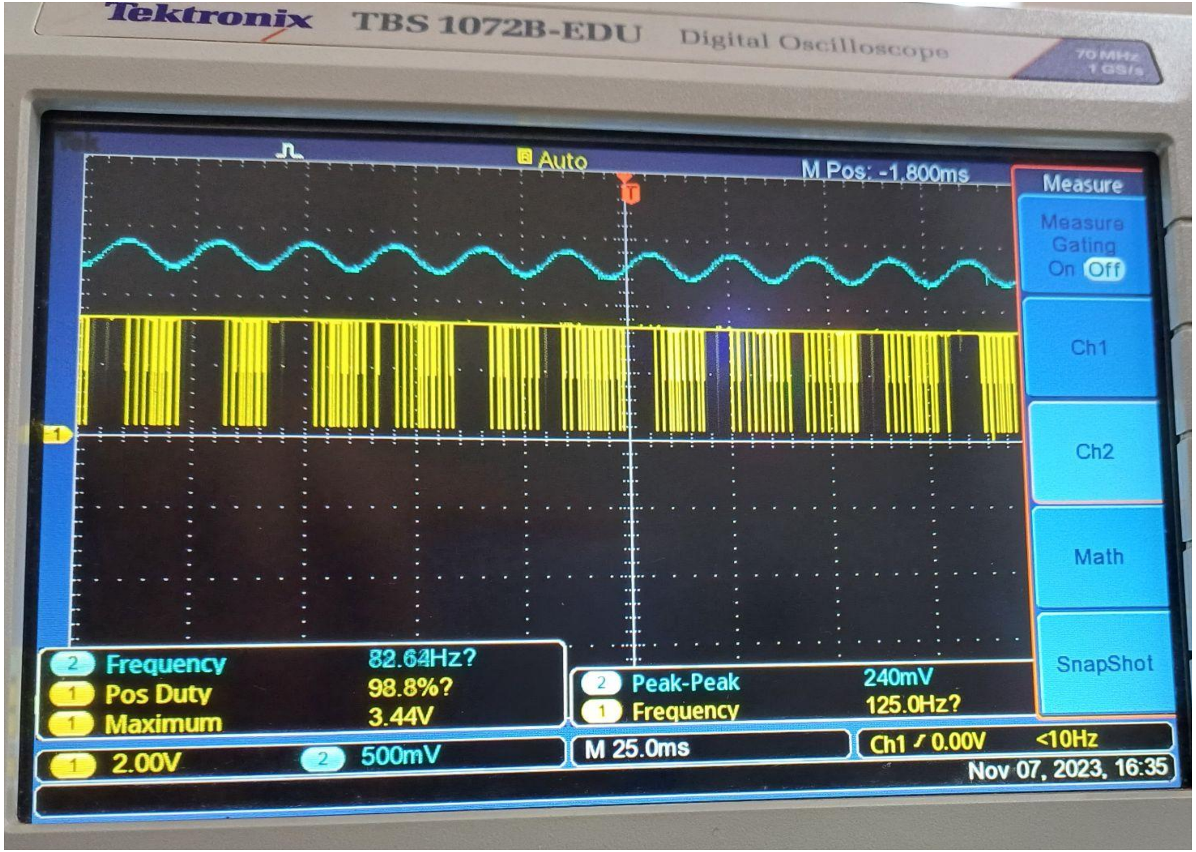


Figure: Results of the amplitude modulation (70%) of the PWM waveform blue: filtered pwm signal; yellow: pwm signal generated by the microcontroller

Results

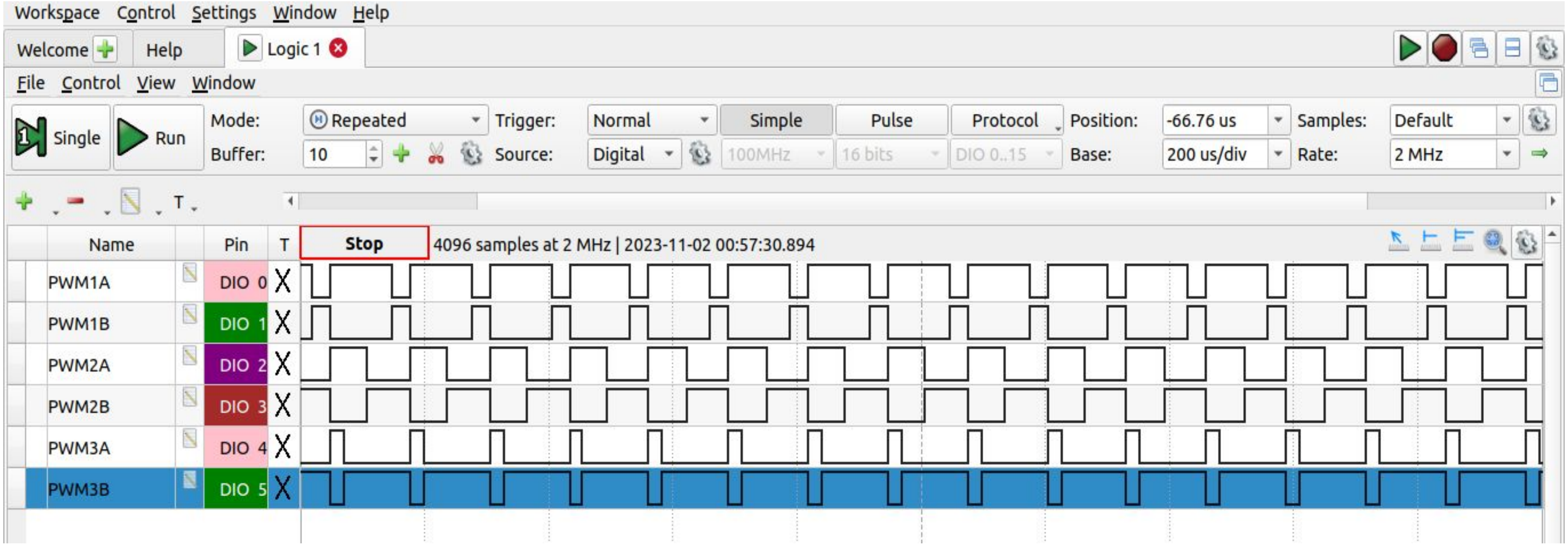
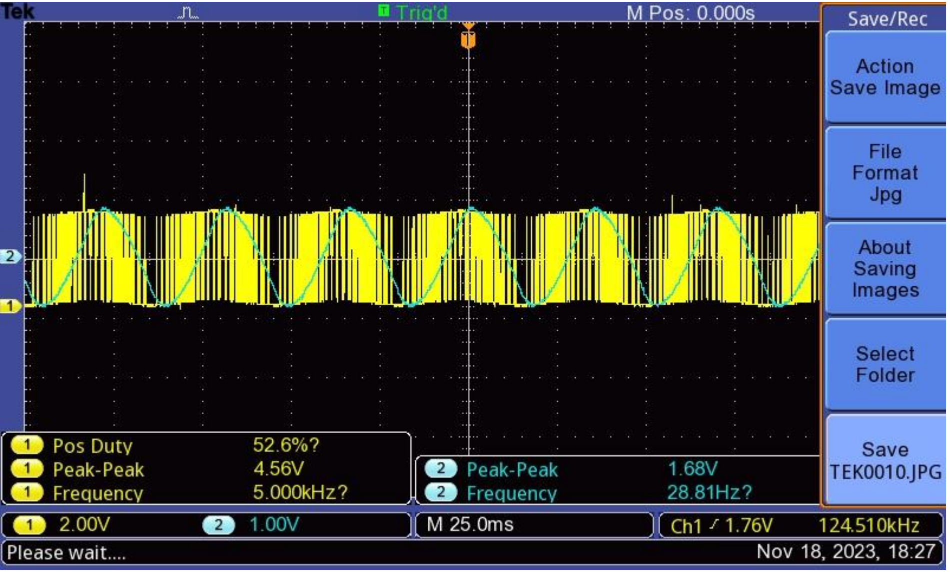


Figure: 6 PWM signals generated using TI F28379D (C2000 MCU)

Results: Frequency Modulation



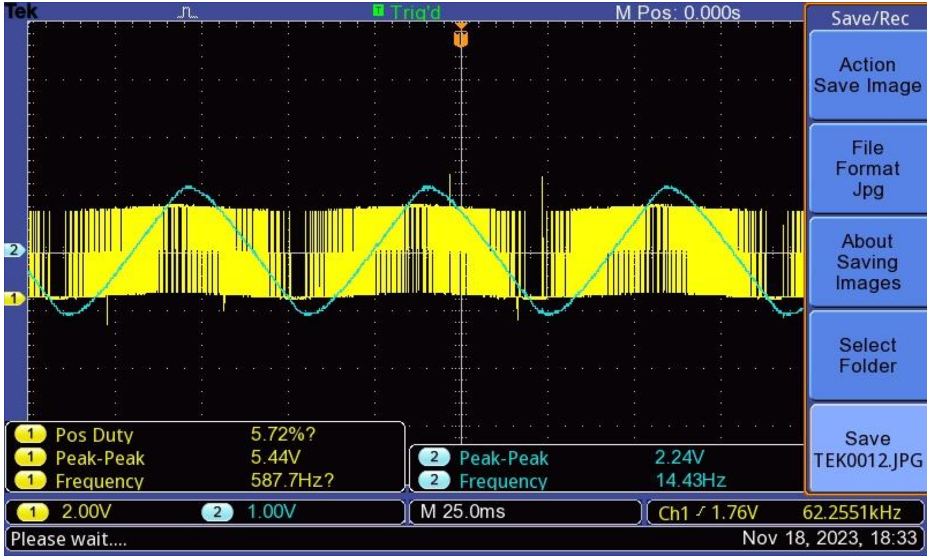
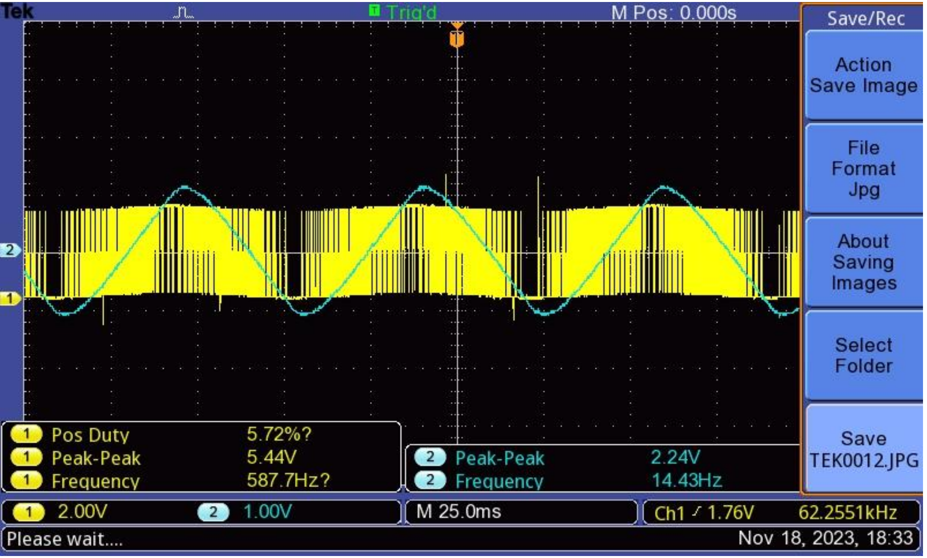


Figure: Left: 30Hz; Right:15Hz

Results: Frequency Modulation



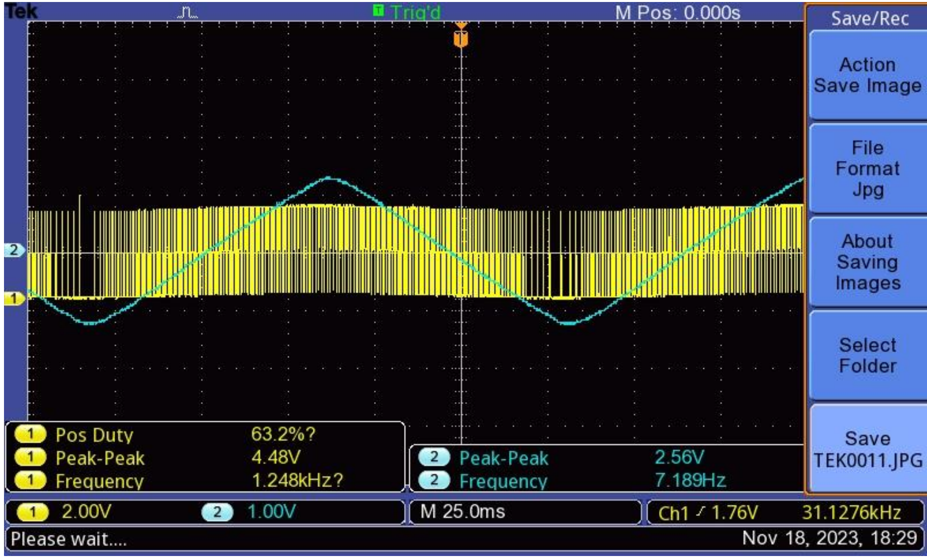
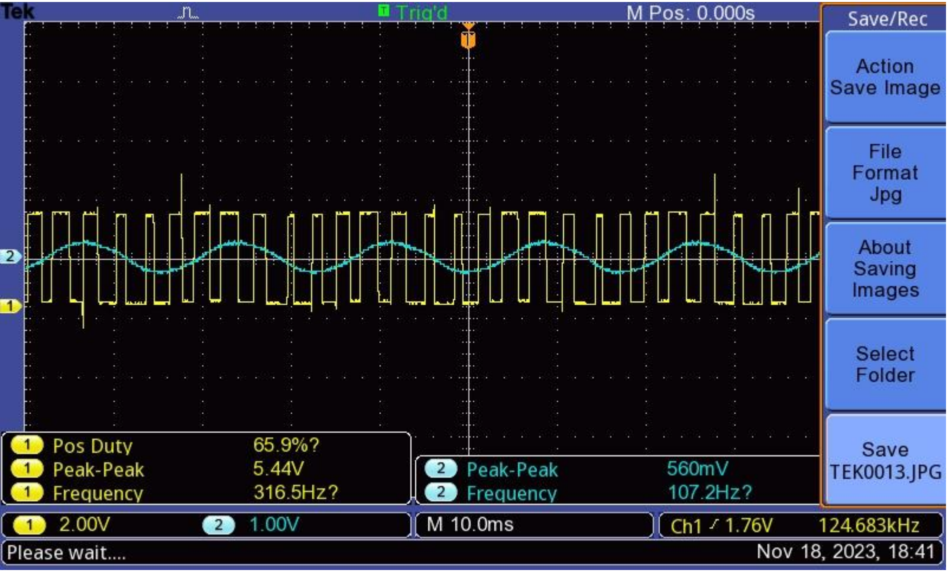


Figure: Left: 15Hz; Right:7.5Hz

Results: Amplitude Modulation



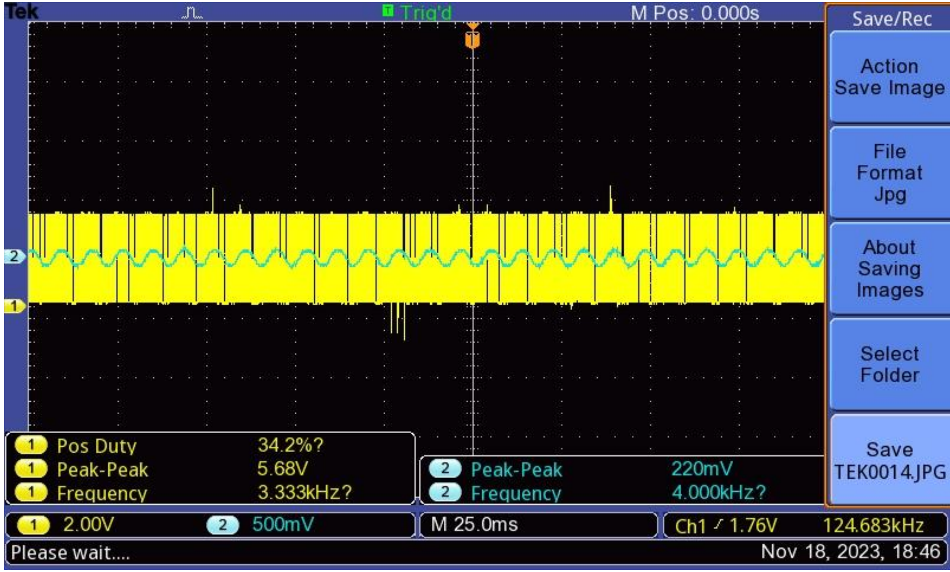


Figure: Left: 560 mV Amplitude(p-p); Right: 220 mV Amplitude(p-p)

Results: 3-phase signal

Figure: 3-phase sinusoidal signals obtained after filtering the corresponding PWM output

Conclusion and Further scope

- Studied the type of EV Chargers in the market.
- Studied the different industry standard communication protocols.
- Generation of 3-phase PWM signals.
- The entire system can be implemented by designing and integrating all blocks.
- Using a secure communication protocol.
- Designing a Modbus(TCP) Control System.

References

- ModBus Technical Reference Manual
- Modbus Official Website
- Modbus C Support
- Modbus Data Frame
- EV Chargers Talk by Prof. Satish
- CAN Reference
- Pradeep: EV Chargers
- EV Chargers

Acknowledgement:

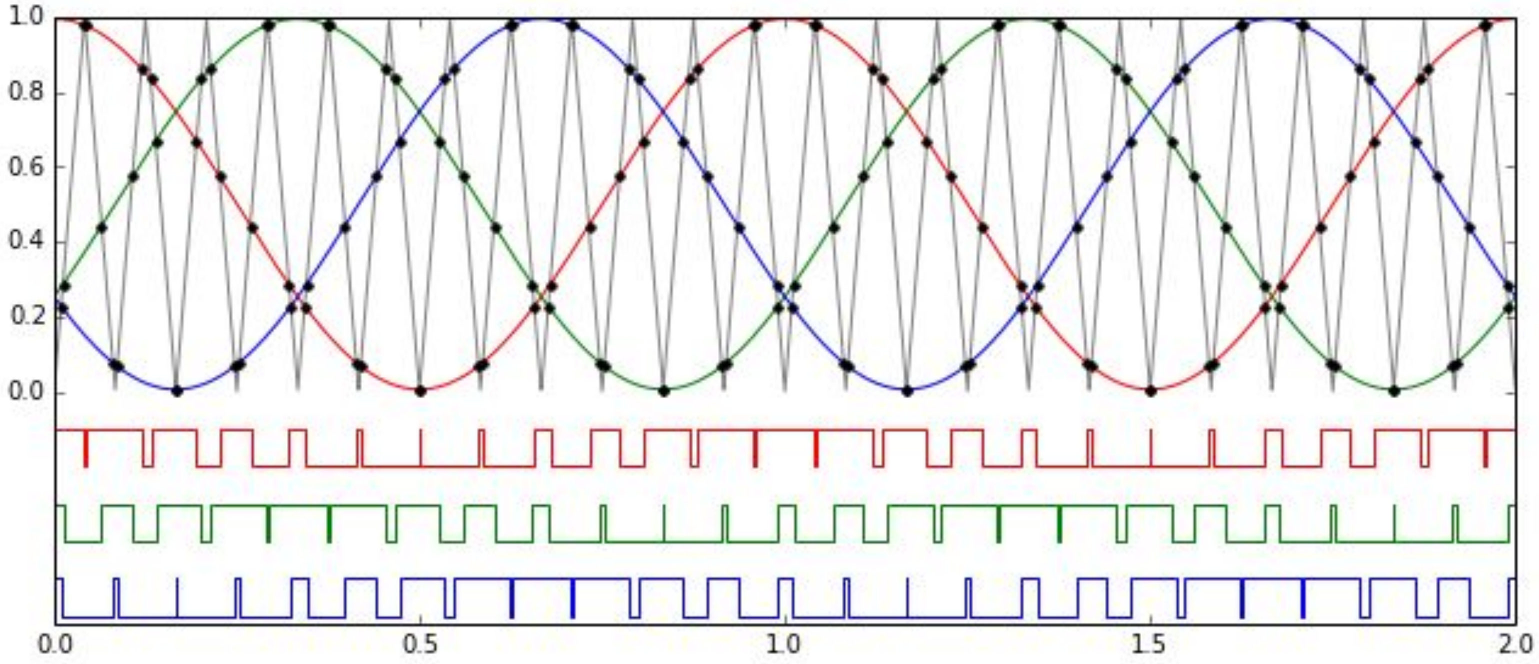
I would like to express my sincere gratitude to our supervisor Prof Abhijit for guiding us throughout this BTP.

We came to know about so many new things and has given us a great hands-on experience in working with a few more embedded systems. Hoping to collaborate further!

Thank you!

Questions?

The 3 phase signal we want to generate



Bidirectional EVSE Block Diagram

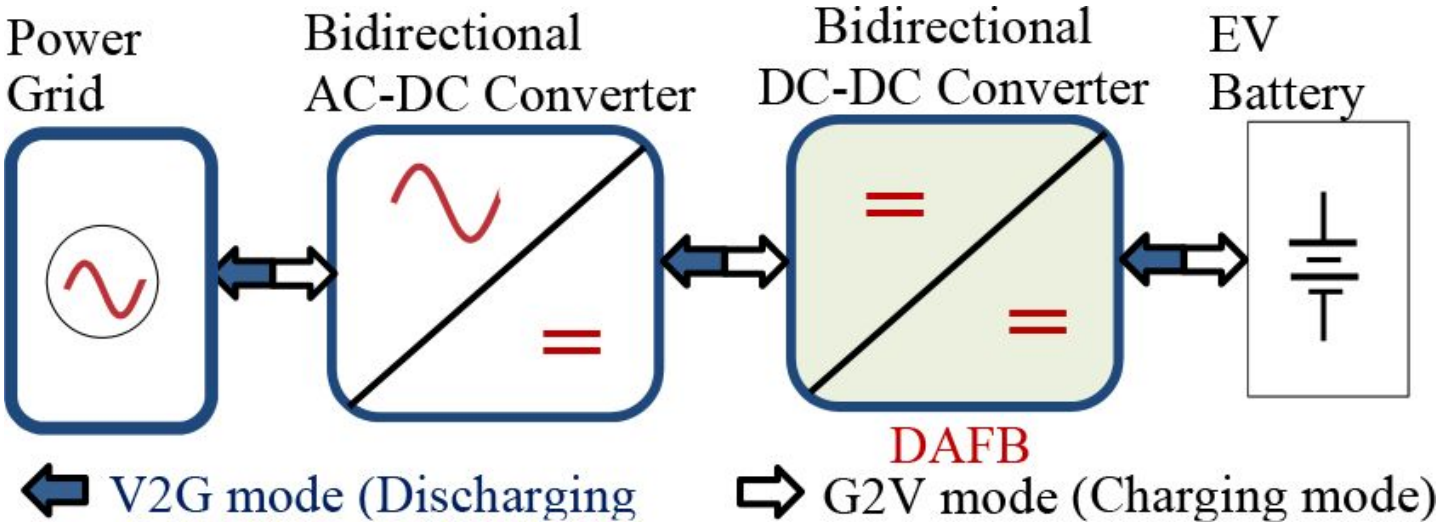


Figure 2: Block Diagram of a Bidirectional Charger

CONSTRUCTION OF A MODBUS TCP DATA PACKET