SINGLE PHASE H – BRIDGE THREE LEVEL INVERTER

A project report submitted in partial fulfilment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

in

ELECTRICAL AND ELECTRONICS ENGINEERING

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SP-2022

ACKNOWLEDGEMENT

Foremost, we would like to express our sincere gratitude to our supervisor Dr. Deepak Verma for continuous support throughout the project work, for his patience, motivation, enthusiasm, and immense knowledge. It has been an absolute privilege to work under his supervision. We are immensely thankful to him for his constant supervision and invaluable encouragement, and for guiding us with perfection in doing this project.

We take this opportunity to sincerely acknowledge the **Head of Department, Mr. P.S. Rathore** and all the faculty members of BIT Mesra, Jaipur Campus for their support and help during our project work.

We are extremely grateful BIT MESRA JAIPUR CAMPUS, for their cooperation, guidance and for providing us suitable environment that have helped us a lot in successful completion of this project.

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CERTIFICATE OF APPROVAL

This is to certify that the project titled " **SINGLE PHASE H – BRIDGE THREE LEVEL INVERTER**" submitted by Mohit Sharma (BTECH/25100/18), Akshiv Agrawal (BTECH/25057/18) and Aastha Mathur (BTECH/25056/18), is hereby approved as a credible study of research topic and has been presented in satisfactory manner to warrant its acceptance as prerequisite to the degree for which it has been submitted.

It is understood that by this approval, the undersigned do not necessarily endorse any conclusion drawn or opinion expressed therein, but approve the thesis for the purpose for which it is submitted.

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DECLARATION CERTIFICATE

We, Mohit Sharma (BTECH/25100/18), Akshiv Agrawal (BTECH/25057/18), Aastha Mathur (BTECH/25056/18) hereby declare that the project entitled **" SINGLE PHASE H – BRIDGE THREE LEVEL INVERTER"** submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Electrical and Electronics of Birla Institute of Technology Mesra, Ranchi is an authentic work carried out by us under the supervision of Dr. Deepak Verma.

The work in this report has not been submitted by us for the award of any other degree or any other institute. We have taken care in all respects to honor the intellectual property right and have acknowledged the contribution of others for using them for this academic purpose.

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ABSTRACT

The inverter is a power electronic device that converts DC input supply to symmetric AC voltage of standard magnitude and frequency at the output side. In this project, single phase 3 level H-bridge multilevel inverter is used to convert different voltages of DC into respected AC voltages. Available conventional inverters have several disadvantages such as complex structures, cost, higher number of components and low efficiency.

This project presents a single phase 3 level H-bridge multilevel inverter which uses a micro-controller, opto-couplers, soft switching using MOSFETS. In the first stage, 230V AC voltage converts into 12V DC voltage using centre tapped step down transformer and bridge rectifier, which uses in charging mode for various applications such as UPS (Uninterruptible Power Supply). In the Final stage, 230V DC voltage convert into 230V sinusoidal AC voltage using switching of three level H-bride for power mode in various applications. Power quality is also measured using DSO of generated AC signal.

Experimental results of implemented model and switching technique for MOSFETs are presented to authenticate the implemented topology.

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CHAPTER – 1
INTRODUCTION

1.1 Foreword

Nowadays, most of the things are dependent on electricity and with the expansion and growth of information-related businesses, electric devices, uninterruptible power supplies (UPS) will continue to play a key role in providing power quality against various line problems (outage, sag, surge, undervoltage, overvoltage, spike, frequency variation, noise, and harmonic distortion. Uninterruptible Power Supply (UPS) systems provide uninterrupted, reliable, and high-quality power for vital loads. UPS systems also suppress line transients and harmonic disturbances. Applications of UPS systems include medical facilities, life supporting systems, data storage and computer systems, emergency equipment, telecommunications, industrial processing, and on-line management systems. UPS is one of the applications of the inverters for converting voltages from AC to DC or DC to AC.

Multilevel cascade inverters are used to eliminate the bulky transformer required in case of conventional multi-phase inverters. Multilevel inverters produce a stepped output phase voltage with a refined harmonic profile when compared to a two-level inverter. The concept of multilevel inverters, introduced about 30 years ago, entails performing power conversion in multiple voltage steps to obtain improved power quality, lower switching losses, reducing harmonic distortion and higher voltage capability. Nowadays, there are mainly three types of multilevel inverters present in the market : the diode-clamped, flying capacitor and cascaded H-bridge structures.

The Diode clamped multi-level inverter used the diodes to provide the multiple voltages through the different phases to the capacitor banks connected in series. The diode has a limited amount of voltage transfer capacity. This makes to draw the high input DC voltage and provides less output voltage. To cover this drawback more switches, diodes, and capacitors are used. For a back-to-back power transfer system, the arrangement of switches is important and this type of inverters will provide high efficiency.

The Flying capacitor’s multilevel inverter working is the same as that of the diode clamped multi-level inverter. The capacitors will play a major role in the inverter as they are connected in the series. The switching states are the same as that of the diode clamped multilevel inverter but the diodes are absent here. The switches will be reduced as the capacitors maintain a good stable balance in phase. The circuit arrangement uses only the switches and capacitors so the circuit complexity is decreased compared to the diode clamped multi-level inverter. The switching losses are high in this inverter as the high-frequency switching operations will take place. This multi-level inverter can control both the active and reactive power. It is also cost-effective with good efficiency.

The arrangement of the cascaded H-bridge multi-level inverter is done by the arrangement of the circuit as H-bridge. There are so many H bridge cells in this inverter. In one H-bridge cell, there are four switches and the four diodes connected together. The output of each cell has three types such as positive voltage, negative voltage, and zero. This H-bridge arrangement is used in both single and multi-level inverters. In this inverter, each cell needs the separate input supply and the outputs rare gathered together and given to the load.

Among these inverter topologies, cascaded multilevel inverter reaches the higher output voltage and power levels, and the higher reliability due to its modular topology and the simplicity. The circuit arrangement of cascaded H-bridge type multilevel inverter is very easy and the cost is very less compared to the other types. The cascaded H-bridge can be used on many levels. This is a more efficient multi-inverter compared to the other two. However, the main drawback of this H-bridge inverter is the switching process. The switching time lags and sometimes it becomes hard for the switching conditions but nowadays, there are so many modern technologies thanks to power electronic with which we can make possible soft switching such as MOSFETs and IGBTs.

1.2 Full Bridge or “H-Bridge” Voltage Source Inverter

A single-phase full bridge inverter (topology of H-bridge inverter) is a switching device that generates an AC voltage in the output on the application of DC voltage in the input by adjusting the switch ON and OFF. The voltage in the output of a full bridge inverter is either -VDC,+VDC or 0. The circuit of this type of inverter consists of 4 diodes connected in anti-parallel with 4 controlled switching devices such as switch, BJT, thyristor, MOSFET, IGBT. Here we are using MOSFET switch. These diodes are known as feedback diodes because these diodes feedback the stored energy in load back to DC source. In this project, we use the resistive load and because of that feedback diodes have no use. The working principle of single-phase full bridge inverter is based on the sequential triggering of MOSFETs placed diagonally opposite. This means, for half of time period, MOSFETs S3 & S4 will be triggered while for the remaining half of time period, S1 & S2 will be triggered. Only two MOSFETs are turned ON in half of the time period. By observing the signal we get from TLP circuit, only S1 and S2 triggers and load is connected to source through S1 and S2 and hence, the load voltage is equal to supply voltage with positive polarity. As soon as this signal removed, switches S1 and S2 gets turned off and at the same time we send another signal with phase delay and switches S3 and S4 get trigger. Now the load connects to source through S3 and S4 and hence, load voltage is equal to supply voltage with negative polarity. By this method, we get AC voltage from DC voltage.

CHAPTER - 2

LITERATURE REVIEW

B. Mahato, S. Majmudar, S. Vatsyayan and K. C. Jana [1], We have taken inverter configuration which is built for 3-level laboratory and the experimental outcomes are added in this paper. The experimental results verify the simulation outcomes and confirms the effectiveness of the proposed topology. Both the testing methods (simulation & experimental) are carried out with the same value of R Load. Comparison with new topologies is also studied by making generalized formulae and plotting different graphs as well.

P. Nithara and R. P. Eldho [2], In this research paper the analysis between different controllers used in standalone Single-phase Photovoltaic (PV) inverters has been presented. Mainly 2 controllers are used such as Proportional Integral controller (PI) and Proportional Resonant (PR) controller. Both PI controller and PR controller can regulate the voltage during load variation. By using PR controller the steady state error of the system can be reduced.

K. S. Kumar, J. B. Edward, K. Chimonyo and M. C. Rushambwa [3], From this paper we have taken the topology of our main circuit and the simulation study using MATLAB/SIMULINK. The circuit is then controlled using TLP circuit which is given DC Supply.

J. Li, Q. Zhang and X. Sun [4], From this paper we have taken the Circuit diagram of Single Phase Three Level Inverter. We have used the PWM Strategy for inverter. The respective modes of operation have been explained in the paper. The simulation in MATLAB/SIMULINK has been given in the paper.

T. -T. Tran, M. -K. Nguyen, Y. -C. Lim and J. -H. Choi [5] The introduced inverter merges a boost converter and a single-phase inverter in a single-phase single-stage inverter. The proposed inverter has a simpler topology and uses the minimum number of power electronic components. Also, a simple pulse width modulation technique is shown. The experimental results are also shown to validate the precise performance of the introduced inverter.

Palanisamy, R. & Krishnasamy, Vijayakumar [6] and [7] To make a 3-level inverter 4 switches(Mosfet) are required and to drive those 4 switches they require 4 separate MOSFET driver circuit made of TLP250 and a dc supply is required to drive the TLP and a microcontroller to generate the pulses such that our Mosfet operates in a particular way.

Hota, V. Sonti, S. Jain and V. Agarwal [8], Technique to eliminate common mode voltage in single phase multilevel inverter by inserting a third leg in 3rd stage. The third inverter leg or arm is used in single phase MLI by inserting a 3rd leg in the power stage . The third inverter leg is used to address the issue of CMV in single phase MLI. A generalised solution of for MLI to eliminate CMV using 3rd leg arm is presented . A novel PWM strategy is also proposed to operate the proposed topology.

M. Ciobotaru, R. Teodorescu and F. Blaabjerg [9], This paper is aimed at presenting a single-stage converter for single-phase PV systems. Two different current controllers have been implemented and an experimental comparison between them has been made. A complete control structure for the single-phase PV system is also presented.

G. M. Tina and G. Celsa [10], The aim of this work is the study and the complete description of a single-phase grid connected system in all its part: inverter, unipolar SPWM, inverter control strategy. The implemented inverter control strategy allows to regulate the active and reactive power flow separately

N. Ahmed and Z. R. Khan [11], SPWM Generation In the proposed sine wave inverter, an H-bridge driving configuration is used. If this H-bridge is driven with an SPWM signal, an SPWM can be found on the load. After filtering that, a pure sine wave is easily be found across the load. This is the concept of a sine wave inverter.

An H bridge is built with four switches. To drive the Hbridge, four signals are needed. There are two signals (S1 and S4) at 50 Hz in a push-pull configuration, and the other two (S2 and S3) are SPWM signals (3 kHz). Fig. 5 and 6 show the circuit diagram and the four signals of H-bridge circuit. The upper arms of the bridge are switched by a 50Hz signal, and the lower arms are switched by 20 kHz modulated signals. In this work, MOSFET has been used for the switching device.

Q. Lan, B. Li and M. Jie [12], the mathematical model of single-phase grid-connected inverter is analyzed, in order to realize grid-connected inverter.

P. Nithara and R. P. Eldho [13], In this research paper the analysis between different controllers used in standalone Single-phase Photovoltaic (PV) inverters has been presented. Mainly 2 controllers are used such as Proportional Integral controller (PI) and Proportional Resonant (PR) controller. Both PI controller and PR controller can regulate the voltage during load variation. By using PR controller the steady state error of the system can be reduced.

B. Proca and M. Comanescu [14], This paper presents a control method for the single-phase inverter that is looking to reduce the harmonic content of the output voltage, especially for the situation when the inverter feeds a crestfactor load. In this case, the currents are non-sinusoidal and relatively distorted; as a result, the THD is higher than the specification allows. The method proposed uses a voltage controller followed by a current controller - both are implemented in the stationary reference frame. The voltage controller uses a harmonic elimination method based on modulation-demodulation.

T. Sharifi, A. H. Ali biglo, M. Mirsalim, S. Farzamkia and J. S. Moghani [15], This paper presents a modified quasi-Z-source inverter with a smaller number of switching devices. In a wide range of modulation index, the output voltage of the proposed inverter has a lower THD compared to Quasi-Z source cascade multilevel inverter. To illustrate the superior advantages of the proposed topology over the conventional, both inverters are studied for the same condition. Various modulation indexes are considered and performance of both topologies are analyzed. By varying the modulation index in both inverters, different voltage amplitudes can be achieved. The obtained results from several simulations demonstrate the higher performance of the proposed topology with lower THD in the output voltage. The most important feature of the proposed topology can be mentioned as reducing the number of semiconductor devices, which leads to reducing the implementation cost of the inverter.

P. Li, R. Li, X. Lin and H. Feng [16], Inverters are commonly used in renewable energy systems as interface. Total Harmonic Distortion (THD) is a key index of judging its effectiveness. In this paper, a direct THD oriented MPC method is proposed. Firstly, a cost function which is a linear combination of DC bias, fundamental frequency deviation and THD of one cycle (20ms at 50Hz) is designed and the weight factors are obtained by offline calculation.

V. S. Kirthika Devi and S. G. Srivani [17], This paper proposes a modified phase shift pulse width modulation technique which is suitable for both single phase and three phase system for a conventional cascaded H bridge multilevel inverter. The carrier phase shift PWM method which is proposed in this paper improves the output voltage waveform and reduces the total harmonic distortion when compared with the conventional phase shift PWM method. The modified pwm is analyzed using a seven-level cascaded H bridge multilevel inverter for both single phase as well as for three phase system, and this PWM can also be applied to N number of levels for cascaded H bridge inverter depending upon their angle calculations.

U. K. Kalla, A. Verma, B. Singh and K. Joshi [18], The multilevel inverter technology has gained a tremendous significance in the research area. This paper proposed a new controller for generating the switching sequence of power devices used in multilevel inverter to produce the desired output. An embedded code has been developed to control the switching states of different IGBT switches. To validate the effectiveness of the proposed technique to control the multilevel inverter switching states MATLAB simulation of 3-level, 5-level and 17-level using cascaded H bridge topology of multi-level inverter is presented in this paper.

P. Jamuna, C. C. A. Rajan, K. Gowri and V. Vijayasanthi [19], This paper deals with the design and analysis of new h-bridge based single and three phase cascaded multilevel inverter. It has two types of sources: symmetric and asymmetric source. In this topology asymmetric source is preferred because it provides large number of output voltage level with minimum number of switches. This new H-bridge based cascaded multilevel inverter is able to increase output voltage levels with reduced number of power electronic device drive circuits, and DC voltage sources.

J. Korhonen et al. [20], Cascaded H-bridges has been a topic of interest in drives and grid inverter applications, as the topology has an inherent ability to produce output power with low distortion. The multilevel output voltage waveform produced by the topology can increase the apparent switching frequency in direct proportion to the number of cascaded cells. When identical H-bridge cells are used, the inverter is assumed to load each H-bridge symmetrically. The conventionally used pulse width modulation (PWM) methods, such as phase-shifted PWM and level-shifted PWM, suffer from either inferior line-to-line voltage or asymmetric loading of the H-bridges.

J. Prakash, S. K. Sahoo and S. P. Karthikeyan [21], Multilevel inverter technology has emerged recently as a very important alternative in the area of high power and medium voltage energy control. This paper carried out the analysis and simulation of H-bridge multilevel inverter. To control the output voltage modulation techniques like Sinusoidal Pulse Width Modulation, Multicarrier Pulse Width Modulation and Space Vector Pulse Width Modulation are applied.

CHAPTER – 3
MULTILEVEL INVERTER

Multilevel Inverter (MLI) gives the solution to the basic structure of inverter by modifying the parameters, size and components in order to achieve different levels (m-level) by adding output voltages to produce stepped waveform. Each level is attained due to commutation of switches. It has overcome the drawbacks faced by PWM technique which has been for more than 25 years. By increasing the levels in the MLI, the system complexity increases which in turn creates voltage misbalancing problem which is considered to be the only major problem regarding MLI. But it reduces the harmonic content based on number of levels.

Now a day's many industrial applications have begun to require high power. Some appliances in the industries, however, require medium or low power for their operation. Using a high-power source for all industrial loads may prove beneficial to some motors requiring high power, while it may damage the other loads. Some medium voltage motor drives and utility applications require medium voltage. The multi-level inverter has been introduced since 1975 as an alternative in high power and medium voltage situations. The Multilevel inverter is like an inverter and it is used for industrial applications as an alternative in high power and medium voltage situations.

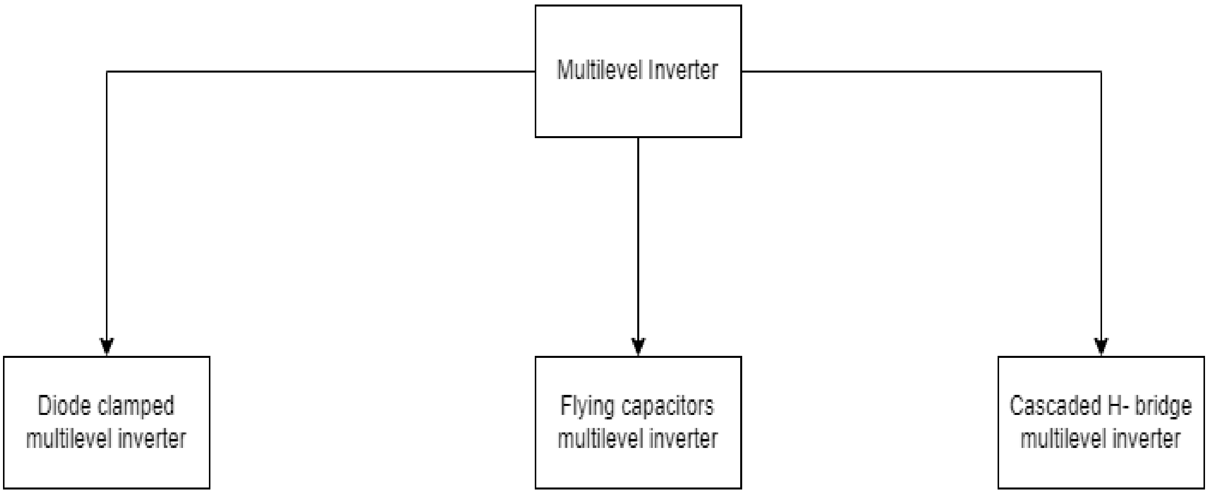


Fig. (1) – Classification of Multi-level inverter

3.1 Diode Clamped Multilevel Inverter:

The main concept of this inverter is to use diodes and provides the multiple voltage levels through the different phases to the capacitor banks which are in series. A diode transfers a limited amount of voltage, thereby reducing the stress on other electrical devices. The maximum output voltage is half of the input DC voltage. It is the main drawback of the diode clamped multilevel inverter. This problem can be solved by increasing the switches, diodes, capacitors. Due to the capacitor balancing issues, these are limited to the three levels. This type of inverters provides high efficiency because of the fundamental frequency used for all the switching devices and it is a simple method of the back-to-back power transfer systems.

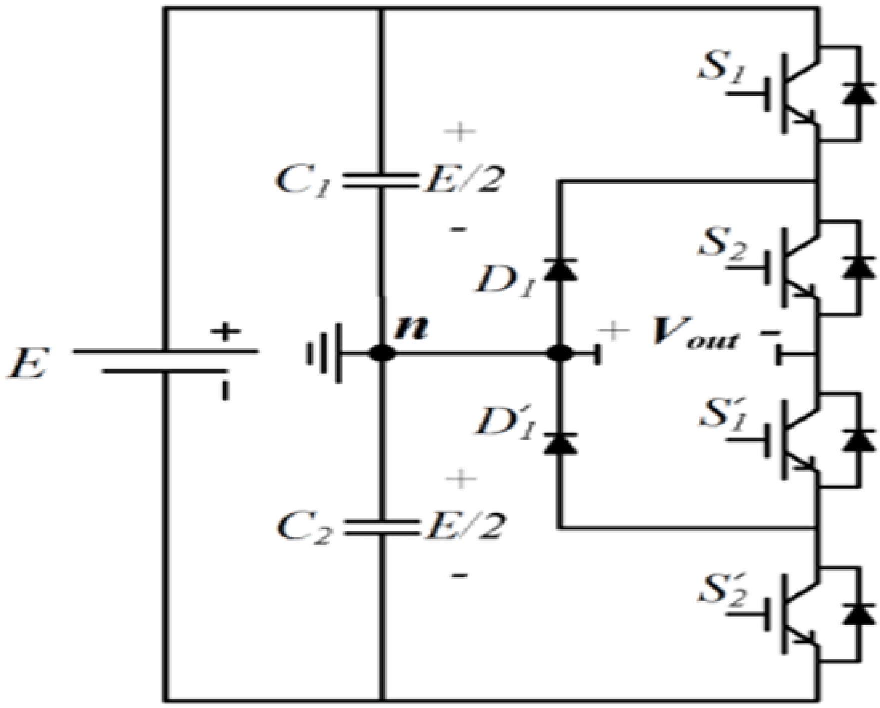


Fig. (2) – 3-level diode clamped Multilevel Inverter

3.11 Applications of Diode Clamped Multilevel Inverter:

- Static var compensation
- Variable speed motor drives
- High voltage system interconnections
- High voltage DC and AC transmission lines

3.2 Flying Capacitors Multilevel Inverter:

The main concept of this inverter is to use capacitors. It is of a series connection of capacitor clamped switching cells. The capacitors transfer the limited amount of voltage to electrical devices. In this inverter switching states are like in the diode clamped inverter. Clamping diodes are not required in this type of multilevel inverters. The output is half of the input DC voltage. It is a drawback of the flying capacitors multilevel inverter. It also has the switching redundancy within the phase to balance the flying capacitors. It can control both the active and reactive power flow. But due to the high-frequency switching, switching losses will take place.

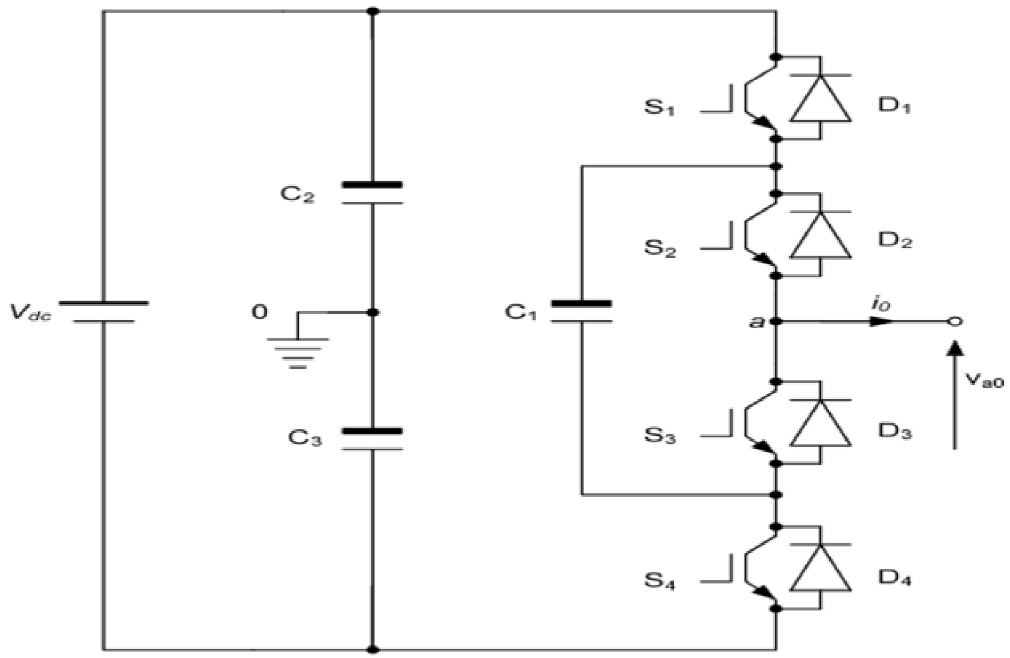


Fig. (3) - 3-level Flying Capacitors Multilevel inverter

3.21 Applications of Flying Capacitors Multilevel Inverter

- Induction motor control using DTC (Direct Torque Control) circuit
- Static var generation
- Both AC-DC and DC-AC conversion applications
- Converters with Harmonic distortion capability
- Sinusoidal current rectifiers

3.3 Cascaded H-Bridge Multilevel Inverter:

The cascaded H-bride multilevel inverter is to use capacitors and switches and requires a smaller number of components in each level. This topology consists of a series of power conversion cells and power can be easily scaled. The combination of capacitors and switches pair is called an H-bridge and gives the separate input DC voltage for each H-bridge. It consists of H-bridge cells and each cell can provide the three different voltages like zero, positive DC, and negative DC voltages. One of the advantages of this type of multi-level inverter is that it needs a smaller number of components compared with diode clamped and flying capacitor inverters. The price and weight of the inverter are less than those of the two inverters. Soft-switching is possible by some of the new switching methods. Multilevel cascade inverters are used to eliminate the bulky transformer required in case of conventional multi-phase inverters, clamping diodes required in case of diode clamped inverters and flying capacitors required in case of flying capacitor inverters. But these require a large number of isolated voltages to supply each cell.

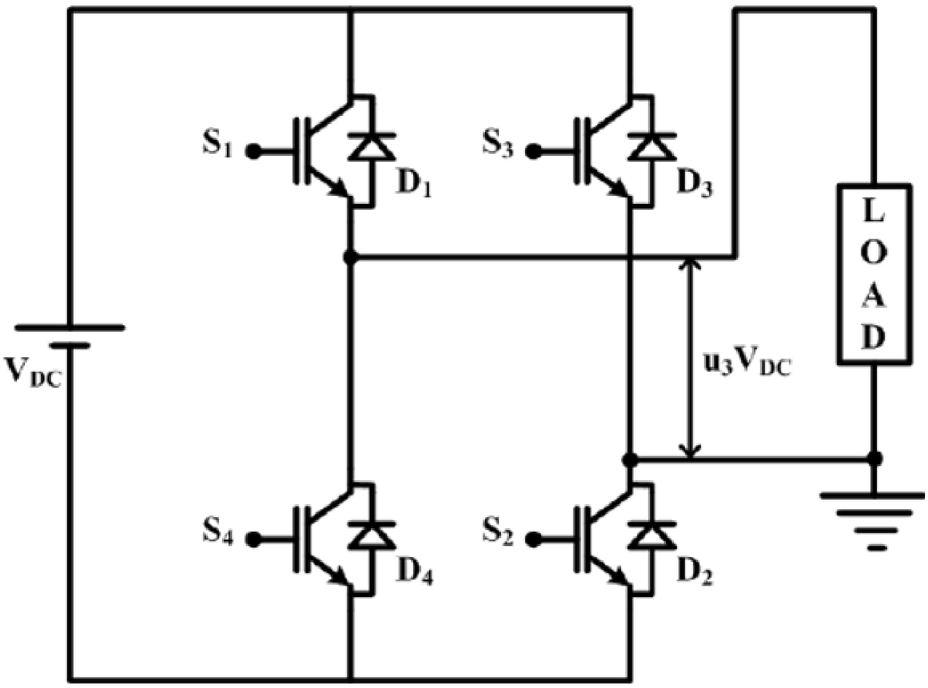


Fig. (4) - 3-level cascaded H-bridge multilevel inverter

3.31 Applications of Cascaded H-Bridge Multilevel Inverter

- Motor drives
- Active filters
- Electric vehicle drives
- DC power source utilization
- Power factor compensators
- Back-to-back frequency link systems
- Interfacing with renewable energy resources.

3.4 Advantages of Multilevel Inverter:

The multilevel converter has several advantages, that is:

1. **Common Mode Voltage:**

The multilevel inverters produce common-mode voltage, reducing the stress of the motor and don't damage the motor.

2. **Input Current:**

Multilevel inverters can draw input current with low distortion

3. **Switching Frequency:**

The multilevel inverter can operate at both fundamental switching frequencies that are higher switching frequency and lower switching frequency. It should be noted that the lower switching frequency means lower switching loss and higher efficiency is achieved.

4. **Reduced harmonic distortion:**

Selective harmonic elimination technique along with the multi-level topology results the total harmonic distortion becomes low in the output waveform without using any filter circuit.

CHAPTER – 4

COMPONENTS REQUIRED

4.1 Switch Used-MOSFET (20N60S5)

Fig. - (5) MOSFET **Fig. – (6) Symbol of MOSFET**

The MOSFET (Metal Oxide Semiconductor Field Effect Transistor) transistor is a semiconductor device that is widely used for switching purposes and for the amplification of electronic signals in electronic devices. A MOSFET is either a core or integrated circuit where it is designed and fabricated in a single chip because the device is available in very small sizes. The introduction of the MOSFET device has brought a change in the domain of switching in electronics.

A MOSFET is a four-terminal device having source(S), gate (G), drain (D) and body (B) terminals. In general, the body of the MOSFET is in connection with the source terminal thus forming a three-terminal device such as a field-effect transistor. MOSFET is generally considered as a transistor and employed in both the analog and digital circuits. This is the basic introduction to MOSFET

The functionality of MOSFET depends on the electrical variations happening in the channel width along with the flow of carriers (either holes or electrons). The charge carriers enter into the channel through the source terminal and exit via the drain.

The width of the channel is controlled by the voltage on an electrode which is called the gate and it is located in between the source and the drain. It is insulated from the channel near an extremely thin layer of metal oxide. The MOS capacity that exists in the device is the crucial section where the entire operation is across this.

A MOSFET can function in two ways :-

- Depletion Mode
- Enhancement Mode

Depletion Mode

When there is no voltage across the gate terminal, the channel shows its maximum conductance. Whereas when the voltage across the gate terminal is either positive or negative, then the channel conductivity decreases.

Enhancement Mode

When there is no voltage across the gate terminal, then the device does not conduct. When there is the maximum voltage across the gate terminal, then the device shows enhanced conductivity.

4.11 Working Principle of MOSFET

The main principle of the MOSFET device is to be able to control the voltage and current flow between the source and drain terminals. It works almost like a switch and the functionality of the device is based on the MOS capacitor. The MOS capacitor is the main part of MOSFET.

The semiconductor surface at the below oxide layer which is located between the source and drain terminal can be inverted from p-type to n-type by the application of either a positive or negative gate voltage respectively. When we apply a repulsive force for the positive gate voltage, then the holes present beneath the oxide layer are pushed downward with the substrate.

The depletion region populated by the bound negative charges which are associated with the acceptor atoms. When electrons are reached, a channel is developed. The positive voltage also attracts electrons from the n+ source and drain regions into the channel. Now, if a voltage is applied between the drain and source, the current flows freely between the source and drain and the gate voltage controls the electrons in the channel. Instead of the positive voltage, if we apply a negative voltage, a hole channel will be formed under the oxide layer.
MOSFET is of two types :-

- P-channel MOSFET
- N-channel MOSFET

P-channel MOSFET

The P- channel MOSFET has a P- Channel region located in between the source and drain terminals. It is a four-terminal device having the terminals as gate, drain, source, and body. The drain and source are heavily doped p+ region and the body or substrate is of n-type. The flow of current is in the direction of positively charged holes.

When we apply the negative voltage with repulsive force at the gate terminal, then the electrons present under the oxide layer are pushed downwards into the substrate. The depletion region populated by the bound positive charges which are associated with the donor atoms. The negative gate voltage also attracts holes from the p+ source and drain region into the channel region.

N-channel MOSFET

The N-Channel MOSFET has an N- channel region located in between the source and drain terminals. It is a four-terminal device having the terminals as gate, drain, source, body. In this type of Field Effect Transistor, the drain and source are heavily doped n+ region and the substrate or body are of P-type.

The current flow in this type of MOSFET happens because of negatively charged electrons. When we apply the positive voltage with repulsive force at the gate terminal then the holes present under the oxide layer are pushed downward into the substrate. The depletion region is populated by the bound negative charges which are associated with the acceptor atoms.

Upon the reach of electrons, the channel is formed. The positive voltage also attracts electrons from the n+ source and drain regions into the channel. Now, if a voltage is applied between the drain and source the current flows freely between the source and drain and the gate voltage controls the electrons in the channel. Instead of positive voltage if we apply negative voltage then a hole channel will be formed under the oxide layer.

4.12 MOSFET REGIONS OF OPERATION

To the most general scenario, the operation of this device happens mainly in three regions and those are as follows:

- **Cut-off Region** – It is the region where the device will be in the OFF condition and there zero amount of current flow through it. Here, the device functions as a basic switch and is so employed as when they are necessary to operate as electrical switches.
- **Saturation Region** – In this region, the devices will have their drain to source current value as constant without considering the enhancement in the voltage across the drain to source. This happens only once when the voltage across the drain to source terminal increases more than the pinch-off voltage value. In this scenario, the device functions as a closed switch where a saturated level of current across the drain to source terminals flows. Due to this, the saturation region is selected when the devices are supposed to perform switching.
- **Linear/Ohmic Region** – It is the region where the current across the drain to source terminal enhances with the increment in the voltage across the drain to source path. When the MOSFET devices function in this linear region, they perform amplifier functionality.

Type	**Package**	**Ordering Code**	**Marking**
SPW20N60S5	PG-TO247	Q67040-S4238	20N60S5

$\boldsymbol{V_{DS}}$	$\boldsymbol{R_{DS(on)}}$	$\boldsymbol{I_D}$
600V	0.19Ω	20A

DATASHEET FOR MOSFET :-

Electrical Characteristics, at $T_J = 25°C$ unless otherwise specified

Parameter	**Symbol**	**Conditions**	**Values**			**Unit**
			Min.	**Typ.**	**Max.**	
Drain-source breakdown voltage	$V_{(BR)DSS}$	V_{GS}=0V, I_D=0.25Ma	600	-	-	V
Drain-Source avalanche breakdown voltage	$V_{(DR)DS}$	V_{GS}=0V, I_D=20a	-	700	-	V
Gate Threshold Voltage	$V_{GS(th)}$	I_D=100µA, $V_{GS} = V_{DS}$	3.5	4.5	5.5	V

Zero gate voltage drain current	I_{DSS}	V_{DS}=600V, V_{GS}=0V, Tj = 25°C, Ti = 150°C	- -	0.5 -	5 250	μA
Gate-Source leakage current	I_{GSS}	V_{GS}=20V, V_{DS}=0V	-	-	100	Na
Drain-source on-state resistance	$R_{DS(on)}$	V_{GS}=10V, I_D= 13A, Tj = 25°c, Ti = 150°C	- -	0.16 0.43	0.19 -	Ω
Gate input resistance	R_G	f = 1MHz, Open drain	-	12	-	Ω
Characteristics						
Transconductance	g_{ts}	$V_{DS} \geq 2 \times I_D \times R_{DS(on)max}$, I_D= 13A	-	12	-	S
Input Capacitance	C_{iSS}	$V_{GS} = 0V, V_{DS} = 25V,$ f = 1MHz	-	3000	-	pf
Output Capacitance	C_{OSS}		-	1170	-	
Reverse Transfer capacitance	C_{rss}		-	28	-	
Effective output capacitance, energy related	$C_{o(er)}$	$V_{GS} = 0V, V_{DS} = 0V\ TO\ 480V$	-	83	-	pf
Effective output capacitance, time related	$C_{o(tr)}$		-	160	-	
Turn-on delay time	$t_{d(on)}$	$V_{DD} = 350V,$ V_{GS}=0/10v, $I_D = 20A,$ $R_G = 3.6\Omega$	-	120	-	ns
Rise time	t_r		-	25	-	
Turn-off delay time	$t_{d(off)}$		-	130	195	
Fall time	t_t		-	30	45	
Gate charge characteristics						
Gate to source charge	Q_{gs}	V_{DD}= 350V, I_D=20A	-	21	-	Nc
Gate to drain charge	Q_{gd}		-	47	-	
Gate charge total	Q_g	V_{DD}=350V, I_D= 20A, V_{GS}= 0 to 10V	-	79	103	Nc
Gate plateau voltage	$V_{(plateau)}$	V_{DD}=350V, I_D= 20A	-	8	-	V
Electrical Characteristics, at $T_j = 25°C$, unless otherwise specified						
Inverse diode continuous forward current	I_S	$T_C = 25°C$	-	-	20	A

Inverse diode direct current, pulsed	I_{SM}	$T_C = 25°c$	-	-	40	A
Inverse diode forward voltage	V_{SD}	V_{GS}= 0V, $I_F = I_S$	-	1	1.2	V
Reverse recovery time	t_{rr}	$V_R = 350V, \quad I_F = I_S,$ $\frac{di_F}{dt} = 100A/\mu s$	610	-	-	ns
Reverse recovery charge	Q_{rr}		12	-	-	µC

Table – (1) Datasheet for MOSFET (20N60)

4.2 OPTOCOUPLER (TLP 250)

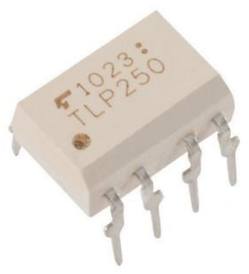


Fig. – (7) TLP250 (Opto-coupler)

Pin Configuration of TLP-250 Optocoupler	
PIN	**DESCRIPTION**
1	N.C.
2	Anode
3	Cathode
4	N.C.
5	GND
6	$V_{O\ (output)}$
7	V_O
8	V_{CC}

Table – (2) Pin Configuration

DATASHEET FOR TLP-250 OPTOCOUPLER :-

- Input threshold current: I_F ……………………………………….5mA(max.)
- Supply current (I_{CC}) ……………………………………………… 11mA(max.)
- Supply voltage (V_{CC}) ……………………………………………….10−35V
- Output current (I_O) ……………………………………………… ±1.5A (max.)
- Switching time (t_pLH/t_p HL) …………………………………… 1.5μs(max.)
- Isolation voltage ………………………………………………….2500V_{rms} (min.)
- UL recognized …………………………………………… UL1577, file No.E67349
- Option (D4) type
  VDE approved: DIN VDE0884/06.92,certificate No.76823
  Maximum operating insulation voltage: 630VPK
  Highest permissible over voltage: 4000VPK

An optocoupler or optoelectronic coupler is an electronic component that basically acts as an interface between the two separate circuits with different voltage levels. Optocouplers are common component by which electrical isolation can be supplied between the input and output source. It is a 6-pin device and can have any number of photodetectors.

Here, a beam of light emitted by a light source exists as an only contact between input and output. Due to this, we can have an insulation resistance of megaohms between the two circuits. In high voltage applications where the voltage difference between the two circuits differs by several thousand volts, such isolation is favorable. The use of all such electronic isolators lies in all that conditions where the signal is to pass between two isolated circuits.

4.21 Construction of an Optocoupler

An optocoupler mainly consists of an infrared LED and a photosensitive device that detects the emitted infrared beam. The semiconductor photosensitive device can be a photodiode, phototransistor, a Darlington pair, SCR or TRIAC.

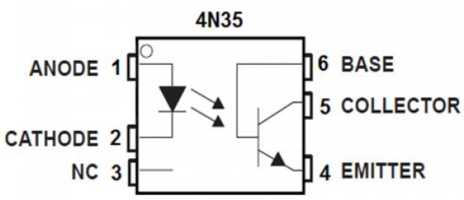


Fig. (8) – Optocoupler

The infrared LED and the device that are light sensitive is packed in a single package. The LED is kept on the input side and the light-sensitive material is placed on the output side. A resistance is connected at the beginning of the circuit which is used to limit the current and the other resistance is connected between the supply voltage and the collector terminal.

4.22 Working of an Optocoupler

An Optocoupler is a combination of LED and a Photo-diode packed in a single package. When a high voltage appears across the input side of the Optocoupler, a current start to flow through the LED.

Due to this current LED will emit light. This emitted light when falls on a phototransistor cause a current to flow through the same. The current flowing through the phototransistor is directly proportional to the supplied input voltage. An input resistance placed at the beginning of the circuit will decrease the amount of current flowing through the LED if its value is increased. As the LED glows due to this current, hence, when current will be low so as the light intensity of LED.

As we have already discussed earlier the intensity of emitted light by the LED will be equal to the corresponding current flowing through the phototransistor. This means that the low-intensity light emitted by the LED will cause a low-level current to flow through the phototransistor. Thus, a changing voltage is generated across the collector-emitter terminal of the transistor.

In this way, an incoming signal from the input circuit is coupled to the output circuit.

4.23 Advantages of an Optocoupler

- Optocouplers allow easy interfacing with logic circuits.
- Electrical isolation provides circuit protection.
- It allows wideband signal transmission.
- It is small in size and lightweight device.

4.24 Disadvantages of an Optocoupler

- The operational speed of Optocouplers is low.
- In case of a very high power signal, the possibility of signal coupling may arise.

4.25 Applications of an Optocoupler

- It is used in high power inverters.

- In AC to DC converters optocouplers are widely used.

4.3 BRIDGE RECTIFIER (D15SB80)

Fig. – (9) Bridge Rectifier (D15SB80)

Bridge Rectifiers are circuits that convert alternating current (AC) into direct current (DC) using diodes arranged in the bridge circuit configuration. Bridge rectifiers typically comprise of four or more diodes. The output wave generated is of the same polarity irrespective of the polarity at the input.

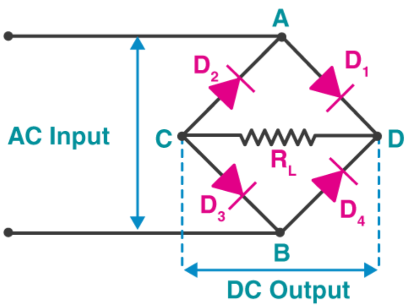


Fig. (10) – Bridge Rectifier

Bridge rectifiers are in the same class of electronics as half-wave rectifiers and full-wave rectifiers. Figure 5 shows such a bridge rectifier composed of four diodes D1, D2, D3, and D4 in which the input is supplied across two terminals A and B in the figure while the output is collected across the load resistor RL connected between the terminals C and D.

Now consider the case wherein the positive pulse appears at the AC input i.e., the terminal A is positive while the terminal B is negative. This causes the diodes D1 and D3 to get forward biased and at the same time, the diodes D2 and D4 will be reverse biased.

As a result, the current flows along the short-circuited path created by the diodes D1 and D3 (considering the diodes to be ideal). Thus, the voltage developed across the load resistor RL will be positive towards the end connected to terminal D and negative at the end connected to the terminal C.

Next, if the negative pulse appears at the AC input, then terminals A and B are negative and positive respectively. These forward biases the diodes D2 and D4, while reverse biasing D1 and D3 which causes the current to flow in the direction.

At this instant, one has to note that the polarity of the voltage developed across RL is identical to that produced when the incoming AC pulse was positive in nature. This means that for both positive and negative pulse, the output of the bridge rectifier will be identical in polarity.

However, it is to be noted that the bridge rectifier's DC will be pulsating in nature. In order to obtain a pure form of DC, one has to use a capacitor in conjunction with the bridge circuit

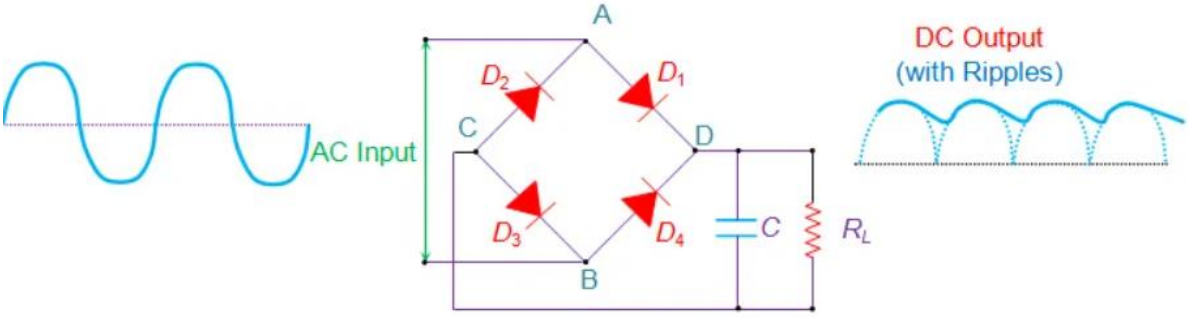


Fig. (11) – Bridge rectifier with RC filter

In this design, the positive pulse at the input causes the capacitor to charge through the diodes D1 and D3. However as the negative pulse arrives at the input, the charging action of the capacitor ceases and it starts to discharge via RL.

This results in the generation of DC output which will have ripples in it as shown in the figure. This ripple factor is defined as the ratio of the AC component to the DC component in the output voltage.

DATASHEET FOR D15SB80 BRIDGE RECTIFIER :-

MAXIMUM RATINGS AND ELECTRICAL CHARACTERISTICS :-			
PARAMETERS	**SYMBOL**	**D15SB80**	**UNITS**
Maximum repetitive voltage	V_{RRM}	800	V
Maximum RMS voltage	V_{RMS}	560	V
Maximum DC blocking voltage	V_{DC}	800	V
Maximum DC reverse current at $@T_A$ = 25°c	I_R	10	μA
Rated DC blocking voltage $@T_A = 125°c$		500	

Maximum average forward rectified output current at	With heatsink $T_C = 100°C$	I_O	15	A
	Without heatsink $T_A = 25°C$		3.5	
Peak Forward Surge Current, 8.3ms single half sine wave superimposed on rated load		I_{FSM}	250	A
Rating of fusing (t < 8.3)		l2t	240	A2sec
Maximum Instantaneous Forward Voltage @ 7.5A		V_F	1.0	V
Dielectric strength terminals to case, AC 1 min current 1mA		Vdia	2.5	KV
Maximum thermal on P.C.B without heat-sink		$V_{\theta JA}$	23	$°C/W$
Resistance per leg on Al plate heat sink		$V_{\theta JC}$	1.5	$°C/W$
Operating and Storage Temperature Range		T_J, T_{STG}	150, -55 ~ 150	$°C$
Mounting torque		T_{or}	Rating Torque : 0.8	N.m

Table - (3) Datasheet for Bridge Rectifier

4.4 DIODE (IN4007)

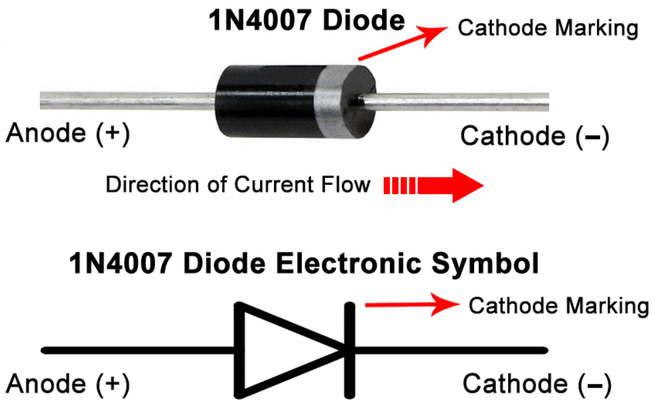


Fig. (12) – DIODE

A diode is defined as a two-terminal electronic component that only conducts current in one direction (so long as it is operated within a specified voltage level). An ideal diode will have zero resistance in one direction, and infinite resistance in the reverse direction.

Although in the real world, diodes can't achieve zero or infinite resistance. Instead, a diode will have negligible resistance in one direction (to allow current flow), and very high resistance in the reverse direction (to prevent current flow). A diode is effectively like a valve for an electrical circuit.

Semiconductor diodes are the most common type of diode. These diodes begin conducting electricity only if a certain threshold voltage is present in the forward direction (i.e. the "low resistance" direction). The diode is said to be "forward biased" when conducting current in this direction. When connected within a circuit in the reverse direction (i.e. the "high resistance" direction), the diode is said to be "reverse biased".

The diode is said to be "forward biased" when conducting current in this direction. When connected within a circuit in the reverse direction (i.e. the "high resistance" direction), the diode is said to be "reverse biased".

A diode only blocks current in the reverse direction (i.e. when it is reverse biased) while the reverse voltage is within a specified range. Above this range, the reverse barrier breaks. The voltage at which this breakdown occurs is called the "reverse breakdown voltage".

When the voltage of the circuit is higher than the reverse breakdown voltage, the diode is able to conduct electricity in the reverse direction (i.e. the "high resistance" direction). This is why in practice we say diodes have a high resistance in the reverse direction – not an infinite resistance.

A PN junction is the simplest form of the semiconductor diode. In ideal conditions, this PN junction behaves as a short circuit when it is forward biased, and as an open circuit when it is in the reverse biased. The name diode is derived from "di–ode" which means a device that has two electrodes. Diodes are commonly used in many electronics projects and are included in many of the best Arduino starter kits.

4.41 Working Principle of a Diode

A diode's working principle depends on the interaction of n-type and p-type semiconductors. An n-type semiconductor has plenty of free electrons and a very few numbers of holes. In other words, we can say that the concentration of free electrons is high and that of holes is very low in an n-type semiconductor.

Free electrons in the n-type semiconductor are referred to as majority charge carriers, and holes in the n-type semiconductor are referred to as minority charge carriers.

A p-type semiconductor has a high concentration of holes and a low concentration of free electrons. Holes in the p-type semiconductor are majority charge carriers, and free electrons in the p-type semiconductor are minority charge carriers.

DATASHEET FOR IN4007 DIODE :-

- Repetitive Reverse Voltage V_{rrm} Max ………………………………… 1kV
- Forward Current I_F ……………………………………………………1A
- Diode Configuration ……………………………………………………… Single
- Forward Voltage V_F Max. ………………………………………………1V
- Forward Surge Current I_{FSM} Max ……………………………………30A
- Operating Temperature Max. ……………………………………………$150^{\circ}C$
- Diode Case Style ………………………………………………DO-41 (DO-204AL)
- No. of Pins ………………………………………………………………2 Pins
- Product Range …………………………………………………………1N4007

4.5 STEP DOWN TRANSFORMER

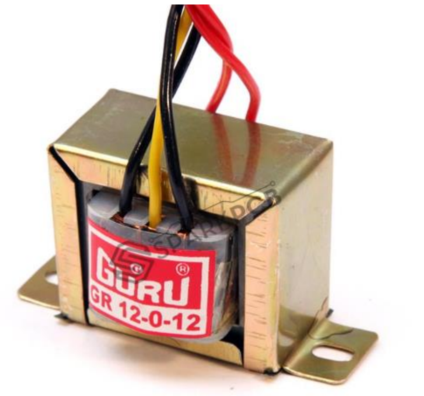


Fig. (13) – TRANSFORMER

A step-down transformer is a type of transformer that converts the high voltage (HV) and low current from the primary side of the transformer to the low voltage (LV) and high current value on the secondary side of the transformer. The reverse of this is known as a step-up transformer.

A transformer is a type of static electrical equipment that transforms electrical energy (from primary side windings) to magnetic energy (in transformer magnetic core) and again to the electrical energy (on the secondary transformer side). A step-down transformer has a wide variety of applications in electrical systems and transmission lines.

When it comes to the operation voltage, the step-up transformer application can be roughly divided into two groups: LV (voltages up to 1 kV) and HV application (voltages above 1 kV).

Just as transformers can step down the voltage – going from a higher primary side voltage to a lower secondary side voltage – they can also step up the voltage, going from a lower primary side voltage to a higher secondary side voltage. These are known as step-up transformers.

The transformer turns ratio (n) for a step-down transformer is approximately proportional to the voltage ratio:

$$n = \frac{V_P}{V_S} = \frac{N_P}{N_S}$$

Where $V_{P,S}$ are voltages, and $N_{P,S}$ are the turns numbers on the primary (LV) and secondary (HV) sides respectively. The primary side of a step-down transformer (HV side) has a larger number of turns than the secondary side (LV side).

That means energy flows from the HV to the LV side. The voltage is stepped down from the primary voltage (input voltage) to the secondary voltage (output voltage).

This equation can be rearranged for the formula for the output voltage (i.e. secondary voltage). This is sometimes referred to as the step-down transformer formula.

$$V_S = \frac{N_S \times N_P}{N_P}$$

The first LV application refers to the transformers in electronic devices. Supplying the electronic circuits requires a low voltage value (e.g. 5V, even lower values nowadays).

A step-down transformer is used to provide this low voltage value which is suitable for electronics supplying. It transforms home voltage (230/120 V) from primary to a low voltage on the secondary side which is used for electronic supplying.

If electronic devices are designed to have higher nominal power, transformers with high operating frequency are used (kHz-s). The transformers with higher nominal power value and 50/60 Hz nominal frequency would be too large and heavy. Also, the daily used battery chargers use the step-down transformer in its design.

2.5.1 Step-down Transformer Applications

The step-down transformers have a very important function in a power system. They lower the voltage level and adapt it to energy consumers. It is performed in several steps described below:

- A long-distance energy transmission system should have a voltage level as high as possible. With high voltage and low current, the transmission power loss $I^2 \times R$ will be significantly decreased. A power grid is designed that has to be connected with the transmission system with the different voltage levels. Step-down transformers are used in the interconnection of transmission systems with different voltage levels. They decrease voltage level from high to lower value (e.g. 765/220 kV, 410/220 kV, 220/ 110 kV). These transformers are huge and have very high nominal power (even 1000 MVA). In this case, when the transformer turns ratio is not high the autotransformers are usually installed.
- The next voltage level transformation step is adapting the transmission voltage to the distribution level. The characteristic voltage ratios, in this case, are 220/20 kV, 110/20 kV (also the LV secondary voltages 35 kV and 10 kV can be found). The nominal power of those transformers is up to 60 MVA (usually 20 MVA). The on-load tap changer is almost always installed in these transformers. Voltage regulation is the main function of tap changer. In the USA the tap changer is based on the LV side, and in the rest of the world mostly on the HV transformer side.
- The final voltage transformation step is adapting the voltage to the home voltage level. These transformers are known as small distribution transformers with nominal power up to 5 MVA (mostly below 1 MVA) and with nominal voltage values 35, 20, 10 kV on HV side and 400/200 V on LV side. It is noticeable that those transformers have a high turns ratio. They usually have de-energized tap changer with 5 tap position (+/- 2 tap position) and do not have on-load tap changer.

DATASHEET FOR 12-0-12 CENTER TAPPED TRANFORMER :-

- Input Voltage …………………………………………………. 230V AC
- Output Voltage …………………………………………….. 12V, 12V or 0V
- Output Current ………………………………………………… 500mA
- Mounting ………………………………………………… Vertical Mount Type
- Soft Iron Core

4.6 VOLTAGE REGULATOR (LM7812)

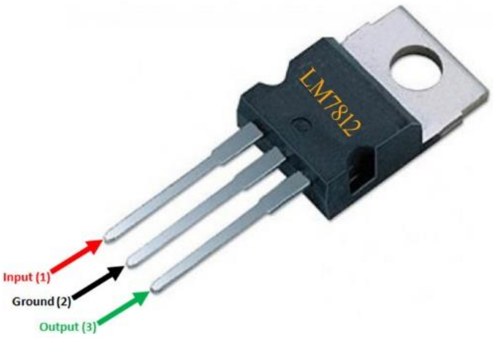


Fig. (14) – Voltage Regulator

DATASHEET FOR LM7812 VOLTAGE REGULATOR :-

ABSOLUTE MAXIMUM RATINGS ($T_a = 25$℃)			
Description	**Symbol**	**Value**	**Unit**
Input Voltage	V_{IN}	35	V
		40	
Power dissipation	P_D	15	W
Operating Temperature	T_{amb}	-20 to +80	$°C$
Storage Temperature Range	T_{stg}	-55 to +150	$°C$

ELECTRICAL CHARACTERISTICS ($T_a = 25°C$ unless specified otherwise) $V_{IN} = 19V, I_O = 100mA, T_a = 25°C$						
Description	**Symbol**	**Test Condition**	**Min**	**Typ**	**Max**	**Unit**
Output Voltage	V_O	$I_O = 5mA \sim 1.5A$ $V_{IN} = 15\sim27V,$ $P_D = 15W$	11.5		12.5	V
Description	**Symbol**	**Test Condition**	**Min**	**Typ**	**Max**	**Unit**
Line Regulation	R_{EGV}	$V_{IN} = 14.5\sim30V$			120	mV
Load Regulation	R_{EGL}	$I_O = 5mA\sim1.5A$			120	mV
Quiescent Current	I_Q				8.0	mA

Quiescent Current Change	I_Q	$V_{IN} = 14.5\sim30V$			1.0	mA
		$I_O = 5mA\sim1.5A$			0.5	mA
Input Voltage	V_{IN}		14.5		30	V
Ripple Rejection Ratio	R_R	$V_{IN} = 15\sim25V$, f=120Hz	55			dB
Max Output Current	I_{OM}	$T_J = 25°C$		2.2		A
Output Voltage Drift	V/T	$I_O = 5mA$, $T_J = 0\sim125°C$		-0.8		mV/$°C$
Output Noise Voltage	V_{NO}	F = 10Hz ~100KHz		10		µV
Short Circuit Current Limit	I_{SC}	$T_J = 25°C$		2.0		A

Table – (4) Datasheet for LM7812 Voltage Regulator

4.7 MICROCONTROLLER (ARDUINO UNO)

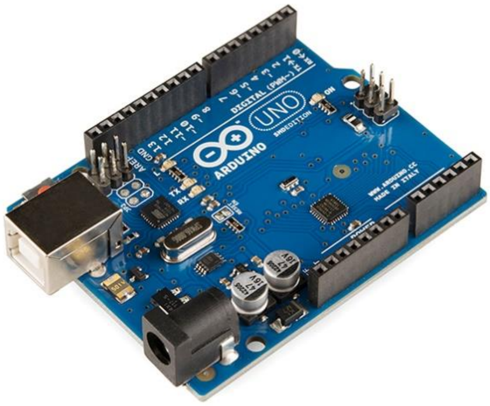


Fig. (15) – Arduino Uno

Arduino UNO is a low-cost, flexible, and easy-to-use programmable open-source microcontroller board that can be integrated into a variety of electronic projects. This board can be interfaced with other Arduino boards, Arduino shields, Raspberry Pi boards and can control relays, LEDs, servos, and motors as an output.

This board contains a USB interface i.e., USB cable is used to connect the board with the computer and Arduino IDE (Integrated Development Environment) software is used to program the board.

The unit comes with 32KB flash memory that is used to store the number of instructions while the SRAM is 2KB and EEPROM is 1KB.

The operating voltage of the unit is 5V which projects the microcontroller on the board and its associated circuitry operates at 5V while the input voltage ranges between 6V to 20V and the recommended input voltage ranges from 7V to 12V.

4.71 COMPONENETS :

The Arduino UNO board contains the following components and specifications:

ATmega328: This is the brain of the board in which the program is stored.

Ground Pin: there are several ground pins incorporated on the board.

PWM: the board contains 6 PWM pins. PWM stands for Pulse Width Modulation, using this process we can control the speed of the servo motor, DC motor, and brightness of the LED.

Digital I/O Pins: there are 14 digital (0-13) I/O pins available on the board that can be connected with external electronic components.

Analogue Pins: there are 6 analogue pins integrated on the board. These pins can read the analogue sensor and can convert it into a digital signal.

AREF: It is an Analog Reference Pin used to set an external reference voltage.

Reset Button: This button will reset the code loaded into the board. This button is useful when the board hangs up, pressing this button will take the entire board into an initial state.

USB Interface: This interface is used to connect the board with the computer and to upload the Arduino sketches (Arduino Program is called a Sketch)

DC Power Jack: This is used to power up the board with a power supply.

Power LED: This is a power LED that lights up when the board is connected with the power source.

Micro SD Card: The UNO board supports a micro-SD card that allows the board to store more information.

3.3V: This pin is used to supply 3.3V power to your projects.

5V: This pin is used to supply 5V power to your projects.

VIN: It is the input voltage applied to the UNO board.

Voltage Regulator: The voltage regulator controls the voltage that goes into the board.

SPI: The SPI stands for Serial Peripheral Interface. Four Pins 10(SS), 11(MOSI), 12(MISO), 13(SCK) are used for this communication.

TX/RX: Pins TX and RX are used for serial communication. The TX is a transmit pin used to transmit the serial data while RX is a receive pin used to receive serial data.

4.72 Applications :

The Arduino boards can work as a stand-alone project and can be interfaced with other Arduino boards or Raspberry Pi boards. Arduino UNO board is used in the following applications.

Weighing Machines

- Traffic Light Count Down Timer
- Parking Lot Counter
- Embedded systems
- Home Automation
- Industrial Automation

SPECIFICATIONS FOR ARDUINO UNO MICROCONTROLLER :-

- Microcontroller …………………………………………….. ATmega328
- Operating Voltage …………..…………………………………… 5V
- Input Voltage (recommended) ……………………….……… 7-12V
- Input Voltage (limits) ………………………………………… 6-20V
- Digital I/O Pins …………………………..…… 14 (of which 6 provide PWM output)
- Analog Input Pins …….…………………..…………………… 6
- Dc Current per I/O Pin ………………….…………………….. 40 mA
- Dc current for 3.3 V Pin ……………………………………… 50 mA
- Flash Memory ………….. 32 KB (ATmega328) of which 0.5 KB used by bootloader
- SRAM ……………………………………………………..….. 2 KB (ATmega328)
- EEPROM …….………………………………..…………… 1 KB (ATmega328)
- Clock Speed ………………………………………………….. 16 MHz

4.8 MULTIMETER

A multimeter is a measuring instrument that can measure multiple electrical properties. A typical multimeter can measure voltage, resistance, and current, in which case it is also known as a volt-ohm-milliammeter (VOM), as the unit is equipped with voltmeter, ammeter, and ohmmeter functionality. Some feature the measurement of additional properties such as temperature and volume.

Analog multimeters use a microammeter with a moving pointer to display readings. Digital multimeters (DMM, DVOM) have numeric displays and have made analog multimeters virtually obsolete as they are cheaper, more precise, and more physically robust than analog multimeters.

A multimeter is the combination of a DC voltmeter, AC voltmeter, ammeter, and ohmmeter. An un-amplified analog multimeter combines a meter movement, range resistors and switches; VTVMs are amplified analog meters and contain active circuitry.

For an analog meter movement, DC voltage is measured with a series resistor connected between the meter movement and the circuit under test. A switch (usually rotary) allows greater resistance to be inserted in series with the meter movement to read higher voltages. The product of the basic full-scale deflection current of the movement, and the sum of the series resistance

and the movement's own resistance, gives the full-scale voltage of the range. As an example, a meter movement that required 1 mA for full-scale deflection, with an internal resistance of 500 Ω, would, on a 10 V range of the multimeter, have 9,500 Ω of series resistance.

For analog current ranges, matched low-resistance shunts are connected in parallel with the meter movement to divert most of the current around the coil. Again, for the case of a hypothetical 1 mA, 500 Ω movement on a 1 A range, the shunt resistance would be just over 0.5Ω.

Moving coil instruments can respond only to the average value of the current through them. To measure alternating current, which changes up and down repeatedly, a rectifier is inserted in the circuit so that each negative half cycle is inverted; the result is a varying and nonzero DC voltage whose maximum value will be half the AC peak to peak voltage, assuming a symmetrical waveform. Since the rectified average value and the root mean square (RMS) value of a waveform are only the same for a square wave, simple rectifier-type circuits can only be calibrated for sinusoidal waveforms. Other wave shapes require a different calibration factor to relate RMS and average value. This type of circuit usually has fairly limited frequency range. Since practical rectifiers have non-zero voltage drop, accuracy and sensitivity are poor at low AC voltage values.

To measure resistance, switches arrange for a small battery within the instrument to pass a current through the device under test and the meter coil. Since the current available depends on the state of charge of the battery which changes over time, a multimeter usually has an adjustment for the ohm scale to zero it. In the usual circuits found in analog multimeters, the meter deflection is inversely proportional to the resistance, so full-scale will be 0 Ω, and higher resistance will correspond to smaller deflections. The ohms scale is compressed, so resolution is better at lower resistance values.

Amplified instruments simplify the design of the series and shunt resistor networks. The internal resistance of the coil is decoupled from the selection of the series and shunt range resistors; the series network thus becomes a voltage divider. Where AC measurements are required, the rectifier can be placed after the amplifier stage, improving precision at low range.

Digital instruments, which necessarily incorporate amplifiers, use the same principles as analog instruments for resistance readings. For resistance measurements, usually a small constant current is passed through the device under test and the digital multimeter reads the resultant voltage drop; this eliminates the scale compression found in analog meters, but requires a source of precise current. An auto ranging digital multimeter can automatically adjust the scaling network so the measurement circuits use the full precision of the A/D converter.

In all types of multimeters, the quality of the switching elements is critical to stable and accurate measurements. The best DMMs use gold plated contacts in their switches; less expensive meters use nickel plating or none at all, relying on printed circuit board solder traces for the contacts. Accuracy and stability (e.g., temperature variation, or aging, or voltage/current history) of a meter's internal resistors (and other components) is a limiting factor in long-term accuracy and precision of the instrument.

Fig. (16) – Multimeter

4.9 POWER QUALITY ANALYSER

Fig. (17) – Power quality analyser

Power Analyzer is the tool used to monitor the power quality. The rate of transfer of electricity in an electric circuit is known as Electric power. Electric power is measured in watts – joules per second in S.I units. There are various means to generate power. The power we utilize in our homes is usually produced by electric generators and supplied to homes, industries through the electric power grid. This task is done by the electric power industry. Unwanted variation in power quality could lead to breakdown or cause damage to sensitive equipment. Hence, it is crucial to monitor power quality frequently.

A power analyser, also known as a power quality analyser, is the equipment used to monitor the power quality in devices. Power quality is usually understood as the compatibility between a power/electric source and load plugged in so that the load could function properly. When power quality is low the load could get damaged or may malfunction. There are many causes of poor power quality.

Voltage, frequency of the signal, and waveform are the factors considered to measure power quality. When the power quantity has a steady supply voltage that stays in prescribed limits, and its A.C frequency is steady and close to the rated value with a smooth voltage curve, it is considered as good power quality.

The quality of power may vary due to discontinuity in service, variation in voltage magnitude, Transient currents, harmonics raising in A.C power. For power quality troubleshooting, the power analyser helps in calibrating and eliminating issues such as dips in voltage, swells, harmonics, unbalance etc…seen in electric power.

4.91 Power Analyzer Connections

In the electric power industry, power is generated at the power generator. Then this power is transmitted on electric transmission lines, distributed over this network, and reaches the electricity meters present near the end-user. For effective monitoring of power in the network, Power analysers are installed at three important positions – Main, Distribution switchboards, secondary switchboards.

Mains – This stage consists of devices with high performance and which requires accuracy for monitoring. Power analysers used at this stage must have additional features.

Distribution Switchboards – Power analysers at this stage are dedicated to registering electrical parameters and reporting alarm if any anomalies are found.

Secondary Switchboards – These power analysers are dedicated to monitor and log data of loads connected to the end of the transmission lines. These give full information on the status and power consumption of each load.

There are two methods for measuring electric parameters. Direct current measurement – for this type of measurement circuit should be open. Indirect current measurement – here current transformer clamp is connected to the wire to measure the current. Depending on the field of operation there are various types of power analysers for distinct applications.

For maintenance and inspection tasks power analysers with clamps are preferred. These do not require any extra connections. The three-phase power analyser has three clamps to measure inputs simultaneously.

If the measuring current is within limits of the maximum rated input current of the power analyser, the current-carrying cable can be directly connected to the power analyser input. If the measuring current exceeds the rated input limits then an external current transformer is used to convert the current into a voltage or current signal so that the power analyser could measure it directly.

CHAPTER – 5
PULSE GENERATION USING MATLAB/Simulink

The gate pulse which is used to trigger MOSFET generated by using MATLAB/Simulink and then sends to MOSFETs using Arduino. The following model in Simulink generates two gate pulses with a phase delay which is used to trigger MOSFETs S1, S2 & S3, S4 respectively.

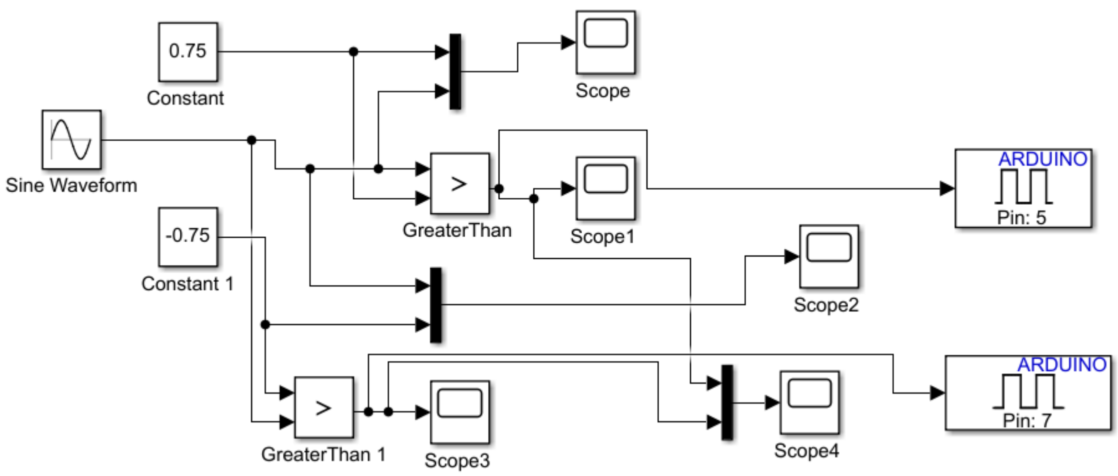
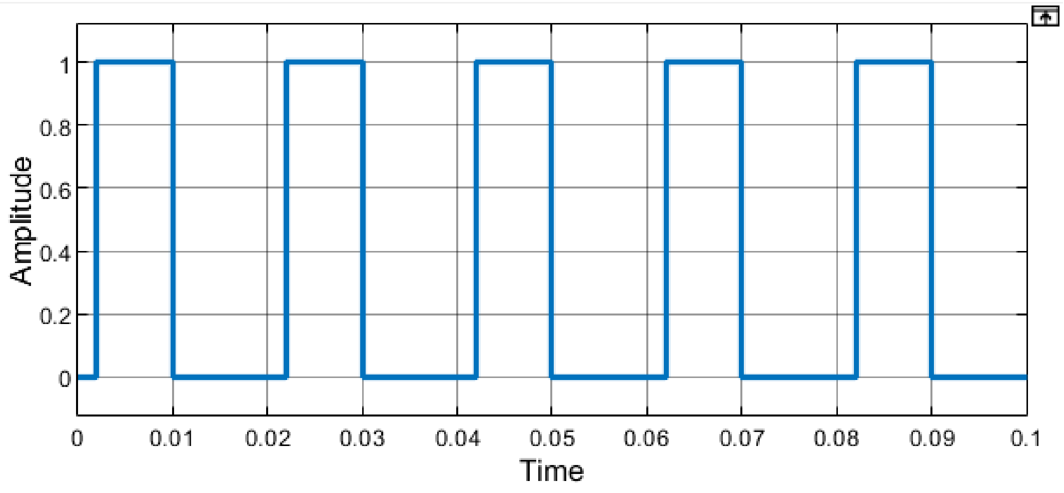
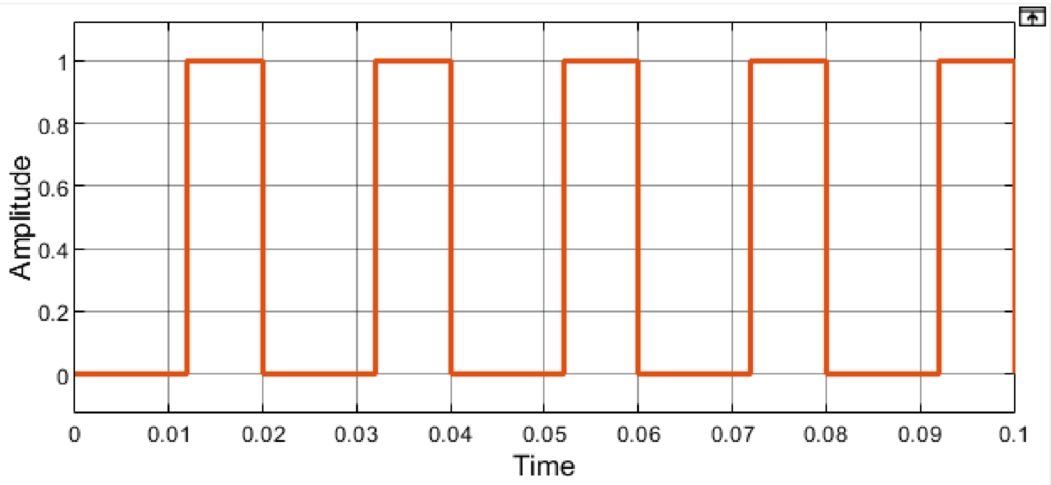


Fig. (18) – Simulink Model for gate pulse generation with phase delay

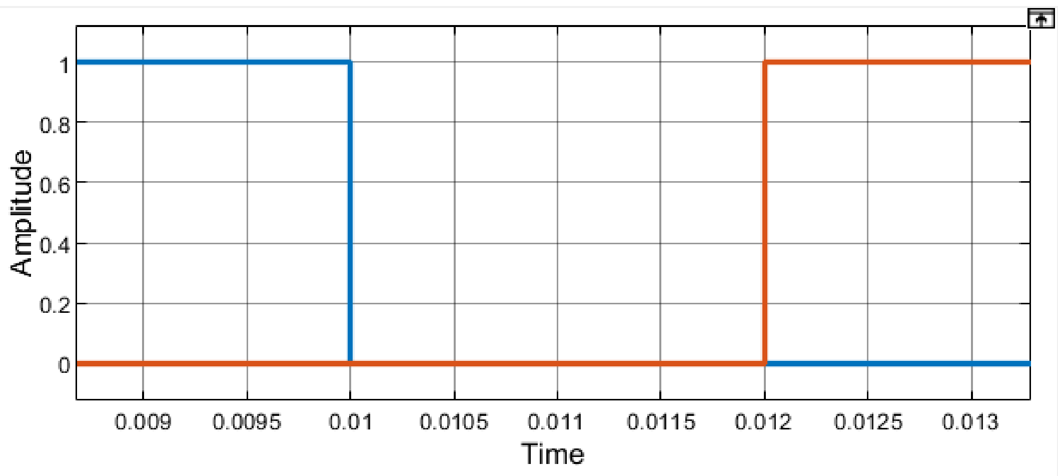
For the H-bridge inverter switches i.e. S1, S2, S3 and S4, gate pulses of 50% duty cycle with 50Hz switching frequency are generated such as that switches S1 and S2 turn on at the same time and switches S3 and S4 turn on at same time. These two pulses send to Arduino Uno microcontroller's pin no. 5 and 7 using Arduino package in MATLAB/Simulink. The pins of Arduino get connected to MOSFETs (pin 5 connects to S1 and S2 while pin 7 connects to S3 and S4). Phase delay between two pulses is necessary to avoid such a scenario in which all MOSFETs get turned on at the same time and damage the circuit. Gate pulse at pin 5 of Arduino turns on switches S1 and S2 and when this pulse becomes 0. After a phase delay, Gate pulse at pin 7 turns on the switches S3 and S4. MATLAB/Simulink results are :


Amplitude
1
0.8
0.6
0.4
0.2
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Time

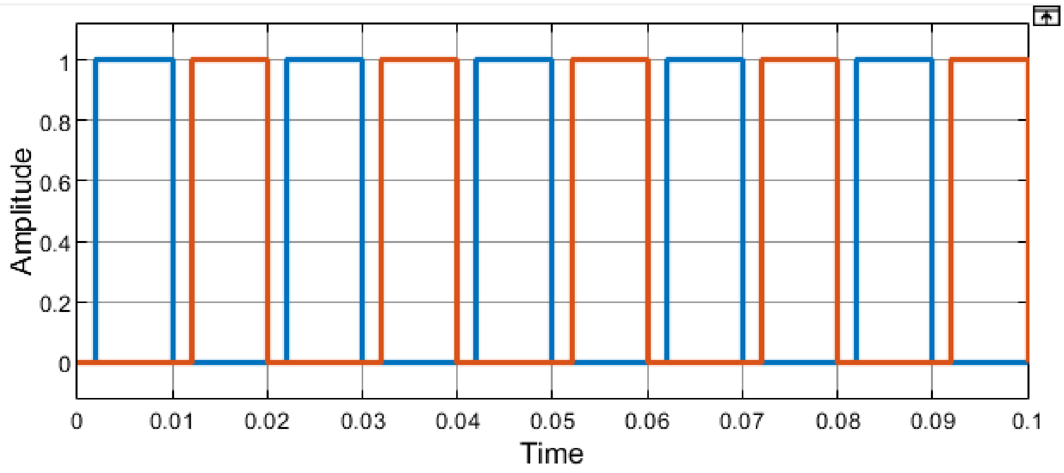
(a)


Amplitude
1
0.8
0.6
0.4
0.2
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Time

(b)


Amplitude
1
0.8
0.6
0.4
0.2
0
0.009
0.0095
0.01
0.0105
0.011
0.0115
0.012
0.0125
0.013
Time

(c)



(d)

Fig. (19) – Simulation result of Pulse generator model. (a.) Gate pulse for Switch S1 & S2 (b.) Gate pulse for Switch S3 & S4 (c.) Phase delay between both gate pulses (d.) Both gate pulses simultaneously.

CHAPTER – 6

TOPOLOGY IMPLEMENTED

The working of this project is mainly divided into three different circuits. One is a DC supply circuit which is used to convert AC to Dc, second one is for driving MOSFETs and the third one (the main circuit) which is used to get AC voltage from DC voltage across load.

6.1 12v DC SUPPLY CIRCUIT

Components required:12-0-12 Transformer, D15SB80 Rectifier, LM 7812 IC, 2200 uf,100nf 100µF capacitors.

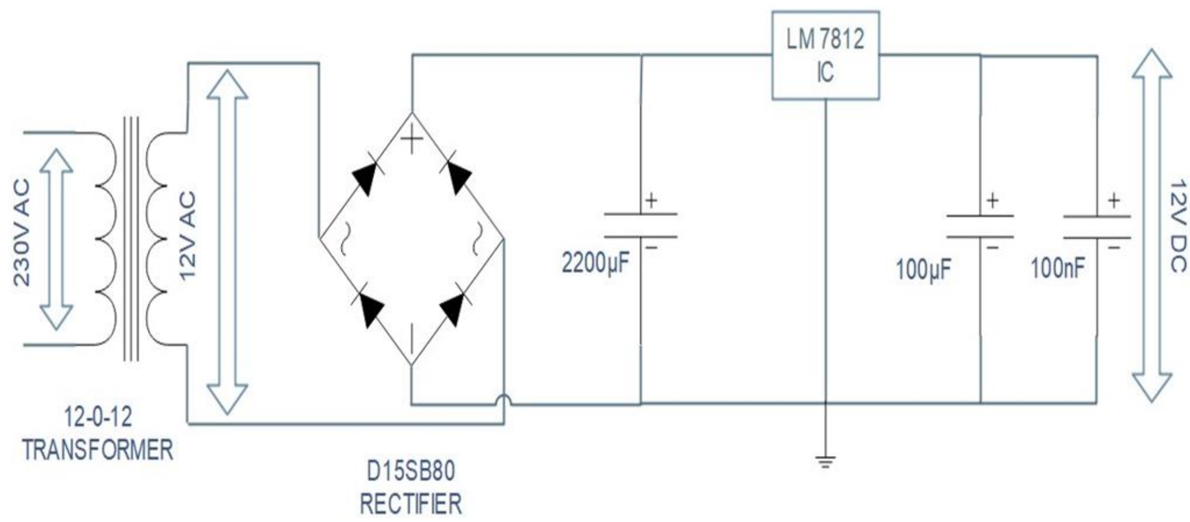


Fig. (20) – 12V DC Supply Circuit

The main purpose of this circuit is to provide a constant 12V DC supply from a 230V AC input source, this circuit is used to give supply to the TLP 250 circuit which is the pulse generating circuit for our H-Bridge.

6.11 Working

We take 230V AC supply as input from the source which is to be stepped down to 12V AC by the help of centre tap step down transformer. Then that 12V AC is converted to 12V DC with the help of D15SB80 Bridge Rectifier but that converted 12V DC would have some AC components in it which is also called as ripples so to removing the ripples form the generated 12V DC output from D15SB80 Bridge Rectifier we use a capacitor of 2200µF to produce a ripple free 12V DC. After that 12V DC is applied to LM7812 Voltage regulator IC which has three pins one for input ,one for output and other one is grounded whose main purpose is to produce a constant 12V DC in case if output from rectifier or transformer is increased then this Voltage regulator IC will still produce constant 12V DC But the input voltage for IC must not be increased more than 40V and in that case we may require heat sink as stepping down excess of voltage will cause more heat to dissipate. At the output of LM7812 Voltage regulator IC we have used another two capacitors of 100nf and100µF to remove ripples from the circuit if any and to stop the sudden change of voltage at the output and produce a constant 12V DC Supply.

6.2 MOSFET TRIGGERING CIRCUIT

Components required: TLP 250 IC, ARDUINO UNO,100µF &100nF Capacitors, 10Ω,1KΩ &10KΩ Resistances, 12V DC Supply from Circuit 1.

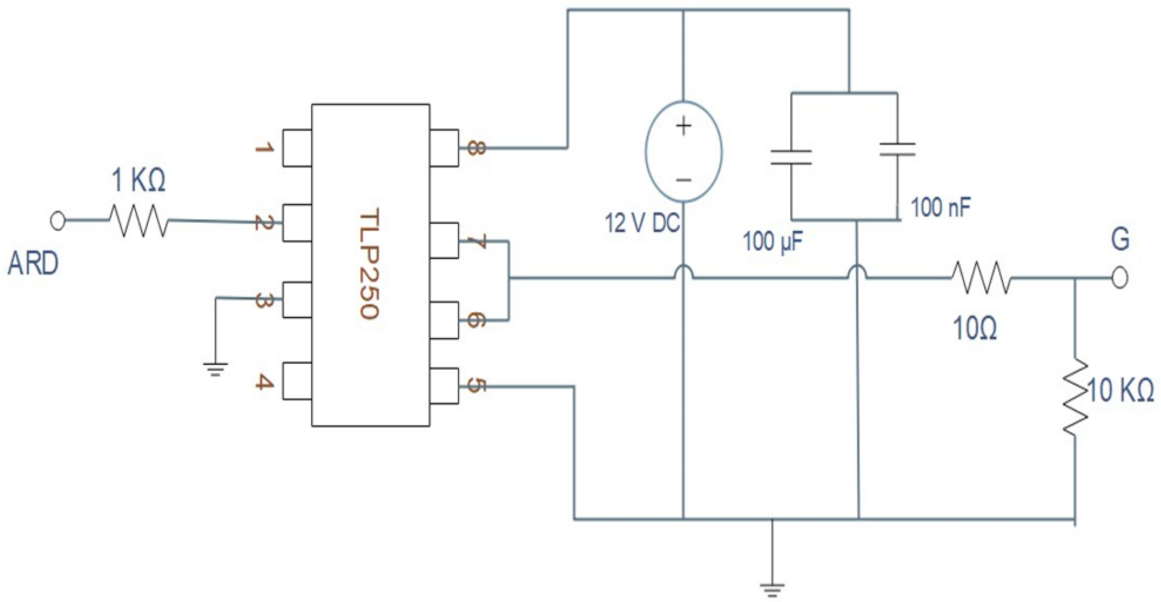


Fig. (21) MOSFET Triggering Circuit

This circuit is mainly used to drive the MOSFET to on stage whenever a high pulse is generated by this circuit which is given as an input to the gate of a MOSFET then that MOSFET will work in ON stage else if low pulse is generated as output then the MOSFET will work in OFF stage, so basically this circuit deals with the switching on and off of the MOSFET (Which is working as a switch in our circuit 3).

6.21 Working

Here we use TLP250 which is a Optocoupler IC which means the input and output are optically isolated means they are electrically insulated but the signal from input is transferred to output by optical signal where input stage has a light emitting diode and output stage have photodiode. The input to TLP250 is given at pin no 2 by ARDUINO UNO and pin no 3 is connected to the ground, the 12V DC supply which we have made in circuit 1 is connected between pin no 8 and 5 and in parallel to this 12V DC Supply and two capacitors of 100µF &100nF are connected in parallel to 12V DC supply between pin 5&8 which protect the TLP250 by stabilizing the voltage across it and act like a decoupling capacitor. Then we have short circuit the pin no 6,7 and have taken the output pulse through them to drive the gate of MOSFET and this output pulse pass through a network of resistance which consist of 10Ω resistance connected between pin 6 and Output and also a shunt resistance of 10KΩ at the Output terminal G for stabilizing the Output pulse which will drive the gate terminal. The rest of the pins (1,4) are left empty. So when the input pulse from ARDUINO is high the output from TLP 250 is also high which means it drive the gate of MOSFET to ON stage and MOSFET which is acting as a switch become close at this time the MOSFET gate takes power from the 12V DC supply and pulled to its level.

When the input from ARDUINO is low then the TLP 250 will produce output as low which open and at that time gate voltage will be pull down to its source voltage level.

6.3 AC VOLTAGE GENERATION CIRCUIT

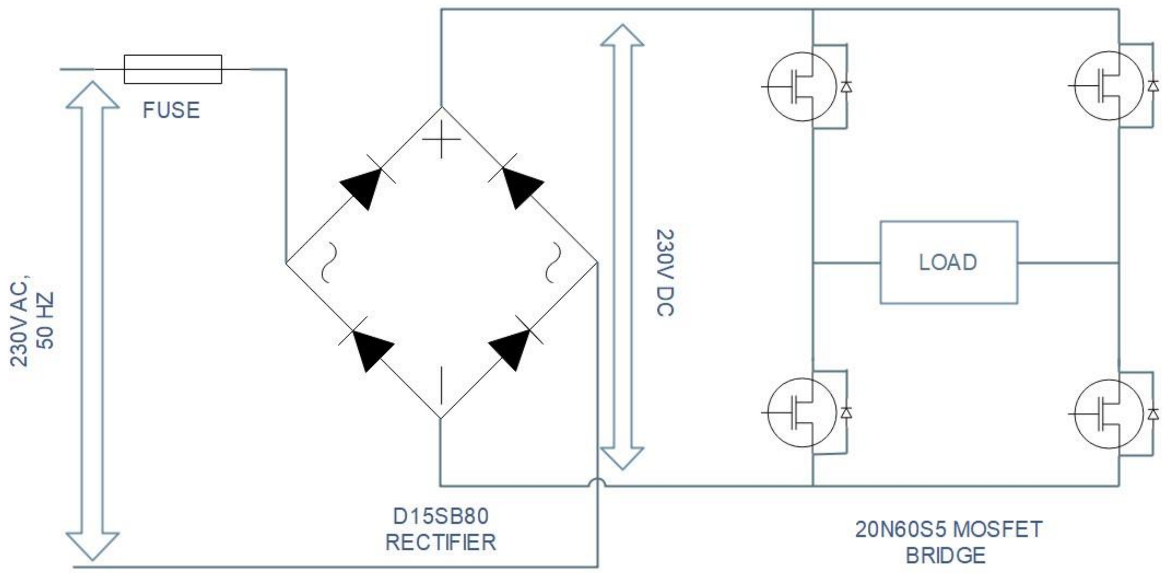


Fig. (22) – AC Voltage generation circuit

The main purpose of this circuit is to provide to get AC voltage from DC voltage across R load. In this circuit we are giving a source voltage of 230 V AC to rectifier in order to get a DC voltage of 230 V, then we are converting it into AC voltage.

6.31 Working

In a full bridge inverter four bidirectional MOSFET (switches) are connected i.e. S1, S2, S3, S4, in this circuit two legs are connected, so it is also known as the H-Bridge inverter.
The two switches are complementary switches which means when the first switch is ON the second switch will be OFF Similarly, when the second switch is ON, the first switch will be OFF. There is a concept of two voltages, first is Pole Voltage and second is Line Voltage. Pole Voltage is V_{a0} and V_{b0}, Line voltage is V_{ab}.
$V_{ab} = V_{a0} - V_{b0}$

The switch configuration is as follows:

At lagging load Condition

Case 1: From φ to π, $V_0 > 0$ and $I_0 > 0$ then switches S1, S2 conducts.
Case 2: From π + φ to 2 π, $V_0 < 0$ and $I_0 < 0$ then switches S3, S4 conducts.
Two Switches will conduct at a time.
S1, S2 - On, $V_{a0} = V_{dc}/2$, $V_{b0} = -V_{dc}/2$

At Leading Load Condition

Case1: From 0 to π – φ, $V_0 > 0$ and $I_0 > 0$ then switches S1, S2 conducts
Case2: From π to 2 π – φ, $V_0 < 0$ and $I_0 < 0$ then switches S3, S4 conducts
Two Switches will conduct at a time.
S1, S2 - On, $V_{a0} = V_{dc}/2$, $V_{b0} = -V_{dc}/2$

Now , Applying KVL in the loop containing switches S1 and S2, then
$V_0 = V_{ab} = V_{dc}$
$V_{ab} = V_{a0} - V_{b0} = V_{dc}$

Switch current and Source current will be in the same direction, so Io>0, and Load current (I_L>0). So, Vo>0, Io>0

Now other two switches will conduct at same time
S3, S4 - On, Vo = -Vdc<0, Io<0

Now , Applying KVL in the loop containing switches S3 and S4, then
Vo=-Vdc<0, Io<0.

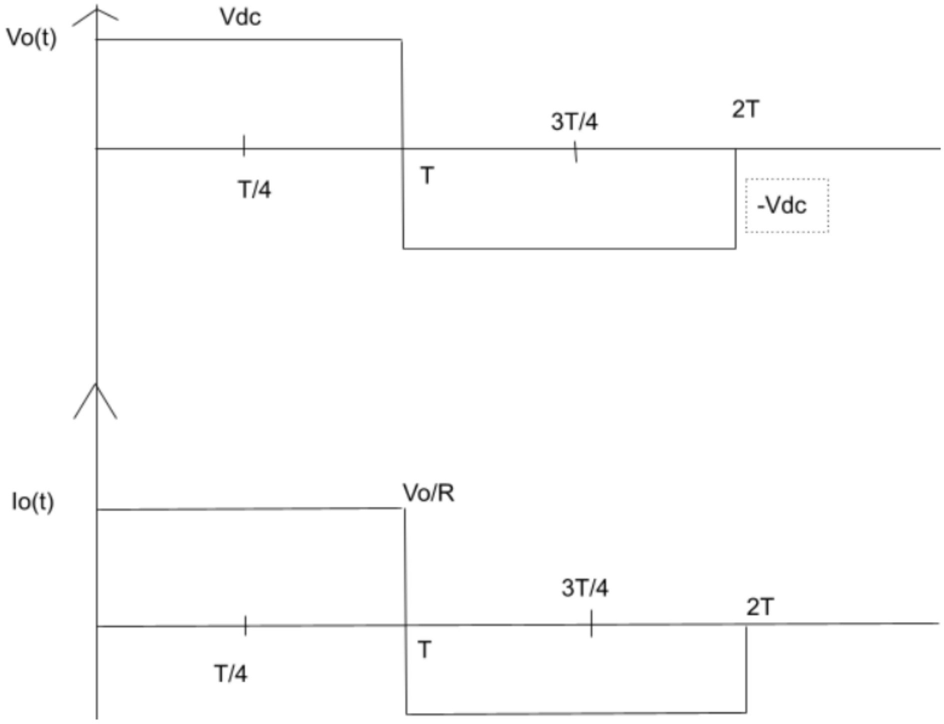


Fig. (23) – Waveform for triggering of MOSFET

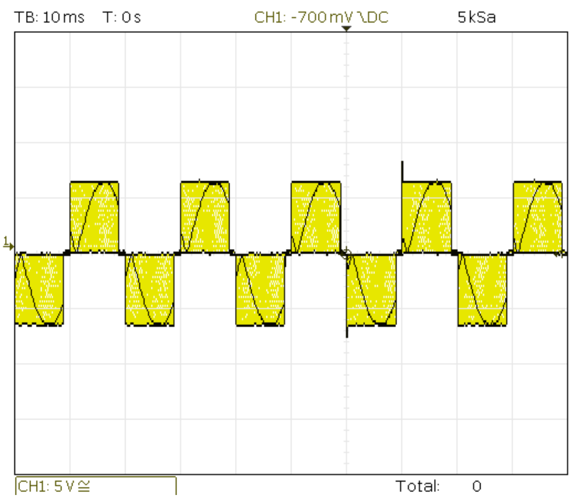
CHAPTER – 7

RESULTS

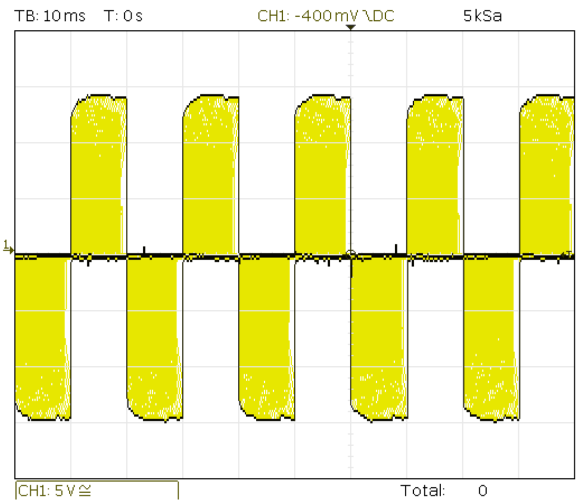
In this section, results of fabricated model are shown. Experimental results are presented to assist and verification of simulation results.

S. No.	Component Name	Component No.
1.	Switch – used MOSFET (*4)	20N60S5
2.	Optocoupler (*4)	TLP250
3.	Bridge Rectifier (*5)	D15SB80
4.	Diode (D1, D2, D3, D4)	IN4007
5.	Resistor	1kΩ, 10kΩ, 10Ω
6.	Capacitor	100µF, 100nF
7.	Capacitor	2200µF (35V), 10µF (35V), 100nF (35V), 100nF (35V)
8.	Transformer	12-0-12 Step down Centre tapped

Table (5) : Values of Components used in Fabricated model



(a)



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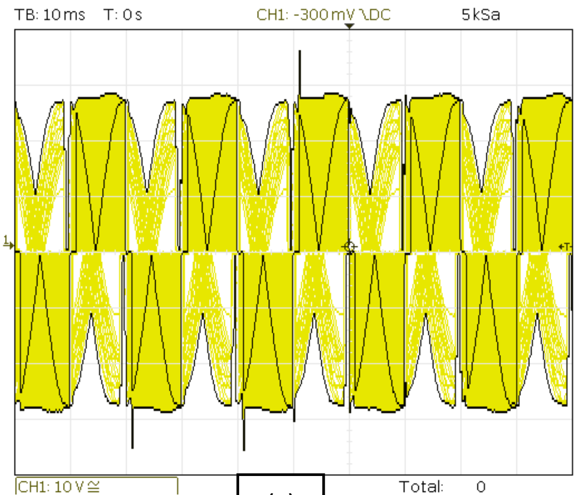

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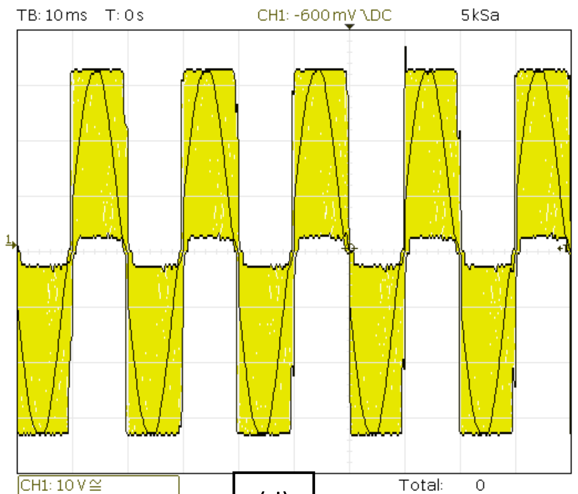

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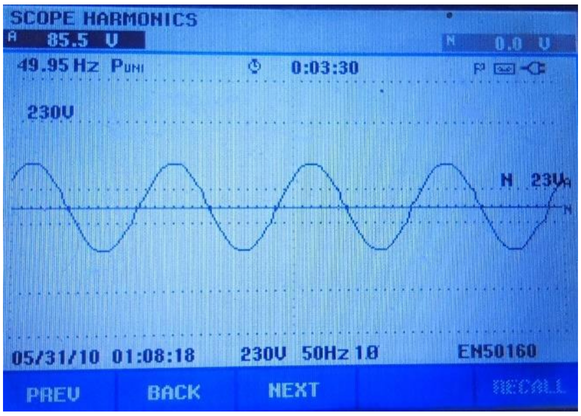

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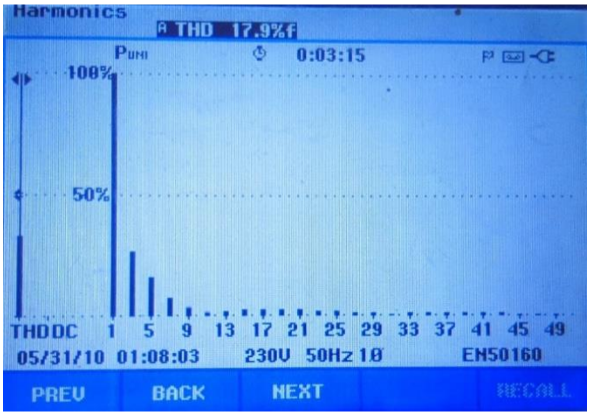

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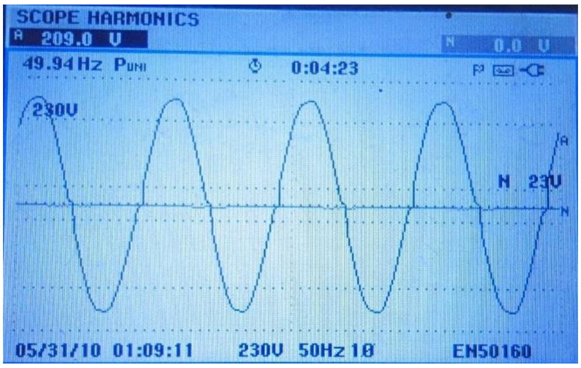

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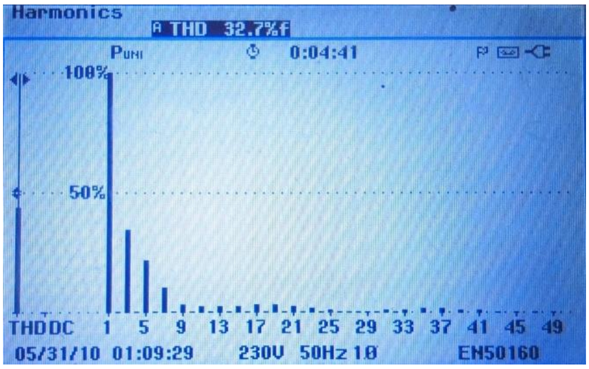
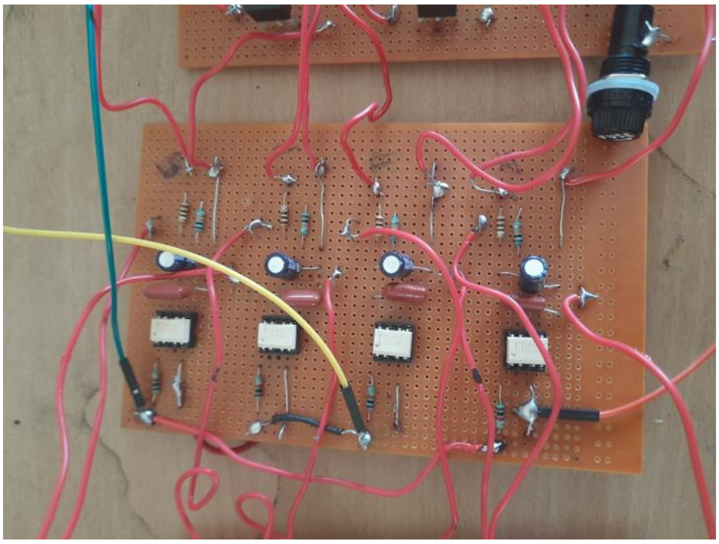


(h)

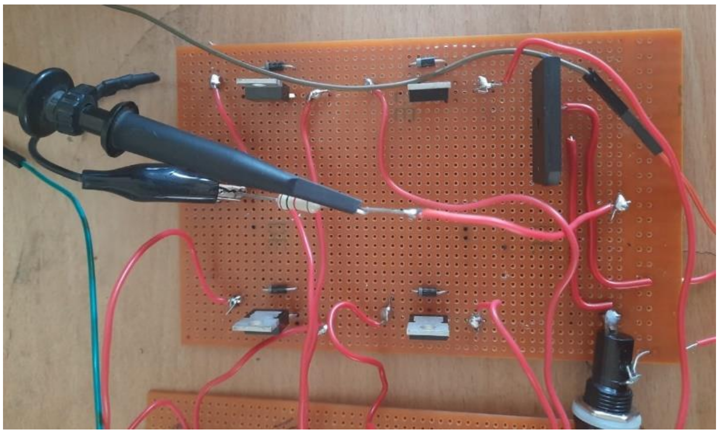
Fig. (24) – Result of fabricated hardware circuit of H-bridge inverter. (a) 50V output sinusoidal waveform (b) 150V output sinusoidal waveform (c) 210V output sinusoidal waveform seen using DSO (d) 230V output sinusoidal waveform (e) Output waveform for 85.5V seen on Power quality Analyser (f) Harmonic distortion (17.9%) for 85.5V (g) Output waveform for 210V input (h) Harmonic distortion (32.7%) for 210V

7.1 Hardware Implementation

In this section, real images of our hardware implementation for completion of the project are shown :



(a)



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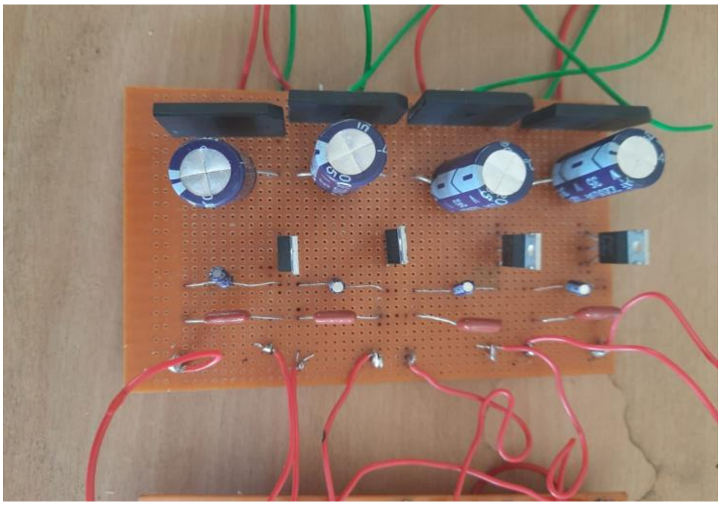

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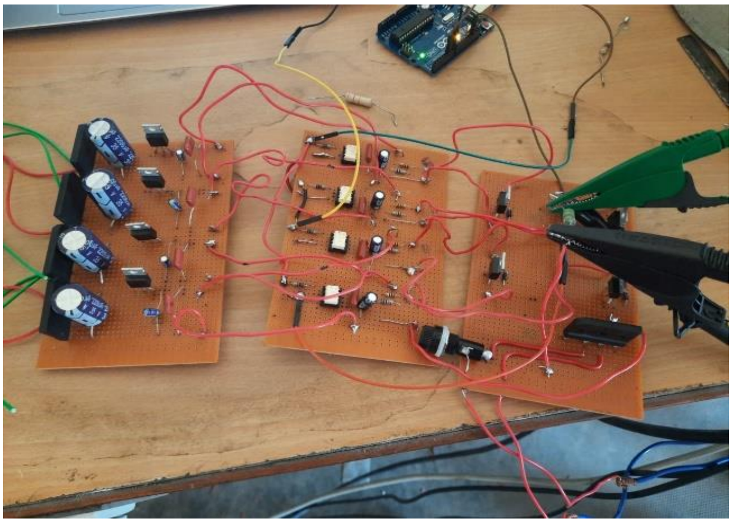

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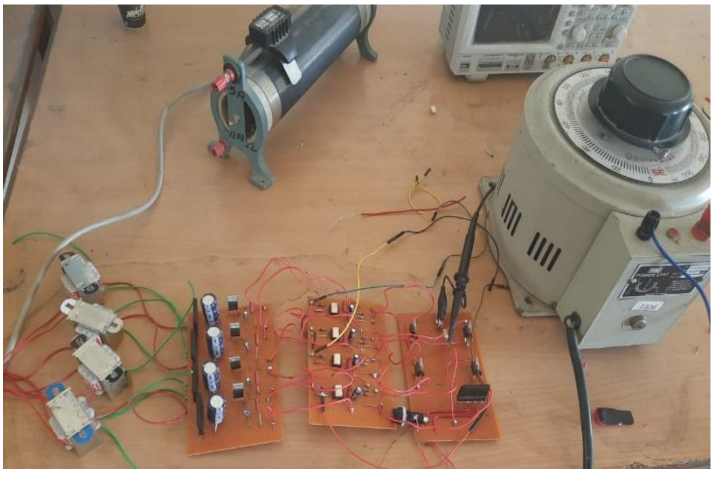
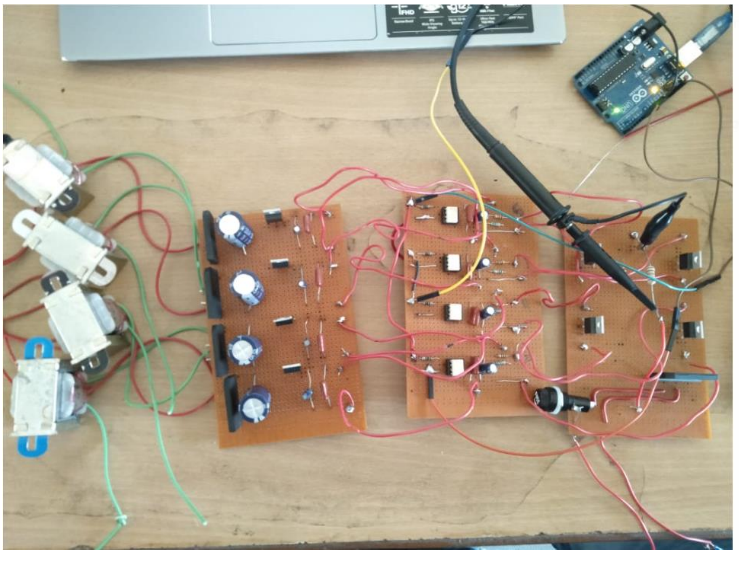


(e)



(f)

Fig. (25) – Images of hardware implementation of single phase 3 level H-bridge inverter. (a) MOSFET triggering circuit. (b) AC Voltage generation circuit (c) 12V DC conversion circuit (d),(e)&(f) Complete setup of single-phase multilevel inverter

CHAPTER-8

CONCLUSION

In this report we have concluded about the hardware implementation of 3 level H bridge inverter, working and results regarding to operation of 3-level H bridge inverter where we analysed about the Ac waveform across load from a dc input and harmonics component across it using power quality analyser and digital oscilloscope. We analysed the operation of inverter till a max AC voltage of 230V.This H-bridge model of multilevel inverter is much more effective than other models as it requires less no of components and switching is done very softly in this model.

CHAPTER – 9

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