

KATHMANDU UNIVERSITY
SCHOOL OF ENGINEERING
DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

FINAL PROJECT REPORT



DESIGN OF SINE WAVE INVERTER

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Sept 2017

CERTIFICATION

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This project has helped us broadened our knowledge in the field of power electronics and it gives us detail idea on how reliability and performance of a power unit depends on an Inverter.

We forward our vote of thankfulness to all persons who directly or indirectly gave a realistic view on this project.

ABSTRACT

The reliability of power unit varies greatly due to many factors including the design of the system, protective features, system's maintenance practices and working conditions. This project aims to design a microcontroller based sine wave inverter using Pulse Width Modulation (PWM) switching scheme to supply AC utilities with emergency power. It involves generating of unipolar modulating signals from a Programmable Interface Computer (PIC16F887A) and using them to modulate a 12V dc MOSFET based full H-Bridge. The focus is on designing an inexpensive, versatile and efficient sine wave inverter that gives a 240V, 600W sine wave output.

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CHAPTER 1

1. INTRODUCTION

1.1 Background

Electrical power exists in two main forms: alternating current (AC) and direct current (DC). The nature of alternating current is that the voltage level can be stepped up or down by use of transformers while that of direct current is that it's possible to store in batteries. Most electrical devices in the world today are designed around AC/DC power conversion. It's therefore necessary to convert the DC power from storage batteries to AC power to power such devices. In practice, DC/AC conversion is done by a power inverter. In today's market, there are two different types of inverters, modified sine wave and pure sine wave inverter. The modified sine wave is similar to a square wave which is less efficient in power consumption. It produces high number of harmonics which affects the devices, hence, reducing its life time. Whereas, a pure sine wave inverter reduces the harmonics to minimum, thus increasing the efficiency of power consumption and life time of AC appliances. It also reduces the audible and electrical noise in audible equipment, TV's, Fluorescent lights and allows inductive load, like fan to run faster and quieter.

1.2 Objectives

The main objective of this project is to design, test and implement a sine wave inverter that converts 12VDC to 240VAC. Further, objectives can be pointed out as:

- To understand working of H bridge unit that is crucial for inverter circuit.
- To implement microcontroller so we can generate the modulating signal for PWM.
- To understand PWM techniques and execute the best option.
- To design a filter circuit that can best develop a sine wave output for the inverter.

1.3 Scope

The following scopes are set out to meet the objectives of the project:

- Inverter unit inclusion in a power system always makes the system more reliable.
- In situation like ours in Nepal, where national grid has to shed the load to maintain the health of the power system, battery backed inverter unit is a very reliable and efficient choice.

CHAPTER 2

2. LITERATURE REVIEW

2.1 Inverter

An inverter is a device that converts the DC output to AC output. The purpose of DC/AC power inversion is typically to take the DC power supplied by a battery, such as a 12V car battery, and transform it into a 240VAC power source operating at 50Hz, emulating the power available at an ordinary household electrical outlet. Inverters are used in applications such as uninterruptible power supply (UPS), adjustable-speed ac motor drivers.

2.2 Classification of Inverters

On the market today, there are two different types of inverters:

- Modified Square Wave (Modified Sine Wave) Inverters
- Pure Sine Wave Inverters

These inverters differ in their outputs, providing varying levels of efficiency and distortion that can affect electronic devices in different ways.

2.2.1 Modified Sine Wave Inverters

A modified sine wave is similar to square wave but instead has a “stepping” look it relates more in shape to a sine wave. This waveform is easier to produce because it is just the product of switching between three values at set frequencies, thereby leaving out the more complicated circuitry needed for a pure sine wave output. Hence, it provides a cheap and easy solution to powering devices that need AC power. However, it comes with significant drawbacks as not all the devices work properly on modified sine wave. Products such as medical equipment, computers are not resistant to the distortion of the signal and must run off of a pure sine wave power source. Modified sine wave inverters approximate a sine wave and have low enough harmonics such that household devices can run on it without significant problems. The main disadvantage of modified sine wave inverter is that its peak voltage varies with the battery voltage.

2.2.2 Pure Sine Wave Inverters

Pure Sine Wave Inverters represent the latest inverter technology. The waveform power produced by these inverters is same as or better than power delivered by the utility. Usually, sine wave inverters are more expensive than modified sine wave inverters due to their added circuitry.

There are two methods in which the low voltage DC power is inverted to AC power:

- The low voltage DC power is first boosted to high voltage power source using a DC-DC booster then converted to AC power using pulse width modulation.
- The low voltage DC power is first converted to AC power using pulse width modulation and then boosted to high AC voltage using a boost transformer.

The second method is adopted these days because of its ability to produce a constant output voltage compared to the first method where an additional circuitry is required to boost the voltage and maintain it.

2.3 PWM techniques for Pure Sine Wave Inverter

Variation of duty cycle of PWM signal provides a voltage across the load in a specific pattern that will appear to the load as AC signal. A pure sine wave is only produced after passing the signal through a low pass filter. The pattern in which PWM signal varies can simply be generated using analog components or a digital microcontroller. Either of the two options generate a sinusoidal PWM that controls the output of the inverter.

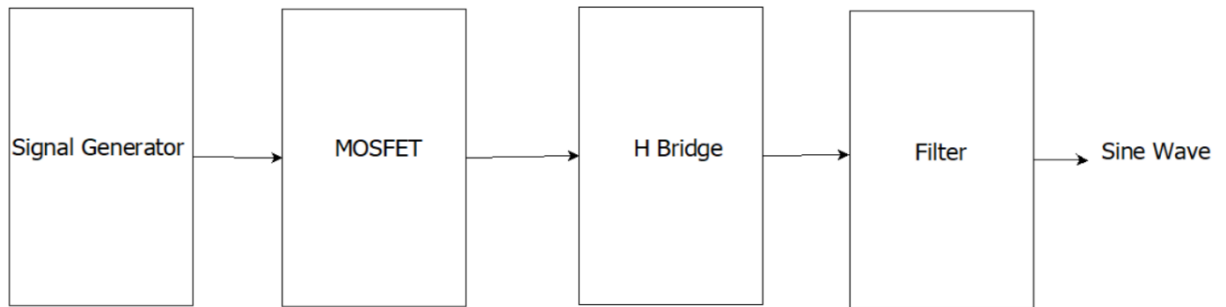


Figure 1 Inverter Block Diagram

It is clear from the block diagram that the first step in designing a sine wave inverter is signal generation to control the power switches arranged in H bridge configuration to switch the DC power to AC power.

2.3.1 Pulse Width Modulation

PWM is a powerful technique for controlling analog with a processor's digital outputs. It is also known as pulse duration modulation. The leading edge of the carrier pulse remains fixed and the occurrence of the trailing of the pulses varies. PWM signals find a wide application in modern electronics. Some of the reasons are:

- **Reduced Power Loss:** Switching circuit tends to have less power consumption because the switching unit is almost always powered off or hard on. Common circuits that utilize this feature include switched mode power supplies (SMPS), power inverters and motor drivers.
- **Easy to generate:** PWM signals are quite easy to generate. Many modern microcontrollers include PWM hardware within the chip.; using this hardware often takes very less attention from the microcontroller and the process can be run in background without interfering the main code execution.
- **Digital to Analog Conversion:** Pulse Width Modulation can function effectively, as a digital to analog converter when combined with appropriate filtering. The fact that the duty cycle of a PWM signal can be accurately controlled using a simple counting technique makes it an effective digital to analog converter.

The desired PWM technique must have the following features:

- Good utilization of DC supply voltage, possibly a high voltage gain.
- Linearity of voltage control.
- Low amplitude of lower order harmonics of output voltage to minimize the harmonic content of output currents.
- Low switching losses in inverter switches.
- Sufficient time allowance for proper operation of the inverter switches and control system.

There are many types of PWM techniques used in sine wave inverters. The commonly used techniques are:

- Single or 2 level PWM: It is the simplest way to produce the PWM signal. It is done through comparison of a low-power reference sine wave with a triangular wave as shown below. The reference sine wave and the carrier signal is fed as an input to a comparator, the output of the comparator unit will be a 2 level PWM signal.

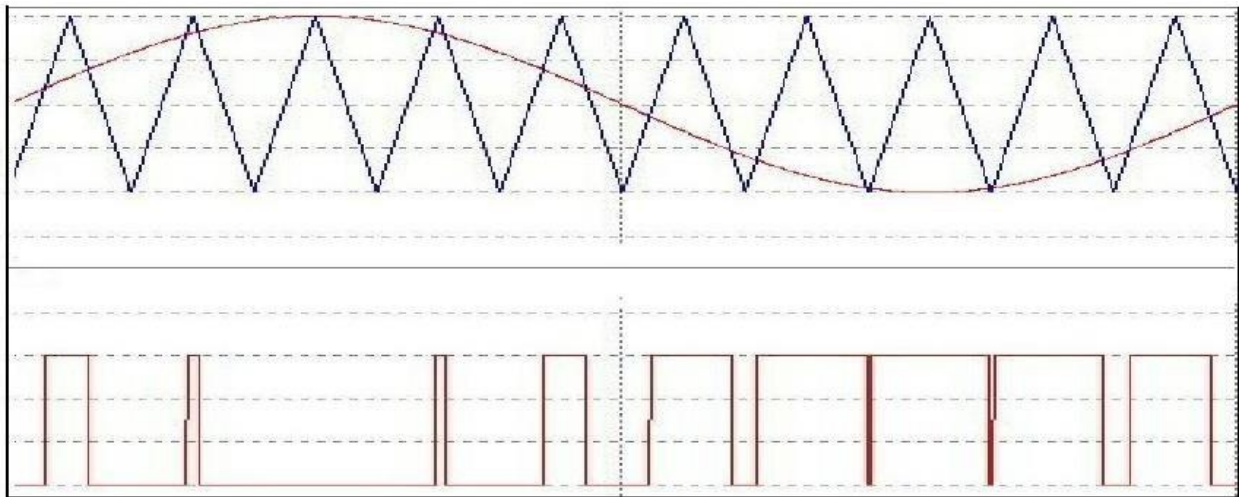


Figure 2 Two level PWM

- Multilevel PWM: The harmonic content can be reduced greatly by using several pulses in each half-cycle of the output voltage. There exist different levels of multiphase PWM producing an improved output with increase of the levels of the PWM used. The most common types are: 3 levels PWM, 5 levels PWM, 7 levels and 9 levels PWM. The choice of which level of PWM is to be used is determined by trade-off between cost of the inverter and quality of the output. To balance the cost and quality of the output, usually 3 levels PWM is used.

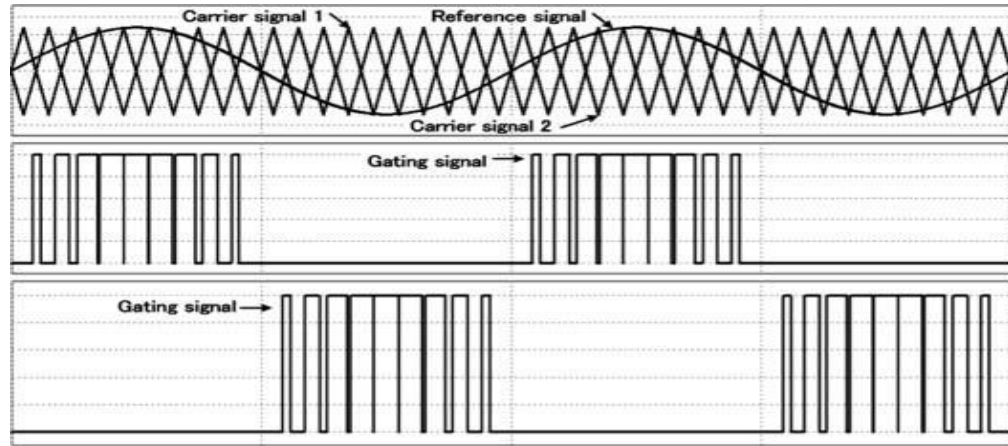


Figure 3 Three Levels PWM

In power converters and motors, PWM technique is widely used means of powering alternating current devices with an available direct current source. PWM is an extensively used technique in DC/AC conversion. Variation of duty cycle in the PWM signal that is subjected to DC voltage across the load in a specific pattern makes the voltage across the load to appear as AC voltage. The pattern at which duty cycle can be varied for PWM signal can be done via analog circuitry, microcontroller, or specific PWM integrated techniques.

Analog PWM control requires the generation of both reference and carrier signal that is fed to the comparator which creates output signal based on the difference between the signals. The reference signal is sinusoidal and the frequency of the desired output signal, while the carrier signal is often wither a saw tooth wave or triangular wave at a frequency significantly greater than the message signal. When the carrier signal is greater than the reference, the comparator's output is at one state, when the reference is at higher voltage than carrier signal, the comparator's output is at its second state.

A digital microcontroller PWM requires a reference signal, sometimes called a modulating signal or control signal, which is sinusoidal in this case, and a carrier signal, which is triangular wave that controls the switching frequency. Microcontroller modules are used to compare these signals and produce a PWM output.

In our case, we control the timing of firing of the switches in H bridge configuration and also the duty cycle of the switches which generate the PWM signal. This signal is fed to the filter circuit to decrease the harmonics. However, the complexity of overall circuit increases with all these units and make it a complex control system.

2.3.2 H-bridge Configuration

An H bridge configuration or full bridge converter is a switching arrangement composed of four switches in a configuration that resembles an H. By controlling different switches in the bridge, a positive, a negative or a zero potential can be placed across a load. When the load is motor, those states can be termed as forward, reverse and off states.

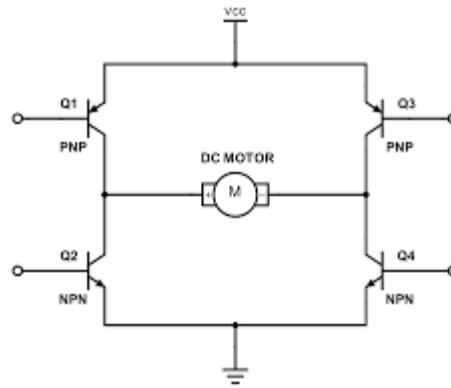


Figure 4 H bridge

Q1, Q2, Q3, Q4 are switches that can be switched with certain pattern and duty cycle to generate a PWM signal. The choice of types of switches varies according to the task, however the governing principle of operation is the same.

2.3.3 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 gate terminal must be approximately 10V higher than the drain terminal for N channel MOSFETs to conduct. This difference in voltage is often achieved using integrated circuits like MOSFET drivers which pump the charge or bootstrap the voltage. These chips are capable of quickly charging the input capacitance of the MOSFET (C_{giss}) 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. Our inverter implements all N-channel MOSFETs, due to its increased current handling capabilities. To overcome the difficulty of having gate voltage to be at 10V higher potential than the drain voltage, the driver uses an external source to charge a bootstrapping capacitor connected between Vcc and source terminals. The bootstrapping capacitor provide gate charge to 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 refers to this process and how the MOSFET uses it to bootstrap itself.

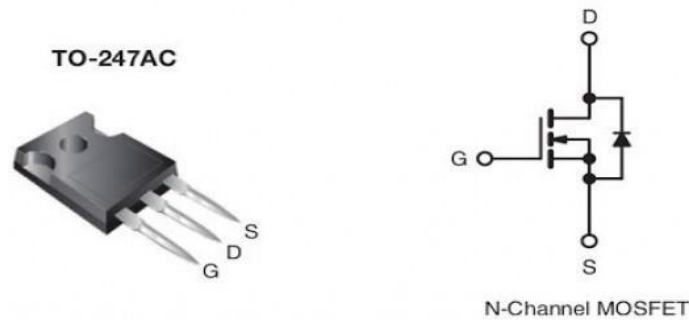


Figure 5 N channel MOSFET

2.3.4 Microcontroller

A microcontroller is a compact integrated circuit designed to perform a specific operation, it consists of relatively simple CPU combined with some functions such as a crystal oscillator, timers, watchdog, serial and analog I/O etc. Program memory in the form of NOR flash or OTP ROM is also often included on the chip, as well as typically small read/write memory.

Microcontrollers are designed for small applications. Unlike microprocessors, simplicity is the top priority in microcontrollers. Microcontrollers may operate at 32 kHz, as this is adequate for many typical applications, enabling low power consumption. They will generally have the ability to retain the functionality while waiting for an event such as button press to occur or other interrupt; power consumption while sleeping (CPU clock and other peripherals off) may be just few 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 I/O devices, microcontrollers make it economical to digitally control even more devices and processes.

In order to control the H bridge, the four MOSFETs must be controlled. This control can be achieved via analog circuits or a microcontroller. In this case, we choose a microcontroller over the analog system for several reasons:

- It is simpler to adapt: In analog systems, it is always difficult to adapt to the changes demanded by the output. In many cases, analog circuits are designed for single purpose and therefore a single output. However, this inverter must adapt to the changes in frequency and voltage standards set accordingly in different places. With microcontrollers, this change can be done by merely changing a program's code. While for analog system, for a distinct change, it would require a different circuit everytime.

- Feedback can easily be made available in microcontrollers. In this kind of system, where load variance is almost expected, a feedback is always necessary to control the power flow into the load. With a microcontroller, it is possible to watch the power output continuously and change the duty cycle based on whether or not load requires additional power or is it being oversupplied.

2.4 Filter

Filter is used to block the higher frequency components from output signal and allow only the desired bandwidth to be at the output. The bandwidth of the filter unit determines the bandwidth of digital to analog converter. Filters are classified based on performances. They are:

- Active filters (built using op-amps)
- Passive Filter (built solely using resistors, inductors, and capacitors)

Active filters avoid impedance loading issues suffered by low pass filters, where the upstream or downstream impedances surrounding the filter can change the filter properties. Passive filters can offer low cost and reduced design complexity.

With active filters, one must also consider the gain bandwidth of the op-amps used. The gain bandwidth represents the upper frequency that the op-amp can effectively handle when used in a closed-loop circuit configuration with small signal input. In terms of active low-pass filters, input signal components with frequency higher than gain bandwidth will be attenuated since the op-amp can't handle such frequencies. Op-amps with such high bandwidth are expensive.

Passive filters do not suffer much from gain bandwidth problems. The biggest drawback of these passive filters is always impedance related. Upstream and downstream impedances can affect the performances of the filter. In our scenario, the upstream of the filter is PWM output from the DSP. This is a low output-impedance source that will not significantly affect the filter. In downstream, one can use a low cost voltage follower op-amp to create a high-impedance output. Since the op-amp is in the signal chain after the low pass filter, an op-amp with large bandwidth is not needed.

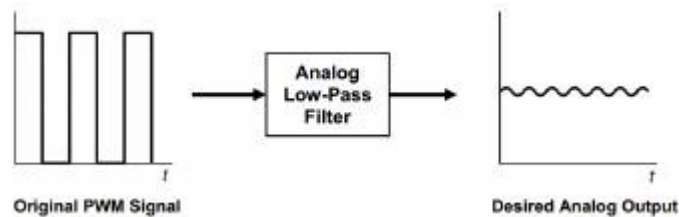


Figure 6 Low Pass Filter

2.5 Transformer

Transformer is an electrical device that transfers energy between two circuit points via electromagnetic induction. Transformer is used as a safe and reliable approach to change the AC voltage levels. It also provides isolation and makes the circuit efficient. A transformer consists of two windings of wire that are wound around a common core to provide electromagnetic coupling between the windings. The core material is often a laminated iron core. The coil that receives the electrical input energy is referred to as the primary winding, the output coil is the secondary winding. An ideal transformer induces secondary voltage V_s as a proportion to the primary voltage V_p and respective winding turns as given by equation: $(V_p / V_s) = (N_p / N_s) = (I_s / I_p) = a$

Where a is the winding ratio which decides if the transformer is a step up or step down transformer. V_p designates source impressed voltage while V_s designates output voltage.

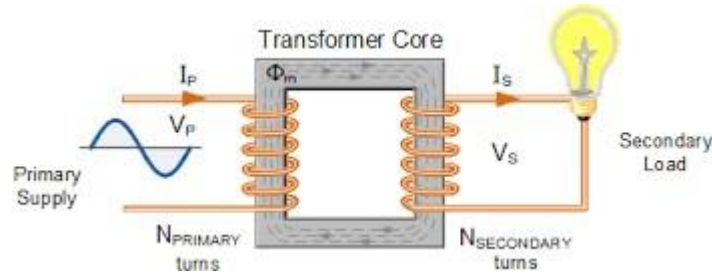


Figure 7 Transformer

CHAPTER 3

3. Design

The construction of a sine wave inverter can be complex when thought of as a whole but when broken up into smaller divisions, it becomes much easier to handle each unit. The following sections detail each specific part of the project and describes how specific unit is constructed and interacts together with all the units that result in the production of a 240VAC sine wave inverter.

The block diagram below shows the various units of the project that is used to build the product. The signal generator is simply a microcontroller that generates both the PWM and square wave signals needed in controlling the N- channel MOSFETs in the H-bridge configuration. The output from the H-bridge is then sent to the transformer (booster) and a low pass filter so that final output is a sine wave.

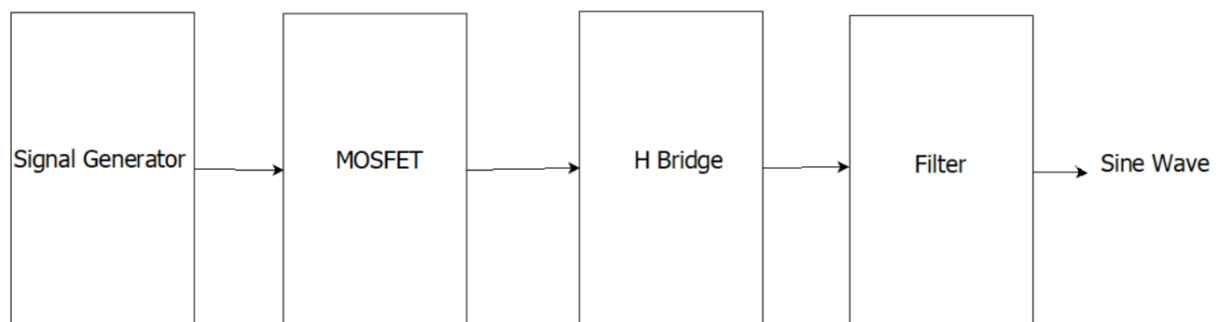


Figure 8 Block Diagram

3.1 Signal Generator

The signal generator is a low cost microcontroller that is used to generate PWM signals. It has built in PWM modules. In this experiment, PIC16F877A was used that was able to store required commands to generate necessary PWM and square wave waveforms. In PIC16F877A there are 40 pins each with different functions. Port C has two output that produces PWM while Port B is driven high and low to give a square wave. The microcontroller is tasked with generating four control signals to drive two MOSFET drivers. They are two 50hz square waves, each at 180^0 phase angle of each other, and two 2-level, 2kHz pulse width modulation signals operating at a switching frequency of 50Hz also at 180^0 phase angle of each other.

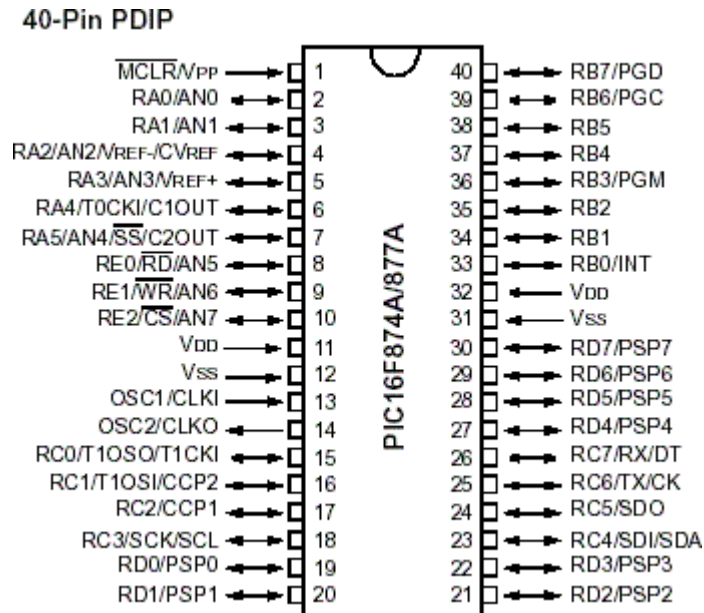


Figure 9 PIC16F874A 40 pins

Carrier frequency(C)= 2 kHz, message frequency(M)= 50Hz

Number of PWM projections per quarter cycle(P)=C/M=2000/(50*4)=10

Initial duty (I)=50%, Overall duty(O)=100%

Duty change for a quarter cycle=(O-I)/P=(100-50)/10=5

A delay of 305us was introduced to prevent one side of H-bridge switches being On at the same time. The following steps should be taken when configuring the CCP module for PWM operation:

- Set the PWM period by writing to the PR2 register.
- Set the PWM duty cycle by writing to the CCPR1L register and CCP1CON
- Make the CCP1 and CCP2 pins an output by clearing the TRISC 26
- Configure the CCP1 and CCP2 modules 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 trigger is generated by a compare match and will reset Timer. CCP2 Module: Capture/Compare/PWM Register 2 (CCPR2) is also 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 Timer. Since we are working on Port C, TRISC register is used to control the direction of port C pins, either as input or output. And we are clearing the TRISC register so TRISC=0 making the corresponding Port C pins as output pins.

A Program (MIKROC PRO for PIC) was used to write the PIC code.

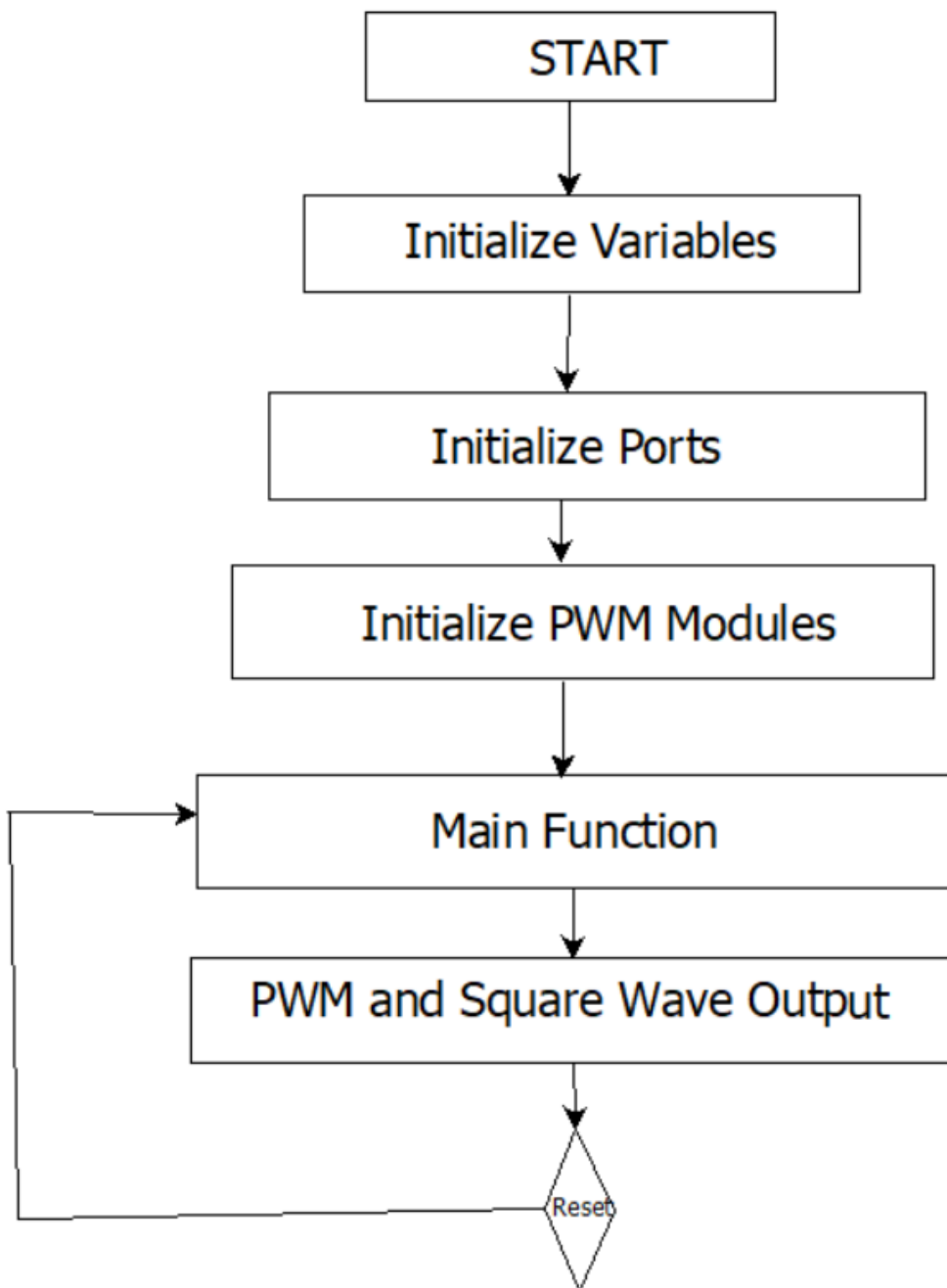


Figure 10 Program Flow Chart

3.2 MOSFET Drivers

The IR2110 High and Low Side Drive device meet all the requirements for driving the N-channel 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 as 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 the voltage difference of approximately 10V above the drain to source voltage. With a full bridge two of these devices are utilized. A typical connection of IR2110 is shown below:

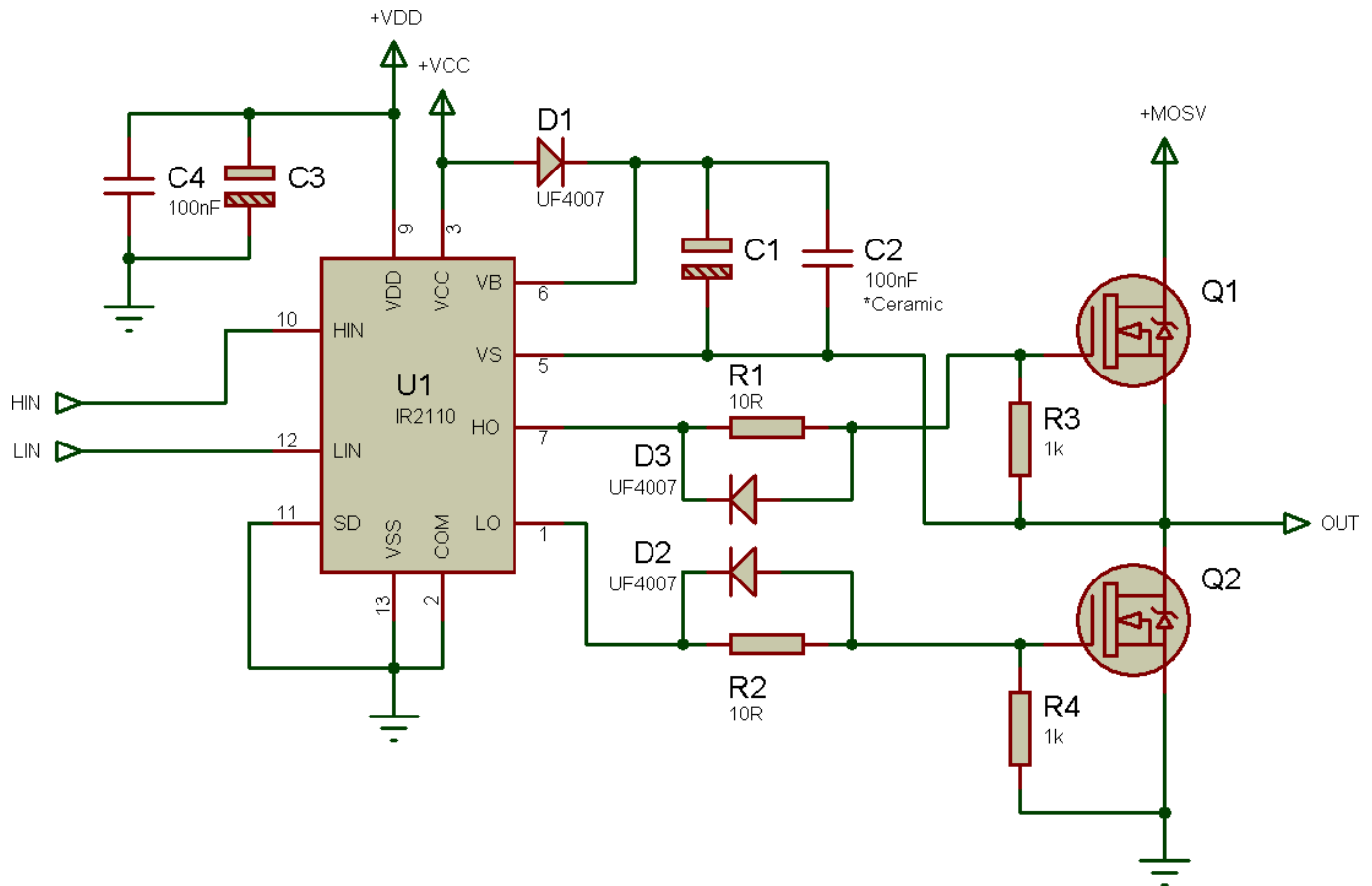


Figure 11 IR2110 MOSFET Driver

Operation of IR2110 is controlled by generated PWM and square signals. The generated PWM and square wave signals are fed to 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 C1 and C2 are connected as shown the figure and are charged via diode D1 from VCC. 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.

The minimum bootstrap capacitor value can be calculated from the following equation:

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

where:

Q_g = Gate charge of high-side FET

f = frequency of operation

$I_{Cbs(leak)}$ = bootstrap capacitor leakage current

$I_{qbs(max)}$ = Maximum V_{BS} quiescent current

V_{CC} = Logic section voltage source

V_f = Forward voltage drop across the bootstrap diode

V_{LS} = Voltage drop across the low-side FET or load

V_{Min} = Minimum voltage between V_B and V_S .

Q_{ls} = level shift charge required per cycle (typically 5 nC for 500 V/600 V MGDs and 20 nC for 1200 V MGDs)

Using the values determined from the data sheets of the components used, the minimum bootstrap capacitor values were calculated.

Q_g = Gate Charge of High Side FET = 220nC

I_{qbs} = Quiescent current for high side driver circuitry = 230uA

Q_{ls} = Level shift charge required per cycle = 5nC (given in application note)

I_{cbs} = Bootstrap capacitor leakage current = 210uA F = Frequency = 50Hz

V_{cc} = Supply Voltage = 12V

V_f = Forward voltage drop across bootstrap diode = 1 V

V_{ls} = Voltage drop across low side FET = 0.5V

V_{min} = Minimum voltage between V_B and V_S = 3v

$C \geq 2[2*220nC + (220uF/50Hz) + 5nC + (210uF/50Hz)] / (12v - 1 - 0.5v - 3v) = 2.412uF$

A safety factor of 5 is taken in consideration thus $C \geq 10.824uF$.

3.3 H-Bridge

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. The IR2110 MOSFET driver integrated circuit was used for level translation between PWM and square signals and voltages required to forward bias high side N-Channel MOSFETs.

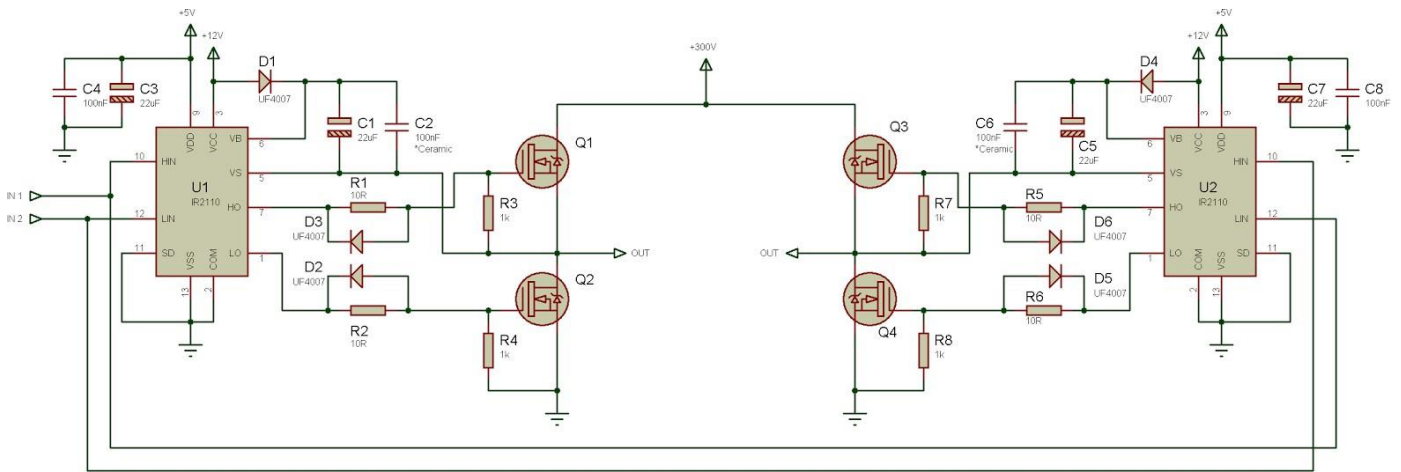


Figure 12 Full H-Bridge Configuration

Driving the four MOSFETs in an H-Bridge configuration allows +12, -12, or 0 volts across the load at any time. To achieve this, the left side of the bridge is driven by PWM signals to determine the output voltage is zero or non-zero. The right side of the H bridge is driven by square wave signals. Let us observe the circuit, once Q1 gets HO signal from MOSFET driver 1 it gets turned on while Q4 gets turned on at the same time by receiving LO signal from MOSFET driver 2, this allows a right side plus – left side minus polarity across Output (Out-Out) as shown in figure above. However when Q1 and Q4 gets turned off, the back emf is seen across the output or in this case it is transformer's coil. A back emf is seen across it with reversed polarity compared to the polarity set up when Q1 and Q4 were turned on. So the reversed polarity back emf will cause a current to flow in the circuit in between Q4 and Q2. If we see in the circuit above, the reverse polarity emf causes current to flow via Q4 to Q2, however Q4's diode is reverse biased when back emf is subjected to it, and it won't conduct, hence we need square wave to keep it on when back emf is subjected to it. Also we need to keep Q2 switched on while switching Q3, so square wave is a must. The MOSFETs used in the design are IRF3808 Power MOSFETs rated for 75V at 140A with power handling capability of 600W.

3.4 Output Filter and Booster

The final component necessary to output a sine wave signal is an output filter. For our circuit we need a basic LC low pass filter.

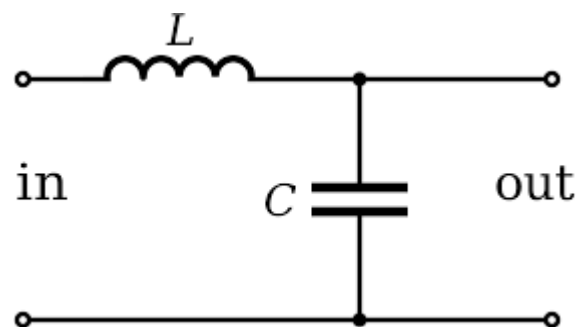


Figure 13 LC filter

This will filter out all the excess noise above the critical frequency. The goal for this was to bring the critical frequency as close as possible to the desired frequency of 50 Hz, removing other harmonics that crop up within the system. The slower the cutoff frequency, the greater the capacitance and inductance required to properly create the filter. Therefore, filter design becomes a tradeoff between the

effectiveness of the filter and the cost and size of the component. The output of the H-bridge was ideally a 50Hz sine wave. Because it was encoded using a 2 kHz PWM signal it was to be filtered.

$$F_c = \frac{1}{2\pi\sqrt{L C}}$$

Using an inductor of 2.07H, requires a capacitor of 4.5μF to obtain the required cutoff frequency. The closest capacitor value was 1μF was used. The selected inductor was to be able to handle at least 50A current and the capacitor at least 50V. A toroidal step up transformer of 45.m14H primary inductance and 2.619H secondary inductance was used to boost 12 volts to 240 volts. A capacitor of 1μF was placed at the output of the secondary coil to filter harmonic distortions.

CHAPTER 4

4. Implementation

4.1 Signal Generator

A 12V dc from the battery was fed to the microcontroller through a 5V constant regulator with ac filter capacitors at both input and output side. The capacitor values were obtained from 7805 regulator datasheet. The microcontroller was clocked with an external clock of 10MHz which was grounded using capacitors whose values were obtained from PIC16F877A datasheet. The High PWM and Square wave output were obtained from pins CCP1 and RB1 while Low PWM and Square wave were obtained from pin CCP2 and RB2 respectively.

4.2 MOSFET Driver

The microcontroller outputs were used to control the MOSFETs Full H-Bridge through MOSFET drivers U1 and U2 whose pins connection was done as shown in IR2112 datasheet. C6 and C8 are stabilizing capacitors which filters all the ac currents. Their values were obtained from the datasheet. C1 and C5 are bootstrap capacitors whose values were calculated in the design. They are charged through diodes D1 and D2. The outputs of the MOSFET drivers were fed to the MOSFET gates through resistors R3, R4, R5 and R6 which controlled the MOSFET switching speed. Their values were obtained from the IR2112 datasheet. Resistor R7, R8, R9 and R10 were used for discharging the capacitance CGS to allow for proper MOSFET switching. The H-Bridge was powered by a 12V dc from the battery and the output was obtained between the outputs PWM and SQR.

4.3 Filter and Transformer

The H-Bridge output was fed to a RL Passive Filter. The values of the inductor L1 and Capacitor C9 were as calculated in the design.

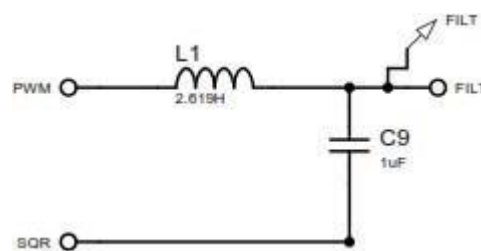


Figure 14 Filter

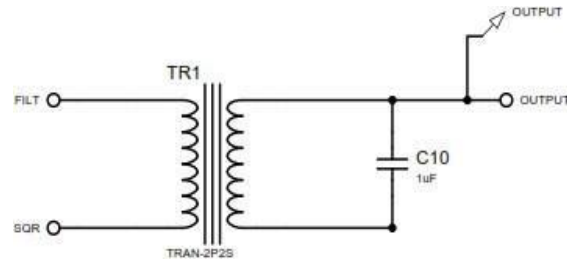


Figure 15 Transformer

The output of the Filter was boosted using a Step-up Transformer with a transformation ratio of 18.3. A capacitor C10 was placed at the output to filter the harmonics. Its value was obtained from a range given in the general transformer output stabilizers.

4.4 Sine Wave Inverter

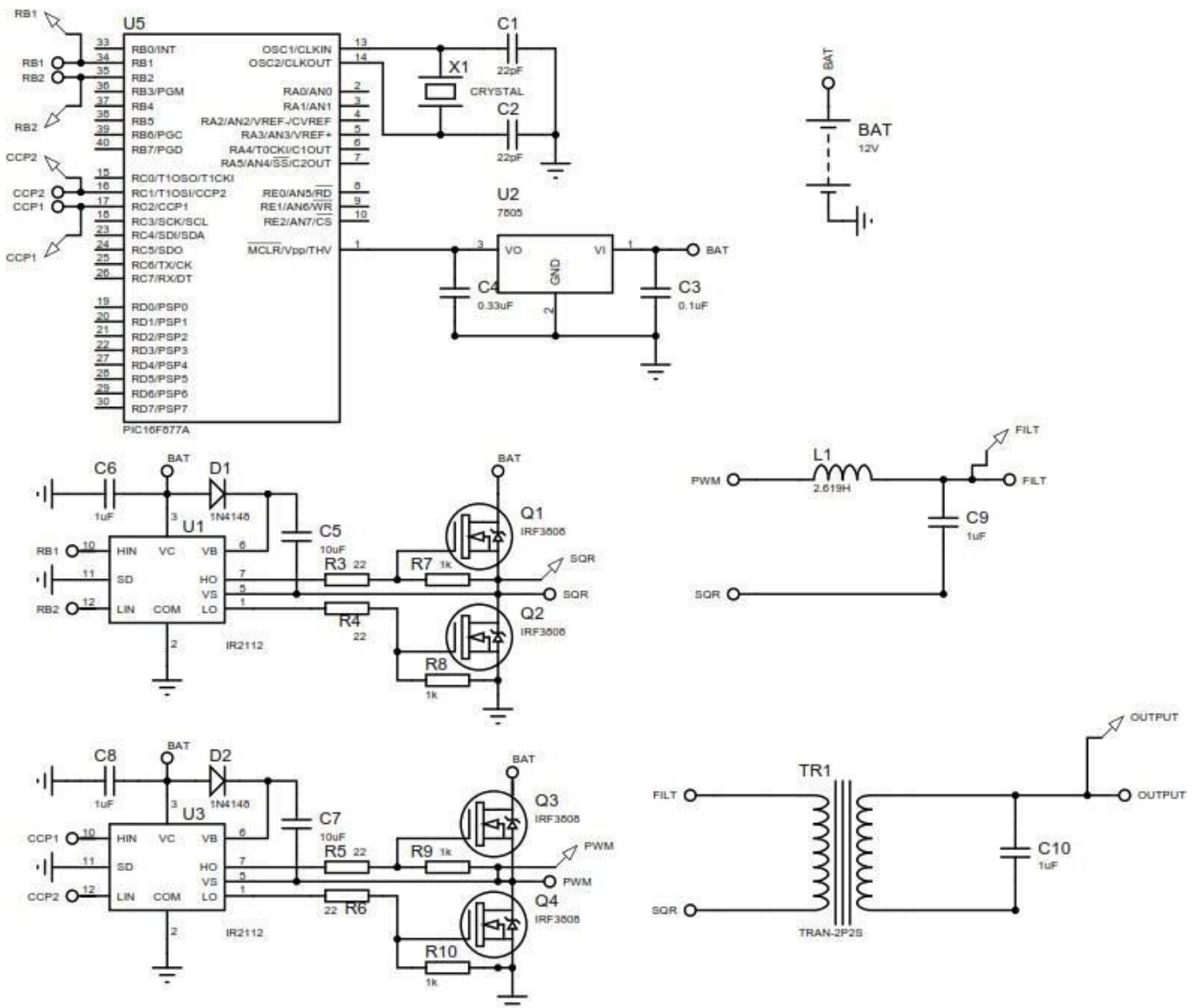


Figure 16 Sine Wave Inverter



Figure 17 Final Circuit

CHAPTER 5

5. Results

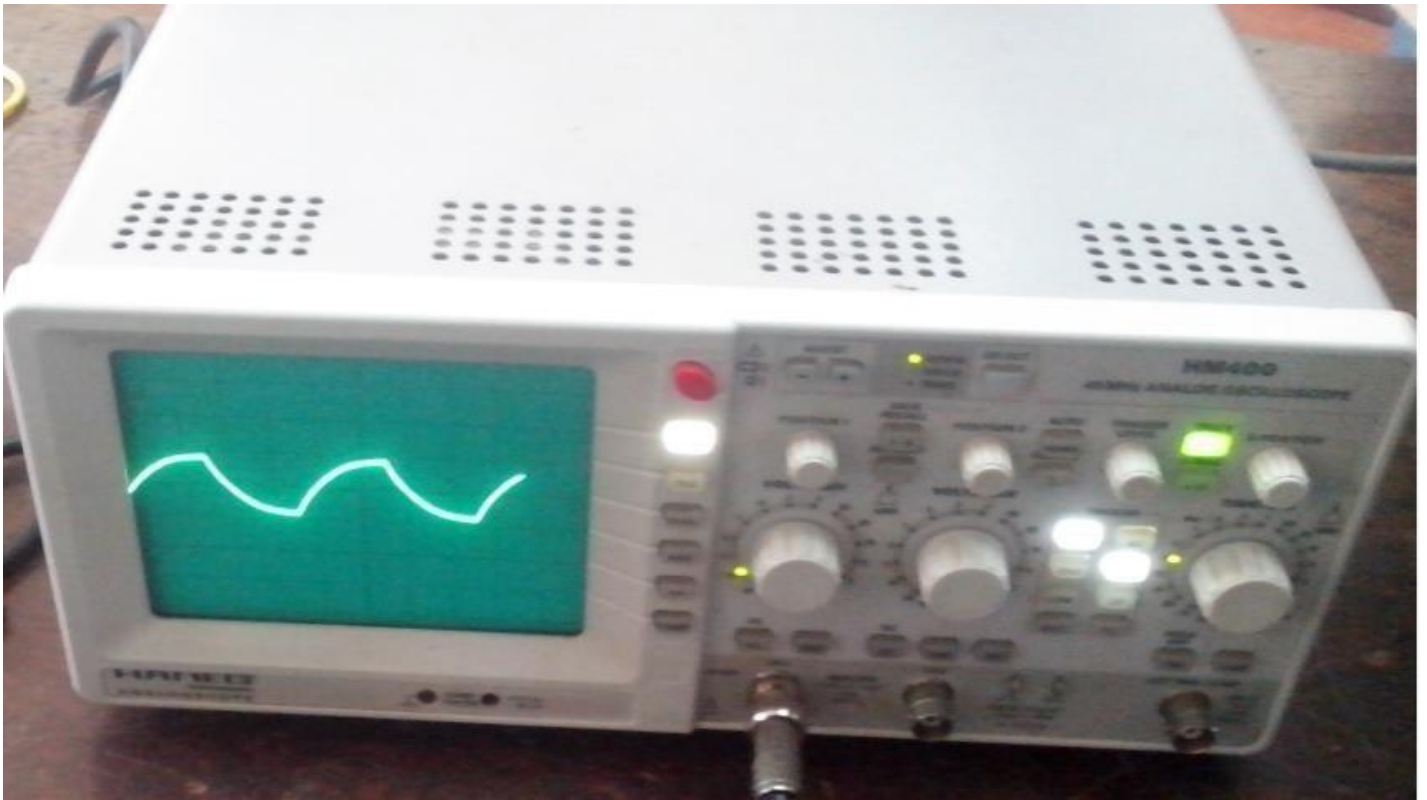


Figure 18 Final Output

CHAPTER 6

6. Conclusion

The basic goal of this project, which is designing and implementing a working DC-AC sine wave inverter that could efficiently provide significant power using 2-level PWM, has been achieved. Different signals were generated to control MOSFET switches arranged in an H-bridge. The aim was to modulate the bridge with a 2 level PWM and obtain a 3 level PWM and filter the bridge output to get a sine wave. Although the final output waveform was not the desired waveform, the design went along in trying to design an affordable sine wave inverter. This project provides a good building block that can be added to many general-use high-power applications, as well as a base to work off for a self-regulating power supply.

APPENDIX

```
void main() { int duty=50; // initial value for duty
TRISB=0; // designate PORTB pins as output
TRISC=0; // designate PORTC pins as output
PORTB=0; // set PORTB Low
PWM1_start(); // start PWM1
PWM2_start(); // start PWM2
PWM1_init(2000); // Initialize PWM1 module at 2KHz
PWM2_init(2000); // Initialize PWM2 module at 2KHz
RB4_bit=1; // Set port RB4 High
while(1){ // endless loop
RB2_bit=1; // set PORT RB2 to High
for(duty=50;duty<100;duty+=50){//increment duty
pwm1_set_Duty(duty*2.55); //set duty
delay_us(130);}
for(duty=50;duty>50;duty-=5){ // decrement duty
pwm1_set_Duty(duty*2.55); // set duty
delay_us(130);}
pwm1_set_Duty(0);
RB2_bit=0; // reset PORT RB2 Low
delay_us(305);
RB1_bit=1; // set PORT RB1 High
for(duty=50;duty>50;duty-=5){ // decrement duty
pwm2_set_Duty(duty*2.55); // set duty
delay_us(130); }
pwm2_set_Duty(0);
RB1_bit=0;// reset PORT RB1 Low
delay_us(305);}
}
```