BRAC UNIVERSITY

Design of a Pure Sine Wave Inverter for PV Application

BY

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Thesis Supervised By

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DECLEARATION

We there by declare that this thesis is based on the results that we have done in our thesis work. Contents of work found by other researchers are mentioned by references. This thesis has never been previously submitted for any degree, neither in whole nor in part.

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Abstract

An inverter circuit by using Sinusoidal Pulse Width Modulation (SPWM) switching schemes is developed to run AC utilities. Inverter is a circuit that converts a DC source to an AC source. DC is one type of energy that is found in solar panels and can be stored in batteries for usage in future. Semiconductor device, Metal Oxide Field Effect Transistor (MOSFET) is used as switch in full bridge (H-Bridge) inverter configuration using Unipolar voltage switching . Driver circuit for MOSFET is also very important as it is used to interface between control circuits (Low voltage part) and inverter (High voltage part). PIC micro controller chip is used to generate modulating signals. The Programmable Interface Computer (PIC) is used PIC16F887 and MOSFET driver is IR2110. At the end of this project, the SPWM output signal is developed from the Micro-controller and applied to the MOSFET driver and the inverter .

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CHAPTER 1

1.1 INTRODUCTION

Electricity is the major source of power for country's most of the economic activities. But in Bangladesh , we have been suffering for the electricity crisis for a long time. To reduce this problem, there are some alternative ways which can help in this purpose. But among all of the methods solar system may be an easy and effective one especially in the rural areas where the electricity has not reached yet.

Solar energy is a renewable energy which possibly has no harm on the environment. A solar panel can maximum produce 128 watt which can run 11 CFl (compact florescent lamp) of 6 watt power, a fan conducted on DC current. Also 19/20 inches black & white television can run. Presently, Grameen shakti, BRAC solar home system and also many companies have a mission to provide electricity to the remote areas and also reduce the crisis of electricity by using the solar energy.

Generally these kinds of projects like solar panels are mostly dependent on the DC appliances. Here, DC sources are converted to the AC source by using an inverter. From several researches, we have found that Grameen and BRAC solar project is dependent on DC applications. Due to lack of proper inverters, the companies provide usage of DC appliances only not AC appliances. The reason is that the existing inverter produces modified sine wave (square sine wave) which causes major power losses and harms to AC appliances.

But in comparing to pure sine wave, it has better performance than modified one and the power loss is less. For that reason , our objective is to design a pure sine wave inverter which can be used in the Solar Home System at an affordable cost. In this project, our aim was to design a pure sine wave inverter which is the digital versioned circuit using micro-controller applications.

1.2 OBJECTIVES

The Objectives of our project is to design an inverter that can be drived by PV panel and can be used to operate AC loads while minimizing the conventional inverter cost and complexity using Micro-controller . Our system's main properties are –

- Generation of a pure sine wave signal from a solar panel reducing the dependency on the fossil fuels and limited energy source .
- Reduction of circuits complexity by using micro-controller to generate modulating signals

1.3 METHODOLOGY

In this project , we have used Battery instead of PV panel as DC source . This DC source is fed to the H-Bridge inverter . In the H-Bridge Inverter , we have used 4 MOSFETs switches . This MOSFETs are used to convert the DC source to AC source . Besides , we have used gate drivers to conduct those MOSFET switches . To generate modulating signals , we have implemented micro-controller where four modulating signals are used to run those MOSFETs switches . Here , unipolar modulation scheme is used . As the modulation were performed in very high frequency , we have implemented a LC low pass filter to remove the harmonics at higher frequencies at the inverter output . To get 220 v AC , we have used step – up transformer .

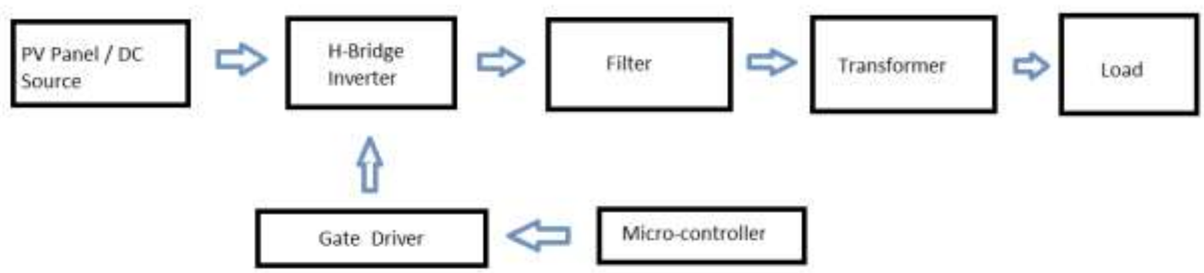


Figure 1 : Block Diagram Of The System

CHAPTER 2

INVERTER:

Inverter or power inverter is a device that converts the DC sources to AC sources. Inverters are used in applications such as adjustable-speed ac motor drivers; uninterruptible power supplies (UPS) and ac appliances run from an automobile battery.

Power inverters produce one of the three different types of wave output:

1. Square Wave
2. Modified Square Wave (Modified Sine Wave)
3. Pure Sine Wave (True Sine Wave)

The three different wave signals represent three different qualities of power output. Square wave inverters result in uneven power delivery that is not efficient for running most devices. Square wave inverters were the first type of inverters made.

2.1 Modified Sine Wave:

Modified sine wave inverters were the second generation of power inverter. The modified sine wave inverter provides a cheap and easy solution to powering device that need AC power. Modified sine wave inverters approximate a sine wave and have low enough harmonics that do not cause problem with household equipments. It does have some drawbacks as not all the devices work properly on a modified sine wave, product such as computer and medical equipment need pure sine wave inverter. The main disadvantage of the modified sine wave inverter is that peak voltage varies with the battery voltage.

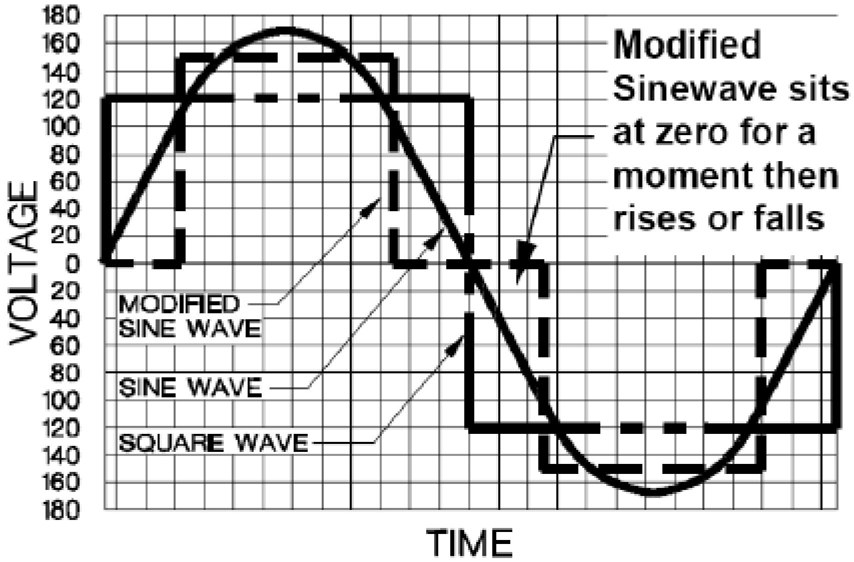


Figure 2: Square, Modified and Pure Sine Wave

2.2 Pure Sine Wave:

Pure sine wave inverter represents the latest inverter technology. The waveform produced by these inverters is same as or batter than the power delivered by the utility. Usually sine wave inverters are more expensive than the modified sine wave inverters due to there added circuitry.

2.3Pulse Width Modulation:

Pulse width modulation (PWM) is a powerful technique for controlling analog with a processor's digital outputs. The applications of PWM are wide variety used like ranging from measurement and communications to power control and conversion. In PWM inverter harmonics will be much higher frequencies than for a square wave, making filtering easier.

In PWM, the amplitude of the output voltage can be controlled with the modulating waveforms. Reduced filter requirements to decrease harmonics and the control of the output voltage amplitude are two distinct advantages of PWM. Disadvantages include more complex control circuits for the switches and increased losses due to more frequent switching.

Control of the switches for sinusoidal PWM output requires (1) a reference signal, sometimes called a modulating or control signal, which is a sinusoidal in this case; and (2) a carrier signal, which is a triangular wave that controls the switching frequency.

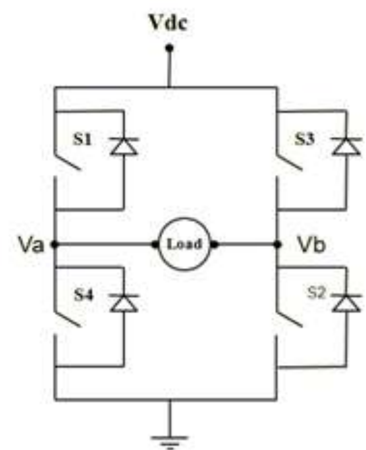


Figure3: A full bridge inverter

2.4 Bipolar Switching:

When the instantaneous value of the sine reference is larger than the triangular carrier, the output is at +Vdc, and when the reference is less than the carrier, the output is at –Vdc.

V_0 = +Vdc for $V_{sin}>V_{tri}$

V_0 = -Vdc for $V_{sin}<V_{tri}$

This version of PWM is bipolar because the output alternates between plus and minus the dc power supply voltage.

From figureX we can see that

S1 and S2 are on when $V_{sin}>V_{tri}$

S3 and S4 are on when $V_{sin}<V_{tri}$

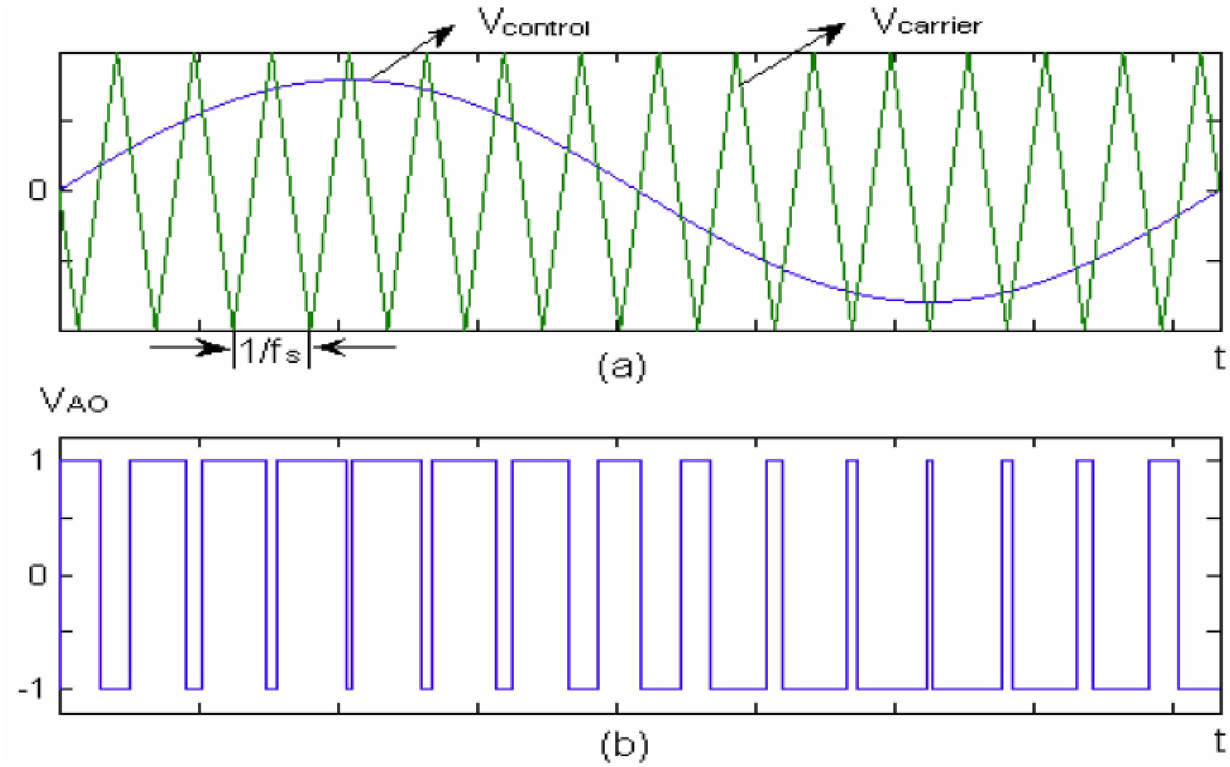


Figure 4: Bipolar pulse width modulation. (a) Sinusoidal reference and triangular carrier. (b) Output is +Vdc when $V_{sin}>V_{tri}$ and is –Vdc when $V_{sin}<V_{tri}$.

2.5 Unipolar Switching:

In a unipolar switching scheme for pulse width modulation, the output is switched from either high to zero or low to zero, rather than between high and low, as in bipolar switching. For unipolar switching control as follows:

S1 is on when $V_{sin}>V_{tri}$

S2 is on when $-V_{sin}<V_{tri}$

S3 is on when $-V_{sin}>V_{tri}$

S4 is on when $V_{sin}<V_{tri}$

Here we can see that switch pair(S1,S4) and (S2,S3) are complementary.

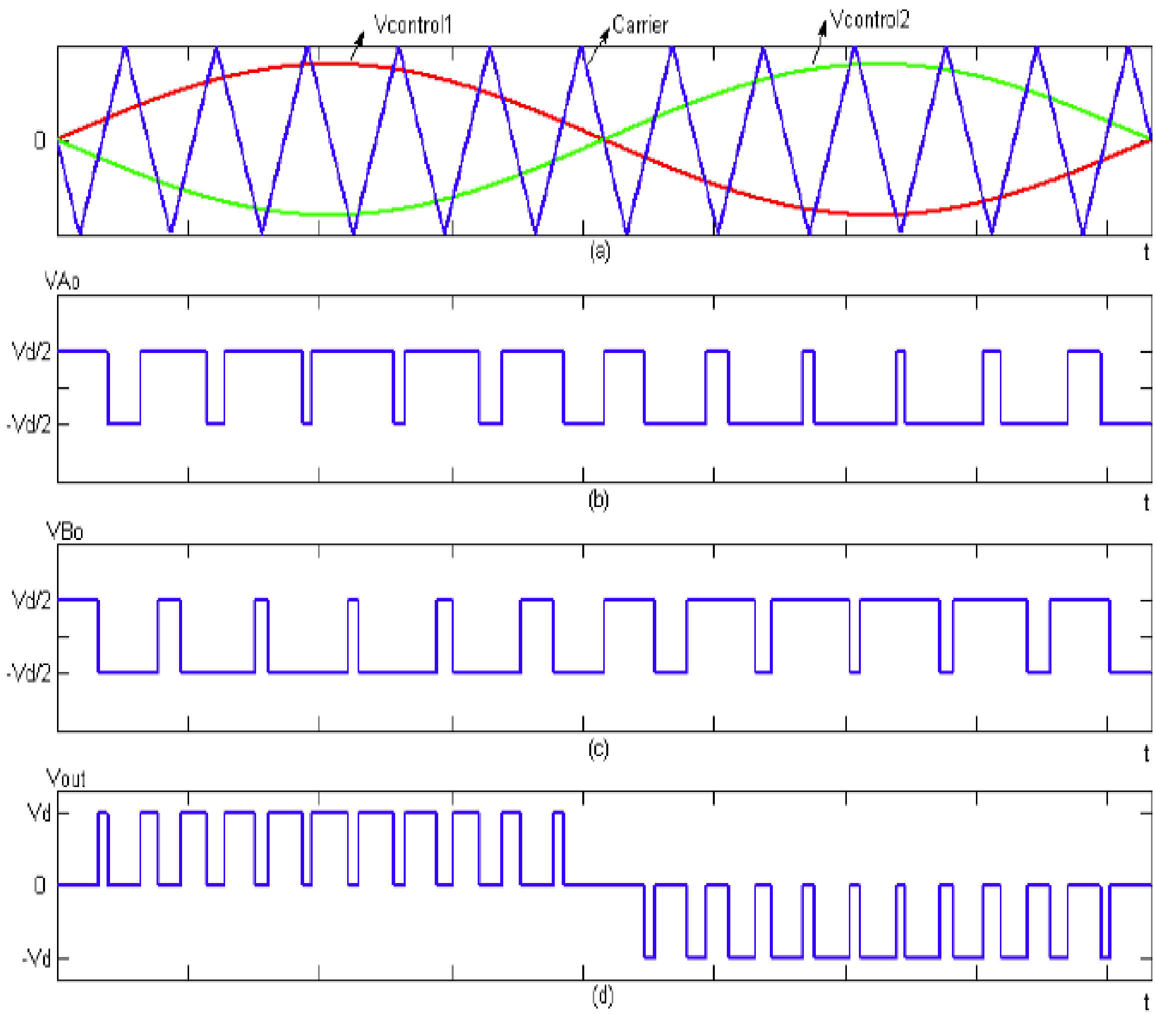


Figure 5: Unipolar PWM scheme and output voltage.

2.6 Modified Unipolar Switching:

In modified unipolar PWM approach two arm switch at different frequencies: one is at fundamental frequency while the other one is at carrier frequency, thus having two high frequency switches and two low frequency switches. It also produces unipolar output voltage wavefrom changing between 0 and +Vdc or between 0 and –Vdc.

In this switching scheme,

S1 is on when $V_{sin}>V_{tri}$ (high frequency)

S4 is on when $V_{sin}<V_{tri}$ (high frequency)

S2 is on when $V_{sin}>0$ (low frequency)

S3 is on when $V_{sin}<0$ (low frequency)

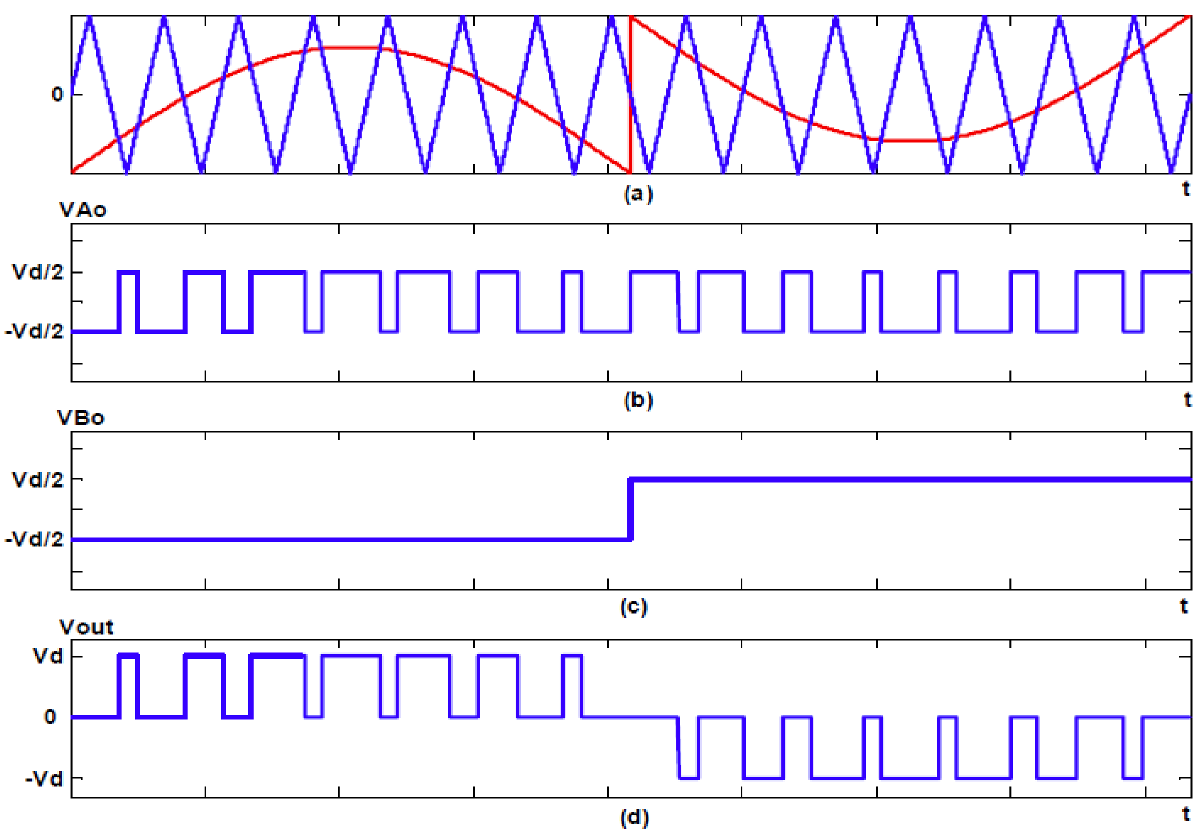
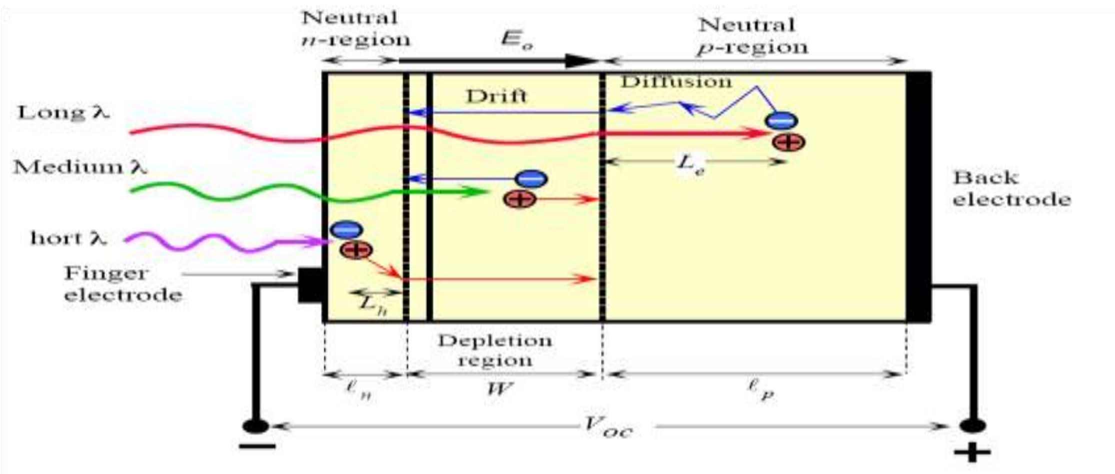


Figure 6: Modified Unipolar PWM scheme and output voltage

CHAPTER 3

3.1 Solar Cell

3.1.1 Construction



The principle of operation of the solar cell (exaggerated features to highlight principles)

In this above schematic diagram of p-n junction of solar cell , there are narrowly and heavily doped n region and lightly doped p region . Between p and n region there are depletion (space charge layer) region . The depletion region tends to p region .There is a built in voltage , Eo in the depletion region .Electrodes attached to the n type must allow the photon to enter to the device . The electrodes has the shape of finger . There is an anti-reflection coating on the surface that allows light to enter into the device .

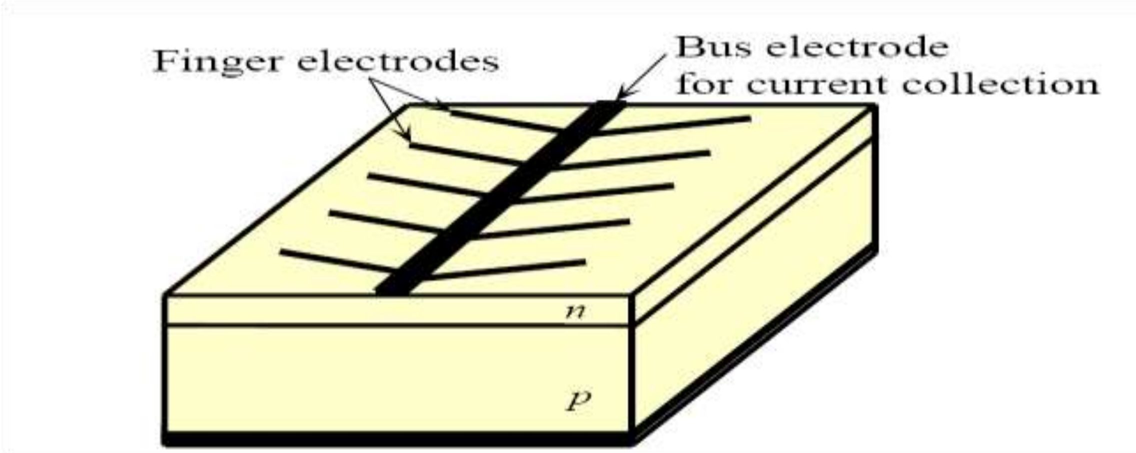


Figure 8 : The Electrodes

3.1.2 Principle of Solar Cell

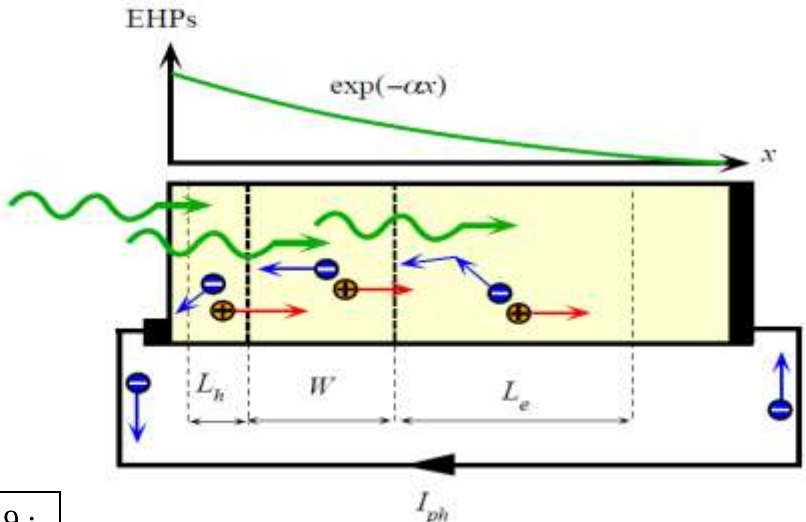


Figure 9 :

Photogenerated carriers within the volume $L_h + W + L_e$ give rise to a photocurrent I_{ph}. The variation in the photegenerated EHP concentration with distance is also shown where α is the absorption coefficient at the wavelength of interest.

Photons entered into the device are absorbed in depletion and p region because the n region is very narrow . The built in voltage , Eo make the EHP (electron hole pair) to be separated that made in this depletion region . The electrons drift to neutral n+ side and holes drift to neutral p side to make the side negative and positive respectively . An open circuit voltage develops between the two sides . If external load is connected , the excess electrons travel to the p side and recombine with the excess holes of p side .The EHPs photo generated by long wavelengths are absorbed in this neutral p side as there is no electric field .

3.1.3 Current Conduction in Solar Cell

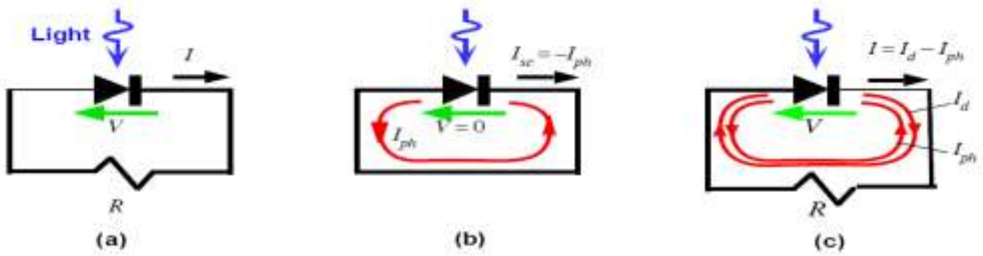


Figure 10: (a) The solar cell connected to an external load R and the convention for the definitions of positive voltage and positive current. (b) The solar cell in short circuit. The current is the photocurrent, I_{ph}. (c) The solar cell driving an external load R. There is a voltage V and current I in the circuit.

We consider to connect a load to a solar cell as in the above figure a .The current (I) and the voltage (v) in this figure convention for the direction of positive current and positive voltage . If the load is short circuit , the current generated by light is called photocurrent Iph . Photocurrent depends on EHPs that is generated in the depletion . If load R is not short circuited like in figure C , the positive voltage occurs in the load as the current passes .This voltage decreases the built in voltage of the p-n junction and leads the minority carrier injection and diffusion just like normal diode . There also occurs a diode current Id in the circuit which arises voltage across R .

In an open circuit the net current is zero . Diode current develops when there is positive voltage and photocurrent . The total current is now shown below

$$I = -I_{ph} + I_0 \left[\exp\left(\frac{eV}{nk_B T} \right) - 1 \right]$$

Here n is the ‘ideality factor’ which depends on the material .

3.1.4 I-V Characteristics Curve

The I-V characteristics curve is shown below . We can see that the normal dark characteristics has been shifted by the photocurrent Iph . The open circuit output voltage , Voc is shown by the point where I-V curve intersects the V-axis . Approximately , the open circuit voltage Voc is 0.4 to 0.6 v .

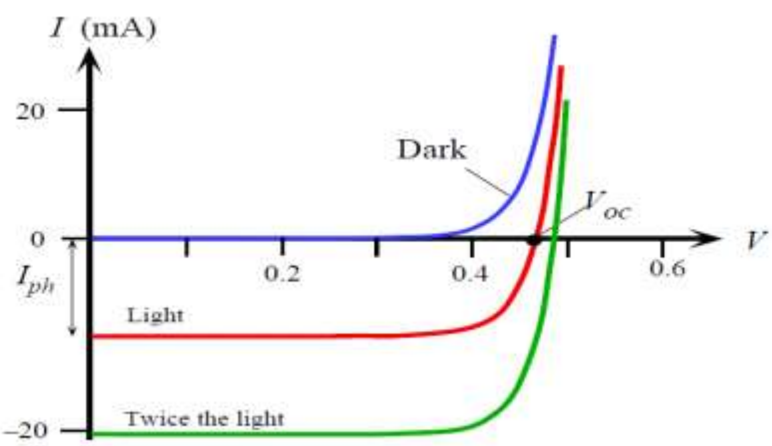


Figure 11:

Typical I-V characteristics of a Si solar cell. The short circuit current is I_{ph} and the open circuit voltage is V_{oc}. The I-V curves for positive current requires an external bias voltage. Photovoltaic operation is always in the negative current region.

From the above equation (1) , load and solar cell has the same voltage . But the current flows through the load has the opposite direction of the voltage and it flows from the high potential to the low potential .

$$I = - V/R……….(2)$$

The actual current and voltage must satisfy both equation (1) and (2) . We can Find the actual current and voltage by solving both equations but it is not an analytical procedure . We can solve this equations graphically by the solar cell characteristics .

The actual current and voltage in the solar cell are easily found by the load line construction . I-V characteristics of equation (2) is a negative slope curve which is shown in the figure below . The load line intersects with solar cell characteristics at P . At P , we have the same current and voltage . Point P satisfies the both equation (1) and (2) and this point is called the operating point of the circuit .

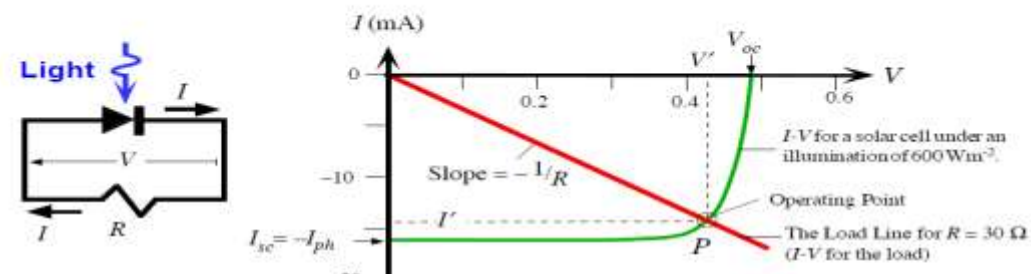
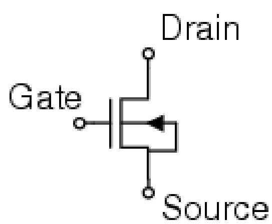


Figure 12: (a) (b)

(a) When a solar cell drives a load R. R has the same voltage as the solar cell but the current through it is in the opposite direction to the convention that current flows from high to low potential. (b) The current I' and voltage V' in the circuit of (a) can be found from a load line construction. Point P is the operating point (I', V'). The load line is for $R = 30\ \Omega$.

3.2.1 **MOSFET Drivers**

When utilizing N-Channel MOSFETs to switch a DC voltage across a load, the drain terminals of the high side MOSFETs are often connected to the highest voltage in the system. This creates a difficulty, as the gate terminal must be approximately 10V higher than the drain terminal for the MOSFET to conduct . Often , integrated circuit devices known as MOSFET drivers are utilized to achieve this difference through charge pumps or bootstrapping techniques. These chips are capable of quickly charging the input capacitance of the MOSFET (Cgiss) quickly before the potential difference is reached, causing the gate to source voltage to be the highest system voltage plus the capacitor voltage, allowing it to conduct. A diagram of an N-channel MOSFET with gate, drain, and source terminals is shown in below Figure.



There are many MOSFET drivers available to power N-Channel MOSFETs through level translation of low voltage control signals into voltages capable of supplying sufficient gate voltage. Advanced drivers contain circuitry for powering high and low side devices as well as N and P-Channel MOSFETs. In this design, all MOSFETs are N-Channel due to their increased current handling capabilities. To overcome the difficulties of driving high side N-Channel MOSFETs, the driver devices use an external source to charge a bootstrapping capacitor connected between Vcc and source terminals. The bootstrap capacitor provides gate charge to the high side MOSFET. As the switch begins to conduct, the capacitor maintains a potential difference, rapidly causing the MOSFET to further conduct, until it is fully on . The name bootstrap component refers to this process and how the MOSFET acts as if it is “pulling itself up by its own boot strap”.

3.3 SNUBBER CIRCUIT

Power semiconductors are the heart of power electronics equipment. “Snubber” is the term used to describe a device consisting of a resistor and a capacitor connected in series. It is intended to be connected in parallel with the contacts of a switch or a relay to reduce arcing. Snubbers are frequently used in electrical systems with an inductive load where the sudden interruption of current flow often leads to a sharp rise in voltage across the device creating the interruption. This sharp rise in voltage is a transient and can damage and lead to failure of the controlling device. A spark is likely to be generated (arcing), which can cause electromagnetic interference in other circuits. The snubber prevents this undesired voltage by conducting transient current around the device. Although the original reason for using snubbers was to prolong the life of contacts by reducing arcing in mechanical Snubbers are circuits which are placed across semiconductor devices for protection and to improve performance.

3.3.1 MAJOR JOBS

Reducing or eliminating voltage or current spikes, limiting dI/dt or dV/dt, shaping the load line to keep it within the safe operating area (SOA),transferring power dissipation from the switch to a resistor or a useful load, reducing total losses due to switching, reducing EMI by damping voltage and raising current.

3.3.2 TYPES OF SNUBBER

There are many different kinds of snubbers but the two most common ones are the resistor-capacitor (RC) damping network and the resistor-capacitor-diode (RCD) turn-off snubber.

In this case we have worked with the resistor capacitor diode snubbers.

3.3.3 RCD Snubber circuit

Typical turn-off waveforms for this snubber are given in following figure. These waveforms assume that $L_p = 0$. The effect of L_p will be considered shortly. The key feature of these waveforms is that the switch voltage rises slowly as the switch current falls. This means that the high peak power associated with simultaneous maximum voltage and current is eliminated. The net result is much lower peak stress and switching loss. Voltage waveforms for two different values of C_s are shown. In this example $I_o = 10$ A and $E_o = 300$ V. As C_s is made larger the peak power and the switching loss will be lower. However, larger C_s means greater loss in R_s when the switch turns on and C_s is discharged through R_s and the switch. Again we see the tradeoff between snubber efficacy and loss.

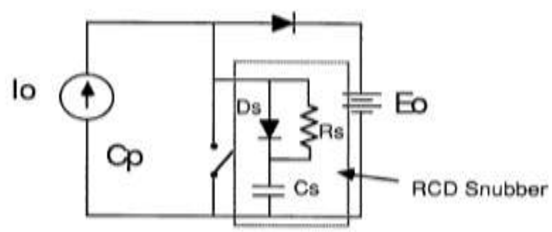


Figure 15 : Snubber Circuit

Depending on the size of C_s the switch voltage may reach E_o before, at the same time, or after the switch current reaches zero. The case where $E = E_o$ at the instant that $I = 0$ is defined as a "normal" snubber and $C_s = C_n$ where:

$$C = \frac{I_0 t_s}{2E_o}$$

Where ts is the fall time of the switch current.

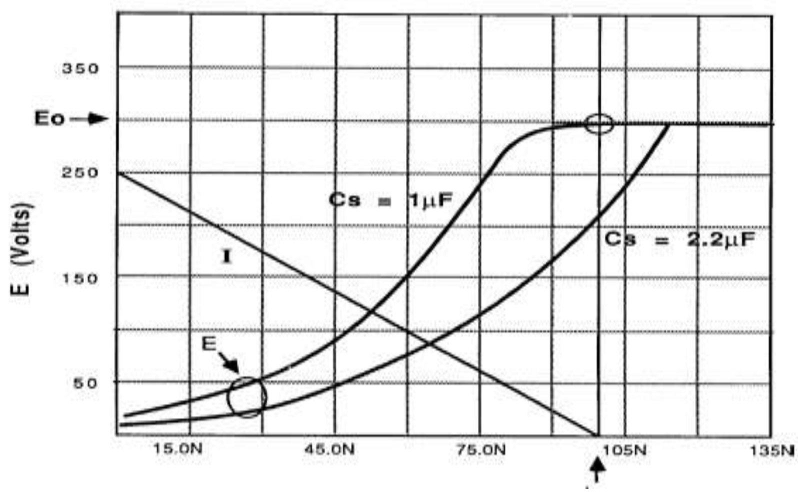


Figure 16 : E-C characteristics

The relationships between C_n, switching loss, peak switch stress, snubber loss and total loss is shown in the graph above. Snubber size is shown relative to C_n. When even a small snubber is used ($C_s < C_n$) the switching loss drops quickly. As C_s is made larger however, the improvement in switch loss decreases. For example, for $C_s = C_n$, the switch loss is down to 16%. Making C_s larger will reduce the switching loss only a small amount but will increase the snubber loss substantially. There is in fact a broad minimum loss around $C_s = 0.45\ C_n$, where the total loss is reduced to 53% of what it would have been without the snubber. It is important to remember that C_p is part of C_s and that the actual value for $C_s = .45\ C_n - C_p$. For $C_s/C_n = 2$ the total loss is equal to what it would have been if no snubber were used ,however the switching load line will have very low stress.

In those cases where the primary concern is to reduce the total switching loss, the value for C_s is usually set to .5 Cn. In this case R_s is selected to allow the voltage on C_s to decay to a small value during the minimum switch on time ($t_{on,\ min}$). The capacitor voltage decay is a simple RC exponential and in two time constants ($t = R_sC_s$) will be down to 0.14 E_o. This is usually sufficient. The value of R_s is then:

$$R = \frac{2}{t_{on\,\min} C_s}$$

When L_p is significant there will be voltage overshoot during turn-off. If E_1 must be controlled then different values for C_s may be necessary and a compromise made. The loss will be lower but the peak voltage is higher for the RCD snubber. This is typical. For similar total loss, C_s can be larger in the RCD snubber which will reduce E_1.Increasing C_s to 1.2 nF reduces E_1 to 424 V. C_s could be increased further but for the same total loss, E_1will still be higher in the RCD snubber.

3.3.4 Component selection and layout

The components in snubbers can be very highly stressed and must therefore be selected with some care.

Layout and inductance :

One of the primary reasons for using snubbers is the presence of parasitic inductances (Lp) in the circuit which generate voltage spikes and ringing when excited by the switching action. Larger parasitic inductance means larger snubber components and more dissipation. Before actually designing the snub-ber, it is important to minimize the circuit parasitic inductances and careful circuit layout is the key.

Because of the very large dI/dt's which are common in snubbers, small amounts of parasitic inductance within the snubber can interfere with snubber action leading to higher than expected peak voltages. Parasitic inductance comes from two sources: intrinsic to the components due to physical size and lead configuration and from the layout. Component inductance can be minimized by the choice of package and can be further reduced by using several smaller devices in parallel. Paralleling is particularly useful in high power snubbers because in addition to allowing lower inductance configurations, it can improve the surface area-volume ratio allowing better cooling and higher rms currents. The primary source of layout inductance is the connection from the snubber components to the switch. The snubber components should be placed as close as possible to the switch terminals. The components should be arranged so that the current loop formed by the snubber has a small an area (low inductance)

Capacitor selection:

Snubber capacitors are subjected to high peak and rms currents and high dV/dt. The pulses have high peak and rms amplitudes. CDE has several types of capacitors which are particularly well suited to snubber applications. Table 1 show the various types and characteristics of capacitors intended for snubber applications.

Table 1

Cornell Dubilier Capacitors for Snubber Applications

STYLE	PACKAGE	DIELECTRIC	ELECTRODE	VOLTS RANGE	CAP RANGE	dV/dt	Irms
CD16 CDV16 CDV19 CD30 CDV30	Dipped with radial leads	Mica	Foil	500-1500 VDC	100-10,000 pF	>10,000 V/µs	Up to 9 A
WPP	Wrap & Fill axial leads	Polypropylene	Foil	250-1000 VDC	0.001-2.0 µF	300-10,000 V/µs	Up to 10 A
DPF DPP	Wrap & Fill axial leads	Polypropylene	Foil	250-2000 VDC	0.01-0.47 µF	3000-10,000 V/µs	Up to 10 A
SCD	Box type, direct mount to IGBT	Polypropylene	Double Metallized	600-2000 VDC	0.1-10 µF	100-2000 V/µs	Up to 50 A
940 941	Wrap & Fill axial leads	Polypropylene	Double Metallized	600-3000 VDC	0.1-4.7 µF	100-2000 V/µs	Up to 25 A
942 943	Wrap & Fill axial leads	Polypropylene	Hybrid-metallized PP/ Foil	600-2000 VDC	0.1-4.7 µF	500-5000 V/µs	Up to 25 A

Resistor selection:

As pointed out earlier, it is important that Rs, in an RC snubber, have low self inductance. Inductance in Rs will increase the peak voltage (E1) and tend to defeat the purpose of the snubber.Low inductance is also desirable for Rs in an RCD snubber but is not as critical since the effect of a small amount of inductance is to slightly increase the reset time of Cs and reduce the peak current somewhat in the switch at turn-on. The normal choice for Rs is usually carbon composition or metal film. For higher power levels low inductance wire wound resistors, such as the Dale Electronics NH types, can biased with some care to verify the actual residual inductance and its effect on the snubber action. Again, it is in the RC snubbers that parasitic inductance is most critical.

Advantages:

In addition to peak voltage limiting, the circuit can reduce the total circuit loss, including both switching and snubber losses. Much better load lines can be achieved, allowing the load line to pass well within the SOA.·For a given value of Cs, the total losses will be less The shunt capacitance across the switch (Cp) is a useful part of the snubber.

Disadvantage:

There is also one disadvantage however. Because of the diode across Rs, the effective value for Rs, during the charging of Cs, is essentially zero. This is not the optimum value and, for a given Cs, E1 will be higher than it would be in an optimized RC snubber.

3.4 Opto-coupler Isolator:

Opto-couplers consist of a GaAlAs light emitting diode and an integrated photo detector. We use here TLP250 optocoupler. The opto-coupler used to isolate between high voltage of the inverter and low voltage of the microcontroller, there are many situations where signals and data need to be transferred from one subsystem to another within a piece of electronics equipment ,or from piece of equipment to another, without making a direct ohmic electrical connection. Often this is because the source and destination are (or maybe at times) at very different voltage levels, like a microcontroller which is operating on 5Vdc but being used to control power inverter which is switching 300Vdc.In such situation the link between the two must be an isolated one to protect the microcontroller from over voltage damage. We used Opto-coupler (TLP250) for isolating between the H bridge inverter gates and the PWM output from the PIC microcontroller.

3.5 MICRO-CONTROLLER

A microcontroller (also microcontroller unit, MCU or µC) is a small computer on a single integrated circuit consisting of a relatively simple CPU combined with support functions such as a crystal oscillator, timers, watchdog, serial and analog I/O etc. Neither program memory in the form of NOR flash or OTP ROM is also often included on chip, as well as a, typically small, read/write memory.

Microcontrollers are designed for small applications. Thus, in contrast to the microprocessors used in personal computers and other high-performance applications, simplicity is emphasized. Some microcontrollers may operate at clock frequencies as low as 32 kHz, as this is adequate for many typical applications, enabling low power consumption (mill watts or microwatts). They will generally have the ability to retain functionality while waiting for an event such as a button press or other interrupt; power consumption while sleeping (CPU clock and most peripherals off) may be just nanowatts, making many of them well suited for long lasting battery applications.

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, remote controls, office machines, appliances, power tools, and toys. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes.

3.5.1 PIC Microcontroller:

PIC microcontroller was used in this project to obtain the gate signal of the inverter switches using SPWM. PIC 16F877A was used to generate the Modified Sine Wave gate signals and PIC 16F887 was used to generate Sine Wave gate signals. Both have 40 pins with different functions.

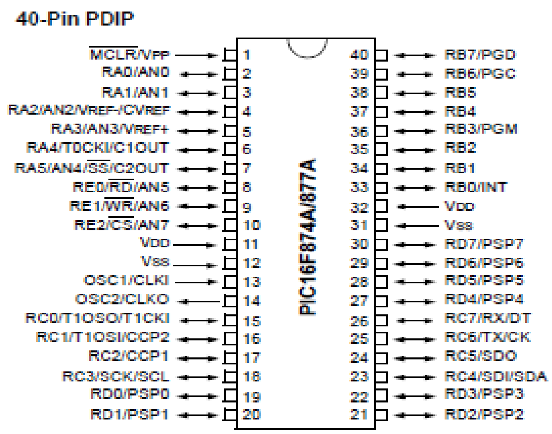


Fig: PIC 16F877A

Two PICs were programmed in order to drive switches for Modified Sine Wave and Sine Wave inverter. Program MPLAB was used to write the PICs codes. The PICs codes are attached in appendix (A).

3.5.2MICROCONTROLLER SETUP FOR PWM OPERATION:

The following steps should be taken when configuring the CCP module for PWM operation:

1. Set the PWM period by writing to the PR2 register.

2. Set the PWM duty cycle by writing to the CCPR1L register and CCP1CON<5:4> bits.

3. Make the CCP1 pin an output by clearing the TRISC<2> bit.

4. Set the TMR2 prescale value and enable Timer2 by writing to T2CON.

5. Configure the CCP1 module for PWM operation.

CCP1 Module:

Capture/Compare/PWM Register 1 (CCPR1) is comprised of two 8-bit registers: CCPR1L (low byte) and CCPR1H (high byte). The CCP1CON register controls the operation of CCP1. The special event triggers is generated by a compare match and will reset Timer1.

CCP2 Module:

Capture/Compare/PWM Register 2 (CCPR2) is comprised of two 8-bit registers: CCPR2L (low byte) and CCPR2H (high byte). The CCP2CON register controls the operation of CCP2. The special event trigger is generated by a compare match and will reset Timer1 and start an A/D conversion (if the A/D module is enabled).

3.6 Filtering:

Filters come in many different packages, with many different advantages – and disadvantages. For example, a digital filter is easily reconfigurable and can have almost any frequency response desired. If the response is simply low pass/high pass/band pass behavior with a set frequency, an active filter can be made to have a very sharp edge at the cutoff, resulting in enormous reductions in noise and very little attenuation of the signal. These, however, require op-amps. Op-amps capable of filtering a 120V RMS sine wave exist, but they are expensive, since the op-amp must be able to source hundreds of watts, and must be very large to do so without burning. Digital filters have a similar drawback and, designed with TTL and CMOS technology, can only work with small signals. Lastly we come to a passive filter. Generally large in size and very resistive at low frequencies, these filters often seem to have more of a prototyping application, or perhaps use in a device where low cost is important, and efficiency is not. Given these choices, an application such as a high power sine inverter is left with only one viable option: the passive filter. This makes the design slightly more difficult to accomplish. Noting that passive filters introduce higher resistance at lower frequencies (due to the larger inductances, which require longer wires), the obvious choice is to switch at the highest possible frequency. The problem with this choice, however, is that the switching MOSFETs introduce more switching losses at higher frequencies. This would imply that we should switch slower to improve our switching efficiency, which contradicts the filter's need for a higher frequency.

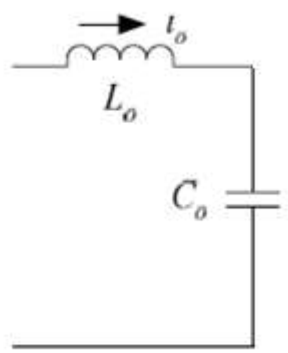


Fig: Basic Low Pass Filter

Chapter 4

4.1 Implementing the Design:

4.1.1 Software design:

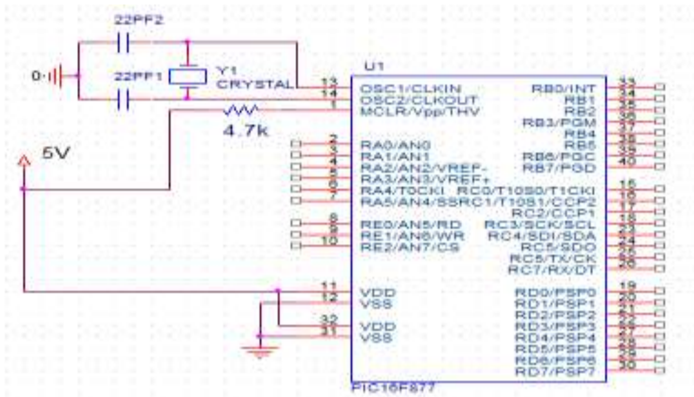


Fig: Basic Implementation of PIC Microcontroller

After constructing the basic circuit of the PIC microcontroller 16F877,and programmed it we use port C (pin RC1) to output pulses for converter and also port C (pin RC1 & RC2) to SPWM for H bridge.

4.1.2 H-BRIDGE:

H bridge inverter is used to convert DC voltage to AC voltage, and as we saw in theoretical part it consist from four MOSFET transistors and we use (IRF3205), on the other hand the data sheet of transistor in appendix(C). And the following fig shows the practical H Bridge that we designed it in our project

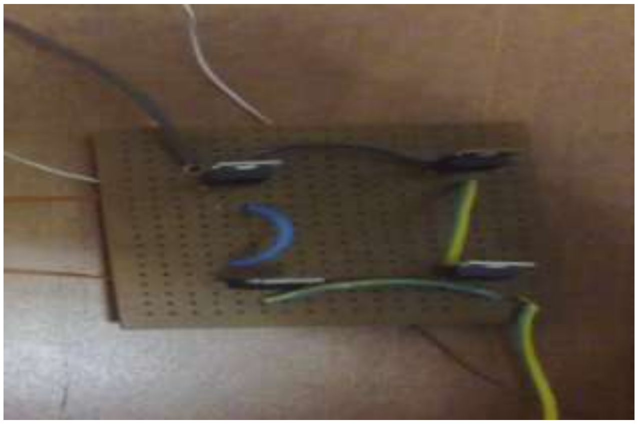


Fig: A Practical H-Bridge

4.1.3 H-Bridge with IR2110

Generating a sine wave centered on zero volts requires both a positive and negative voltage across the load, for the positive and negative parts of the wave, respectively. This can be achieved from a single source through the use of four MOSFET switches arranged in an H-Bridge configuration. To minimize power loss and utilize higher switching speeds, N-Channel MOSFETs were chosen as switches in the bridge. Level translation between PWM signals and voltages required to forward bias high side N-Channel MOSFETS, the IR2110 MOSFET driver integrated circuit was chosen. A diagram of the H-Bridge circuit with MOSFETS and drivers is shown in below Figure.

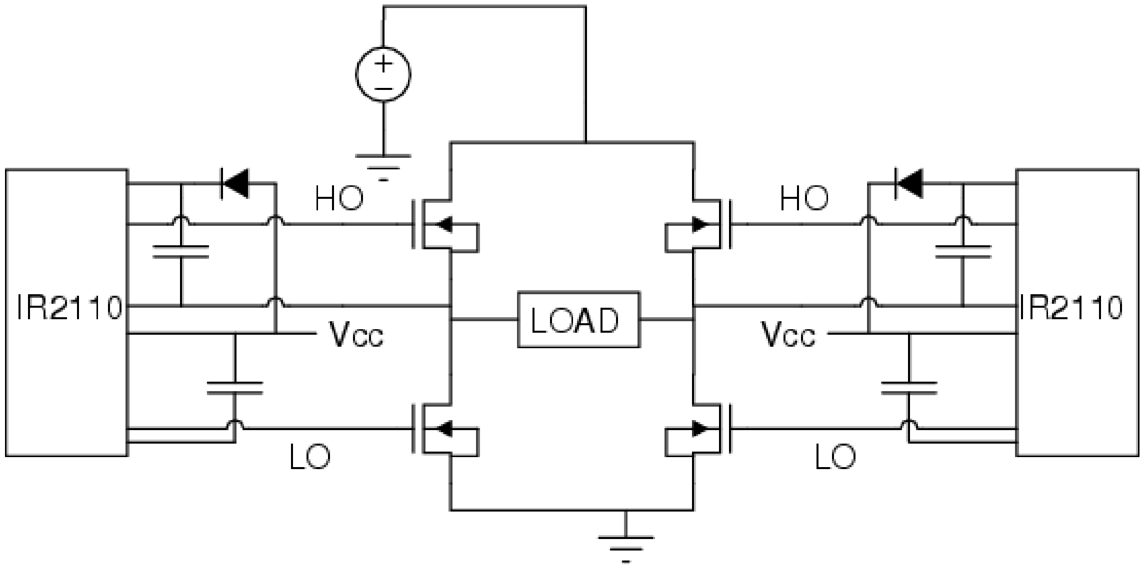


Figure : H-Bridge with MOSFET Driver (IR 2110)

The IR2110 High and Low Side Drive device exceeds all requirements for driving the MOSFETs in the bridge. It is capable of up to 500V at a current rating of 2A at fast switching speeds. This device is required to drive the high side MOSFETS in the circuit designated HO, due to the fact that the gate to source voltage must be higher than the drain to source voltage, which is the highest voltage in the system. This device utilizes a bootstrapping capacitor to maintain a voltage difference of approximately 10V above the drain to source voltage. With a full bridge configuration, two of these devices are utilized, as shown in the above figure. A typical connection of a single IR2110 device is shown in the below Figure.

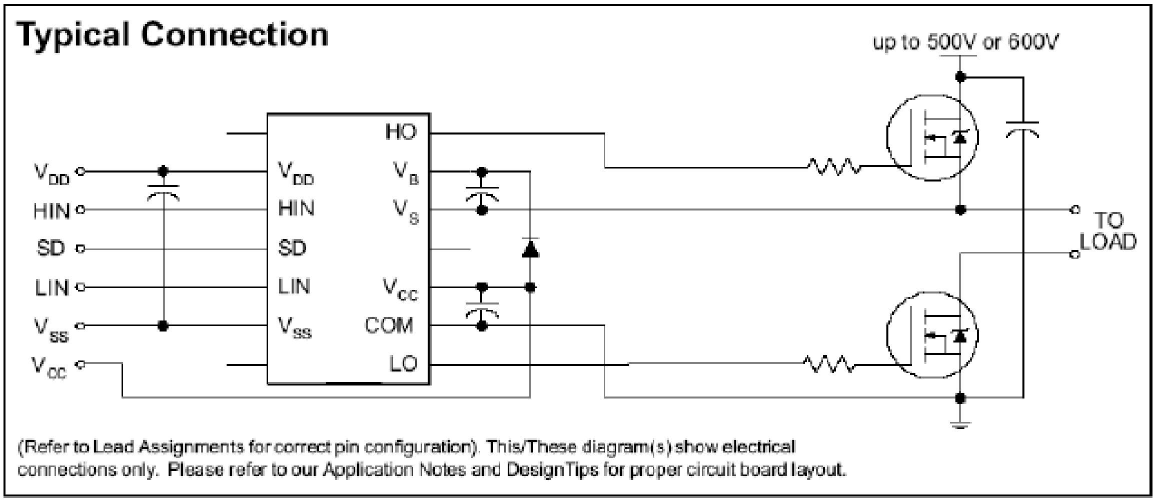


Figure : Typical Connection of IR 2110

Operation of the IR2110 device will be controlled through generated PWM signals. The PWM signal will be fed to the HIN and LIN pins simultaneously. If the internal logic detects a logic high, the HO pin will be driven; if a logic low is detected, the LO pin will be driven. The SD pin controls shut down of the device and will be unused and tied to ground. Additional pins that require external connections are the Vss pin which will be tied to ground, the Vcc pin which will be tied to 12V, pins requiring connections to bootstrapping components and outputs to the MOSFETS. Bootstrapping capacitors and diodes will be connected as designated. The values for these components are calculated from International Rectifier’s AN978 application note, HV Floating MOSFET Driver ICs. The formula for minimum bootstrap capacitor value obtained from this document is shown below.

$$C \geq \frac{2\left[2Q_g + \frac{I_{qbs(max)}}{f} + Q_{ls} + \frac{I_{Cbs(leak)}}{f}\right]}{V_{cc} - V_f - V_{LS} - V_{Min}}$$

4.1.4 Filter Design:

The other major obstacle in the implementation of this project was the design of the filter, the original design was a simple one pole inductor capacitor low pass filter designed for passing all signals fewer than 3 kHz. Also the filter components needed to be capable of handling at least 400volts and 4amps (for reliability reasons) these parts were very large and bulky. The problem arouse when we were searching for these parts. The inductor alone was to weigh five pounds and have a length of six inches.

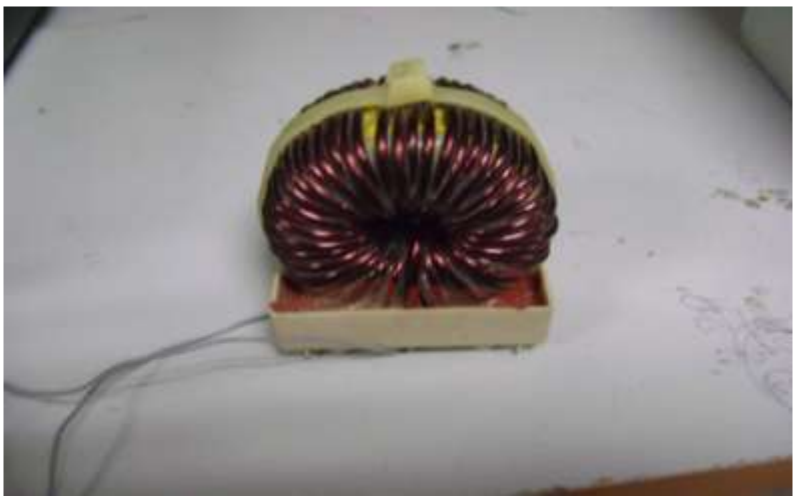


Fig: Large and bulky inductor used in our application

Chapter 5

Experimental Inputs and Corresponding Outputs

5.1 Gate drive input:

-On pin 10(Hin1 of IR2110)

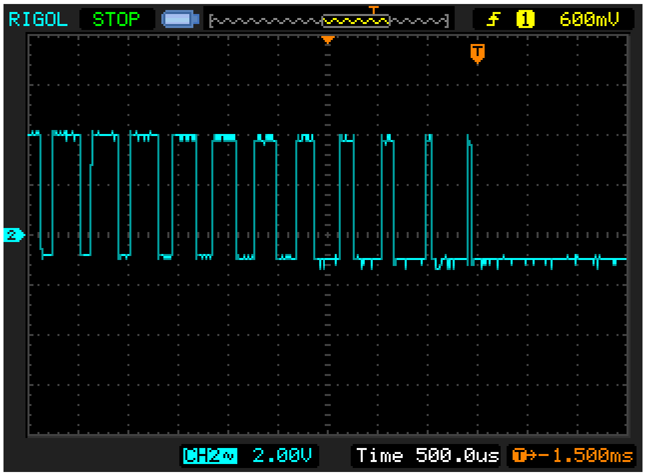


Fig: IR2110 High-input1 (Hin1)

-On pin 10(Hin2 of IR2110)

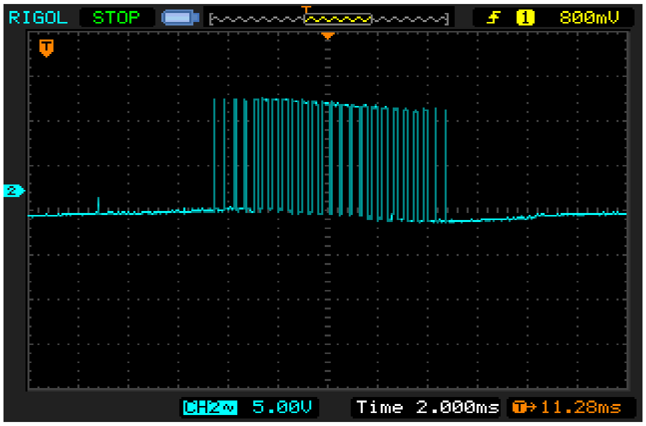


Fig: IR2110 High-input2 (Hin2)

-On pin 12(Lin1 of IR2110)

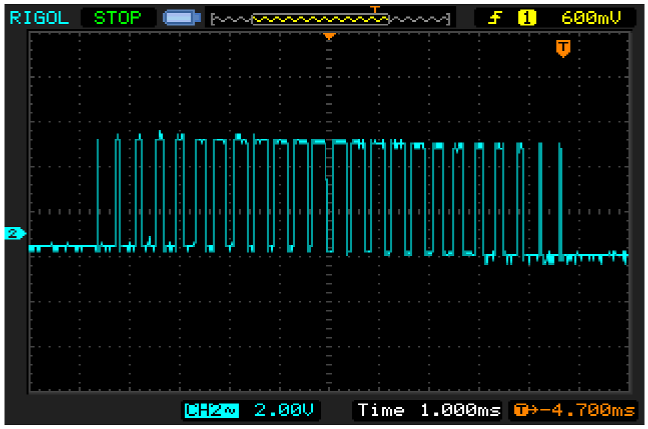


Fig: IR2110 Low-input1 (Lin1)

-On pin 12(Lin2 of IR2110)

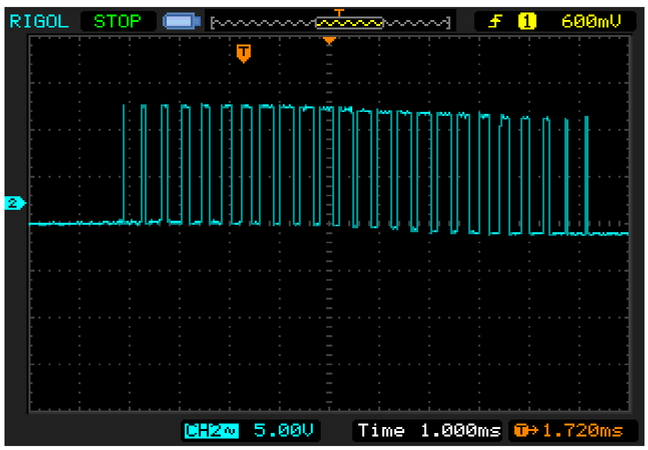


Fig: IR2110 Low-input2 (Lin2)

5.2 Full Bridge Inverter Output:

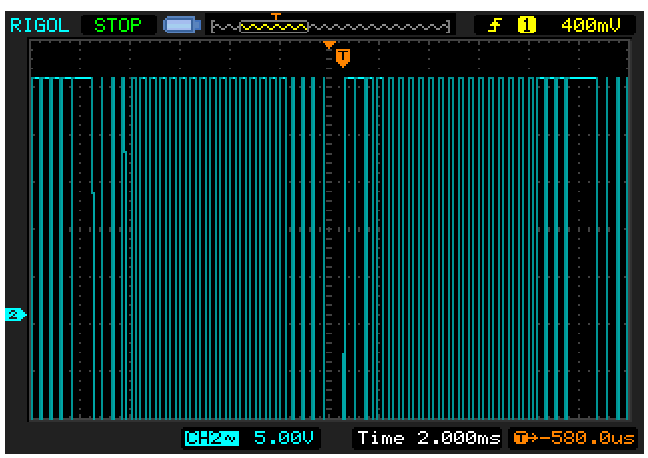


Fig: PWM output of inverter

5.3 Experimental results:

5.3.1 **Full Bridge Inverter Output with LC Filter:**

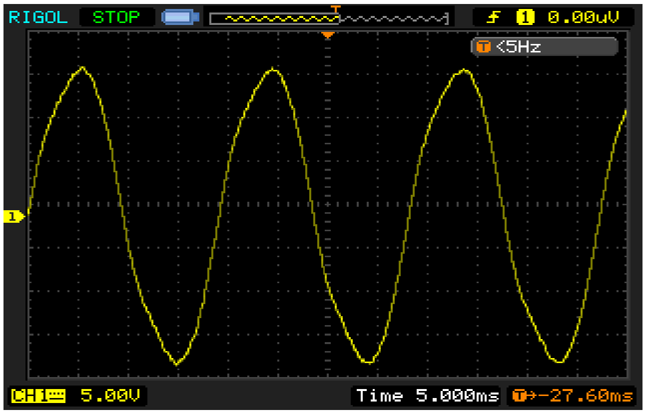


Fig: Sine Wave output

5.3.2 Full Bridge Sine Wave Inverter Output with FFT:

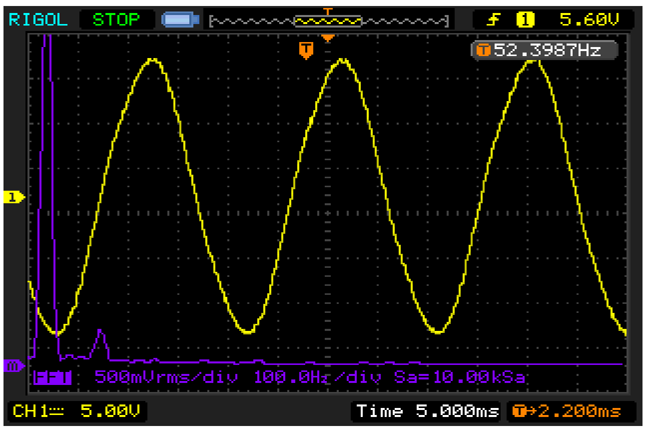


Fig: Sine wave output with FFT

Chapter 6

6.1 Circuit Overview:

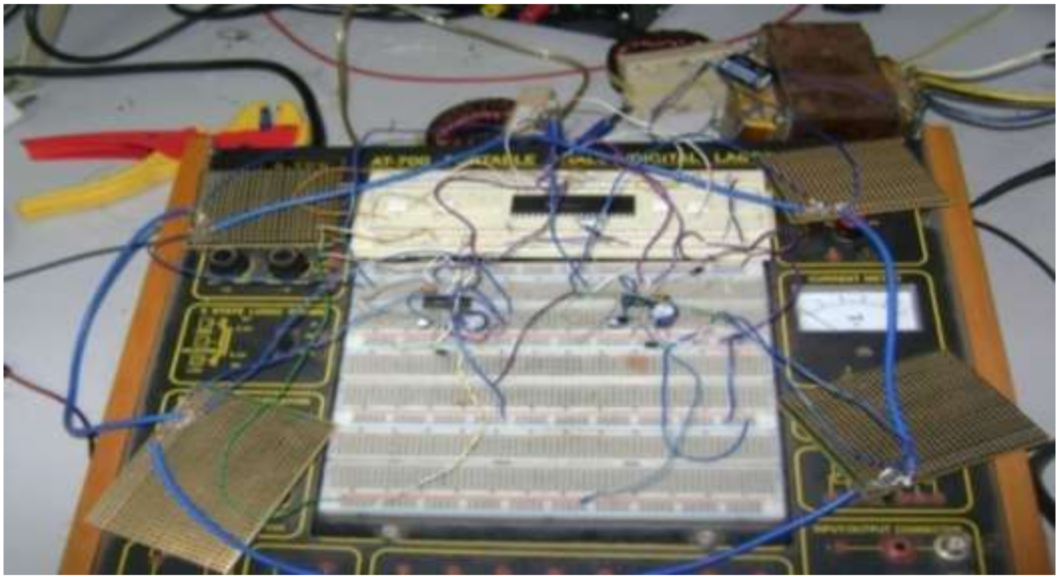


Fig: sine wave inverter circuit overview

6.2 Sine Wave Inverter with Load:

Fig: sine wave inverter with resistive load

Chapter 7

Characteristics of the inverter:

7.1 Sine wave inverters:

As explained earlier, most DC-AC inverters deliver a modified sine wave Output voltage, because they convert the incoming DC into AC by using MOSFET transistors as electronic switches. This gives very high conversion efficiency, but the alternating pulses. Output waveform is also relatively rich in harmonics. Some appliances are less than happy with such a supply waveform, however. Examples include light dimmers, variable speed drills, sewing machine speed controls and some laser printers. Because of this, inverter manufacturers do make a small number of models which are designed to deliver a pure sine wave output. Generally speaking these inverters use rather more complex circuitry than the modified sine wave type, because it's hard to produce a pure sine wave output while still converting the energy into AC efficiently. As a result pure sine wave inverters tend to be significantly more expensive, for the same output power rating. The most common type of pure sine wave inverter operates by first converting the low voltage DC into high voltage DC, using a high frequency DC-DC converter. It then uses a high frequency PWM system to convert the high voltage DC into chopped AC, which is passed through an L-C low pass filter to produce the final clean 50Hz sine wave output. This is like a high-voltage version of the single-bit digital to analog conversion process used in many CD players.

7.2 Voltage spikes:

Another complication of the fairly high harmonic content in the output of modified sine wave inverters is that appliances and tools with a fairly inductive load impedance can develop fairly high voltage spikes due to inductive - back EMF - These spikes can be transformed back into the H bridge, where they have the potential to damage the MOSFETs and their driving circuitry. It's for this reason that many inverters have a pair of high-power zener diodes connected across the MOSFETs the zeners conduct heavily as soon as the voltage rises excessively, protecting the MOSFETs from damage. Or there are transistors with build in diode to protect from these back voltages.

7.3 Capacitive loading:

Actually there’s a different kind of problem with many kinds of fluorescent light assembly: not so much inductive loading, but capacitive loading. Although a standard floury light assembly represents a very inductive load due to its ballast choke, most are designed to be operated from standard AC mains power. As a result they are often provided with a shunt capacitor designed to correct their power factor when they are connected to the mains and driven with a 50Hz sine wave. The problem is that when these lights are connected to a DC-AC inverter with its Modified sine wave output, rich in harmonics, the shunt capacitor doesn’t just correct the power factor, but drastically over corrects. Because its impedance is much lower at the harmonic frequencies. As a result, the floury assembly draws a heavily capacitive load current, and can easily overload the inverter. In cases where fluorescent lights must be run from an inverter, and the lights are not going to be run from the mains again, usually the best solution is to either remove their power factor correction capacitors altogether or replace them with a much smaller value.

7.4 Frequency stability:

Although most appliances and tools designed for mains power can tolerate a small variation in supply frequency, they can malfunction, overheat or even be damaged if the frequency changes significantly. Examples are electromechanical timers, clocks with small synchronous motors, turntables in older. And many reel-to-reel tape recorders. To avoid such problems, most DC-AC inverters include circuitry to ensure that the inverter's output frequency stays very close to the nominal mains frequency: 50Hz, or 60Hz. in some inverters this is achieved by using a quartz crystal oscillator and divider system to generate the master timing for the MOSFET drive pulses. Others simply use a fairly stable oscillator with R-C timing, fed via a voltage regulator to ensure that the oscillator frequency doesn't change even if the battery voltage varies quite widely in our project we programmed IC which is called PIC to give me SPWM with frequency 50Hz.

7.5 Effect of Operating Temperature:

The power output of an inverter is dramatically decreased as its internal temperature rises (this is sometimes called its 5, 10 & 30 minute rating; but in reality if the inverter cannot remove the heat quick enough, then the power will rapidly drop off). Many of our models are rated at a staggering 40°C, such as Prosine, with a classic comparison between a Pro sine 1000 and a low cost 1500watt modified as follows. The following chart provides a comparison between the Prosine 1000i rated at 40°C and a common 1500watt inverter rated at 25°C. [5]

7.6 Efficiency:

It is not possible to convert power without losing some of it (it's like friction). Power is lost in the form of heat. Efficiency is the ratio of power out to power in, expressed as a percentage. If the efficiency is 90 percent, 10 percent of the power is lost in the inverter. The efficiency of an inverter varies with the load. Typically, it will be highest at about two thirds of the inverter's capacity. This is called its "peak efficiency." The inverter requires some power just to run itself, so the efficiency of a large inverter will below when running very small loads in a typical home, there are many hours of the day when the electrical load is very low. Under these conditions, an inverter's efficiency may be around 50 percent or less. Because the efficiency varies with load, don't assume that an inverter with 93 percent peak efficiency is better than one with 85 percent peak efficiency. If the 85 percent efficient unit is more efficient at low power levels, it may waste less energy through the course of a typical day.

Conclusion

The main aim of our project work we have achieved that is converting the DC voltages into AC voltage . We were successful to have output of 40watt at the frequency of 60 Hz .By using this , we drived a CFL bulb of 11watt and a fan of 28 watt . By achieving this success , we are quite confident to apply this experience for our daily appliances through using the input as Photovoltaic source at cheap cost .

Appendix

Appendix A

In this appendix we show the two PIC codes which we use them.

PIC CODE for Modified Sine Wave inverter: (Here we used MICRO C as a compiler)

- void main() {
- TRISC.RC2=0;
- TRISC.RC1=0;
- PR2=239;
- T2CON.T2CKPS0=0;
- T2CON.T2CKPS1=0;
- CCPR1L=50;
- CCP1CON.CCP1X=0;
- CCP1CON.CCP1Y=0;
- CCP1CON.CCP1M2=1;
- CCP1CON.CCP1M3=1;
- CCPR2L=100;
- CCP2CON.CCP2X=0;
- CCP2CON.CCP2Y=0;
- CCP2CON.CCP2M2=1;
- CCP2CON.CCP2M3=1;
- T2CON.TMR2ON=1;
- while(1)
- {
- CCPR1L=239;
- CCPR2L=0;
- Delay_ms(9);
- CCPR1L=0;
- CCPR2L=0;
- Delay_ms(1);
- CCPR1L=0;
- CCPR2L=239;
- Delay_ms(9);
- CCPR1L=0;
- CCPR2L=0;
- Delay_ms(1);
- }
- }

PIC Code for Sine wave Inverter:

- #if defined(__PCM__)
- #include <16F877A.h>
- #fuses XT,NOWDT,NOPROTECT,NOLVP
- #use delay(clock=4000000)
- #use rs232(baud=9600, xmit=PIN_C6, rcv=PIN_C7)

- #elif defined(__PCB__)
- #include <16C56.h>
- #fuses HS,NOWDT,NOPROTECT
- #use delay(clock=20000000)
- #use rs232(baud=9600, xmit=PIN_A3, rcv=PIN_A2)

- #elif defined(__PCH__)
- #include <18F458.h>
- #fuses HS,NOWDT,NOPROTECT,NOLVP
- #use delay(clock=20000000)
- #use rs232(baud=9600, xmit=PIN_C6, rcv=PIN_C7)

- #elif defined(__PCD__)
- #include <30F2010.h>
- #fuses HS, NOWDT, NOPROTECT
- #use delay(clock=20000000)
- #use rs232(baud=9600, UART1A)
- #endif

- #define a PIN_B0
- #define b PIN_B1
- #define c PIN_B2
- #define d PIN_B3

- #define Pwm disable
- #define Pwm enable CCP1

- **SET ansel;**

- **enable sei;**

- **#define F_CPU 4000000**
- **#code_block e0**
- **#define LCD ++**

- **void pos_sin()**
- **{**

- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(21);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(245);**
- ///////////////////////**2**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(42);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(224);**
- ////////////////////////**3**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(63);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(203);**
- **//////////////////////4**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(83);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(183);**
- **//////////////////////5**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(102);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(164);**
- **/////////////////////6**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(120);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(146);**
- **/////////////////////7**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(137);**
-

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(129);**
- ////////////////////////**8**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(153);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(113);**
- ////////////////////////**9**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(167);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(99);**
- ////////////////////////**10**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(180);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(86);**
- ///////////////////////**11**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(190);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(76);**

- **/////////////////////12**

- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(199);**
- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(67);**
- **/////////////////////13**

- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(207);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(59);**
- **/////////////////////14**

- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(212);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(54);**
- **/////////////////////15**

- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(215);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(51);**
- **/////////////////////16**

- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(216);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(50);**
- /////////////////////////
- ////////////////////////
- ////////////////////////**1**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(216);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(50);**

- ///////////////////////////**2**

- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(215);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(51);**
- //////////////////////////**3**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**

- **output_high(d);**
- **delay_us(212);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(54);**
- **/////////////////////////4**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(207);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(59);**
- **/////////////////////////5**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(199);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(67);**
- **/////////////////////////6**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(190);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(76);**
- **/////////////////////////7**
- **output_high(a);**

- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(180);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(86);**
- ///////////////////////**8**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(167);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(99);**
- ///////////////////////**9**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(153);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(113);**
- //////////////////////**10**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(137);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(129);**

- **/////////////////////11**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(120);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(146);**

- **//////////////////////15**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(42);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(224);**
- **//////////////////////16**
- **output_high(a);**
- **output_low(b);**
- **output_low(c);**
- **output_high(d);**
- **delay_us(0);**

- **output_low(a);**
- **output_low(b);**
- **output_high(c);**
- **output_high(d);**
- **delay_us(266);**

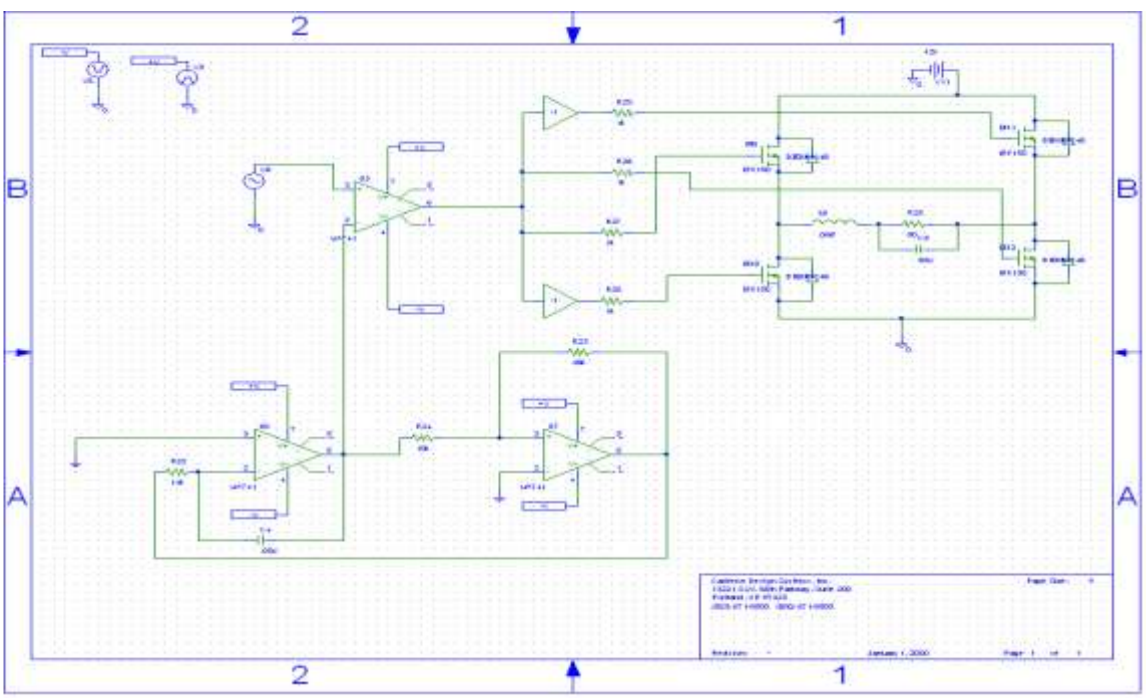
- **//////////////////////////stop**
- **}**
- **void main() {**
- **TRISB=0x00;**
- **while (TRUE) {**
- **pos_sin();**
- **//////////////////////////**

- }
- }

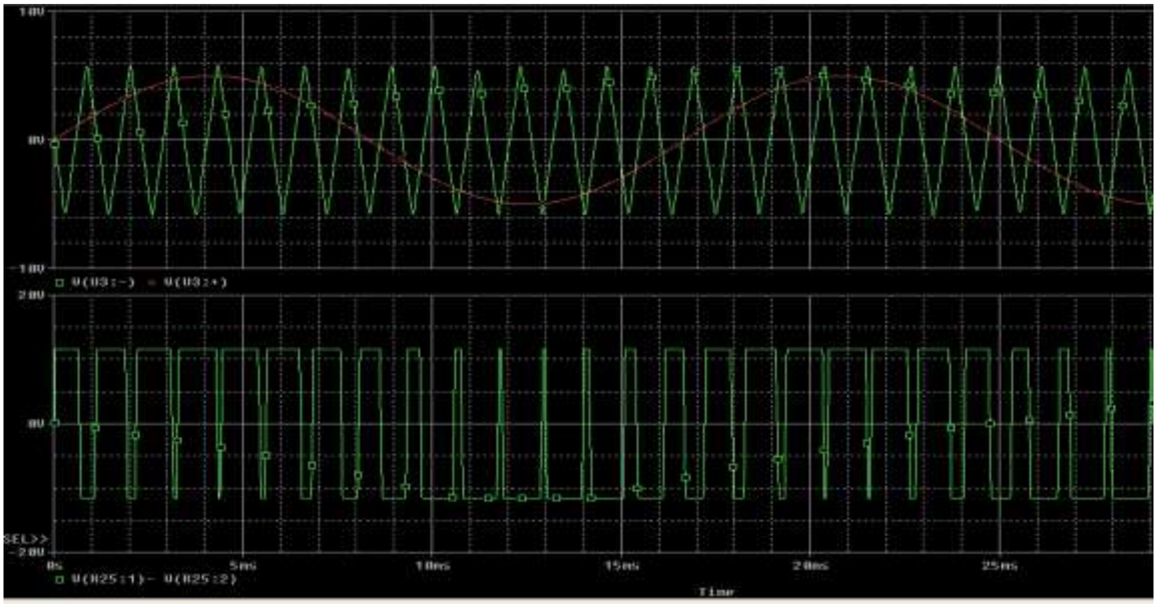
Appendix B

Simulation:

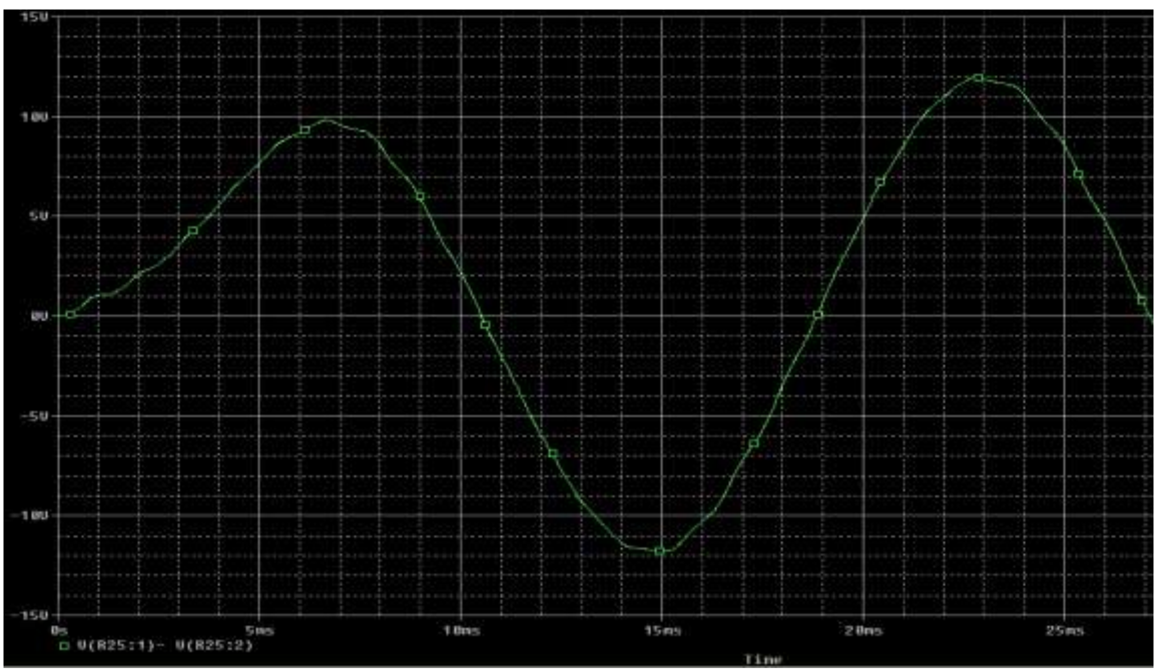
In simulation process we use ORCAD program. For the bipolar PWM approach as we have seen earlier we need triangular wave generator and a sign wave generator. But in ORCAD we don’t have to use sign wave generator as we get built in there. Then we connect it with H-bridge inverter. The figure is shown below:



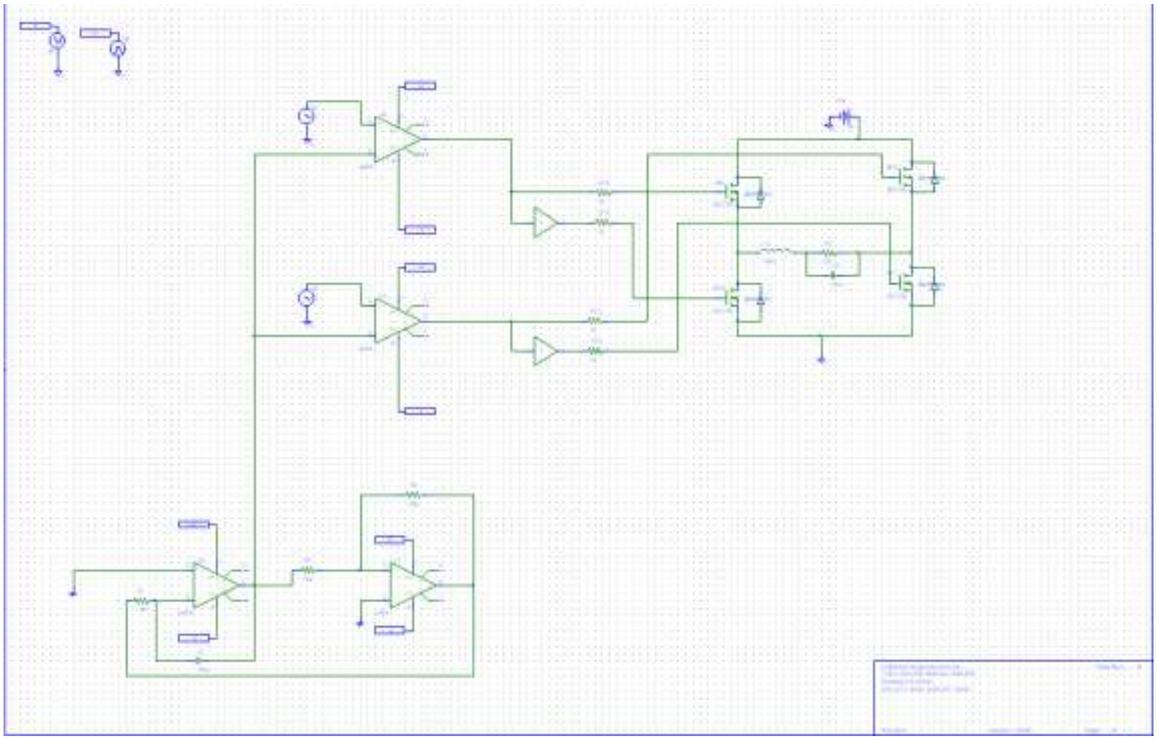
Gate Voltages:

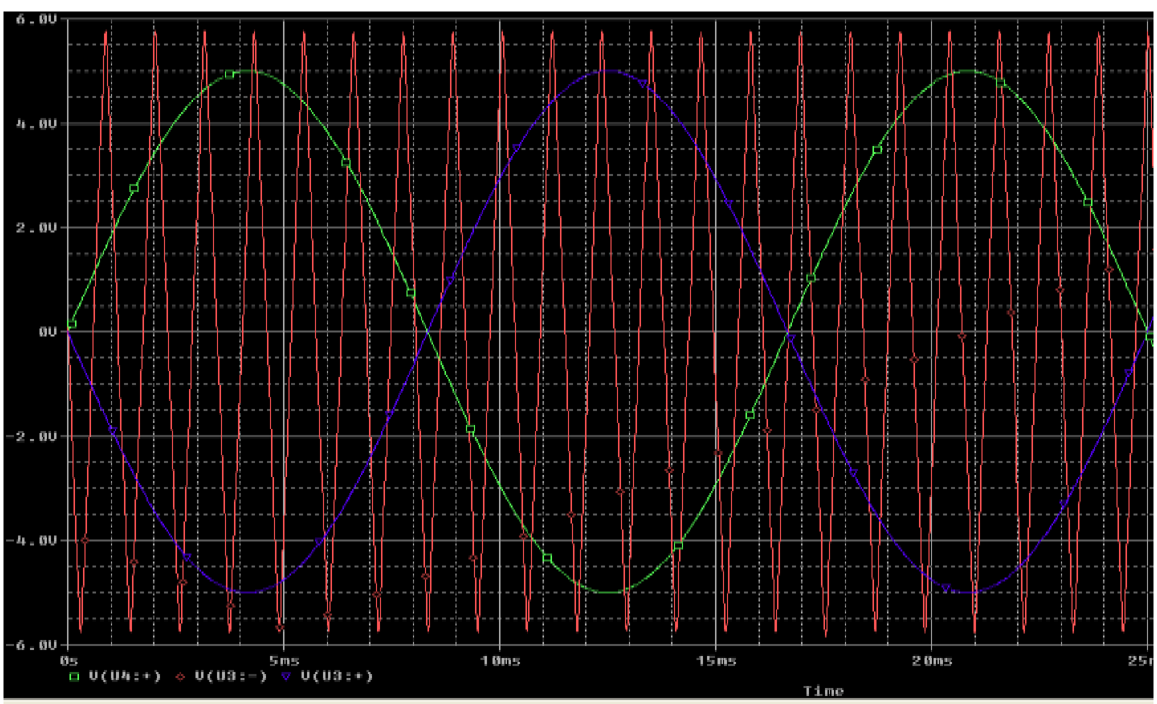


After Low Pass filter:

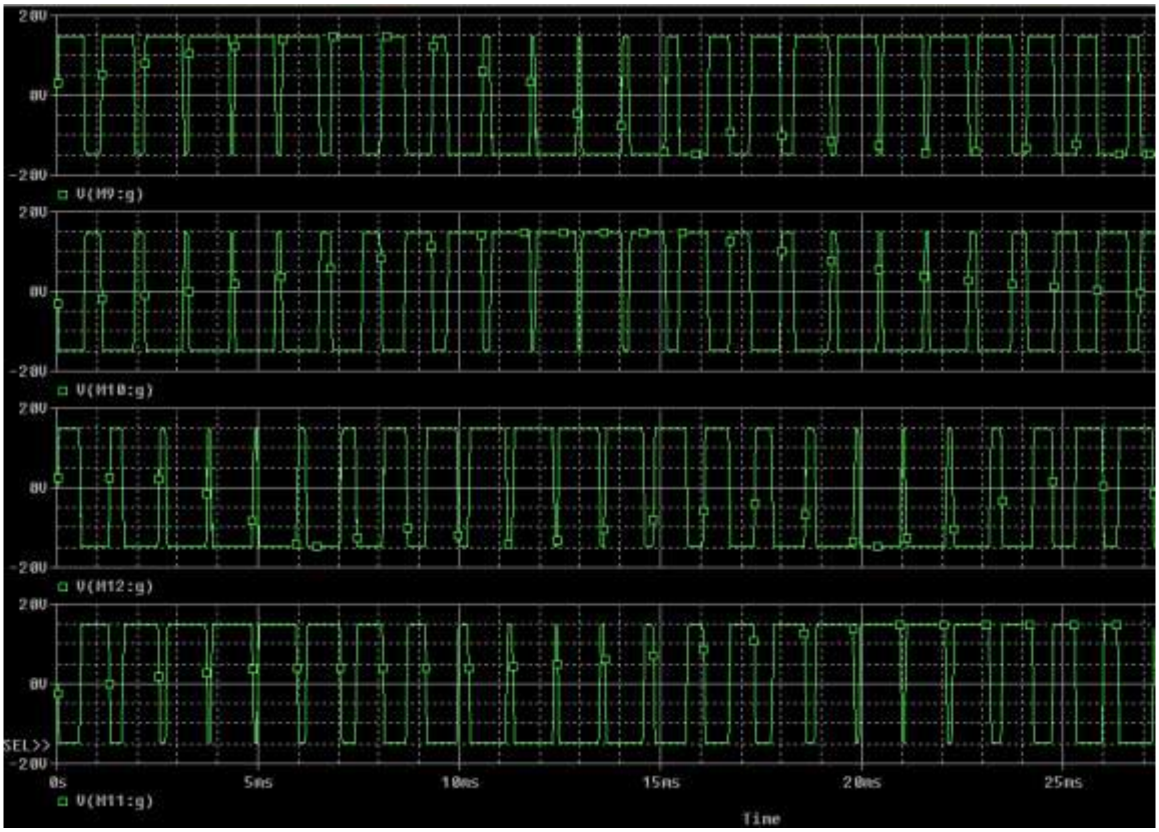


Unipolar:

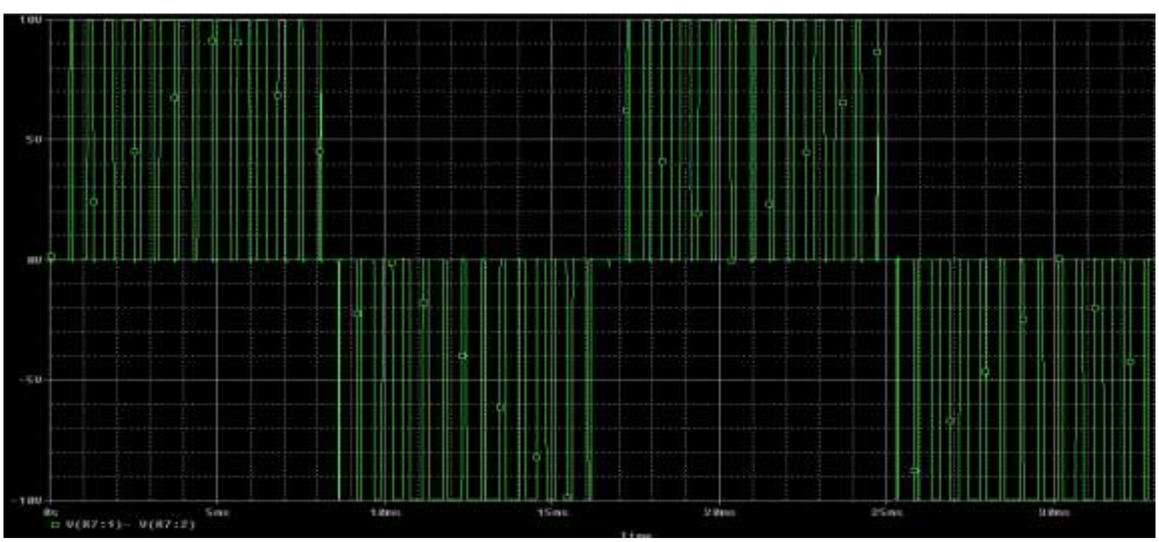



6.0V
4.0V
2.0V
0V
-2.0V
-4.0V
-6.0V
0s
5ms
10ms
15ms
20ms
V(U4:+)
V(U3:-)
V(U3:+)
Time

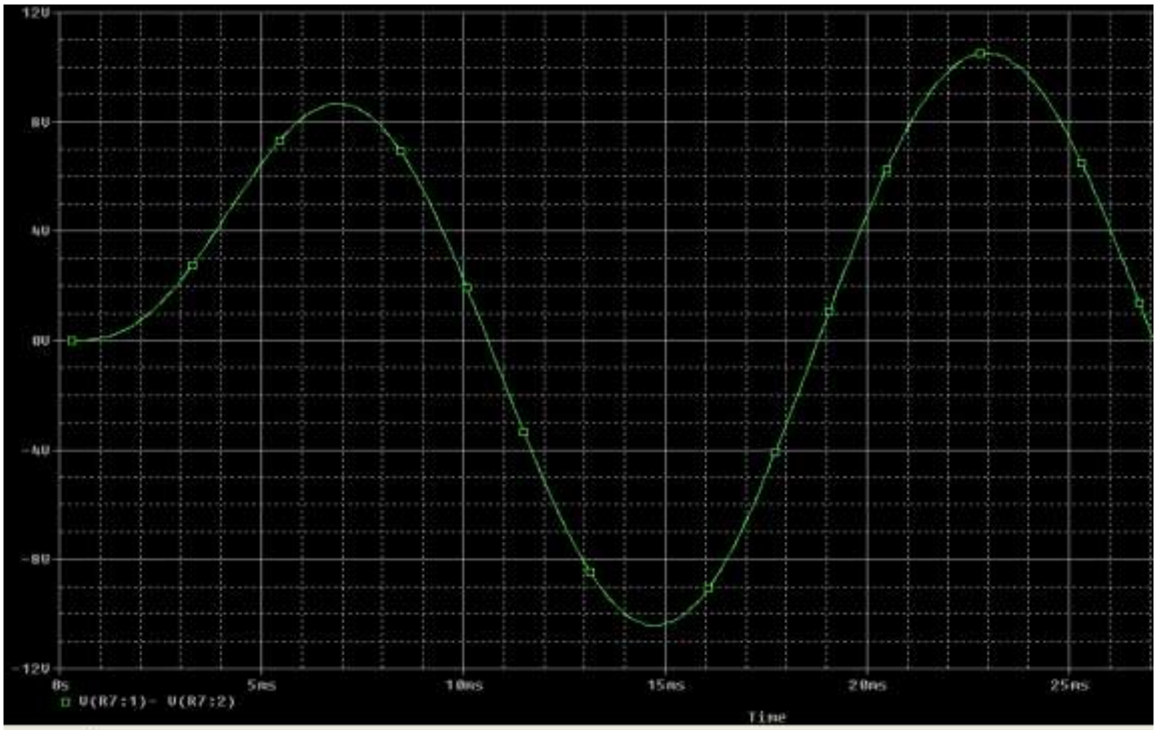
Gate voltages:



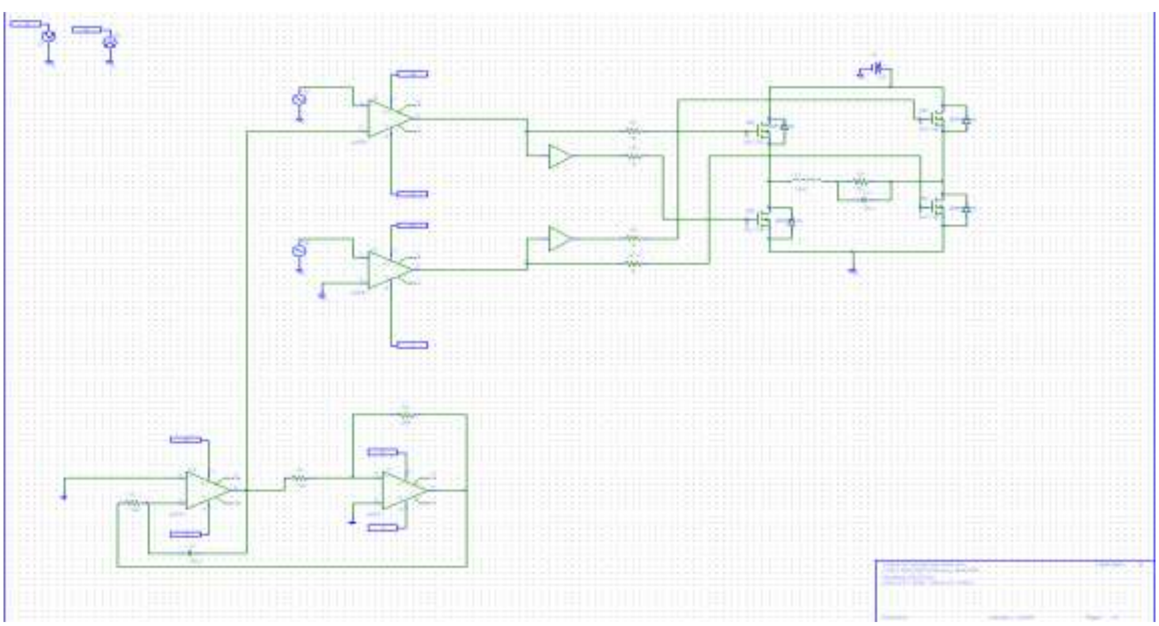
Before LC filter:



Using LC Filter

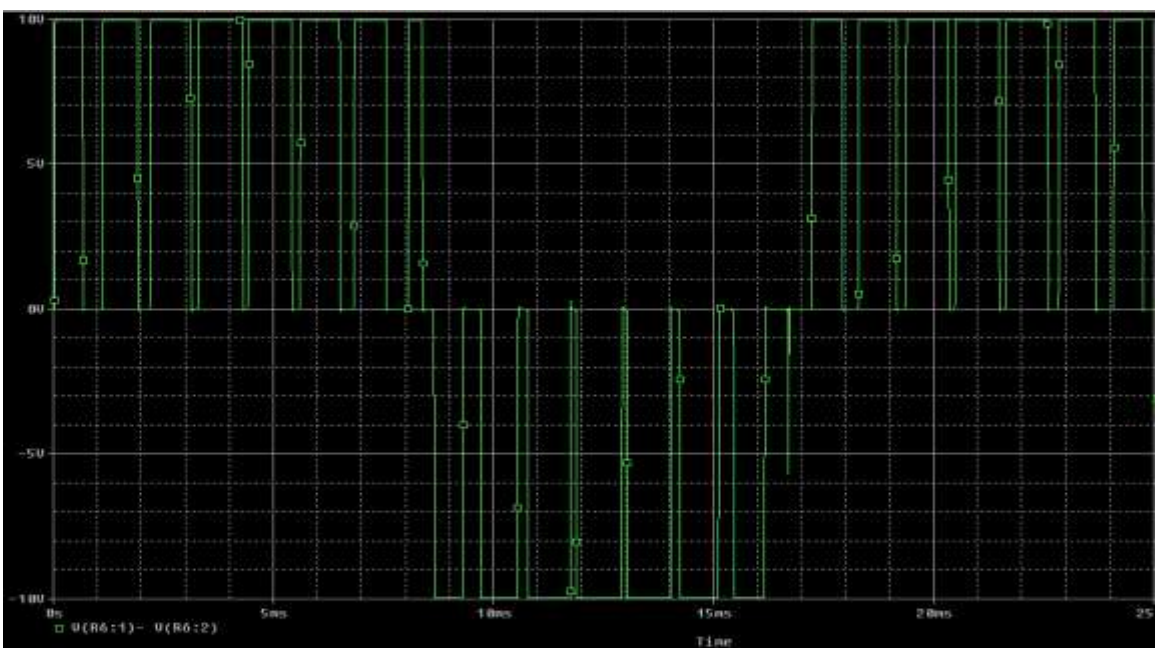


Modified Unipolar:

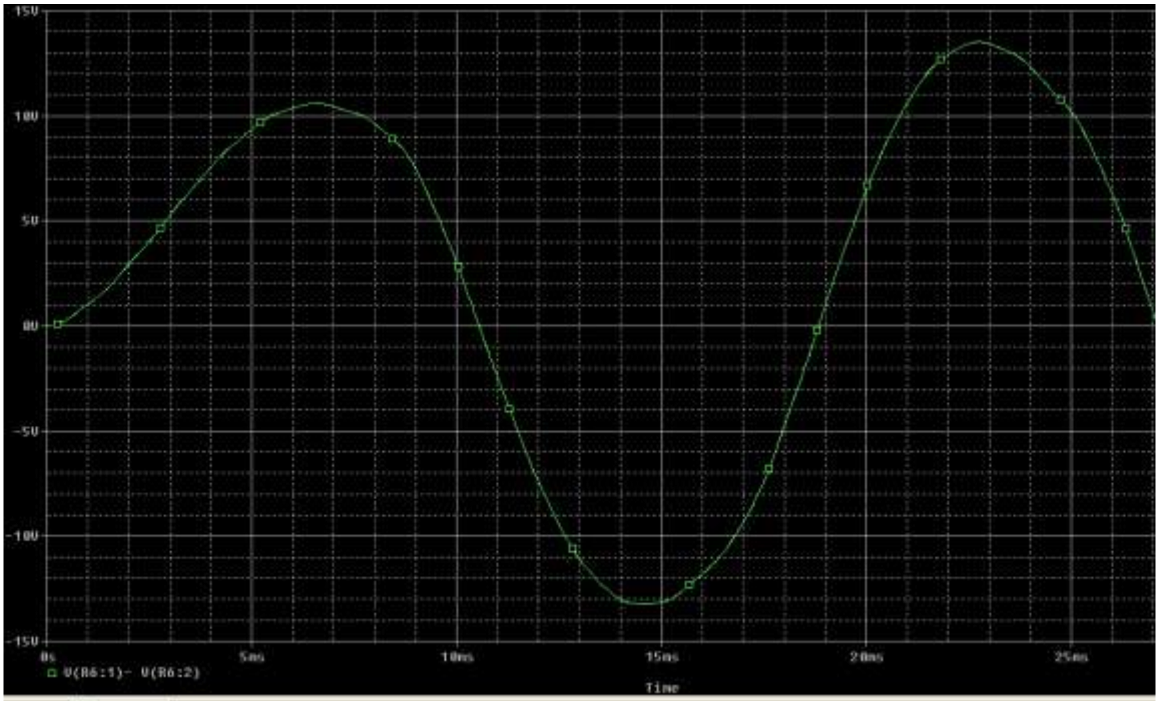


Gate Voltages:

Before LC filter:



After LC Filter:



Appendix C

IRF3205 HEXFET Power MOSFET

VDSS = 55V

RDS(on) = 8.0mOHM

ID = 110A

General characteristics:

- Advanced Process Technology
- Ultra Low On-Resistance
- Dynamic dv/dt Rating
- 175°C Operating Temperature
- Fast Switching
- Fully Avalanche Rated

APPLICATION

Microwave oven, Electromagnetic cooking devices, Rice-cookers etc.

Operating curves:

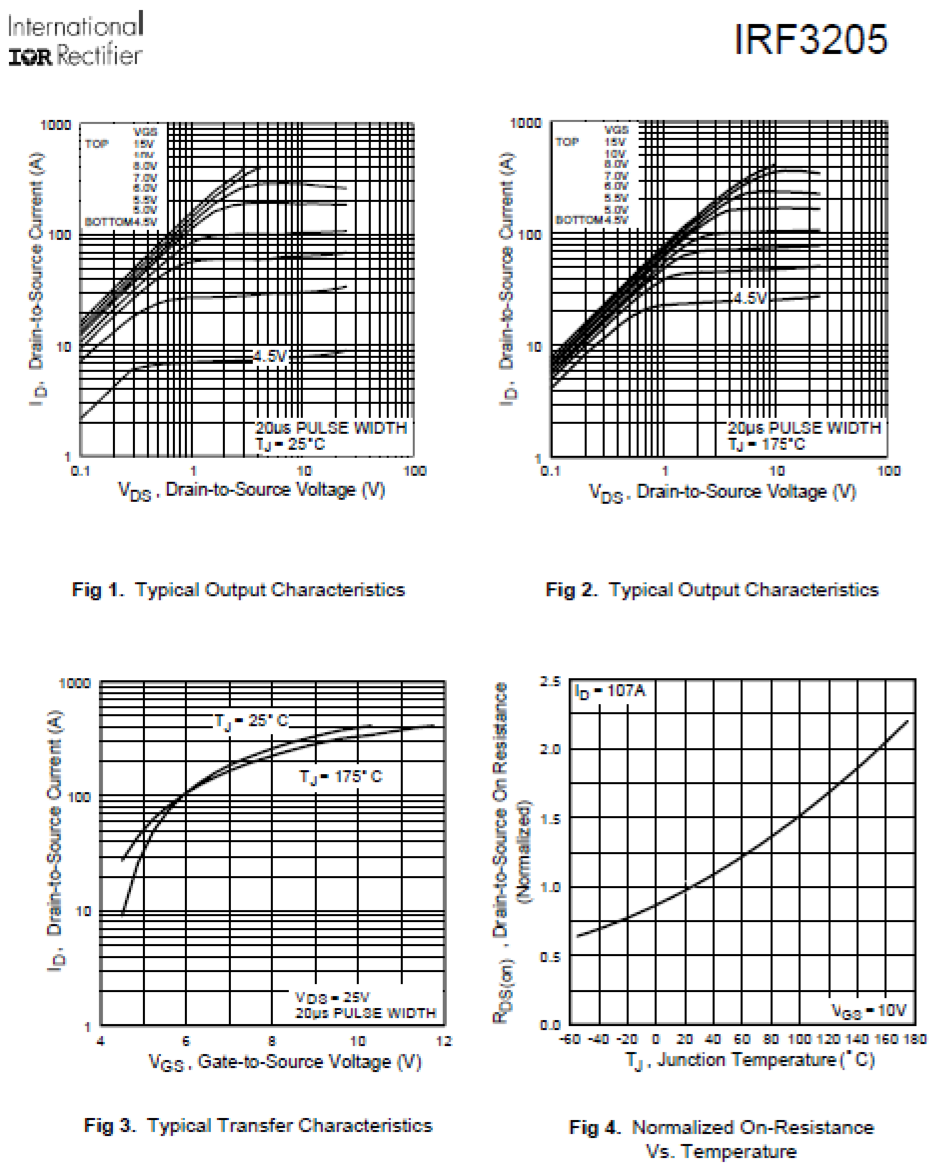


Fig: IRF3205 operating curves

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