COMPARATIVE ANALYSIS AND IMPLEMENTATION OF SUPPLY POWER FACTOR IMPROVEMENT TECHNIQUES IN CONVERTERS

A PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

Certified that this project report entitled **"COMPARATIVE ANALYSIS AND IMPLEMENTATION OF SUPPLY POWER FACTOR IMPROVEMENT TECHNIQUES IN CONVERTERS"** is the bonafide work of

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ABSTRACT

This project "COMPARATIVE ANALYSIS AND IMPLEMENTATION OF SUPPLY POWER FACTOR IMPROVEMENT TECHNIQUES IN CONVERTERS" deals with supply power factor improvement techniques in converters. The single phase full wave semi converter is used to improve the supply power factor.

PIC Microcontroller (16F877A) is used to generate the gate pulses for IGBT. Driver circuit is used to interface the microcontroller with converter. Three techniques are used to improve the supply power factor. By varying the gate pulse of IGBT the output voltage can be varied, correspondingly the power factor can be improved.

Power circuit simulation is done using PSIM. The control circuit simulation is done using PROTEUS software. The output waveforms are seen through CRO. DC motor is used as load. The results are analysed through theoretical values and implemented using the hardware.

ACKNOWLEDGEMENT

The completion of our project can be attributed to the combined efforts made by us and the contribution made in the one form or the other by the individuals we hereby acknowledge.

We wish to place on record our deep sense of gratitude and profound thanks to our guide **Mr.C.Udhayashankar, M.Tech** Electrical and Electronics Engineering Department, for his valuable guidance, constant encouragement, continuous support and co-operation rendered throughout the project.

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Last but not least, we extend our sincere thanks to all our parents and friends who have contributed their ideas and encouraged us for completing the project.

CONTENTS

CHAPTER 1

1. INTRODUCTION

1.1 NEED FOR THE PROJECT:

Phase controlled converters are widely used in present day industries. When the firing angle is increased (i.e., voltage is decreased) the supply power factor becomes lagging. Due to this lagging supply power factor the reactive power consumption is increased. To overcome this problem, the supply power factor is improved through various techniques.

1.2 OBJECTIVE OF THE PROJECT:

This project deals with supply power factor improvement techniques in converters. The single phase full wave semi converter is used for explaining different supply power factor improvement techniques.

- The objective of this project is to control the cosine angle between the voltage and current in the supply side.
- A comparative analysis will be made between various techniques to improve the supply power factor.

CHAPTER 2

2. METHODOLOGY

2.1 BLOCK DIAGRAM

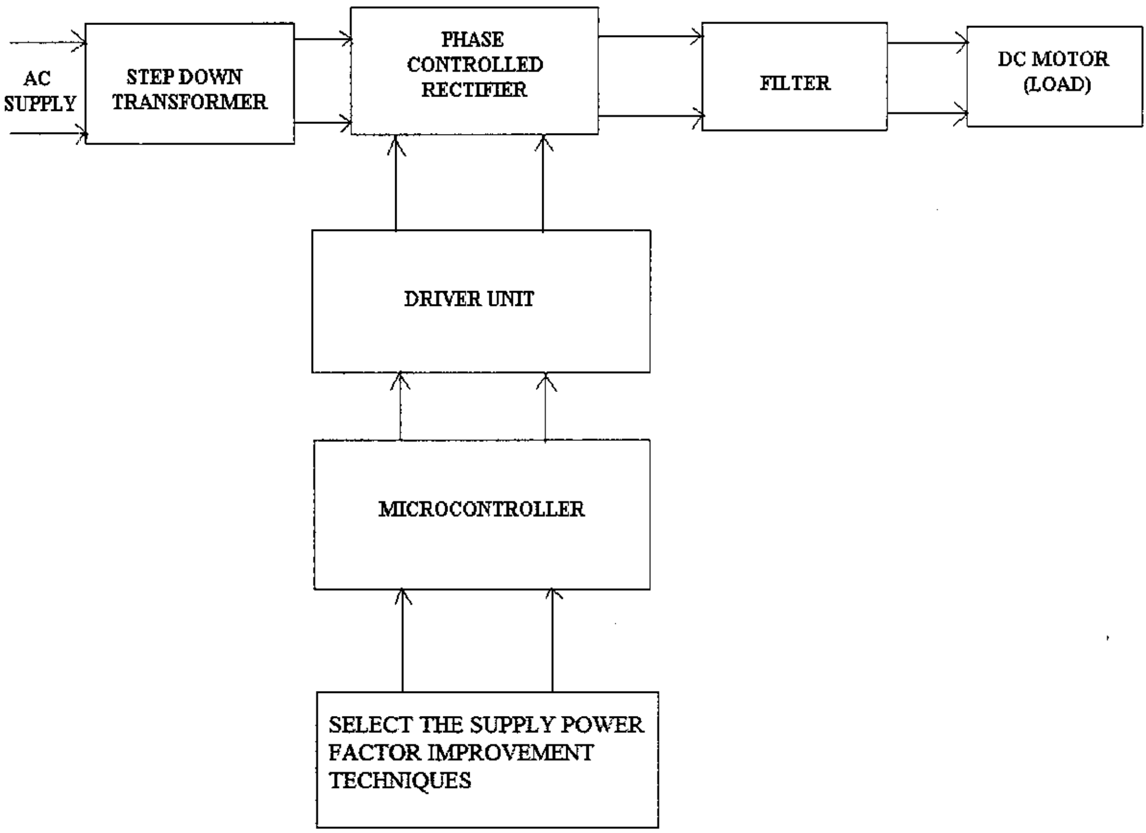


Fig no: 1

Block diagram

2.2CIRCUIT DIAGRAM:

2.2.1 SEMICONVERTER :

The semiconverter consists of two IGBT S1&S2 and two diodes D1&D2. During the positive half cycle S1&D2 will conduct and during the negative half cycle S2&D1 will conduct and the corresponding voltages can be noted. Free wheeling diode(D3) is used to prevent the reverse current from the load.

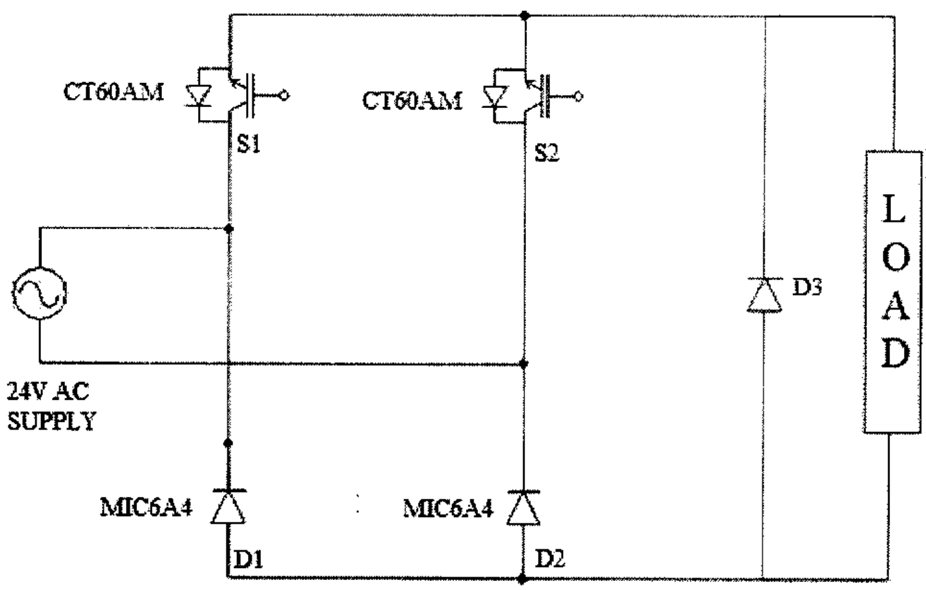


Fig no:2

Semiconverter

2.2.2 DRIVER CIRCUIT:

It is used to provide 9 to 20 volts to switch the IGBT Switches of the rectifier. Driver amplifies the voltage from microcontroller which is 5volts. Also it has an optocoupler for isolating purpose . The optocoupler isolates the power circuit and control circuit.

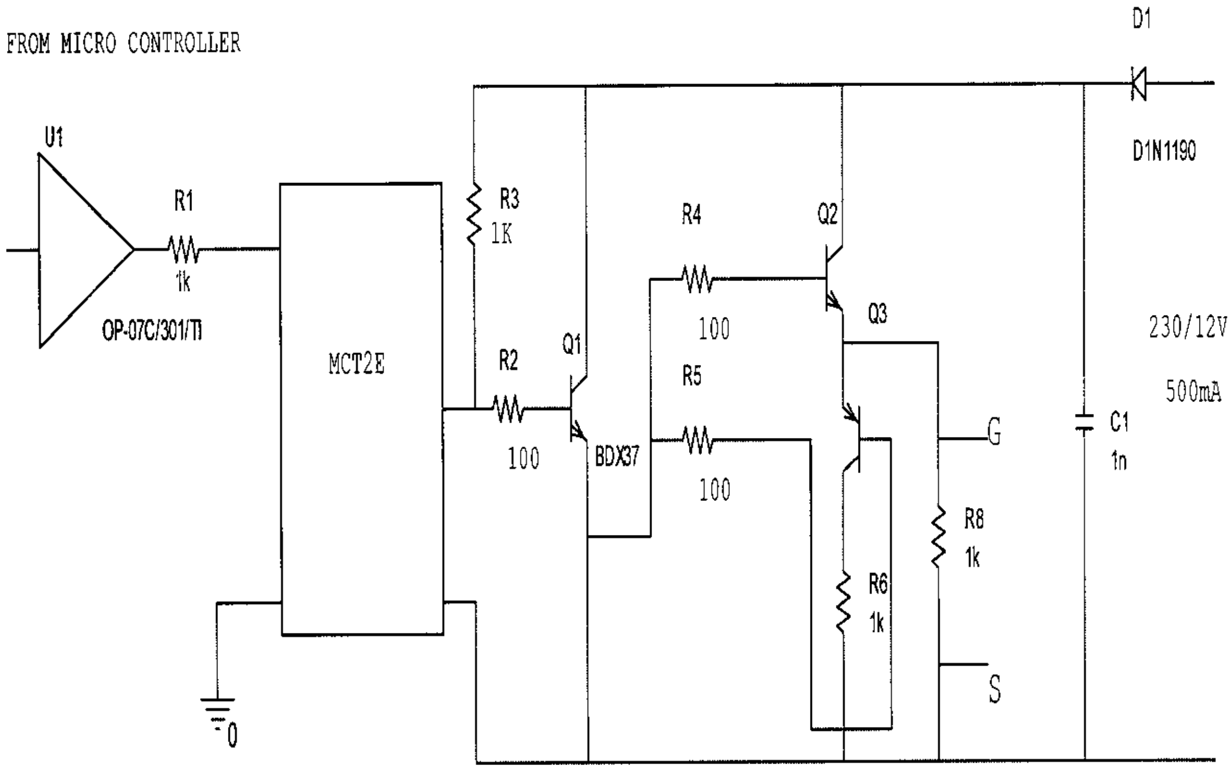


Fig no:3
Driver Circuit

DRIVER CIRCUIT OPERATION:

The driver circuit produces the gating pulses to the IGBT. When a LOW level signal is received from the PIC, LED is forward biased and the phototransistor will conduct thereby giving biasing signal to the transistors Q1 and Q2. Hence a positive triggering pulse for gate of the IGBT is obtained.

When the input from the PIC is HIGH level then the LED is reverse biased. At this time the photo transistor would not conduct and therefore transistors Q1 and Q2 in the circuit will be turned OFF.

Hence a negative triggering pulse for the gate of IGPT is obtained in this case. The transistor Q3 is provided to maintain a zero level after a pulse has been produced in order to maintain a sequence of HIGH and LOW level pulses.

OPTOCOUPLER:

Optocoupler is also termed as optoisolator. Optoisolator a device which contains a optical emitter, such as an LED and an optical receiving element, such as a transistor, diode, or other device that conducts differently when in the presence of light. These devices are used to isolate the control circuit from power circuit.

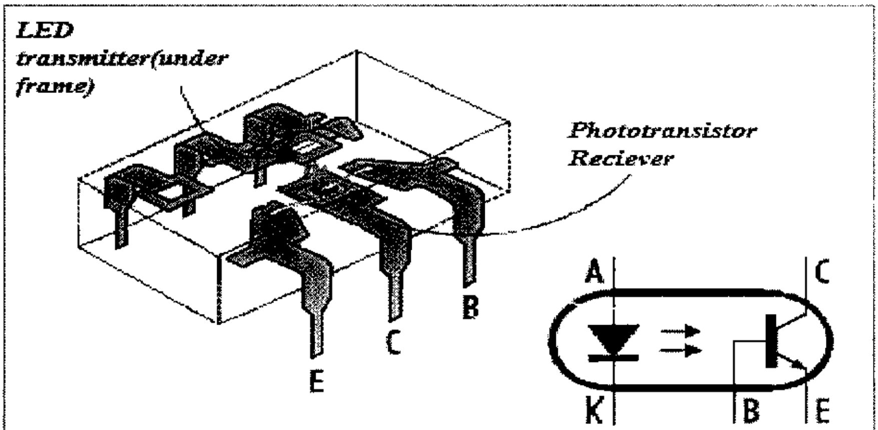


Fig1. Construction of Optocoupler And usual circuit diagram

Fig no: 4
Optocoupler

2.3 METHODS OF SUPPLY POWER FACTOR IMPROVEMENT :

In normal method when the firing angle is increased, the output voltage will decrease resulting in lagging power factor. A load with a power factor of 1.0 results in the most efficient loading of the supply and a load with a power factor of 0.5 will result in much higher losses in the supply system. Poor load current phase angle is generally the result of an inductive load such as an induction motor, power transformer etc. A poor power factor due to an inductive load can be improved by the addition of capacitor at load . The power factor at the source side can be improved by varying the conduction time of IGBT. The circuit of a single phase full wave half (semi) controlled bridge converter (ac-dc) is used as an example. The power factor on the source is improved by varying the conduction of IGBT in single phase semi converter.In our project three different schemes are analysed and the results are compared :

- **Extinction angle control**
- **Symmetrical angle control**
- **Pulse width modulation (PWM) control**

2.3.1 EXTINCTION ANGLE CONTROL :

- The switch, S_1 is turned on at $\omega t=0$, and then turned off by forced commutation at $\omega t=\pi-\beta$
- The switch, S_2 is turned on at $\omega t=\pi$, and then turned off at $\omega t=2\pi-\beta$.
- The output voltage is controlled by varying the extinction angle β.
- The fundamental component of the input current leads the input voltage and so, the power factor is leading.

WAVEFORM :

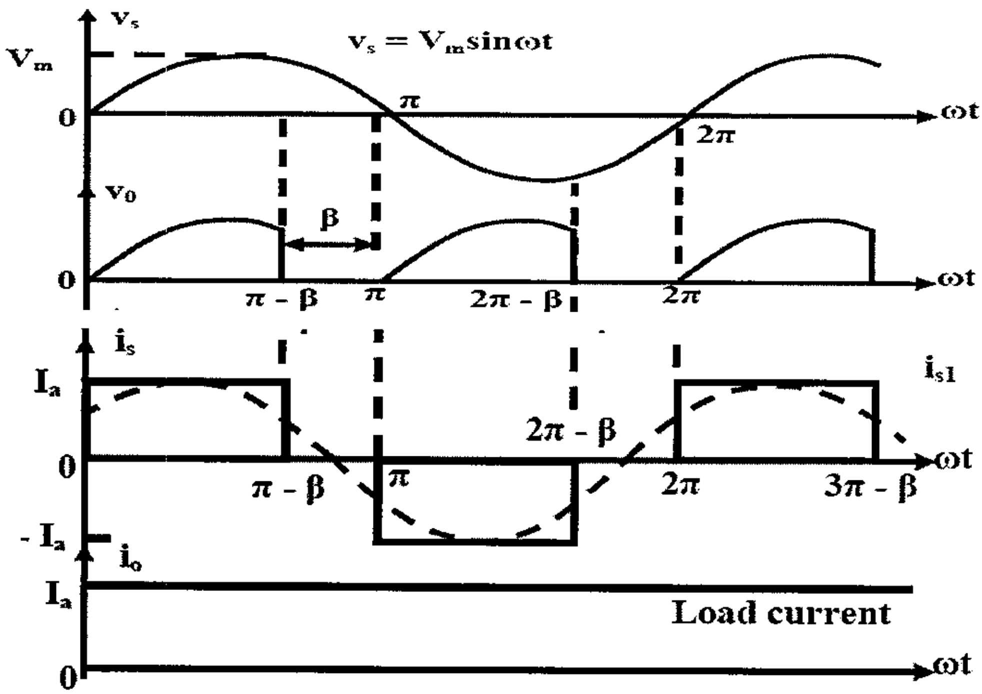


Fig no:5

Waveform for extinction angle control

FORMULAE USED :

<u>Average output voltage :</u>

$$E_{dc} = (E_m/\pi)(1-\cos\beta)$$

Rms supply current :

$$I = (I_a)\sqrt{(\beta/\pi)}$$

RMS n^th harmonic current :

$$I_n = (2\sqrt{2}I_a)/\pi n[\sin(n\beta/2)] \quad \text{where n is odd}$$

Displacement angle :

$$\Phi_n = n\ ((\pi/2)-(\beta/2)) \qquad \text{where n is odd}$$

Supply power factor :

$$P_F = \{\sqrt{2}\ (1-\cos\beta)\}/\sqrt{\pi\beta}$$

Displacement factor :

$$D_F = \cos(\pi/2-\beta/2)=\sin \beta/2,\text{leading}$$

Harmonic factor :

$$H_F = [\ (\pi\beta)/(4(1-\cos\beta))-1]^{1/2}$$

2.3.2 SYMMETRICAL ANGLE CONTROL :

- The switch, S_1 is turned on at $\omega t=(\pi-\beta)/2$ and then turned off at $\omega t=(\pi+\beta)/2$
- The other switch, S_2 is turned on at $\omega t=(2\pi-\beta)/2$ and then turned off at $\omega t=(2\pi+\beta)/2$.
- The output voltage is controlled by varying the extinction angle β.
- The fundamental component of input current is in phase with input voltage and the displacement factor is unity(1.0).

WAVEFORM :

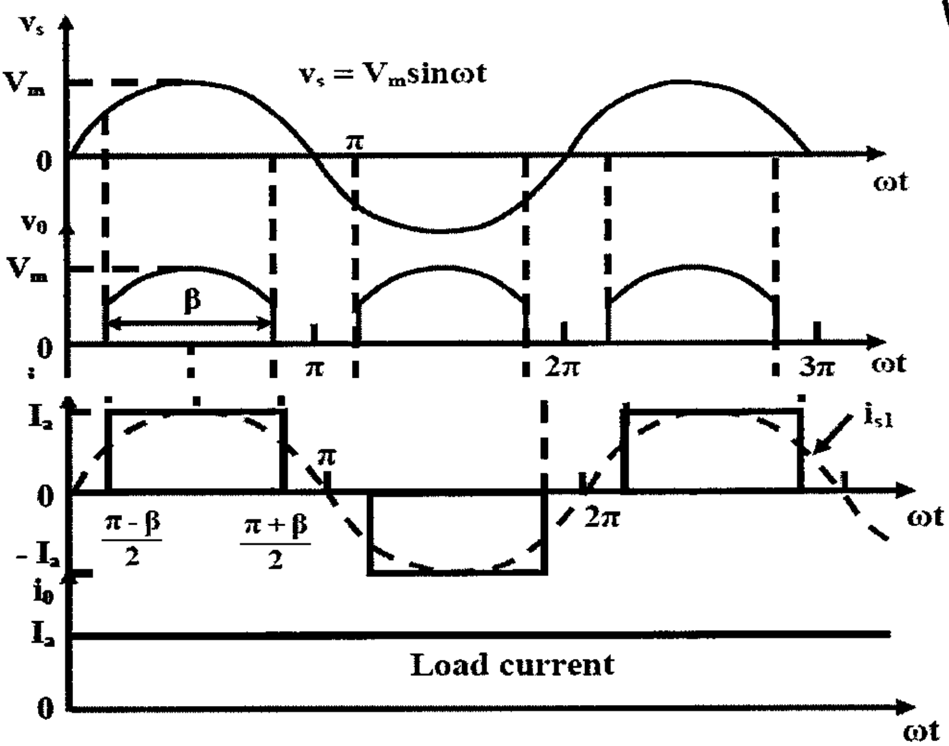


Fig no:6

Waveform for symmetrical angle control

FORMULAE USED :

Average output voltage :

$$E_{dc} = (2E_m/\pi)\ (\cos \alpha)$$

Rms supply current :

$$I = I_a(1-(2\alpha/\pi))^{1/2}$$

RMS n^{th} harmonic current :

$$I_n = 2\sqrt{2}(I_a/\pi n)(\cos n\alpha) \qquad \text{where n is odd}$$

Displacement angle :

$$\Phi_n = \tan^{-1} 0 = 0^0$$

Supply power factor :

$$P_F = \{(2\sqrt{2}\cos\alpha)/\pi\}(1-2\alpha/\pi)^{1/2}$$

Displacement factor :

$$D_F = \cos 0 = 1$$

Harmonic factor :

$$H_F = [\,\pi(\pi-2\alpha)/8\cos^2\alpha - 1]^{1/2}$$

2.3.3 PULSE WIDTH MODULATION :

In this method the reference sine wave is compared with the carrier triangular wave and the output voltage is obtained at the corresponding switching points.If the output voltage of single phase half-controlled converter is controlled by delay angle, extinction angle or symmetrical, there is only one pulse per half cycle in the input current of the converter, and as a result, the lowest order harmonic is third. It is difficult to filter out the lower order harmonic current. In Pulse Width Modulation (PWM) control, the converter switches are turned on and off several times during a half cycle, and the output voltage is controlled by varying the width of pulses. The lowest order harmonic can be eliminated or reduced by selecting the number of pulses per half cycle. However, increasing the number of pulses would also increase the magnitude of higher order harmonics, which could easily be filtered out.

WAVEFORM :

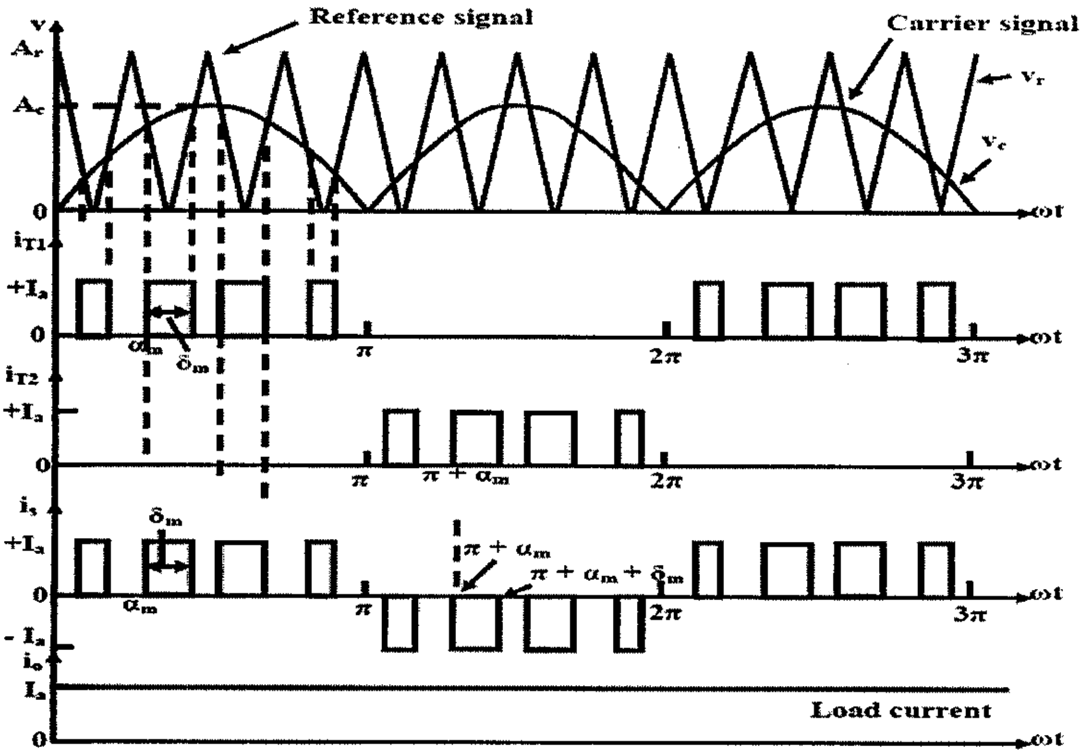


Fig no:7

Waveform for pulse width modulation

FORMULAE USED :

Average output voltage :

$$E_{dc} = (E_m/\pi)\Sigma\,(\cos\alpha - \cos\beta)$$

Rms supply current :

$$I = (I_a/\sqrt{\pi})[\Sigma(\beta-\alpha)]^{1/2}$$

RMS n^{th} harmonic current :

$$I_n = (\sqrt{2}I_a/\pi)\Sigma(\cos\alpha-\cos\beta)$$

Displacement angle :

$$\Phi_n = 0^0$$

Supply power factor :

$$P_F = (I_1/I)(\cos\Phi_1) = I_1/I$$

Displacement factor :

$$D_F = \cos 0 = 1$$

Harmonic factor :

$$H_F = [\,(I^2 - I_1^{\,2})/\,I_1^{\,2}\,]^{1/2}$$

CHAPTER 3

3. SIMULATION

3.1 PSIM:

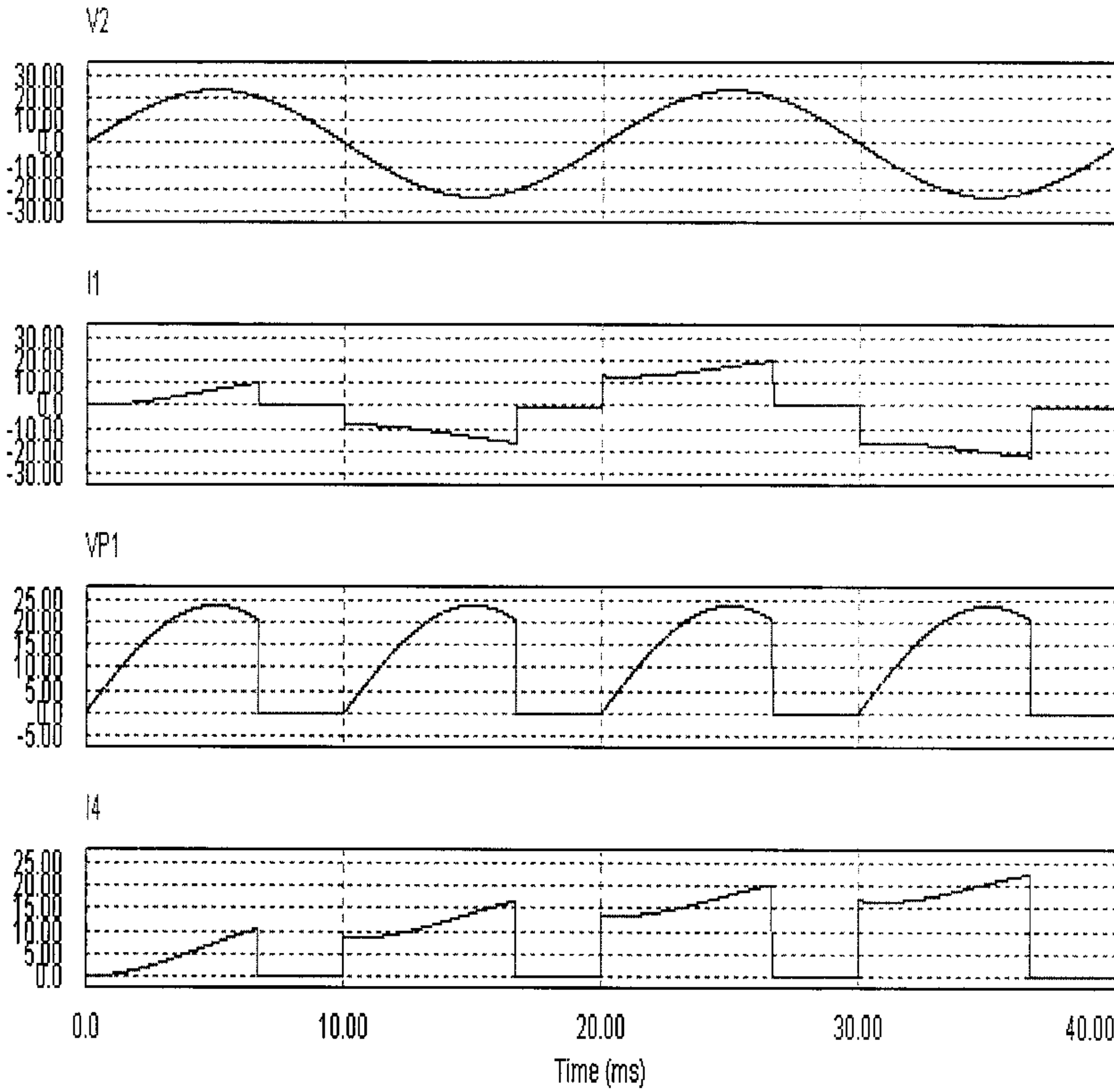
PSIM is a simulation software specifically designed for power electronics and motor drives. With fast simulation and friendly user interface, PSIM provides a powerful simulation environment for power electronics, analog and digital control, magnetics, motor drives, and dynamic system studies. In PSIM, the simulation time step is fixed throughout the simulation. In order to ensure accurate simulation results, the time step must be chosen properly. Factors that limit the time step include the switching period, widths of the pulses/waveforms, and intervals of transients. It is recommended that the time step be at least one magnitude smaller.

PSIM includes the following add-on options:

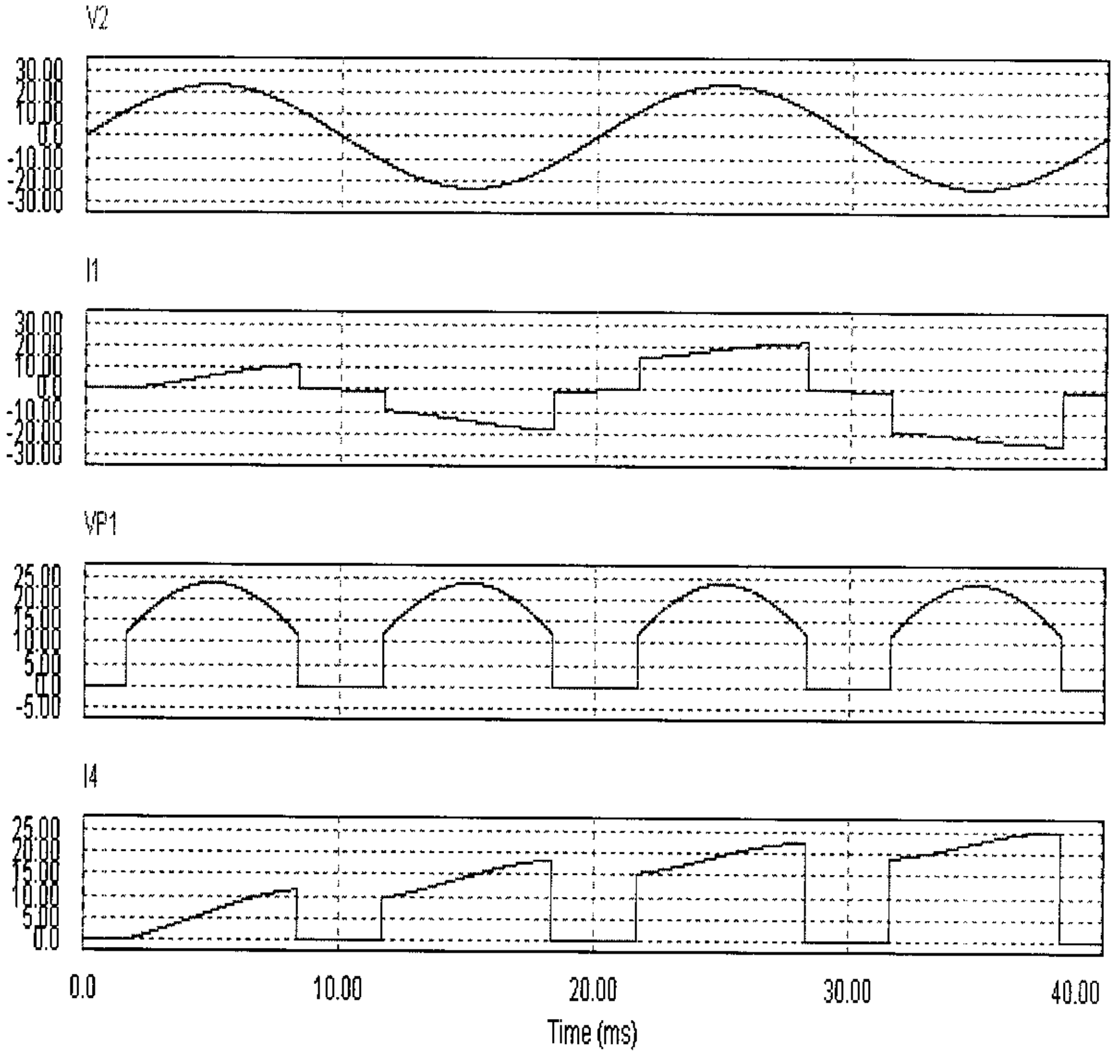
Motor drive module includes built-in electric machine models and mechanical load models for motor drive system studies. Digital control module includes z-domain discrete elements, such as zero-order hold, unit delay, z-domain transfer function blocks, digital filters, for digital control system analysis. Sim coupler module provides the interface for co-simulation between PSIM and Matlab/Simulink. Thermal module provides the capability to calculate semiconductor devices losses.

3.2 SIMULATION OUTPUT :

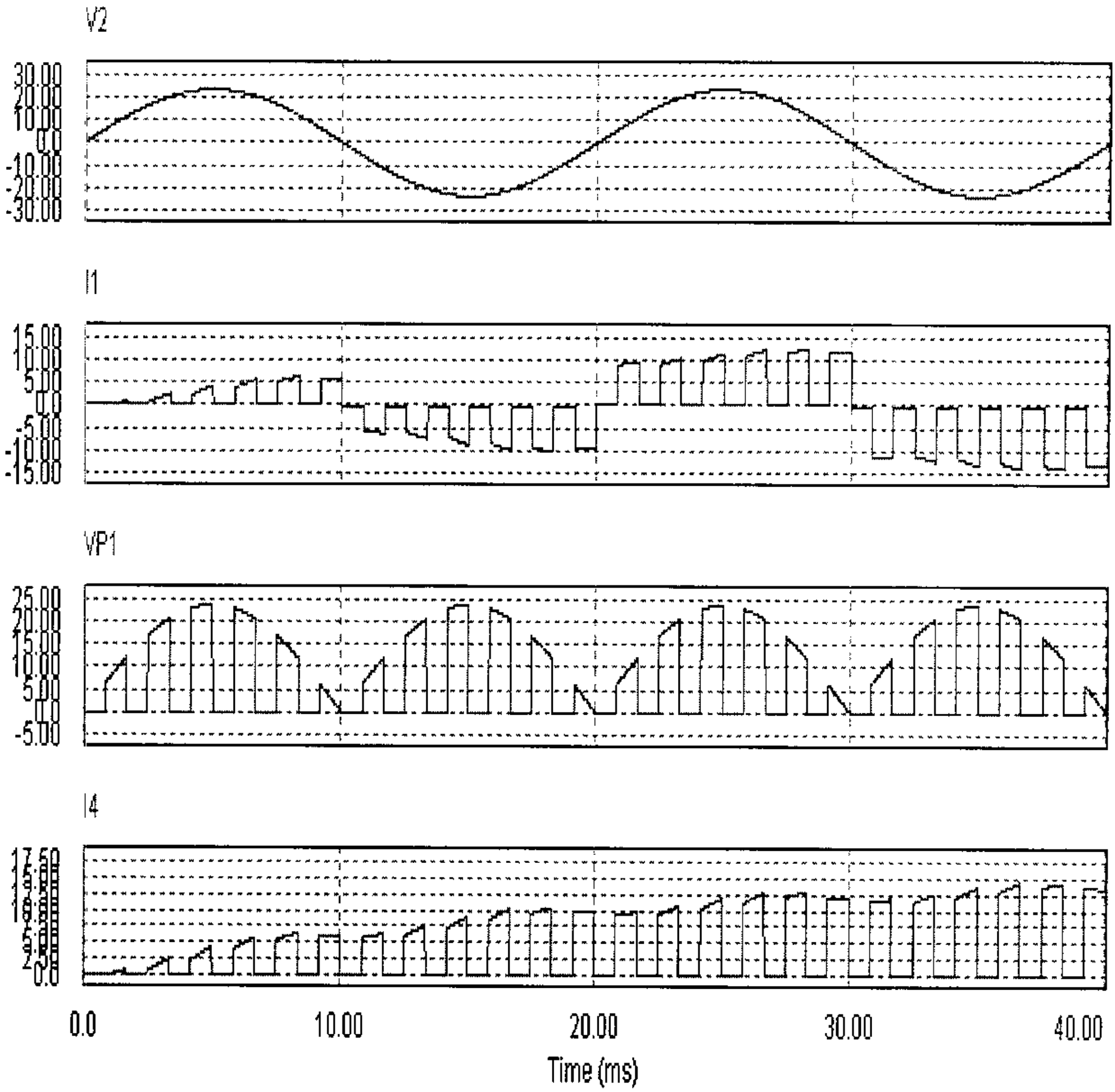
EXTINCTION ANGLE CONTROL :



SYMMETRICAL ANGLE CONTROL :



PULSE WIDTH MODULATION :



CHAPTER 4

4.PIC MICROCONTROLLER

4.1 PERIPHERAL INTERFACE CONTROLLER(PIC):

The microcontroller that has been used for this project is from PIC series. PIC microcontroller is the first RISC based microcontroller fabricated in CMOS (complimentary metal oxide semiconductor) that uses separate bus for instruction and data allowing simultaneous access of program and data memory.

The main advantage of CMOS and RISC combination is low power consumption resulting in a very small chip size with a small pin count. The main advantage of CMOS is that it has immunity to noise than other fabrication techniques.

PIC (16F877) :Various microcontrollers offer different kinds of memories. EEPROM, EPROM, FLASH etc. are some of the memories of which FLASH is the most recently developed. Technology that is used in pic16F877 is flash technology, so that data is retained even when the power is switched off. Easy Programming and Erasing are other features of PIC 16F877.

SPECIAL FEATURES OF PIC MICROCONTROLLER :

CORE FEATURES :

- High-performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed:
  - ✓ DC - 20 MHz clock input
  - ✓ DC - 200 ns instruction cycle
- Up to 8K x 14 words of Flash Program Memory,

- Up to 368 x 8 bytes of Data Memory (RAM)
- Up to 256 x 8 bytes of EEPROM data memory
- Pin out compatible to the PIC16C73/74/76/77
- Interrupt capability (up to 14 internal/external
- Eight level deep hardware stack
- Direct, indirect, and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC Oscillator for reliable operation
- Programmable code-protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low-power, high-speed CMOS EPROM/EEPROM technology
- Fully static design
- In-Circuit Serial Programming (ICSP) via two pins
- Only single 5V source needed for programming capability
- In-Circuit Debugging via two pins
- Processor read/write access to program memory
- Wide operating voltage range: 2.5V to 5.5V
- High Sink/Source Current: 25 mA
- Commercial and Industrial temperature ranges
- Low-power consumption:
  - ✓ < 2mA typical @ 5V, 4 MHz
  - ✓ < 20mA typical @ 3V, 32 kHz
  - ✓ < 1mA typical standby current

PERIPHERAL FEATURES :

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - ✓ Capture is 16-bit, max resolution is 12.5 ns,
  - ✓ Compare is 16-bit, max resolution is 200 ns,
  - ✓ PWM max. resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI. (Master Mode) and I2C. (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with
- 9- bit address detection.
- Brown-out detection circuitry **for Brown-out Reset (BOR)**

TRIGGERING CIRCUIT FOR MICROCONTROLLER :

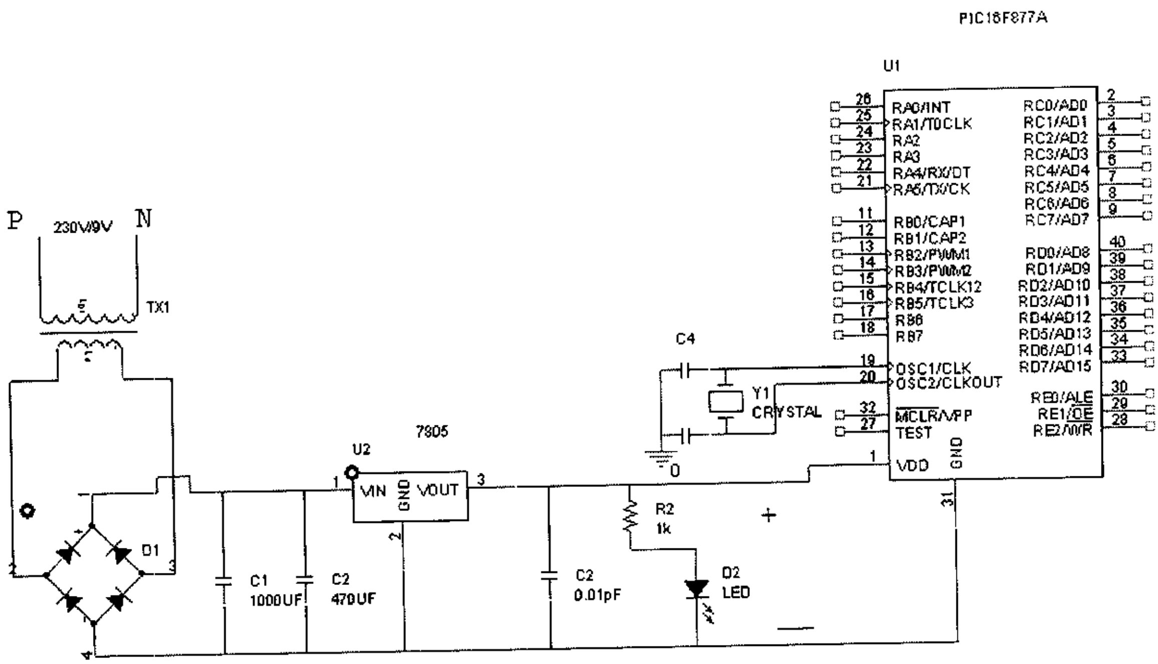


Fig no:8
Triggering circuit for microcontroller

PIN DIAGRAM OF PIC 16F877A :

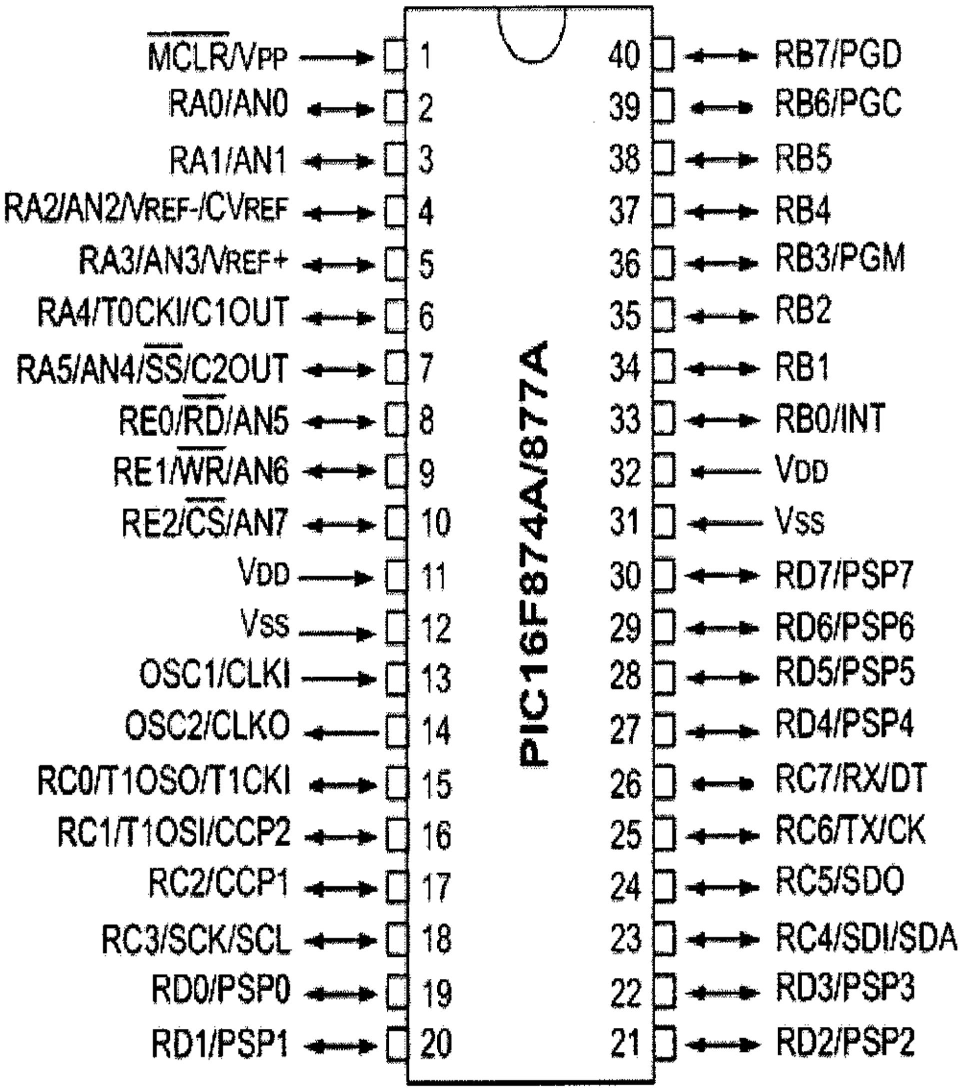


Fig no:9
Pin diagram of PIC16F877A

- It has on chip Timers. There are 3 Timers for usage
- It has in built Analog to Digital Converter
- In built Multiplexer availability for signal Selection
- It has serial as well as Parallel Communication facilities
- In built Capture, Compare and Pulse width modulation
- It has 5 Ports for Internal and External usage

4.2 SOFTWARE USED :

PIC 'C' COMPILER:

The programming for the microcontroller 16F877 is done by using this software. In this programming is prepared in 'c' language and then converted to hexa file.

WINPIC800:

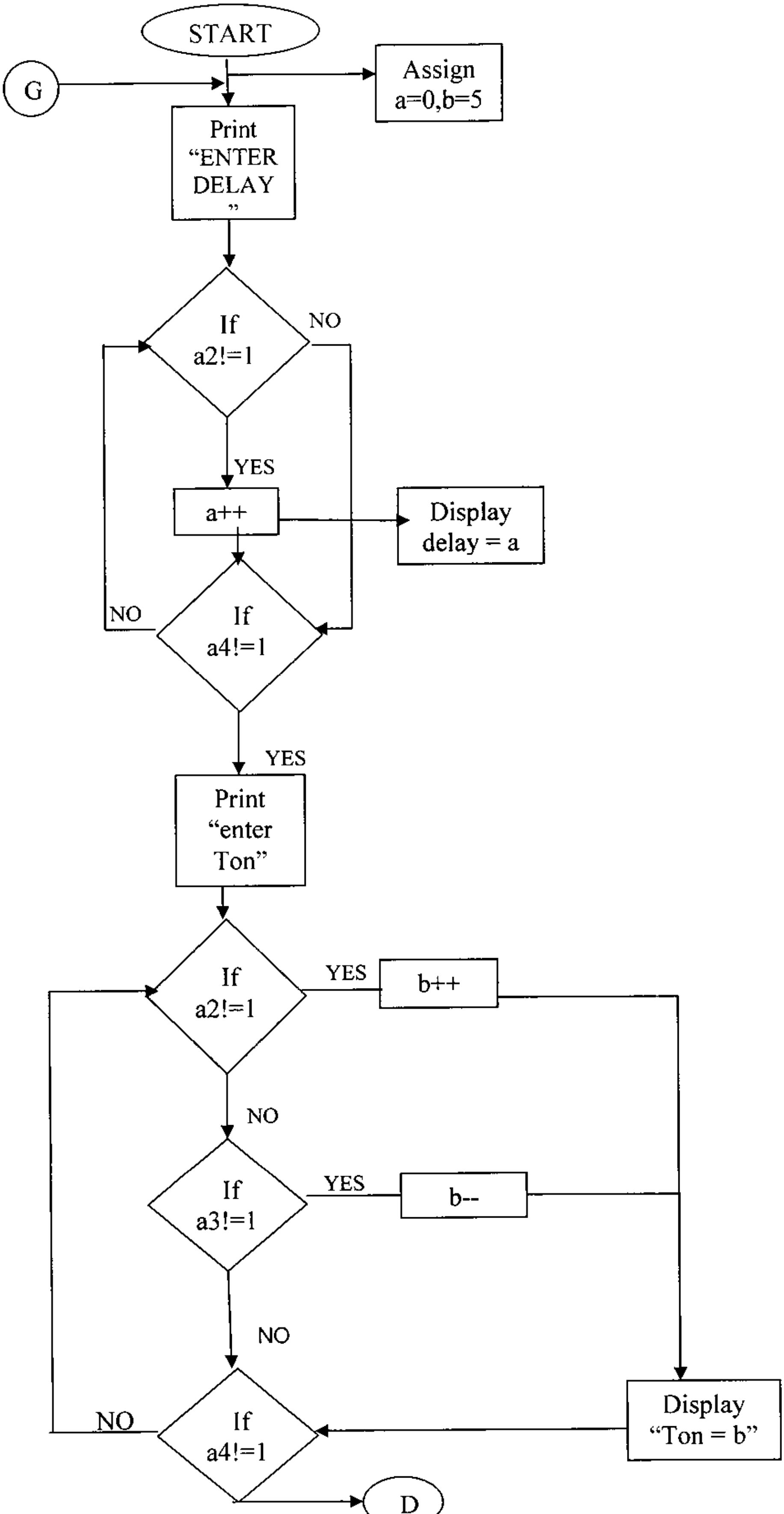
This software is used to embed the program into the microcontroller. Initially program is loaded into the software and transferred to microcontroller by using a specialized interfacing circuit.

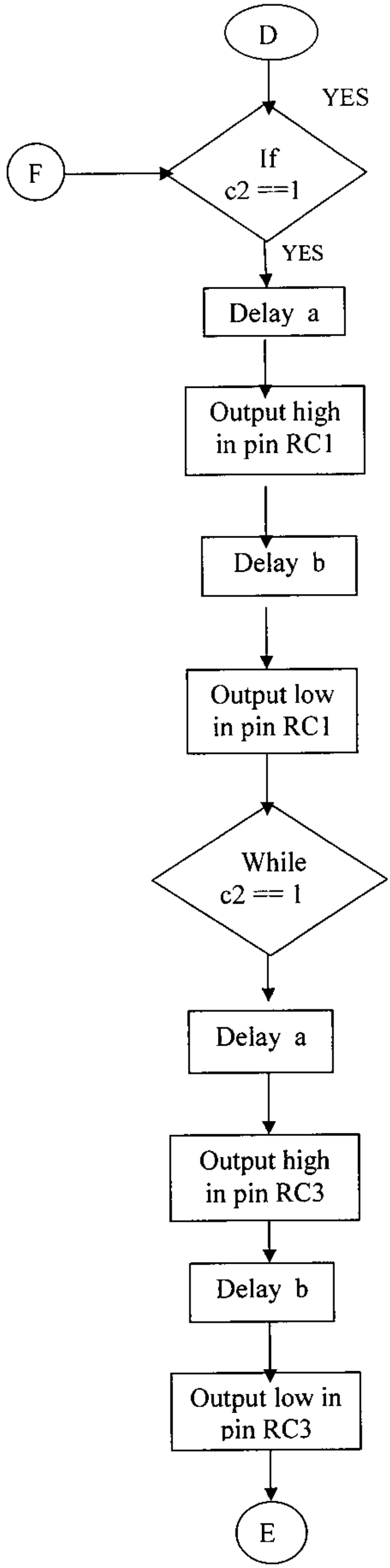
PROTEUS 7 PROFESSIONAL:

It is used to draw a complete circuit for a micro-controller based system and then test it interactively, all from within the same piece of software. Simulation done using this software is used to develop the design.

4.3 FLOWCHART :

Flowchart is the pictorial representation of algorithm. The following flowchart shows the pictorial representation of the coding involved in three methods for the supply power factor improvement techniques.


START
G
Assign
a=0,b=5
Print
"ENTER
DELAY
"
If
a2!=1
NO
YES
a++
Display
delay = a
If
a4!=1
NO
YES
Print
"enter
Ton"
If
a2!=1
YES
b++
NO
If
a3!=1
YES
b--
NO
Display
"Ton = b"
NO
If
a4!=1
D


D
YES
F
If
c2 ==1
YES
Delay a
Output high
in pin RC1
Delay b
Output low
in pin RC1
While
c2 == 1
Delay a
Output high
in pin RC3
Delay b
Output low in
pin RC3
E

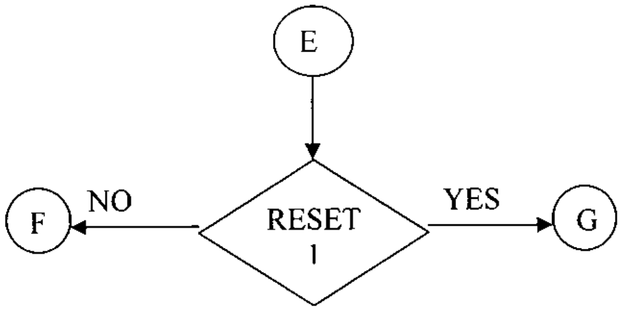


Fig no:10

Flowchart

4.4 SOFTWARE CODING :

EXTINCTION ANGLE & SYMMETRICAL ANGLE CONTROL:

```
#include "C:\Documents and Settings\PRASHANTH\Desktop\myil\power.h"
#include <stdio.h>
#include <lcd.c>
void main()
{
  int a=0;
  int b=5;
  setup_adc_ports(NO_ANALOGS);
  setup_adc(ADC_OFF);
  setup_psp(PSP_DISABLED);
  setup_spi(SPI_SS_DISABLED);
  setup_timer_0(RTCC_INTERNAL|RTCC_DIV_1);
  setup_timer_1(T1_DISABLED);
  setup_timer_2(T2_DISABLED,0,1);
  setup_comparator(NC_NC_NC_NC);
  setup_vref(FALSE);
  SET_TRIS_B(0x00);
  SET_TRIS_C(0x04);
  SET_TRIS_A(0xff);

  lcd_init();

  printf(lcd_putc,"\fEnter delay:");
  while(input(pin_a4)==1)
  {
   if(!input(pin_a2))
```

```
{
  while(!input(pin_a2));
  a++;
  printf(lcd_putc,"\fdelay: %u",a);
 }
 if(!input(pin_a3))
 {
  while(!input(pin_a3));
  if(a>0)
   {
    a--;
    printf(lcd_putc,"\fdelay:%u",a);
   }
 }
}
while(input(pin_a4)!=1);
printf(lcd_putc,"\fEnter T on:");
while(input(pin_a4)==1)
{
  if(!input(pin_a2))
  {
    while(!input(pin_a2));
    if(b<10)
    {
      b++;
      printf(lcd_putc,"\fDelay: %u",b);
    }
  }
  if(!input(pin_a3))
  {
    while(!input(pin_a3));
```

```
if(b>0)
      {
        b--;
        printf(lcd_putc,"\fDelay: %u",b);
      }
   }
 }


 while(1)
{


    if(input_state(pin_c2))
    {
       delay_ms(a);
       output_high(pin_c1);
       delay_ms(b);
       output_low(pin_c1);
       while(input_state(pin_c2));
       delay_ms(a);
       output_high(pin_c3);
       delay_ms(b);
       output_low(pin_c3);
    }



}


  // TODO: USER CODE!!
```

PULSE WIDTH MODULATION:

```
#include<pic.h>
#include<stdio.h>
#include "delay.c"

__CONFIG(0x3f71);

#define DELAY 25

unsigned char x,a=0,ON,OFF;
unsigned char getVal0(void);


void main()
{
        DelayMs(10);
        RBPU=0;
        ADCON1=0x00;
        TRISA=0x3f;
        TRISC=0x00;
        TRISB=0x01;
        INTE=1;
        GIE=1;
        INTF=0;
while(1)
{
        x=getVal0();
        ON =x/10;
        OFF=DELAY-ON;
```

```
	if(a==1)
	{
		PORTC=0x0c;
		DelayMs(ON);
		PORTC=0x00;
		DelayMs(OFF);
	}
	else
	{
		PORTC=0x03;
		DelayMs(ON);
		PORTC=0x00;
		DelayMs(OFF);
	}
}
}

unsigned char getVal0()

{
	unsigned char temp;
	ADCON0=0x49;
	ADGO=1;
	while(ADGO==1);
	temp=ADRESH;
	return temp;

}
```

```
void interrupt dc(void)
{
        if(INTF==1)
        {
        INTF=0;
        a=1;
        }
}
```

CHAPTER 5

5. HARDWARE IMPLEMENTATION :

5.1 PIC SIMULATION CIRCUIT:

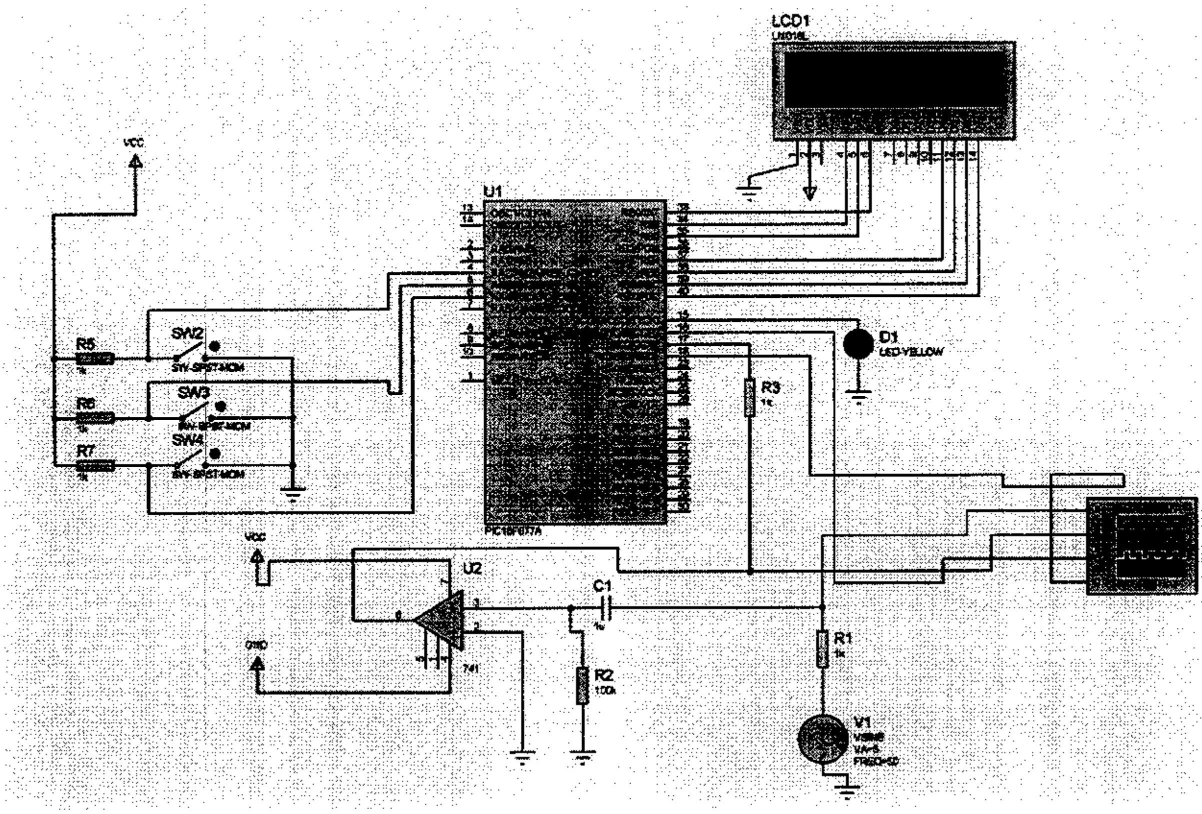


Fig no:11
PIC simulation circuit

5.2 INPUT AND OUTPUT PORT:

Port A is used as input port. Three push switches are used in the input side. When the switch is pushed, it ground corresponding pin. Pin RA2 is connected to the switch which is used to increase the delay value. Pin RA3 is used to decrease the delay value. The switch connected to the Pin RA4 is used as enter. When the enter switch is pressed, value of delay and turn ON period are assigned.

Pin RC2 is used as input pin. The output from zero crossing detector is given to this pin. When the value from ZCD is high pulse is generated and this pulse is taken from output pin.

LCD is connected to the controller through the port B. LCD is used to display the value of delay and turn ON time of pulse generated.

Port C is used as output port. The output is taken from the Pin RC1 and RC3. These outputs are given to the driver circuit.

5.3 ZERO CROSSING DETECTOR:

This circuit is used to detect the zero crossing of input supply. This circuit compares the input AC and ground potential value. Whenever the input supply crosses the ground level, it generates the pulse. These pulses are given to the microcontroller and that generate the pulses from zero position of the input supply. IC741 Operational amplifier is used for zero crossing detector.

5.4 SNUBBER CIRCUIT DESIGN:

Snubber is used to prevent the IGBT from transient over voltages. It is turn on snubber which used to avoid the transient voltages. RC circuit acts as low pass filter for voltage transient. The capacitor acts as short and it absorbs voltage transient.

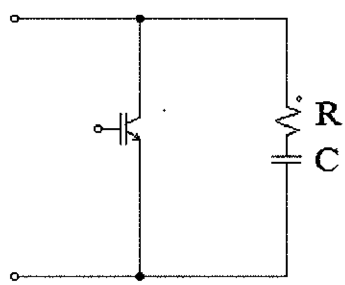


Fig no:12

Snubber Circuit

Let V_m is peak value of supply voltage.

L(source inductance)=0.2mH.

dV/dt=60V/μsec(data sheet).

$\sigma = \text{dampingfactor} = 0.65$

$C = (1/2L)(0.564V_m/(dV/dt))^2$
$= 0.023pF.$

$R = 2\sigma(L/C)^{1/2}$
$= 121\ k\Omega$

5.5 LOAD (DC MOTOR)

Brushed DC motors are widely used in applications ranging from toys to push-button adjustable car seats. Brushed DC motors are inexpensive, easy to drive, and are readily available in all sizes and shapes.

PRINCIPLES OF OPERATION

The construction of a simple BDC motor is shown in Figure 1. All BDC motors are made of the same basic components: a stator, rotor, brushes and a commutator. The following paragraphs will explain each component in greater detail.

STATOR

The stator generates a stationary magnetic field that surrounds the rotor. This field is generated by either permanent magnets or electromagnetic windings. The different types of BDC motors are distinguished by the construction of the stator or the way the electromagnetic windings are connected to the power source.

ROTOR

The rotor, also called the armature, is made up of one or more windings. When these windings are energized they produce a magnetic field. The magnetic poles of this rotor field will be attracted to the opposite poles generated by the stator, causing the rotor to turn. As the motor turns, the windings are constantly being energized in a different sequence so that the magnetic poles generated by the rotor do not overrun the poles generated in the stator. This switching of the field in the rotor windings is called commutation.

BRUSHES AND COMMUTATOR

Unlike other electric motor types (i.e., brushless DC, AC induction), BDC motors do not require a controller to switch current in the motor windings. Instead, the commutation of the windings of a BDC motor is done mechanically. A segmented copper sleeve, called a commutator, resides on the axle of a BDC motor. As the motor turns, carbon brushes slide over the commutator, coming in contact with different segments of the commutator. The segments are attached to different rotor windings, therefore, a dynamic magnetic field is generated inside the motor when a voltage is applied across the brushes of the motor. It is important to note that the brushes and commutator are the parts of a BDC motor that are most prone to wear because they are sliding past each other.

5.6 HARDWARE SETUP :

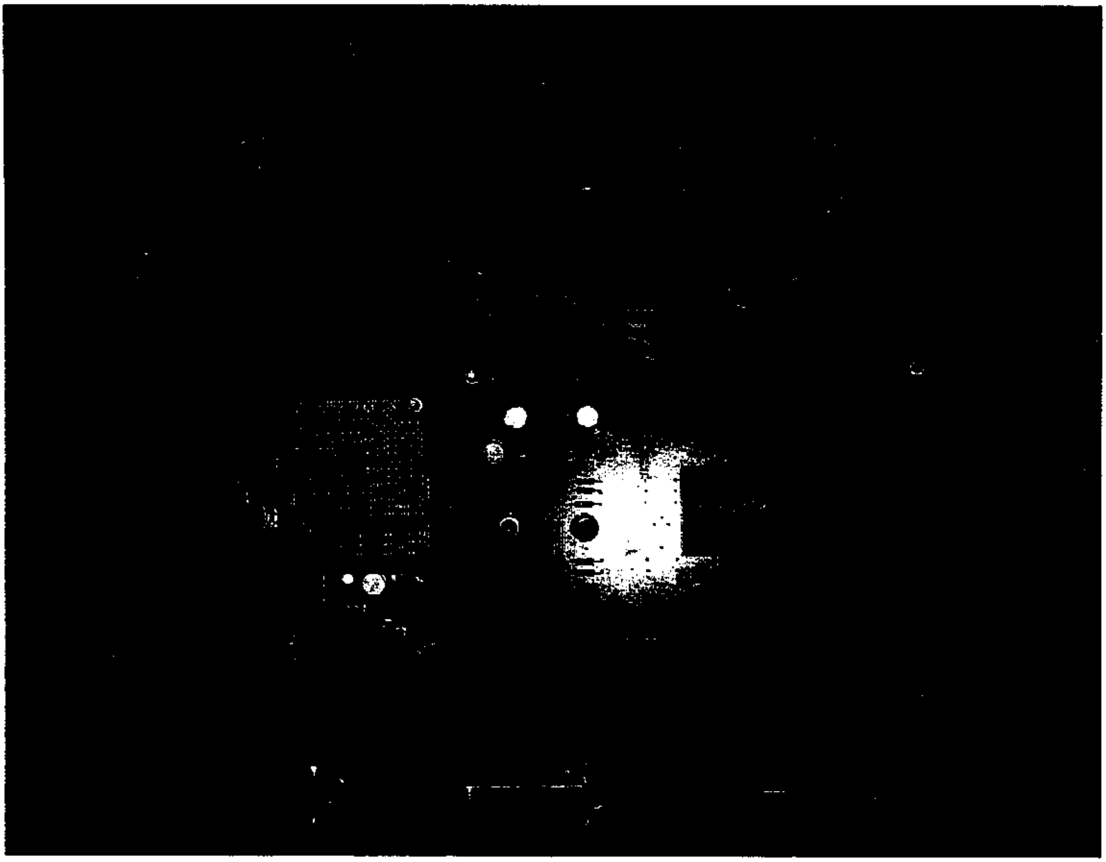


Fig no:13

Hardware setup

The Step down transformer (230/24V) is used to give supply to the power circuit. The step down transformer (230/12V) is used to give supply to the control circuit and driver circuit. The gate pulse for IGBT is generated using PIC Microcontroller. The output voltage of the microcontroller is 5V which is not sufficient to drive IGBT and therefore driver circuit is used to amplify the gate pulse of the PIC from 5V to 12V. DC series motor is used as a load.

5.7 CRO OUTPUT WAVEFORM FOR PWM TECHNIQUE :

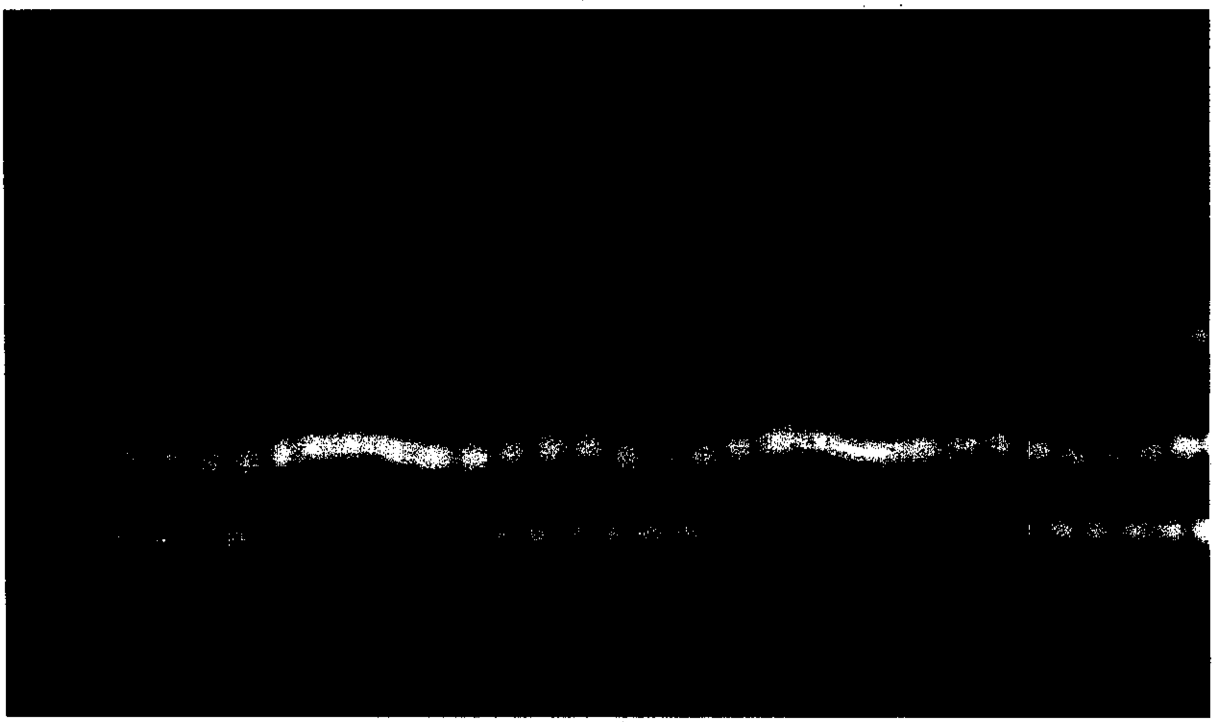


Fig no:14

CRO output waveform for PWM technique

CHAPTER 6

6. ANALYSIS

6.1 THEORITICAL ANALYSIS :

EXTINCTION ANGLE CONTROL :

Ia = 0.5A

Edc = 15.67V

Edc = (Em/π) (1-cosβ)

β = 116.7

Irms(supply) = Ia ($\sqrt{\beta/\pi}$)

= 0.4026A

Is(fund) = [(2$\sqrt{2}$ (0.5))/π] sin(β /2)

= 0.383A

DPF = sin(β/2) = 0.8513

DF = (Is(fund) / Irms) = 0.95

HF = $\sqrt{((1/DF^2) - 1)}$ = 32.86%

PF = DF * DPF = 0.8087

SYMMETRICAL ANGLE CONTROL :

Ia = 0.5A

Edc = 15.67V

Edc = (Em/π) cosα

α = 43.54

Irms(supply) = Ia (1-(2(α/π) $)^{1/2}$

= 0.359A

Is(fund) = [(2$\sqrt{2}$ (0.5))/π] cosα

= 0.326

DPF = 1

$DF = (Is(fund) / Irms) = 0.909$

$HF = \sqrt{((1/DF^2) - 1)} = 45.80\%$

PF = DF * DPF = 0.91

PWM TECHNIQUE :

$\alpha 1 = 10^0$

$\beta 1 = 36^0$

$\alpha 2 = 46^0$

$\beta 2 = 72^0$

$\alpha 3 = 82^0$

$\beta 3 = 108^0$

$\alpha 4 = 118^0$

$\beta 4 = 144^0$

$\alpha 5 = 154^0$

$\beta 5 = 180^0$

$E_{dc} = 15.67V$

(i) $Is(rms) = (Ia/\sqrt{180})(\beta 1 - \alpha 1 + \beta 2 - \alpha 2 + \beta 3 - \alpha 3)^{1/2}$

$= (0.5/\sqrt{180})(11.40)$

$= 0.4248A$

(ii) $Is(fund) = (\sqrt{2}/\pi)(0.5(1.45))$

$= 0.3265A$

(iii) $DPF = \cos\Phi_1 = 1$ (unity)

(iv) $DF = Is(fund) / Is(rms) = 0.3265/0.4248 = 0.7685$

(v) $HF = \sqrt{(1/DF^2)} - 1$

$= 0.8326$

(vi) **PF = DF * DPF = 0.7685**

6.2 ANALYSIS TABLE :

METHODS	I_{rms}	DPF	DF	HF	PF
EAC	0.4026	0.8513	0.95	0.3286	0.8087
SAC	0.359	1	0.909	0.458	0.91
PWM	0.4248	1	0.7685	0.8326	0.7685

6.3 COMPARISON :

As per the above table, the supply power factor is high in Symmetrical angle control technique. The current drawn by this technique is less when compared to other techniques. Thus the reactive power consumption is reduced and the supply power factor is improved.

CHAPTER 7

7. CONCLUSION

7.1 CONCLUSION AND FUTURE SCOPE :

The comparative analysis of techniques for the improvement of power factor in converters was under taken in this project. The results were obtained through simulation. Also, a hardware implementation was done for the pulse width modulation technique.

According to theoretical analysis, symmetrical angle method is most suitable for improving the supply power factor. Pulse width modulation technique is implemented and found that the reactive power consumption is reduced and the supply power factor is improved when compared to normally used delay angle method.

This method can be implemented in full bridge rectifiers and three phase rectifiers. They can also be used for high power applications. These techniques can be implemented in inverters.

7.2 APPLICATIONS :

- It is used to improve the supply power factor in industrial loads.
- It is used as a drive for dc motor.
- It is used for traction purposes such as locomotive drives and trams.
- It is used in HVDC transmission.
- It is used in lift.

REFERENCES

REFERENCES :

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[2] Nabil A. Ahmed' and Emad H. El-Zohri,IEEE, "POWER FACTOR IMPROVEMENT OF SINGLE_PHASE AC VOLTAGE CONTROLLER EMPLOYING EXTINCTION ANGLE CONTROL TECHNIQUE",VOL.13,NO.3, OCT 2004.

[3] E.L.M. Mehl and I.Barbi , "An improved high power factor and low cost single phase rectifier,"IEEE TRANS.IND.APPLICANt.,VOL.33,NO2, pp.485-492, MAR/APR 1977.

[4] Power electronics, by M.D.Singh.

[5] Power electronics, by Rashid.

APPENDIX

APPENDIX :

PIN OUT DESCRIPTION :

Pin Name	DIP Pin#	SOIC Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKIN	9	9	I	ST/CMOS(3)	Oscillator crystal input/external clock source input.
OSC2/CLKOUT	10	10	O	—	Oscillator crystal output. Connects to crystal or resonator in crystal oscillator mode. In RC mode, the OSC2 pin outputs CLKOUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate.
$\overline{MCLR}$/VPP/THV	1	1	I/P	ST	Master clear (reset) input or programming voltage input or high voltage test mode control. This pin is an active low reset to the device.
					PORTA is a bi-directional I/O port.
RA0/AN0	2	2	I/O	TTL	RA0 can also be analog input0
RA1/AN1	3	3	I/O	TTL	RA1 can also be analog input1
RA2/AN2/VREF-	4	4	I/O	TTL	RA2 can also be analog input2 or negative analog reference voltage
RA3/AN3/VREF+	5	5	I/O	TTL	RA3 can also be analog input3 or positive analog reference voltage
RA4/T0CKI	6	6	I/O	ST	RA4 can also be the clock input to the Timer0 module. Output is open drain type.
RA5/$\overline{SS}$/AN4	7	7	I/O	TTL	RA5 can also be analog input4 or the slave select for the synchronous serial port.
					PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	21	21	I/O	TTL/ST(1)	RB0 can also be the external interrupt pin.
RB1	22	22	I/O	TTL	
RB2	23	23	I/O	TTL	
RB3/PGM	24	24	I/O	TTL	RB3 can also be the low voltage programming input
RB4	25	25	I/O	TTL	Interrupt on change pin.
RB5	26	26	I/O	TTL	Interrupt on change pin.
RB6/PGC	27	27	I/O	TTL/ST(2)	Interrupt on change pin or In-Circuit Debugger pin. Serial programming clock.
RB7/PGD	28	28	I/O	TTL/ST(2)	Interrupt on change pin or In-Circuit Debugger pin. Serial programming data.
					PORTC is a bi-directional I/O port.
RC0/T1OSO/T1CKI	11	11	I/O	ST	RC0 can also be the Timer1 oscillator output or Timer1 clock input.
RC1/T1OSI/CCP2	12	12	I/O	ST	RC1 can also be the Timer1 oscillator input or Capture2 input/Compare2 output/PWM2 output.
RC2/CCP1	13	13	I/O	ST	RC2 can also be the Capture1 input/Compare1 output/PWM1 output.
RC3/SCK/SCL	14	14	I/O	ST	RC3 can also be the synchronous serial clock input/output for both SPI and I^2C modes.
RC4/SDI/SDA	15	15	I/O	ST	RC4 can also be the SPI Data In (SPI mode) or data I/O (I^2C mode).
RC5/SDO	16	16	I/O	ST	RC5 can also be the SPI Data Out (SPI mode).
RC6/TX/CK	17	17	I/O	ST	RC6 can also be the USART Asynchronous Transmit or Synchronous Clock.
RC7/RX/DT	18	18	I/O	ST	RC7 can also be the USART Asynchronous Receive or Synchronous Data.
VSS	8, 19	8, 19	P	—	Ground reference for logic and I/O pins.
VDD	20	20	P	—	Positive supply for logic and I/O pins.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in serial programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKIN	13	14	30	I	ST/CMOS(4)	Oscillator crystal input/external clock source input.
OSC2/CLKOUT	14	15	31	O	—	Oscillator crystal output. Connects to crystal or resonator in crystal oscillator mode. In RC mode, OSC2 pin outputs CLK-OUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate.
$\overline{MCLR}$/VPP/THV	1	2	18	I/P	ST	Master clear (reset) input or programming voltage input or high voltage test mode control. This pin is an active low reset to the device.
						PORTA is a bi-directional I/O port.
RA0/AN0	2	3	19	I/O	TTL	RA0 can also be analog input0
RA1/AN1	3	4	20	I/O	TTL	RA1 can also be analog input1
RA2/AN2/VREF-	4	5	21	I/O	TTL	RA2 can also be analog input2 or negative analog reference voltage
RA3/AN3/VREF+	5	6	22	I/O	TTL	RA3 can also be analog input3 or positive analog reference voltage
RA4/T0CKI	6	7	23	I/O	ST	RA4 can also be the clock input to the Timer0 timer/counter. Output is open drain type.
RA5/$\overline{SS}$/AN4	7	8	24	I/O	TTL	RA5 can also be analog input4 or the slave select for the synchronous serial port.
						PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	33	36	8	I/O	TTL/ST(1)	RB0 can also be the external interrupt pin.
RB1	34	37	9	I/O	TTL	
RB2	35	38	10	I/O	TTL	
RB3/PGM	36	39	11	I/O	TTL	RB3 can also be the low voltage programming input
RB4	37	41	14	I/O	TTL	Interrupt on change pin.
RB5	38	42	15	I/O	TTL	Interrupt on change pin.
RB6/PGC	39	43	16	I/O	TTL/ST(2)	Interrupt on change pin or In-Circuit Debugger pin. Serial programming clock.
RB7/PGD	40	44	17	I/O	TTL/ST(2)	Interrupt on change pin or In-Circuit Debugger pin. Serial programming data.
						PORTC is a bi-directional I/O port.
RC0/T1OSO/T1CKI	15	16	32	I/O	ST	RC0 can also be the Timer1 oscillator output or a Timer1 clock input.
RC1/T1OSI/CCP2	16	18	35	I/O	ST	RC1 can also be the Timer1 oscillator input or Capture2 input/Compare2 output/PWM2 output.
RC2/CCP1	17	19	36	I/O	ST	RC2 can also be the Capture1 input/Compare1 output/PWM1 output.
RC3/SCK/SCL	18	20	37	I/O	ST	RC3 can also be the synchronous serial clock input/output for both SPI and I^{2}C modes.
RC4/SDI/SDA	23	25	42	I/O	ST	RC4 can also be the SPI Data In (SPI mode) or data I/O (I^{2}C mode).
RC5/SDO	24	26	43	I/O	ST	RC5 can also be the SPI Data Out (SPI mode).
RC6/TX/CK	25	27	44	I/O	ST	RC6 can also be the USART Asynchronous Transmit or Synchronous Clock.
RC7/RX/DT	26	29	1	I/O	ST	RC7 can also be the USART Asynchronous Receive or Synchronous Data.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as an external interrupt.
2: This buffer is a Schmitt Trigger input when used in serial programming mode.
3: This buffer is a Schmitt Trigger input when configured as general purpose I/O and a TTL input when used in the Parallel Slave Port mode (for interfacing to a microprocessor bus).
4: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

NPN switching transistors 2N2222; 2N2222A

FEATURES

- High current (max. 800 mA)
- Low voltage (max. 40 V).

APPLICATIONS

- Linear amplification and switching.

DESCRIPTION

NPN switching transistor in a TO-18 metal package.
PNP complement: 2N2907A.

PINNING

PIN	DESCRIPTION
1	emitter
2	base
3	collector, connected to case

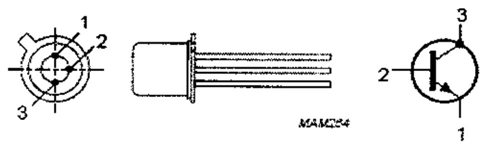

Fig.1 Simplified outline (TO-18) and symbol.

QUICK REFERENCE DATA

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{CBO}	collector-base voltage	open emitter			
	2N2222		–	60	V
	2N2222A		–	75	V
V_{CEO}	collector-emitter voltage	open base			
	2N2222		–	30	V
	2N2222A		–	40	V
I_C	collector current (DC)		–	800	mA
P_{tot}	total power dissipation	$T_{amb} \leq 25$ °C	–	500	mW
h_{FE}	DC current gain	$I_C = 10$ mA; $V_{CE} = 10$ V	75	–	
f_T	transition frequency	$I_C = 20$ mA; $V_{CE} = 20$ V; f = 100 MHz			
	2N2222		250	–	MHz
	2N2222A		300	–	MHz
t_{off}	turn-off time	$I_{Con} = 150$ mA; $I_{Bon} = 15$ mA; $I_{Boff} = -15$ mA	–	250	ns

LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 134).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{CBO}	collector-base voltage	open emitter			
	2N2222		–	60	V
	2N2222A		–	75	V
V_{CEO}	collector-emitter voltage	open base			
	2N2222		–	30	V
	2N2222A		–	40	V
V_{EBO}	emitter-base voltage	open collector			
	2N2222		–	5	V
	2N2222A		–	6	V
I_C	collector current (DC)		–	800	mA
I_{CM}	peak collector current		–	800	mA
I_{BM}	peak base current		–	200	mA
P_{tot}	total power dissipation	$T_{amb} \leq 25$ °C	–	500	mW
		$T_{case} \leq 25$ °C	–	1.2	W
T_{stg}	storage temperature		–65	+150	°C
T_j	junction temperature		–	200	°C
T_{amb}	operating ambient temperature		–65	+150	°C

THERMAL CHARACTERISTICS

SYMBOL	PARAMETER	CONDITIONS	VALUE	UNIT
$R_{th\ j\text{-}a}$	thermal resistance from junction to ambient	in free air	350	K/W
$R_{th\ j\text{-}c}$	thermal resistance from junction to case		146	K/W

CHARACTERISTICS

T_j = 25 °C unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
I_{CBO}	collector cut-off current				
	2N2222	$I_E = 0$; $V_{CB} = 50$ V	–	10	nA
		$I_E = 0$; $V_{CB} = 50$ V; $T_{amb} = 150$ °C	–	10	μA
I_{CBO}	collector cut-off current				
	2N2222A	$I_E = 0$; $V_{CB} = 60$ V	–	10	nA
		$I_E = 0$; $V_{CB} = 60$ V; $T_{amb} = 150$ °C	–	10	μA
I_{EBO}	emitter cut-off current	$I_C = 0$; $V_{EB} = 3$ V	–	10	nA
h_{FE}	DC current gain	$I_C = 0.1$ mA; $V_{CE} = 10$ V	35	–	
		$I_C = 1$ mA; $V_{CE} = 10$ V	50	–	
		$I_C = 10$ mA; $V_{CE} = 10$ V	75	–	
		$I_C = 150$ mA; $V_{CE} = 1$ V; note 1	50	–	
		$I_C = 150$ mA; $V_{CE} = 10$ V; note 1	100	300	
h_{FE}	DC current gain	$I_C = 10$ mA; $V_{CE} = 10$ V; $T_{amb} = -55$ °C			
	2N2222A		35	–	
h_{FE}	DC current gain	$I_C = 500$ mA; $V_{CE} = 10$ V; note 1			
	2N2222		30	–	
	2N2222A		40	–	
V_{CEsat}	collector-emitter saturation voltage				
	2N2222	$I_C = 150$ mA; $I_B = 15$ mA; note 1	–	400	mV
		$I_C = 500$ mA; $I_B = 50$ mA; note 1	–	1.6	V
V_{CEsat}	collector-emitter saturation voltage				
	2N2222A	$I_C = 150$ mA; $I_B = 15$ mA; note 1	–	300	mV
		$I_C = 500$ mA; $I_B = 50$ mA; note 1	–	1	V
V_{BEsat}	base-emitter saturation voltage				
	2N2222	$I_C = 150$ mA; $I_B = 15$ mA; note 1	–	1.3	V
		$I_C = 500$ mA; $I_B = 50$ mA; note 1	–	2.6	V
V_{BEsat}	base-emitter saturation voltage				
	2N2222A	$I_C = 150$ mA; $I_B = 15$ mA; note 1	0.6	1.2	V
		$I_C = 500$ mA; $I_B = 50$ mA; note 1	–	2	V
C_c	collector capacitance	$I_E = i_e = 0$; $V_{CB} = 10$ V; f = 1 MHz	–	8	pF
C_e	emitter capacitance	$I_C = i_c = 0$; $V_{EB} = 500$ mV; f = 1 MHz			
	2N2222A		–	25	pF
f_T	transition frequency	$I_C = 20$ mA; $V_{CE} = 20$ V; f = 100 MHz			
	2N2222		250	–	MHz
	2N2222A		300	–	MHz
F	noise figure	$I_C = 200$ μA; $V_{CE} = 5$ V; $R_S = 2$ kΩ;			
	2N2222A	f = 1 kHz; B = 200 Hz	–	4	dB

CT60AM-18F

INSULATED GATE BIPOLAR TRANSISTOR

ELECTRICAL CHARACTERISTICS (Tch = 25°C)

Symbol	Parameter	Test conditions	Limits			Unit
			Min.	Typ.	Max.	
I_{CES}	Collector-emitter leakage current	V_{CE} = 900V, V_{GE} = 0V	—	—	1.0	mA
I_{GES}	Gate-emitter leakage current	V_{GE} = ±20V, V_{CE} = 0V	—	—	0.5	µA
$V_{GE(th)}$	Gate-emitter threshold voltage	V_{CE} = 10V, I_C = 6mA	2.0	4.0	6.0	V
$V_{CE(sat)}$	Collector-emitter saturation voltage	I_C = 60A, V_{GE} = 15V	—	2.1	2.7	V
C_{ies}	Input capacitance	V_{CE} = 25V, V_{GE} = 0V, f = 1MHz	—	4400	—	pF
C_{oes}	Output capacitance		—	115	—	pF
C_{res}	Reverse transfer capacitance		—	75	—	pF
$t_{d(on)}$	Turn-on delay time	V_{CC} = 300V, I_C = 60A, V_{GE} = 15V, R_G = 10Ω	—	0.05	—	µs
t_r	Turn-on rise time		—	0.1	—	µs
$t_{d(off)}$	Turn-off delay time		—	0.2	—	µs
t_f	Turn-off fall time		—	0.3	—	µs
E_{tail}	Tail loss	I_{CP} = 60A, T_j = 125°C, dv/dt = 200V/µs		0.6	1.0	mJ/pls
I_{tail}	Tail current			6.0	12	A
V_{EC}	Emitter-collector voltage	I_E = 60A, V_{GE} = 0V	—	2.2	3.0	V
t_{rr}	Diode reverse recovery time	I_E = 60A, dis/dt = −20A/µs	—	0.5	2.0	µs
$R_{th(j-c)}$	Thermal resistance (IGBT)	Junction to case	—	—	0.69	°C/W
$R_{th(j-c)}$	Thermal resistance (Diode)	Junction to case	—	—	4.0	°C/W

MAXIMUM RATINGS (Tc = 25°C)

Symbol	Parameter	Conditions	Ratings	Unit
V_{CES}	Collector-Emitter Voltage	V_{GE} = 0V	900	V
V_{GES}	Gate-Emitter Voltage		±25	V
V_{GEM}	Peak Gate-Emitter Voltage		±30	V
I_C	Collector Current		60	A
I_{CM}	Collector Current (Pulse)		120	A
I_E	Emitter Current		40	A
P_C	Maximum Power Dissipation		180	W
T_j	Junction Temperature		−40 ~ +150	°C
T_{stg}	Storage Temperature		−40 ~ +150	°C