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Portable Power Supply

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Abstract

When sometimes people go outside home for a trip or picnic, they may need a 230v AC source, especially when they go to place that doesn't have any access of traditional electric outlet like forests.

So, it wishes to build a device which will provide electrical power and can be portable and easy to transport and compact for everyone who love to go outside for long time.

In this project Li-ion batteries are used to provide electric power to the device. Why Li-ion batteries, because these batteries are the most popular and can be recharged and used on most of electric devices like mobile phones because of their reliability, efficiency and long lasting.

And by using power electronics an inverter will be built to produce pure 230v sine wave in our device, and it will use different DC output ports to charge a phone or a laptop, and this device will provide built in radio and Bluetooth speaker and it will support wireless charging for some devices and it will provide some helpful camping features.

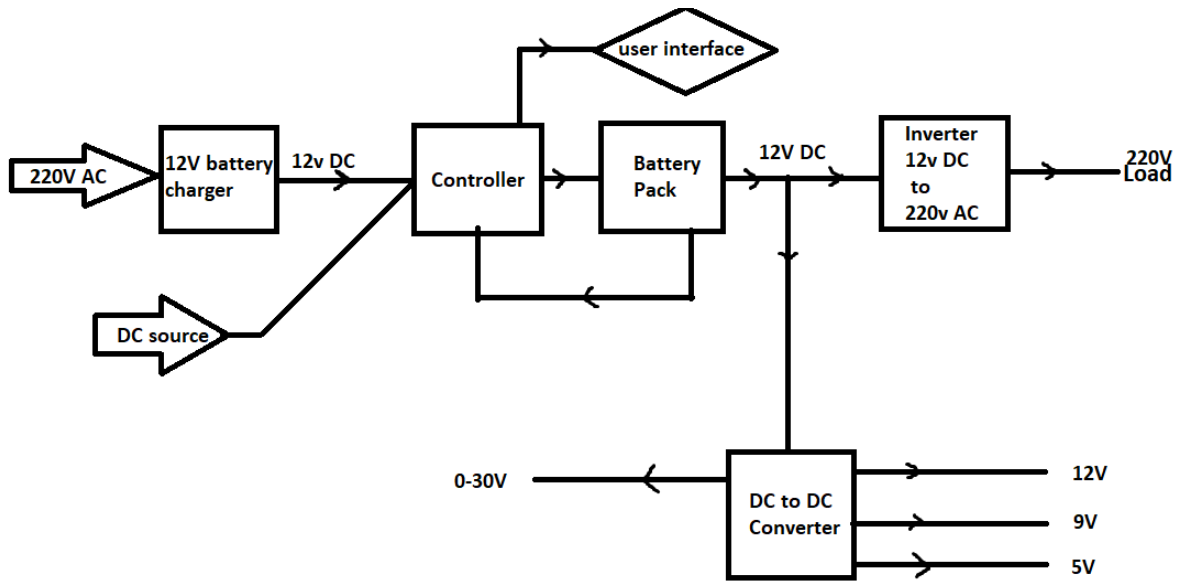


Figure 1: Portable power supply topology.

Chapter 1: Introduction

In a time where technological connectivity and mobility rule the day, having dependable and portable power options is essential. The increasing reliance on electronic gadgets is leading to a pressing need for power sources that can function outside conventional outlets' constraints and offer a versatile and easily obtainable energy option for a range of situations. This introduction lays the groundwork for an in-depth investigation into the world of portable power supplies, covering the problems they solve, the objectives they seek to fulfill, and the range of uses for which they are useful. [1]

A portable power supply is a small, lightweight gadget that may be carried around and used to store and release electricity when needed. It is useful for giving electronic equipment a quick and reliable power supply when access to traditional power outlets is restricted or nonexistent. In order to meet the increasing demand for power solutions that support mobile lifestyles, outdoor activities, and emergency circumstances, portable power supplies are essential. These gadgets enable people to always be linked and energized, guaranteeing that electronic devices work no matter where they are or what conditions are outside of them

Power banks, hand-cranked generators, solar power stations, built-in battery portable power stations, jump starts, and portable generators are a few types of portable power supply. These gadgets are useful in a variety of situations, including travel, camping, hiking, emergency preparedness, building sites, and recreational vehicles.

Even though they are quite adaptable, portable power supply have drawbacks. These consist of restricted capacity, variable output capacities, dependence on outside sources, such as sunshine for solar power plants, and the requirement for recharging on a regular basis. Environmental concerns and balancing portability and power capacity are two major problems in the development of these gadgets.

This paper aims to investigate the field of portable power supply in great detail. The scope entails comprehending the field's applications, difficulties, and possibilities as well as putting forth viable fixes to improve the efficiency and usefulness of portable power supplies.

1.1 Problem Discussion

The modern lifestyle, with its many activities and continual movement, makes it difficult to have continuous access to power. Conventional power supplies are frequently unavailable when traveling, in an emergency, or in an outdoor environment, which might result in situations when electronic devices stop working. In order to close the gap between power supply and demand, portable power supplies are essential. The issue at hand is making sure there is a consistent and dependable power source regardless of the location or outside conditions.



Figure 1.1: Portable power supply [10].



Figure 1.2: Li-ion batteries [10].



Figure 1.3: Camping while using portable power supply [10].

1.2 Aims and Objectives

This study's main goal is to thoroughly investigate and comprehend the portable power supply market while solving the difficulties brought on by the constraints of traditional power sources.

The particular goals consist of:

Identifying Key Applications: Examine the various scenarios and environments where portable power supplies are indispensable, such as outdoor activities, travel, emergencies, and construction sites.

Analyzing Device Types: Investigate the diverse types of portable power supplies available in the market, ranging from power banks to portable generators, assessing their features, functionalities, and suitability for different use cases.

Evaluating Technical Specifications: Delve into the technical aspects of portable power supplies, including capacity, output ports, charging options, and safety features, to understand their capabilities and limitations.

Assessing Environmental Impacts: Explore the environmental implications of portable power supplies, with a focus on sustainable options such as solar power stations, to gauge their eco-friendliness.

Understanding User Considerations: Investigate user considerations when selecting portable power supplies, considering factors such as convenience, versatility, and safety.

1.3 Scope of the Work

This work's scope includes a detailed analysis of the portable power supply market, with a focus on the market's wide range of applications and technological differences. In addition to evaluating the situation of portable power solutions as it stands today, the study will look at future developments and hot topics in the industry. Insights from the research will be beneficial for producers, legislators, and consumers in general, helping to clarify the function and importance of portable power supply in our technologically advanced society.

Chapter 2: Standards, Constraints and Earlier Coursework

2.1 Standards

The portable power supply industry is subject to a variety of national and international standards that ensure safety, performance, and compatibility. Some of the key standards to consider include:

Electrical safety: IEC 62133 for battery-powered portable electronic devices, UL 2557 for stationary and portable batteries, and UN 38.3 for the transport of lithium batteries.

Electromagnetic compatibility (EMC): EN 55022 for radio interference and EN 55024 for conducted emissions.

Environmental regulations: Restriction of Hazardous Substances (RoHS) directive and Waste Electrical and Electronic Equipment (WEEE) directive in the European Union.

Meeting these standards is essential for ensuring the safety and marketability of your portable power supplies. It's crucial to research the specific standards that apply to your target market and ensure your products comply with them.

2.2 Constraints

The design and implementation of this project was under certain restrictions, such as:

- **Cost**: The project members agreed that the cost of this project should not exceed \$400.
- **Size and weight of the power source**: Our power source must not take up a large space and must be relatively small and easy to carry.
- **Battery capacity**: The battery capacity must be chosen carefully because it determines how long the power source can provide electricity, and in our project, we used lithium-ion batteries.
- **Product efficiency**: It must be of relatively high efficiency, in order to serve the consumer well and for a good period of time.
- **Difficulties**: the political situations were too bad, and we couldn't meet each other personally, and couldn't visit the university and we had some power cut issues.

2.3 Earlier Coursework

Some of the courses taken so far in this program have helped in provided basic important knowledge and understanding of the components and techniques used in this project. Below are some of the courses that helped complete this project:

- **Installations:** it helped us to calculate the rated power and suitable cross area of the cables.
- **Power Electronics:** It helped us to construct the different circuits, such as buck-converter, boost-converter, the inverter and others
- **Control of Electric Machines:** to simulate our project in the MATLAB.
- **Microprocessors and Microcontrollers:** it improved our skills to program and connect our project with Arduino board.
- **English for engineers:** it improved our skills to write a full integrated report.

Chapter 3: Literature Review

In this chapter, the literature review of all the aspects related to portable power in general and portable power supply in specific are discussed; in addition to alternative approaches.

3.1 History

For decades, portable power technology has had a significant impact on social progress and improving our daily lives. For example, temporary power supplies give us flexibility in accessing electricity even in remote areas. Also, when going out for a walk or picnic. can also keep essential medical equipment running in hospitals when power goes out and provide relief to those affected by natural disasters.

The principle of portable power is not new, but the modern portable power supply today is a relatively new invention. Its growth can be attributed to several key developments:

The concept of portable power outdates the invention of the lightbulb! Portable power can be traced back all the way to ancient times in the Parthian Period (250 BC to 224 AD). The Baghdad battery was one of the earliest prototypes of portable power. This primitive battery was composed of a clay jar using a stopper made from asphalt. The stopper contained a metal rod wrapped in copper. When filled with vinegar, it created a small electrical voltage.[2]

In the early 19th century, scientists such as Hans Christian Oersted discovered electromagnetism, the electric force generated by magnetism. Oersted began to delve into electromagnetism, placing a compass on a wire through which an electric current flowed, and studying how the compass responded. Ten years later, Michael Faraday began to build on Oersted's findings to better understand how electromagnetism worked. He proposed "Faraday's Law," which describes how magnetic fields induce voltages in electrical circuits. These discoveries laid the foundation for the makeshift electrical devices we use today.[2]

In 1831, Faraday invented the first electric generator, also known as a "dynamo." Throughout the 19th century, many scientists contributed to a better understanding of how to generate electricity through motion rather than through permanently attached magnets. In the late 19th and early 20th centuries, Nikola Tesla began developing generators that produced alternating current (AC).

The advent of portable generators (1920s-1970s):

1920s to 1950s: Portable generators with gasoline or diesel engines become popular, providing off-grid power for camping, construction, and emergencies. However, these generators are noisy, produce smoke, and require refueling.[3]

1960s and 1970s: Developments in solid-state electronics lead to smaller, more efficient inverters that can convert DC power from battery packs into AC power suitable for powering devices.

1980s and 1990s: Advances in battery technology, such as the introduction of sealed lead-acid and gel batteries, increase efficiency and portability. However, these batteries still lack the energy density required for truly portable power solutions.[2]

The Birth of the Modern Portable Power Supply (21st Century to Present):

2000s: The invention of lithium-ion batteries in the 1970s provided the high energy density and portability needed for practical portable power supply. Companies like Goal Zero and Jackery began pioneering the market in the late 2000s, offering compact, rechargeable battery packs with AC and USB ports.

2010-Present: Portable power supplies are growing in popularity for a variety of uses, from camping and outdoor activities to emergency preparedness and off-grid living. Advances in solar panels, wireless charging and smart app control integration have increased their functionality and appeal.[4]

Future trends: The future of portable power plants may include higher power density, faster charging times and greater integration with renewable energy sources such as solar and wind.

Overall, the history of portable power supplies is one of innovation and adaptation. From the clunky batteries and noisy generators of the early days to the sleek, versatile power supplies of today, these devices have come a long way and continue to evolve to meet the growing demand for portable, clean and sustainable energy solutions.

3.2 portable power supplies

A portable power supply is a rechargeable battery-powered generator that can charge and power many devices and appliances via different outputs, such as AC, DC, USB, and Type-C. It can be charged in several ways, such as with a mains adapter, a car charger, or solar panels. It is ideal for outdoor activities, emergency situations, and backup power. It uses lithium-ion or lithium iron phosphate batteries to provide a stable and safe power system.

3.3 Alternative Solutions

The historical evolution of portable power stations reflects the journey from bulky generators to compact lithium-ion powered devices. Current literature explores alternative solutions ranging from renewable energy integration to innovative battery technologies, shaping the future prospects of portable power plants.[5]

The alternative solutions for enhancing portable power stations encompass various features and improvements. These include the incorporation of a removable solar panel for optimal sunlight exposure, the provision of multiple charging ports for diverse device compatibility, and the implementation of a wireless power bank feature that enables the device to charge other devices wirelessly when plugged into an electrical outlet.[5]

Additionally, a remote monitoring system is proposed, allowing users to track battery levels and device status through a smartphone app. To harness renewable energy, solar panels can be integrated, replenishing the lithium-ion battery and extending the device's runtime, especially during daylight hours.

Efficiency is further addressed through the optimization of power consumption in integrated electronics, promoting a longer battery life. For group outings or scenarios requiring multiple device charging, a portable charging station accommodating several devices simultaneously is suggested. In emergency situations where conventional power sources are unavailable, a human-powered charging option involving a small pedal or hand generator is proposed.

To enhance convenience, a foldable design is considered for easy storage and transportation, and a safety dimension is introduced through the inclusion of an emergency beacon or SOS feature. Together, these alternative solutions aim to augment the functionality, efficiency, and versatility of portable power stations for outdoor applications.

Examining other possibilities for portable power plants reveals a thorough plan to improve their efficiency, sustainability, and versatility in different outdoor environments. The suggested solutions cover both the technology and the design fronts. Notable developments in renewable energy integration through solar installations and detachable solar panels are examples of sustainable power sources.

The solutions include features like numerous charging connections, wireless power banks, and remote monitoring through an easy-to-use smartphone app in order to address the growing demand for ease and versatility. The use of energy-efficient devices and power consumption optimization demonstrate the dedication to both energy efficiency and battery life.

The development of human-powered emergency charging substitutes and transportable charging stations for group excursions is another example of versatility.[5]

The consideration of a foldable form for convenient storage and transportation serves as a highlight for the user-centric approach. Furthermore, the emphasis on safety measures, like improved water resistance and durability and SOS functions, increases the dependability of these power plants in demanding outdoor settings. In the end, these substitute approaches provide portable power plants as dependable energy providers as well as necessary partners for people participating in a variety of outdoor pursuits, satisfying changing needs and expectations.

Chapter 4: Methodology

4.1 H-Bridge Inverter:

A H-Bridge inverter is a circuit that switch the polarity of the voltage applied to the load, this circuit used in many applications like robots, dc motors and inverters. It's called H-Bridge because of the shape of the circuit which include four switching elements such as IGBTs, MOSFETs, BJT, etc. represent the letter "H" as shown in figure 4.1. The H-bridge inverter is usually controlled by a PWM signal at the gates of the transistors. [6]

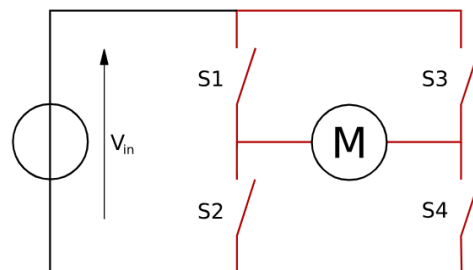


Figure 4.1: Schematic of an H-bridge [6].

The main purpose of the H-Bridge inverter is to change the polarity of the output voltage, so it can invert the DC voltage into AC voltage, so when the switches S1 & S4 are closed and S3 & S2 are opened, positive voltage applied at the load. And when S2 & S3 are closed and S1 & S4

are opened the voltage is negative. So, from this principle S1 & S2 will never be closed together and S3 & S4 also will never close together.[6]

The output voltage of it depends on its modulation index (m) which tells the ratio of the peak AC voltage to the DC voltage, and frequency (f), so it could determine the output voltage using these equations:

$$V_{out} = m * V_{dc} \quad (4.1)$$

$$f = \frac{1}{T_{sw}} \quad (4.2)$$

where T_{sw} is the switching period

[6]

4.2 Buck Converter:

Buck converter is a device used to step down the DC voltage in power electronics, it's widely used in various applications like power supplies, chargers and others. It's known of its simplicity, reliability and effectiveness.[7]

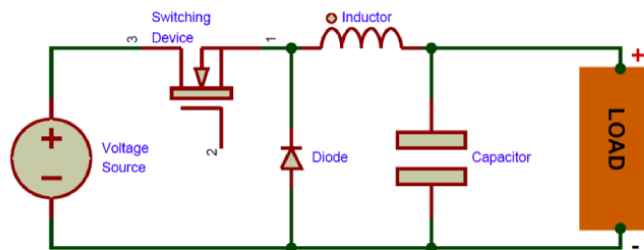


Figure 4.2: Schematic of a buck-converter [9].

The structure of buck converter consists of a switching device, inductor, capacitor and a diode as shown in figure 4.2. while operating the switching devices turns off and on intermittently,

so when the switch is closed the energy stores in the inductor, and when the switch is open the energy in the inductor will discharge in the load. the diode used to make sure there is no reverse current flow and the capacitor to make the output voltage smoother.[7]

The opening and closing operation of the switch happened according to the duty cycle (D) so it's the ratio between the on-state time (T_{on}) and the total time ($T_{on} + T_{off}$)

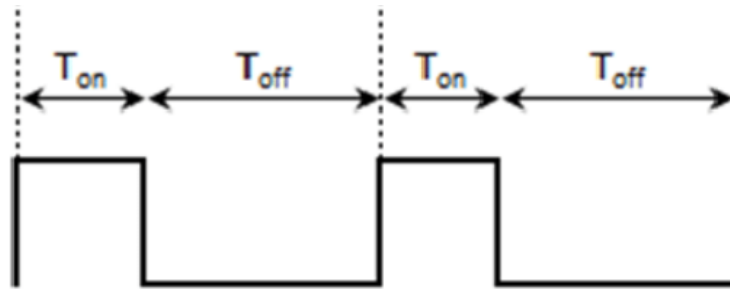


Figure 4.3: Duty Cycle Diagram [6]

$$\text{So } D = \frac{T_{on}}{T} \quad (4.3)$$

This parameter used to determine the output voltage of the buck converter which equals:

$$V_{out} = D * V_{in} \quad (4.4)$$

To design a buck converter, it's needed to choose the right values of the capacity of the capacitor (C) and the inductance of the inductor (L), which are given by these equations:

$$L = (V_{in} - V_o) * D * \frac{T}{\Delta i} \quad (4.5)$$

$$C = \frac{T * \Delta i}{8 * \Delta V_o} \quad (4.6)$$

Where Δi is the difference between $i_{on\ state}$ and $i_{off\ state}$ and ΔV_o is the difference between max and min value of voltage at steady state. [7]

4.3 Boost Converter:

Boost converters are the opposite of buck ones, they step up the voltage, so they boost low DC voltage to higher voltages. They used in many applications like electric vehicles, LED drivers and others.[7]

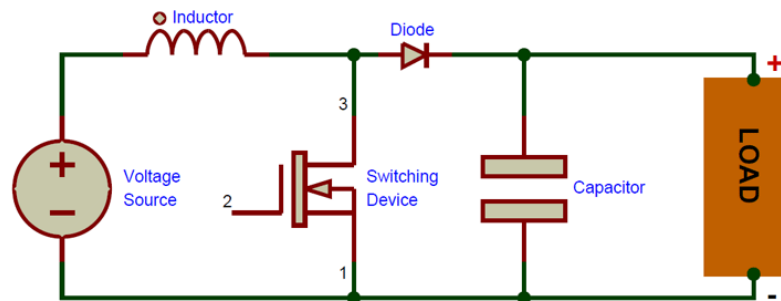


Figure 4.4: Schematic of a boost-converter [9]

The boost converter consists of a switching device to turn on and off while operating, and inductor so when the switch is closed the energy will store in it and when the switch is open it will discharge the energy, and a diode so the energy will only flow to the load, and the capacitor is used to make the output signal smoother. [7]

As mentioned before the opening and closing operation happened according do the duty cycle (D).

As shown in figure 4.3:
$$D = \frac{T_{on}}{T} \quad (4.7)$$

And the output voltage (Vo):
$$V_o = \frac{V_{in}}{1-D} \quad (4.8)$$

To design a boost converter, it's needed to choose the right values of the capacity of the capacitor (C) and the inductance of the inductor (L), which are given by these equations:

$$L = \frac{V_S * D * T}{\Delta i} \quad (4.9)$$

$$C = \frac{D*T*Vo}{R*\Delta Vo} \quad (4.10)$$

Where Δi is the difference between $i_{on\ state}$ and $i_{off\ state}$ and ΔVo is the difference between max and min value of voltage at steady state. [7]

4.4 Battery Management System (BMS)

It is any electronic system that manages a rechargeable battery (cell or battery pack), such as by protecting the battery from operating outside its safe operating area, monitoring its state, calculating secondary data, reporting that data, controlling its environment, authenticating it and balancing it.

A battery pack built together with a battery management system with an external communication data bus is a smart battery pack. A smart battery pack must be charged by a smart battery charger.

4.4.1 Functions of BMS

1- BMS is like a brain of the system, it has many functions to do such as monitoring the data and state of the batteries such as:

- Voltages, input voltage, output voltage and every individual battery voltage.
- Temperature of the system and every individual cell temp. and the coolant intake temp.
- Current flow from the batteries while charging and discharging.
- Health and state of each battery cell.

2- Also, BMS is capable to make some calculations based on the data receiving such as:

- State of charge (SoC) or depth of discharge (DoD), to indicate the charge level of the battery.

- State of health (SoH), it's measurement of the remaining capacity of the battery as % of the original capacity.
- State of power (SoP), the amount of power available for a defined time interval given the current power usage, temperature and other conditions.
- Maximum charge current as a charge current limit (CCL).
- Maximum discharge current as a discharge current limit (DCL).
- Internal impedance of a cell (to determine open circuit voltage).
- Charge (mAh) delivered or stored (sometimes this feature is called coulomb counting).
- Total operating time since first use.
- Total number of cycles.
- Temperature Monitoring.
- Coolant flow for air or liquid cooled batteries.

3- One of human-friendly features is that BMS can communicate with high level hardware like a computer or a laptop or with a Human-Machine Interface (HMI). It use serial communication like USB to transfer and receive data from other hardware.

4- BMS protects the batteries by not letting them to operate out of its safe area, such as:

- Over-charging.
- Over-discharging.
- Over-current during charging.
- Over-current during discharging.
- Over-voltage during charging.
- Under-voltage during discharging.
- Over-temperature.
- Under-temperature.
- Ground fault or leakage current

5- In order to increase the capacity of the batteries, BMS can ensure that all battery cell have the same voltage and same SoC by balancing them. So if one of the batteries is charged more than the other BMS will waste it energy to make it same as others.

4.4.2 BMS Schematic

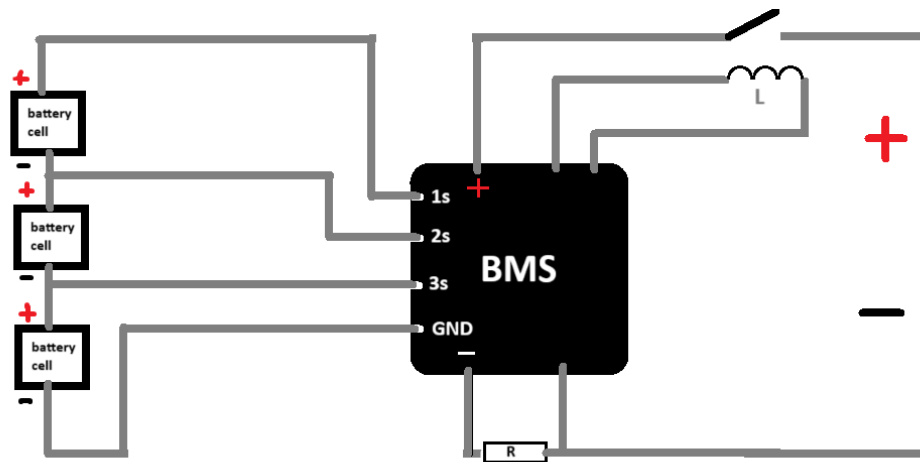


Figure 4.5: Schematic of a BMS

In this project it's used the 3s BMS, which can connect 3 batteries in series as shown in figure 4.5.

This BMS has many I/Os and the inputs (1s,2s,3s and GND) are connected to the battery cells, as shown each connection between cells go to individual input, so the BMS will balance the voltage and the charge of each cell, and to read their data.

And it has a switch on the output positive output pin, and controlled by the BMS using a coil, the switch is used for protection as mentioned before, and there is a resistor R used to measure the output current.

Inside the BMS die there is many circuits and components used for BMS functions which mentioned before.

4.5 Li-ion Battery

Battery is an electric device which store the electric charges inside, and use these charges as electric energy when wanted. It has two terminals the cathode (indicates as positive terminal) and anode (the negative terminal).

There are two types of battery, the disposable and the rechargeable. Disposable are only used when they have enough charges stored inside, and then can't use them again when they fully discharged like alkaline battery. The rechargeable ones can discharge and charged multiple times using suitable dc source, example of them are Li-ion batteries which used in cars, phones, laptops and many other applications. They come in many shapes and sizes to be proper for their device.

In this project Li-ion batteries will be used which are rechargeable and have high energy density, lightweight and long cycle life.

How good a battery can be told according to many characteristics, and the most important ones are:

- Energy density is the amount of energy a battery contains compared to its weight and size, and for li-ion batteries they have high energy density.
- Life cycle is the number of charge and discharge cycles that a battery can complete before losing performance, and li-ion batteries have long life cycle compared to other traditional ones.
- Self-discharge is a phenomenon in batteries in which internal chemical reactions reduce the stored charge of the battery without any connection between the electrodes or any external circuit, and also li-ion batteries have very low self-discharge.

During the discharge process, lithium ions move from the anode to the cathode through the electrolyte, generating electrical current. In the charging phase, this process is reversed. The choice of cathode materials impacts the battery's performance characteristics. And the terminal voltage of this battery varies from 3.7v which is the minimum to 4.2v when it's fully charged.

4.6 Arduino Uno

Arduino is a prototype platform (open-source) based on an easy-to-use hardware and software. It consists of a circuit board, which can be programmed (referred to as a microcontroller) and a ready-made software called Arduino IDE (Integrated Development Environment), which is used to and upload the computer code to the physical board.[8]

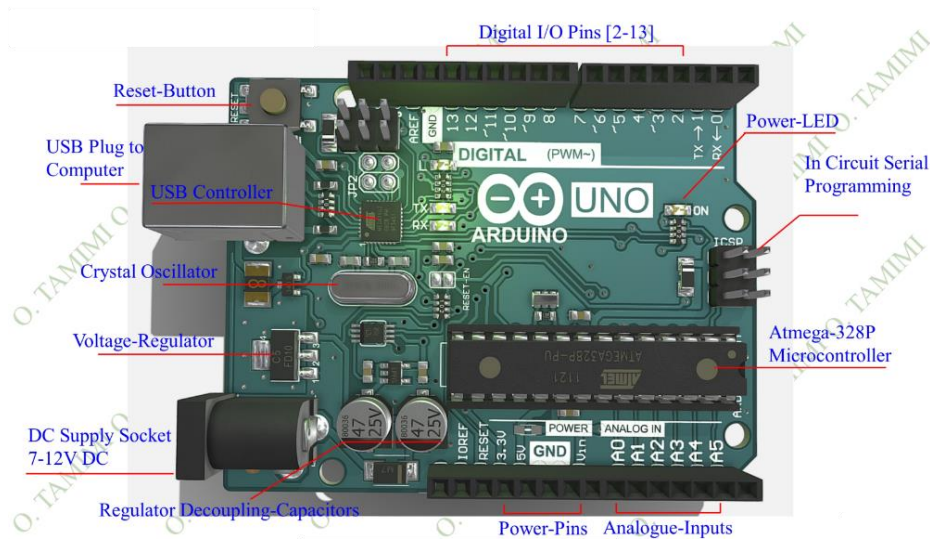


Figure 4.6: Arduino uno board [8]

As shown in figure 4.6 the uno board has many components, first of them are the GPIO ports which used to connect inputs and outputs to the board, they are the digital IOs and the analogue IOs. And it has the controller of it which is the ATmega-328P, it's connected to the GPIOs so it will do what told to do with the GPIOs. It has a USB port to connect it to compute to write the desired program that the controller will do, and can provide power to the board through it so the components will work. In terms of providing power to the board there is two other ways,

it could be supplied using the DC 7v-12v port which can be regulated to 5v, or using the power pins near the analogue IO ports.

In this project this board is used to be connected with some sensors and output display and input buttons, so it's used as a part of HMI for the project, it will have two buttons to switch between the pages in the screen, and a screen to provide a connection between human and the BMS, and sensors are used to measure necessary values to provide them to the LCD screen.



Figure 4.7: 16x2 LCD display

4.7 Hardware

1-Microcontroller A microcontroller (MCU for microcontroller unit) is a small computer on a single metal-oxide-semiconductor (MOS) integrated circuit (IC) chip. A microcontroller contains one or more CPUs (processor cores) along with memory and programmable input/output peripherals. The Arduino uno is used in this project because the project needs high memory so the flash memory for Arduino mega is 32kB, Also it's easy to use hardware and software. And we can read inputs and turn them into outputs.

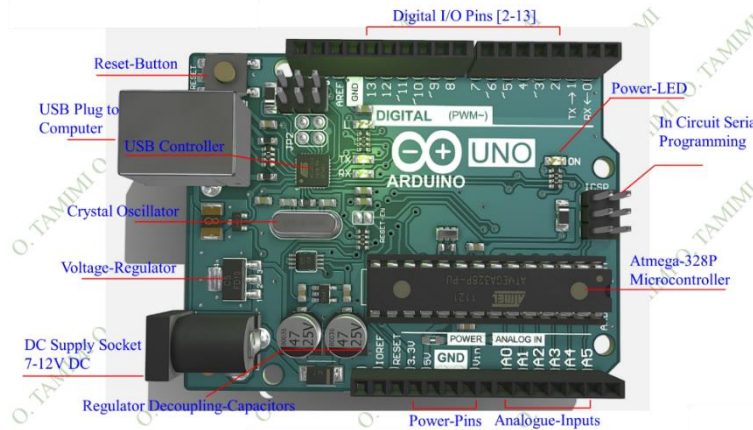


Figure 4.6: Arduino uno board [8]

2-H-bridge The term H-bridge is derived from the typical graphical representation of such a circuit. An H-bridge is built with four switches (solid-state or mechanical). When the switches S1 and S4 (according to the first figure) are closed (and S2 and S3 are open) a positive voltage is applied across the motor. By opening S1 and S4 switches and closing S2 and S3 switches, this voltage is reversed, allowing reverse operation of the motor. Using the nomenclature above, the switches S1 and S2 should never be closed at the same time, as this would cause a short circuit on the input voltage source. The same applies to the switches S3 and S4. This condition is known as shoot through.

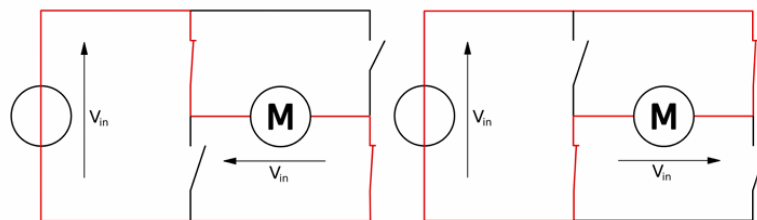


Figure 4.8: H-bridge scheme

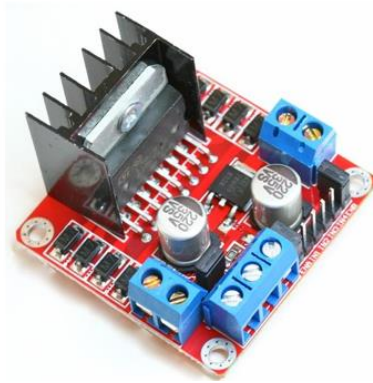


Figure 4.9: H-bridge board

3- Transformer: A transformer is a static electrical device that transfers energy by inductive coupling between its winding circuits. Varying current in the primary winding creates a varying magnetic flux in the transformer's core and thus a varying magnetic flux through the secondary winding. These 49 varying magnetic fluxes induces a varying electromotive force (E.M.F.) or voltage in the secondary winding. The transformer used here is a step-up transformer from 12V to 220V; it is used to step-up the voltage from the output of the H-bridge in order to be able to deliver the appropriate voltage to meet the source voltage.

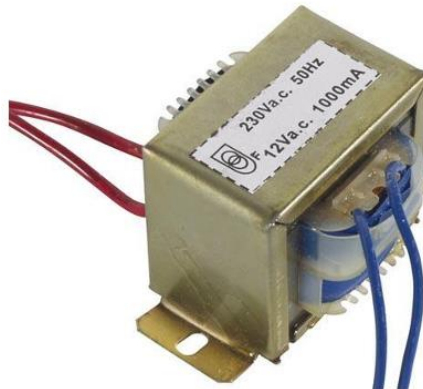


Figure 4.10: 12v/220v transformer

4- LM2596 Buck-converter: The LM2596 series of regulators are monolithic integrated circuits that provide all the active functions for a step-down (buck) switching regulator, capable of driving a 3-A load with excellent line and load regulation.



Figure 4.11: LM2596 Buk-converter

5- XL6009e1 Boost-converter: XL6009e1 is a high-performance boost module with 4A switching current adopting XL6009E1 chip with high frequency switching technology as the core chip, superior performance. Ultra-wide input voltage 3V ~ 32V, the best operating voltage range of 5 ~ 32V. Ultra-wide output voltage 5V ~ 40V. Built-in 4A high efficiency MOSFET switch tube with high efficiency up to 94%.

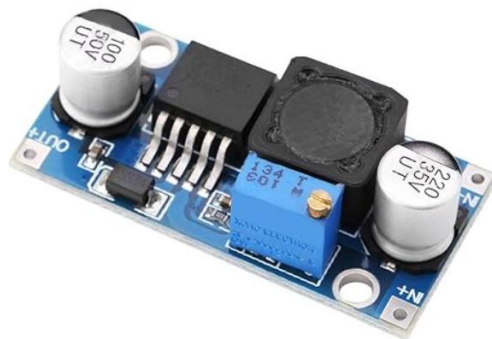


Figure 4.12: XL6009e1 Boost-converter

6- Oscilloscope: Oscilloscopes test and display voltage signals as waveforms, visual representations of the variation of voltage over time. The signals are plotted on a graph, which shows how the signal changes. The vertical (Y) axis represents the voltage measurement and the horizontal (X) axis represents time.

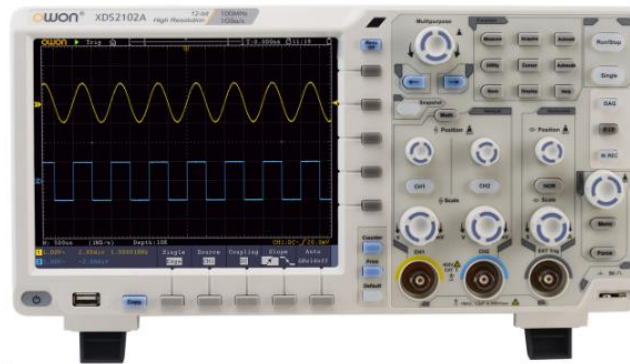


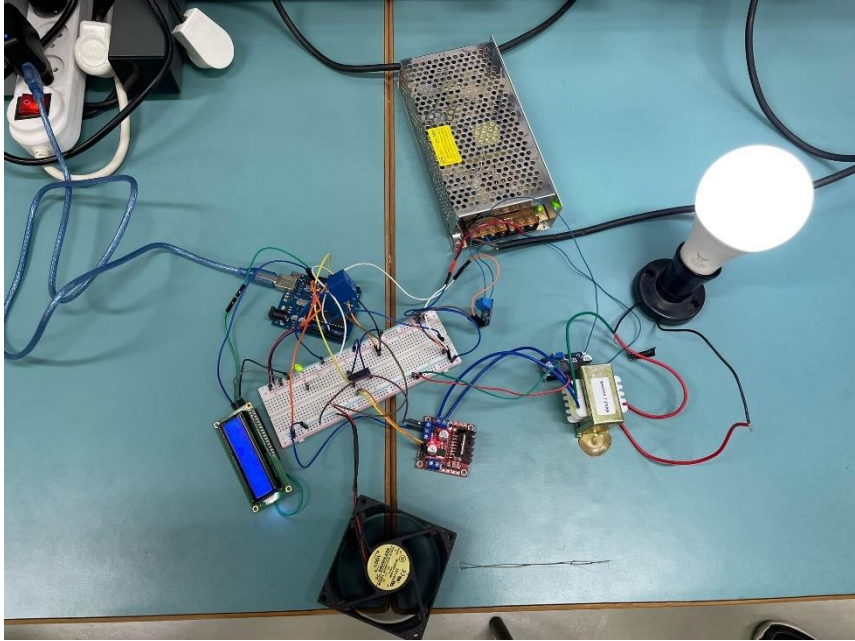
Figure 4.12: Oscilloscope

7- DC power supply: a 12v dc power supply is used to supply the inverter instead of batteries.



Figure 4.13: 12v DC power supply

The whole hardware circuit:



Hardware Results:

Now the whole system output signals will be shown. They were almost the same as the simulating.

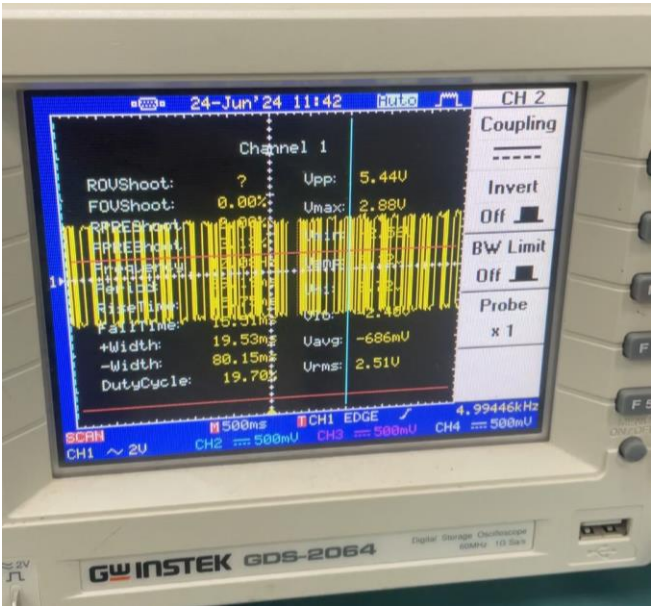


Figure 4.14: PWM signal from the h-bridge

This is output of the h-bridge after feeding it with PWM signal from Arduino board.

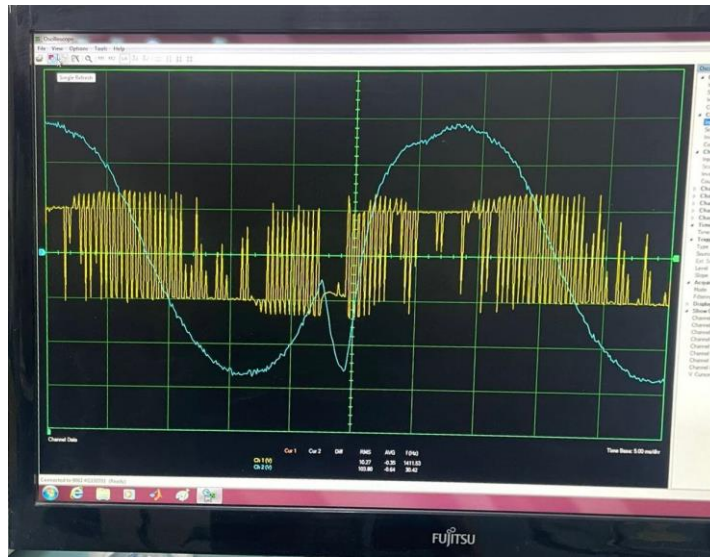


Figure 4.15: output of the transformer with no filter

This is the output of the transformer without using any filtration.

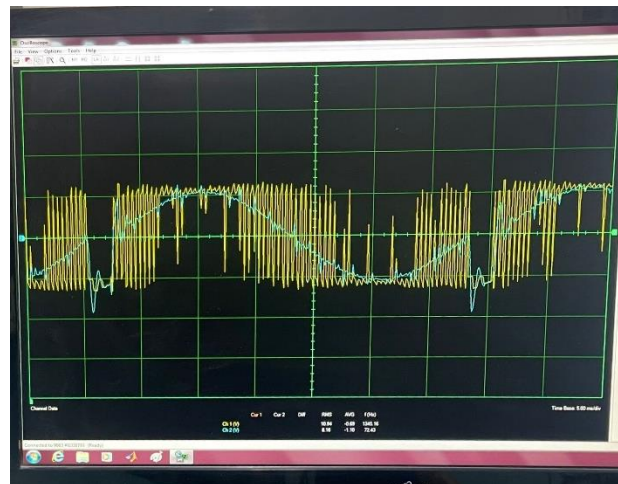


Figure 4.16: output of the transformer with filter

And this is output signal of the transformer after using a filter.

Chapter 5: Simulation Results

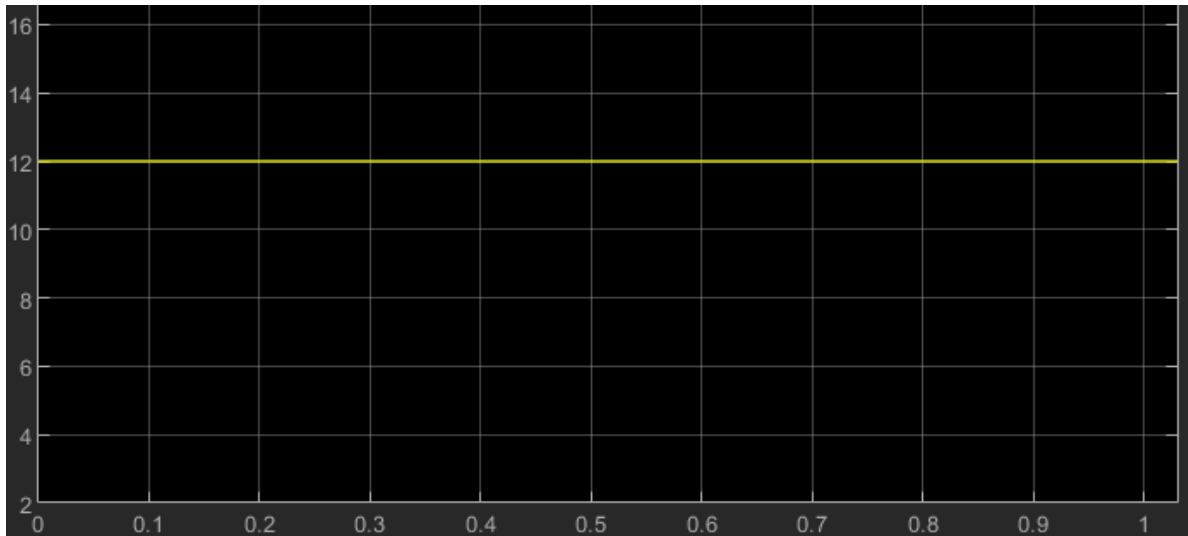


Figure 5.1: 12v source (DC voltage battery).

First as shown in figure 5.1, a 12V dc source from battery cell will start to flow to the system. So, it's the input source.

Then this current will go to the H-bridge inverter which have the four switches to make the current alternative. It's meant to produce 230v 50hz pure AC wave, and to that the switches will open and closed in the right timing, so the minimum amount of harmonic will be produced. A PWM signal will be produced using a comparator and sawtooth wave generator and original 50hz sine wave, connecting both sine wave and sawtooth wave to the comparator will produce a wave that will control the opening and closing operation of the four switches.

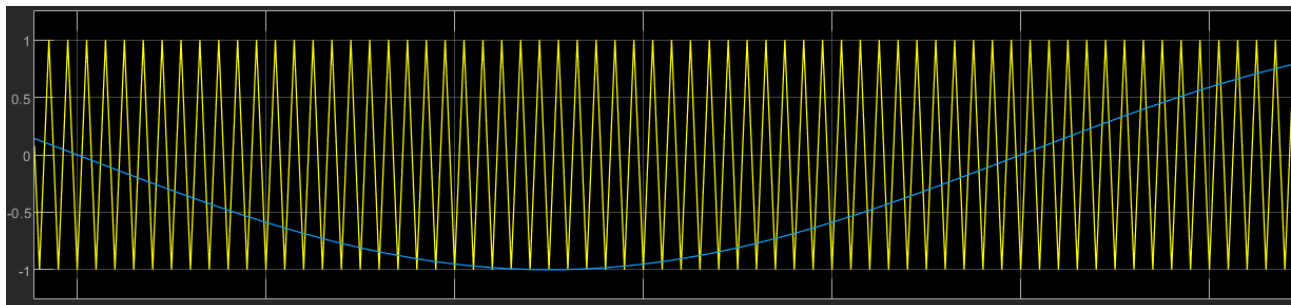


Figure 5.2: sawtooth and sine waves.

As shown in figure 5.2 the sine wave in blue and the sawtooth wave is in yellow, the comparator will compare if the sine wave is larger than sawtooth wave, the output is 1 and if not, the output is zero, so we get this red wave in figure 5.3.

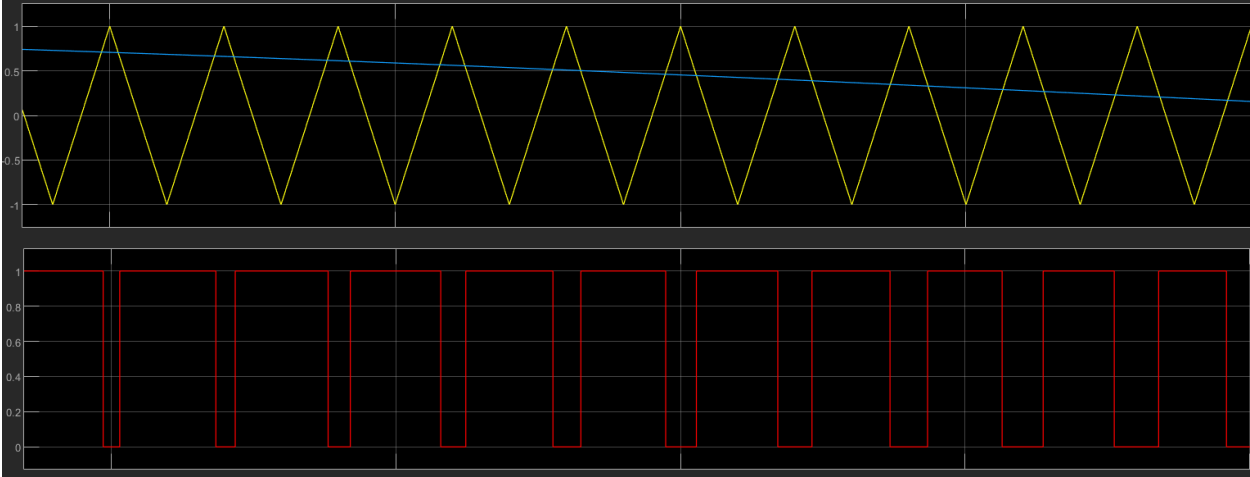


Figure 5.3: output wave from the comparator.

As mentioned in chapter 4.1 before, in the H-bridge inverter only two switches will open in a time and other two will never open in this time, and to make sure this will happen an inverter is placed to these two switches, so the signal is exactly the opposite of the red signal as shown in figure 5.4.

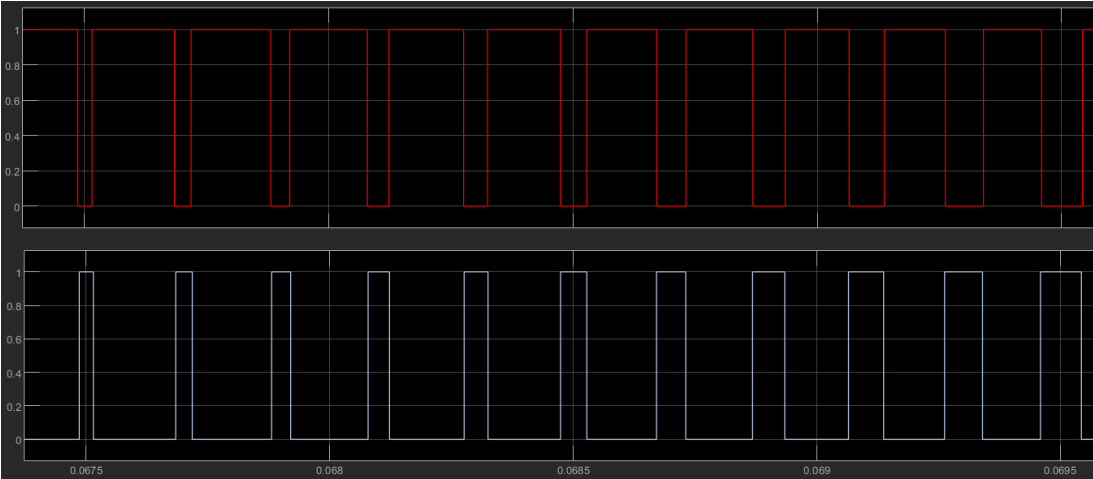


Figure 5.4: the opposite wave using inverter.

Now after generating the suitable signals for the switches, the output signal will be a 50hz sine wave with minimum amount of harmonics helped by series inductor and parallel capacitor as shown in figure 5.5.

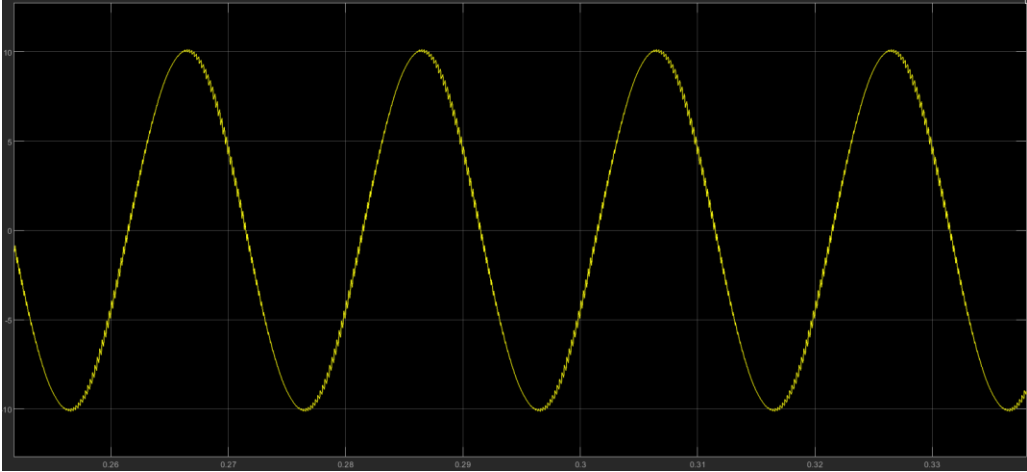


Figure 5.5: sine wave inverter output signal.

If you take a closer look, you will notice the small ripple caused of the harmonic but they are ignored, and the peak value is almost 10V caused by loses and series inductor.

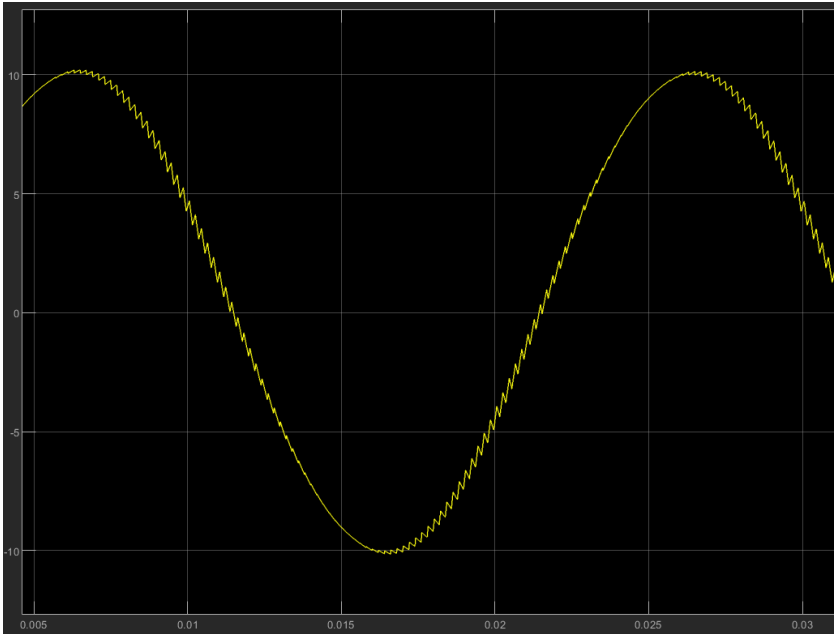


Figure 5.6: ripples in output signal.

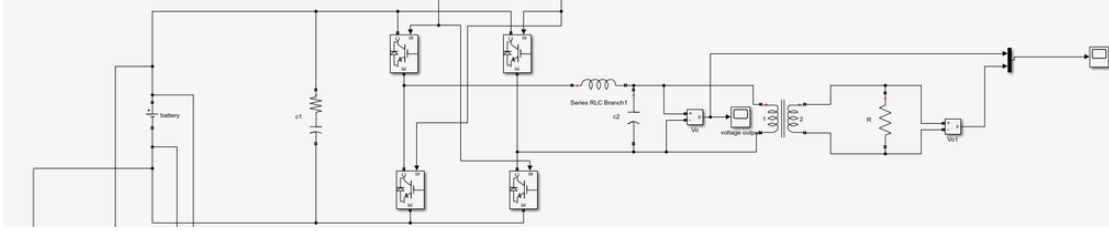


Figure 5a: H-Bridge inverter.

After achieving this sine wave a step-up transformer added so produce 230v AC voltage as shown in figure 5.7

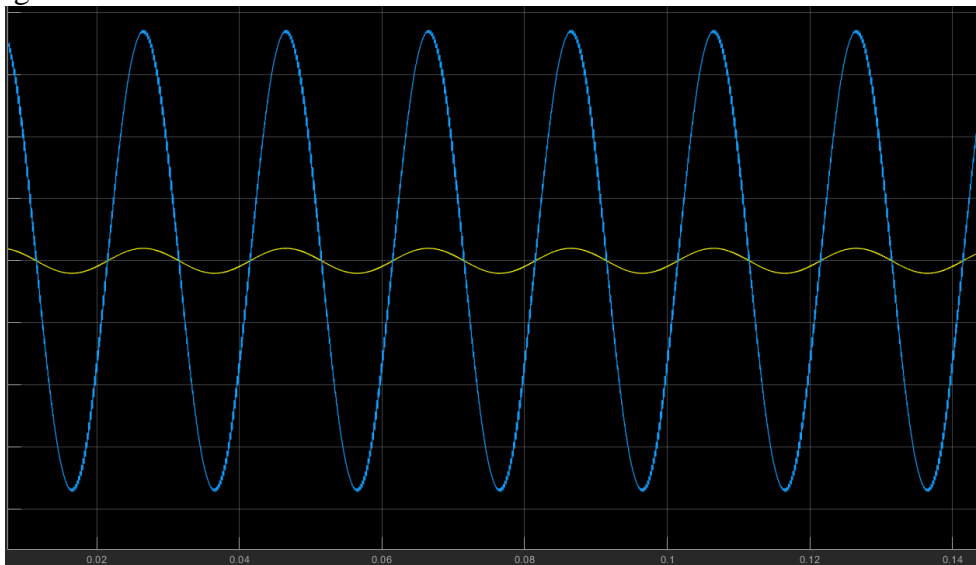


Figure 5.7: before and after using transformer.

Now to get the 5v DC output voltage, the buck-converter is the one to use, connecting the input 12v to it and the output will be like shown in figure 5.7

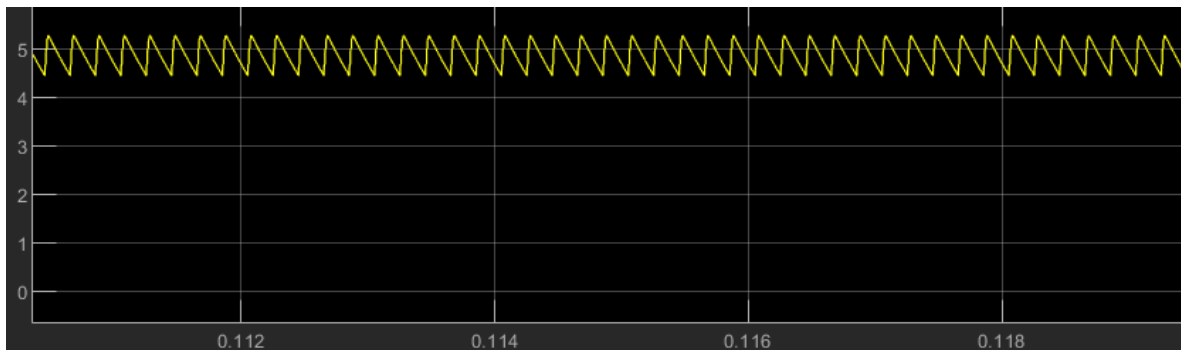


Figure 5.8: output of buck-converter.

A bigger capacitor can be used to make the outout more smoother.

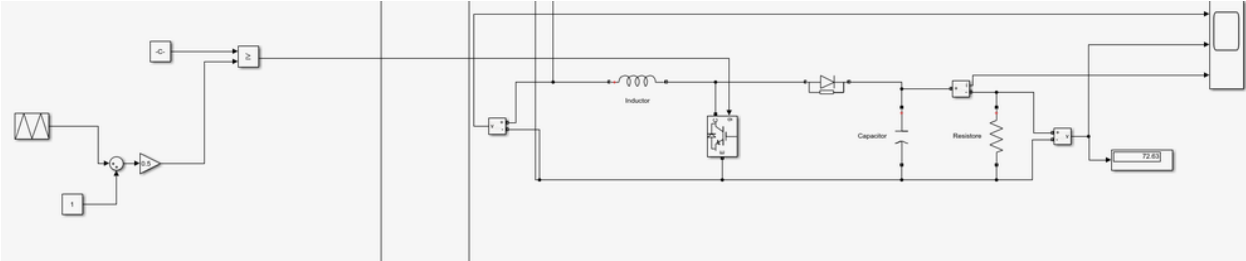


Figure 5b: Buck-converter.

And to get 20v DC voltage, it will use boost-converter, figure 5.9 will show the output of the boost-converter.

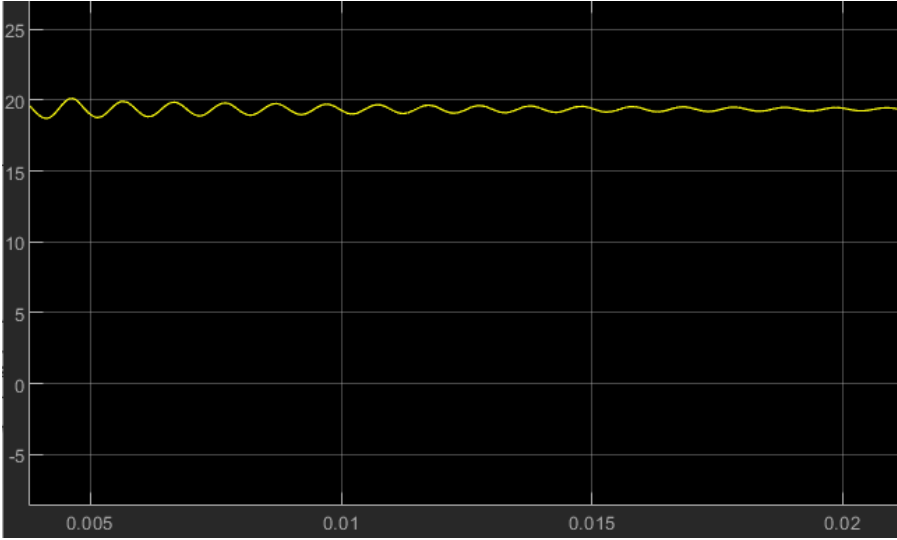


Figure 5.9: boost-converter output voltage.

Variable DC voltage (12v-50v) could be done using boost-converter with variable duty cycle ratio (D), decreasing it will decrease the output voltage and increasing it will increase the voltage as explained in chapter 4.3 using formula number 4.8.

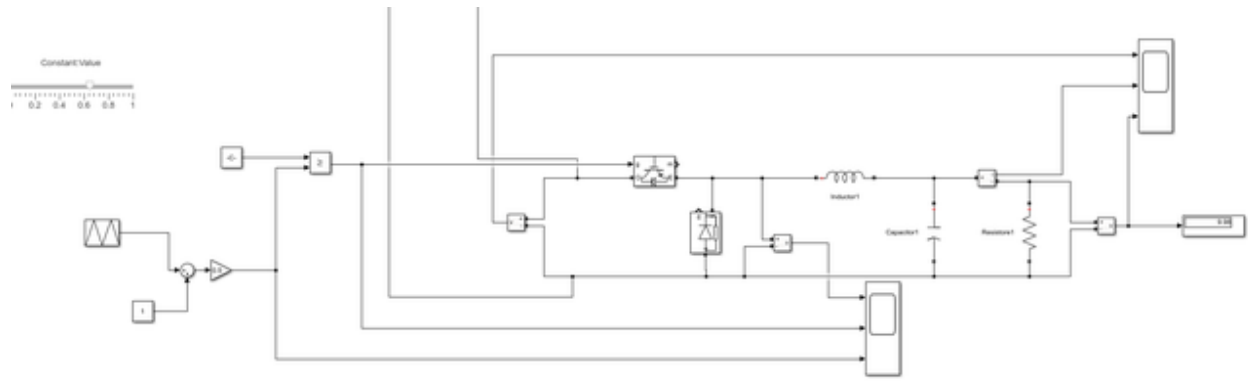


Figure 5c: before and after using transformer

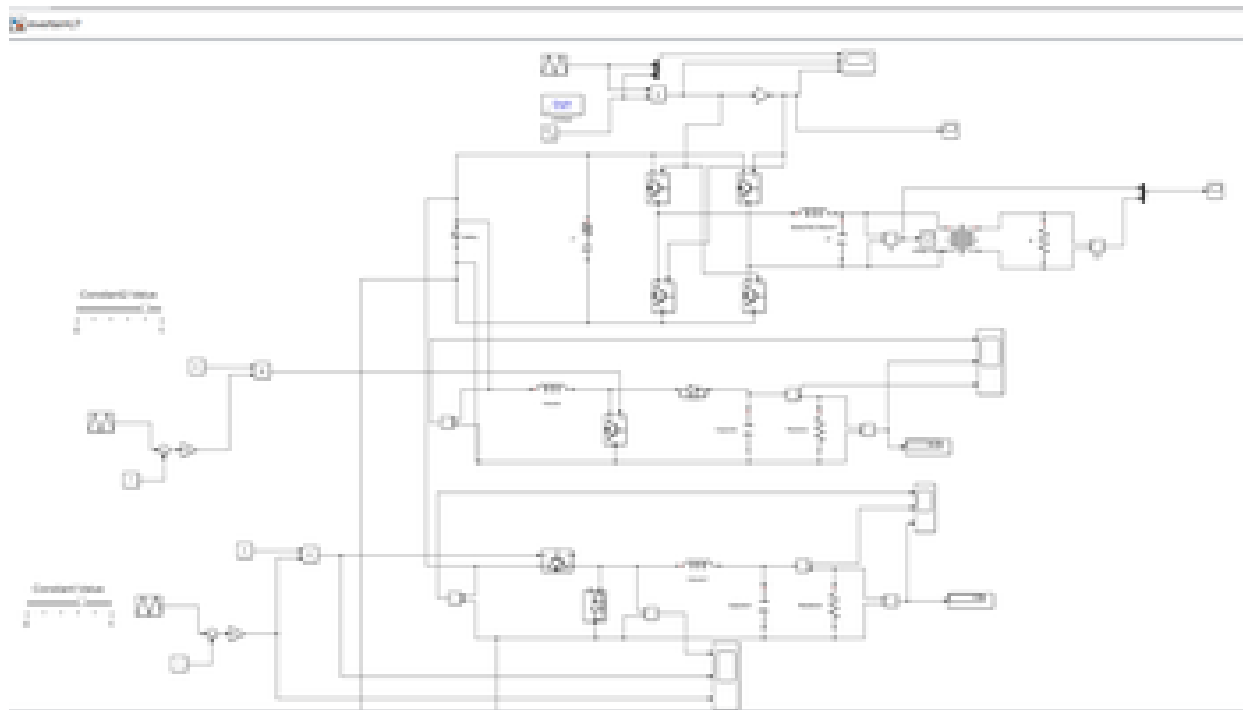


Figure 5d: Whole system.

Chapter 6: Difficulties and problems

- The accuracy of the tools is very low
- difficulty of finding the hardware parts at the beginning of the project.
- Gaza war and politic problems in the area
- Lack of sources
- Difficulty to write the PWM Arduino code

Chapter 7: Conclusion and Future Work

In this research, the problem of power outage can be solved using the portable power supplies, and can go with it anywhere to camp or to make a long trip and so on.

The main objective of this project is to invert the DC voltage to pure AC sinewave and to 5v DC voltage and other DC voltages as needed, so first using h-bridge inverter with PWM signal to control the switches and a filter to make the output signal purer, this built a very good AC sinewave signal. Buck-converter and boost-converter were used to make 5v DC output and 20v DC output and variable output voltage depend on duty cycle.

We hope that we can use more effective batteries which are lighter and smaller and have bigger capacity and have lower current leakage, so the losses will be lower and can use it for more hours and make it easier to carry.

We may add a small PV system to charge the portable power supply while using it so we can get more working hours and make it more effective.

References:

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- [2] https://en.wikipedia.org/wiki/History_of_the_battery
- [3] https://en.wikipedia.org/wiki/Electric_generator
- [4] <https://www.nytimes.com/wirecutter/reviews/best-portable-power-stations/>
- [5] <https://www.energy.gov/>
- [6] Electric Power Systems book by Ned Mohan and Electrical Drives book.
- [7] Pulse Width Modulated DC-to-DC Power Conversion: Circuits, Dynamics, Control, and DC Power Distribution Systems by Byung Cho Choi.
- [8] Microprocessors and Microcontrollers course lectures from teacher Omar Tamimi.
- [9] Proteus 8 Professional application.
- [10] <https://wallpapers.com/>

Appendix:

```
#define PWM_PIN 9           // PWM output pin connected to ENA on L298N
#define IN1_PIN 2          // IN1 connected to digital pin 2
#define IN2_PIN 4          // IN2 connected to digital pin 4
#define PWM_FREQ 50       // PWM frequency in Hz (adjust as needed for your
application)
#define TABLE_SIZE 256   // Size of the sine wave table

#include <Wire.h>
#include <LiquidCrystal_I2C.h>

LiquidCrystal_I2C lcd(0x27, 16, 2);

const int tempPin = A0;    // Analog pin for temperature sensor
const int fanPin = 3;     // Pin for fan control
const int voltagePin = A1; // Analog pin for voltage sensor
const int redLEDPin = 8;  // Digital pin for red LED
```

```

const float tempThreshold = 25.0; // Temperature threshold in degrees Celsius

// Sine wave lookup table (0-255 for 8-bit PWM)
const uint8_t sineTable[256] = {
  127, 130, 133, 136, 139, 143, 146, 149, 152, 155, 158, 161, 164, 167, 170, 173,
  176, 179, 182, 185, 188, 190, 193, 196, 198, 201, 203, 206, 208, 211, 213, 215,
  217, 219, 221, 223, 225, 227, 229, 230, 232, 234, 235, 236, 238, 239, 240, 241,
  242, 243, 244, 245, 246, 246, 247, 247, 248, 248, 248, 248, 248, 248, 248,
  248, 247, 247, 246, 246, 245, 244, 243, 242, 241, 240, 239, 238, 236, 235, 234,
  232, 230, 229, 227, 225, 223, 221, 219, 217, 215, 213, 211, 208, 206, 203, 201,
  198, 196, 193, 190, 188, 185, 182, 179, 176, 173, 170, 167, 164, 161, 158, 155,
  152, 149, 146, 143, 139, 136, 133, 130, 127, 124, 121, 118, 115, 111, 108, 105,
  102, 99, 96, 93, 90, 87, 84, 81, 78, 75, 72, 69, 66, 64, 61, 58,
  56, 53, 51, 48, 46, 43, 41, 39, 37, 35, 33, 31, 29, 27, 25, 23,
  22, 20, 19, 18, 16, 15, 14, 13, 12, 11, 10, 9, 8, 8, 7, 7,
  6, 6, 6, 6, 6, 6, 6, 6, 6, 7, 7, 8, 8, 9, 10, 11,
  12, 13, 14, 15, 16, 18, 19, 20, 22, 23, 25, 27, 29, 31, 33, 35,
  37, 39, 41, 43, 46, 48, 51, 53, 56, 58, 61, 64, 66, 69, 72, 75,
  78, 81, 84, 87, 90, 93, 96, 99, 102, 105, 108, 111, 115, 118, 121, 124
};

void setup() {

  // Initialize serial communication
  Serial.begin(9600);

  // Initialize the LCD
  lcd.init();
  lcd.backlight();

  // Print a message to the LCD
  lcd.setCursor(0, 0);
  lcd.print("Temp & Voltage");

  // Set the fanPin as an output
  pinMode(fanPin, OUTPUT);

  // Set LED pins as outputs
  pinMode(redLEDPin, OUTPUT);

  // Initialize the fan and LEDs as off
  digitalWrite(fanPin, 0);
  digitalWrite(redLEDPin, LOW);
}

```

```

// Set PWM pin as output
pinMode(PWM_PIN, OUTPUT);

// Set IN1 and IN2 as outputs
pinMode(IN1_PIN, OUTPUT);
pinMode(IN2_PIN, OUTPUT);

digitalWrite(IN1_PIN, HIGH);
digitalWrite(IN2_PIN, LOW);

// Set up Timer1 for PWM
TCCR1A = 0; // Clear Timer/Counter Control Registers
TCCR1B = 0;
TCNT1 = 0; // Initialize counter value to 0

// Set compare match register for PWM frequency
OCR1A = 16000000 / (2 * 8 * PWM_FREQ) - 1; // 16 MHz clock, prescaler 8

// Enable Fast PWM mode and set prescaler to 8
TCCR1B |= (1 << WGM12) | (1 << CS11);
TCCR1A |= (1 << WGM10) | (1 << COM1A1);

// Enable Timer1 compare match interrupt
TIMSK1 |= (1 << OCIE1A);
}

volatile uint8_t sineIndex = 0; // Index for the sine wave table

ISR(TIMER1_COMPA_vect) {
OCR1A = sineTable[sineIndex]; // Update PWM duty cycle
sineIndex = (sineIndex + 1) % TABLE_SIZE; // Increment and wrap index

// Swap motor direction at the half cycle
if (sineIndex == 0) {
static bool direction = false;
direction = !direction;
digitalWrite(IN1_PIN, direction);
digitalWrite(IN2_PIN, !direction);
}
}
}

```

```

void loop() {
  // Read temperature sensor value
  int tempValue = analogRead(tempPin);
  float temperature = (tempValue / 1024.0) * 4.88; // LM35 gives 10mV per degree
  Celsius

  // Read voltage sensor value
  int voltageValue = analogRead(voltagePin);
  float voltage = (voltageValue / 1024.0) * 5.0; // Simple voltage divider

  // Display temperature and voltage on LCD
  lcd.setCursor(0, 0); // Set the cursor to the beginning of the second row
  lcd.print("Temp: ");
  lcd.print(temperature);
  lcd.print(" C ");

  lcd.setCursor(0, 1);
  lcd.print("V: ");
  lcd.print(voltage);
  lcd.print(" V ");

  // Control fan speed based on temperature
  if (temperature > tempThreshold) {
    digitalWrite(fanPin, HIGH); // Turn fan on
    digitalWrite(redLEDPin, HIGH); // Turn red led on
  }
  else {
    digitalWrite(fanPin, LOW); // Turn fan off
    digitalWrite(redLEDPin, LOW); // Turn red led on
  }

  // Wait for a second before the next loop
  delay(1000);
}

```