

# Microcontroller based PWM Inverter for Speed Control of a Three Phase Induction Motor

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## ABSTRACT

Three phase induction motor has proven to be an extremely reliable electromechanical energy conversion device for over 100 years. The speed control of induction motor is a crying need for the real world industrial applications. However, there are so many options available for the precise speed control of induction motor except by changing the frequency. Therefore to achieve the goal of speed control of induction motor, there is no alternative of inverters. With the availability of high speed power semiconductor devices, the three phase inverters play the key role for variable speed ac motor drives. In addition to the speed control, the inverter can also provide some unique features, like voltage control, torque control, power factor correction, auto breaking, built in protection system and so forth. In this paper, a three phases PWM inverter using MC3PHAC microcontroller with computer interface is proposed to run a squirrel case induction motor. Some results of the proposed inverter are presented.

**Keywords:** Induction motor, Inverter, Speed control, PWM, MC3PHAC microcontroller

## 1. INTRODUCTION

Industrial drives are predom inantly ac motors of induction type. An estimated 67 percents of ac motors are induction motors, whereas dc motors occupy only 8 percents of the industrial drives [1]. Induction motors are relatively cheap, simple in construction and can be used in hostile environment [2]. The widespread proliferation of power electronics and ancillary control circuits into motor control system in the past two or three decades have led to a situation where motor drives, which process about two third of the worlds electric power into mechanical power, are on the threshold of processing all of the power via power electronics. The days of driving motors directly from the fixed ac or dc mains via mechanical adjustment are over. The ever increasing demand for greater productivity and higher quality of most of the industrial products that we used in our everyday lives means that all aspect of dynamic response and accuracy of motor drives have to be inc reased. Issue of energy efficiency and harmonics proliferation into the supply grid are also increasingly affecting the choices for motor drives circuitry [3].

Induction motor with squirrel-case rotors are the workhorses of industry because of their low c ost and rugged construction [4-5]. Speed co ntrol of i nduction motor is a c rying need i n industrial application. By changing the frequency, speed of induction motor can be controlled precisely. Therefore, to achieve the goal of speed control of induction motor there is no alternative of inverters. Moreover, inverter not only control the speed of induction motor but it has also some unique features like voltage control, torque control, power factor correction, auto breaking, built in protection system etc. The core of a power electronic apparatus consists of a converter built on a matrix of power semiconductor switching devices that works under the guidance of control electronics [6-8].

With the availability of high speed power semiconductor devices, the three phase inverter play the key role for variable speed ac motor drives. In this paper, a Microcontroller based three phase Pulse Width Modulation (PWM) inverter with necessary control circuits to run a three phase squirrel-case induction motor is presented. Some results and constructed circuits [9] are also presented.

The paper is organized as follows. The Section 2 shows the three phase VSI topology. The Section 3 describes the algorithm of control system. The Section 4 highlights some experimental results and finally some concluding remarks are drawn in the Section 5.

## 2. THREE PHASE VSI TOPOLOGY

The standard three phase voltage source inverters (VSI) is shown in fig. 1. It should be noted that the switches of any leg of the inverter ( $S_1$  and  $S_4$ ,  $S_3$  and  $S_6$ , or  $S_5$  and  $S_2$ ) can not be switched on simultaneously because these would result in a short circuit across the dc supply voltage.

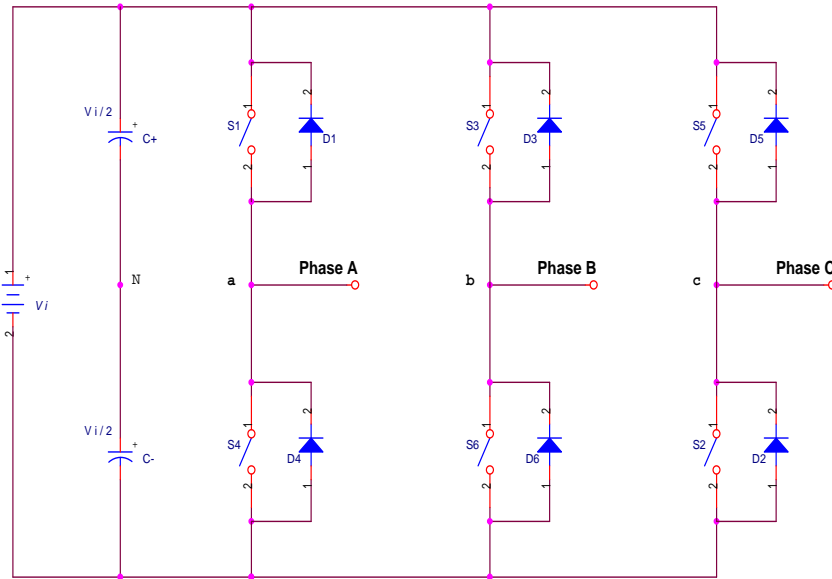


Fig. 1: Three-phase VSI topology

The six valid switch states that produce non-zero ac output voltage of three phase inverter is shown in table 1. In order to generate a given voltage waveform, the inverter moves from one state to another. The resultant ac output line voltages consist of discrete values of voltages that are  $v_i$ , 0, and  $-v_i$  for the topology shown in Fig. 1.

Table 1: Valid switch states for a three phase voltage source inverter.

Switch State	State No.	$V_{ab}$	$V_{bc}$	$V_{ca}$	Space Vector
$S_1, S_2$ and $S_6$ are on and $S_4, S_5$ and $S_3$ are off.	1	$v_i$	0	$-v_i$	$V_1=1+j0.577$
$S_2, S_3$ and $S_1$ are on and $S_5, S_6$ and $S_4$ are off.	2	0	$v_i$	$-v_i$	$V_2=j1.155$
$S_3, S_4$ and $S_2$ are on and $S_6, S_1$ and $S_5$ are off.	3	$-v_i$	$v_i$	0	$V_3=-1+j0.577$
$S_4, S_5$ and $S_3$ are on and $S_1, S_2$ and $S_6$ are off.	4	$-v_i$	0	$v_i$	$V_4=-1-j0.577$
$S_5, S_6$ and $S_4$ are on and $S_2, S_3$ and $S_1$ are off.	5	0	$-v_i$	$v_i$	$V_5=-j1.155$
$S_6, S_1$ and $S_5$ are on and $S_3, S_4$ and $S_2$ are off.	6	$v_i$	$-v_i$	0	$V_6=1-j0.577$

The selection of states in order to generate the given waveform is done by the modulating technique that ensures the use of only the valid states. In order to produce  $120^\circ$  out of phase load voltages, three modulating signals that are  $120^\circ$  out of phase are used. Fig. 2 shows the ideal waveforms of three phase VSI SPWM.

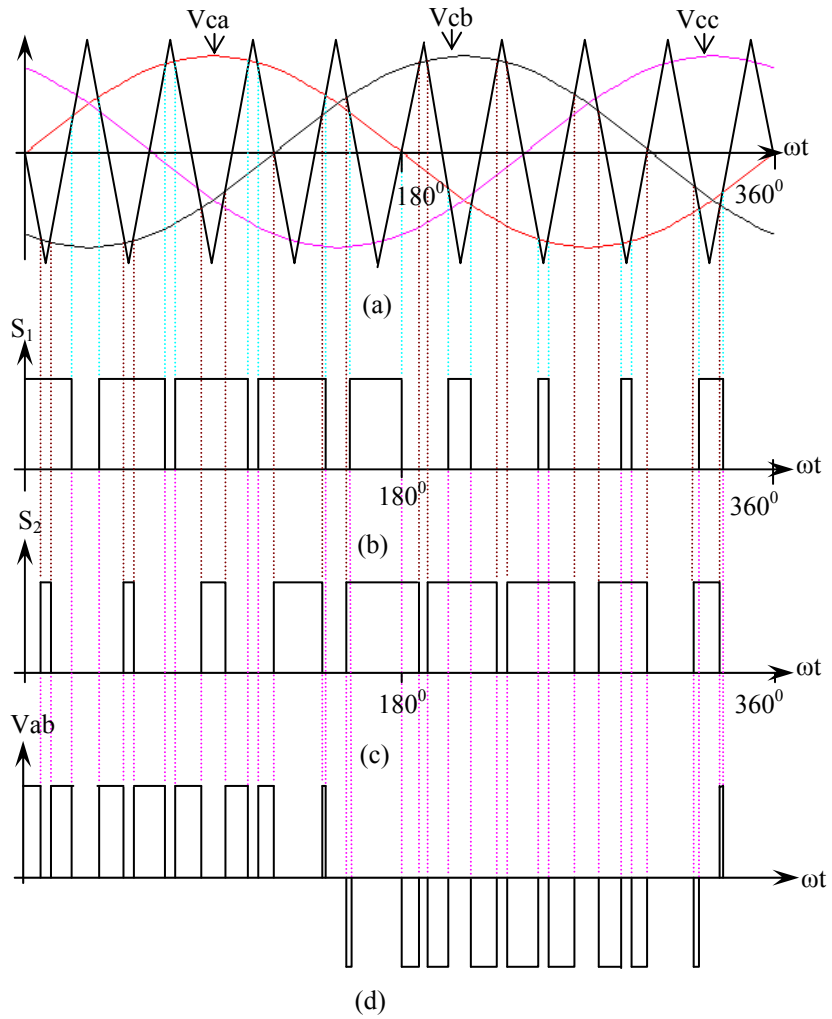


Fig. 2: Three phase VSI ideal waveform for the SPWM, (a) carrier and modulating signals, (b) switch  $S_1$  state, (c) switch  $S_2$  state and (d) ac output voltage.

### 3. CONTROL SYSTEM

The block diagram of proposed inverter is shown in Fig. 3. The main parts of the inverter are power part, opto-coupler, control part and computer interfacing.

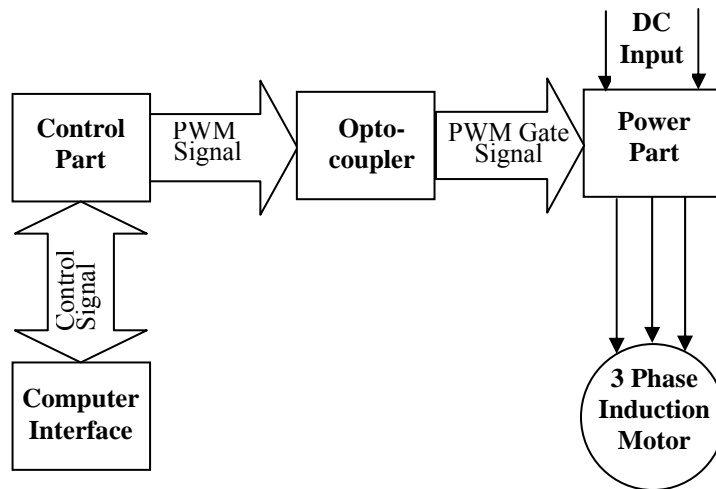


Fig. 3: Block diagram of proposed inverter.

### 3.1 Power Part

The main component of the power part is the power MOSFETs. Six free wheeling diodes one with each MOSFET is used for the bypass of back e.m.f. The schematic diagram of the power part is shown in Fig. 4. The input dc voltage of the power part is supplied from a three phase rectifier. We need four separate grounds for the operation of inverter for upper MOSFETs (one for each) and one for lower MOSFETs along with six PWM signals. We make these grounds available along with respective gate signals through opto coupler.

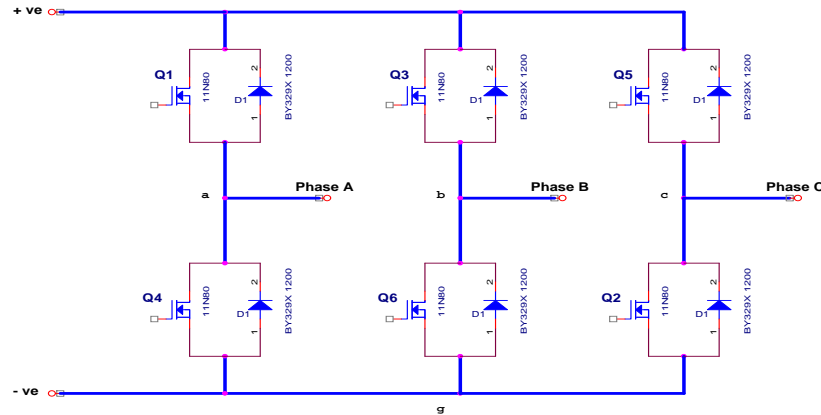


Fig. 4: Schematic of power part of inverter.

### 3.2 Opto-Coupler

The main objective of opto-coupler is to make an electrical isolation between high voltage power part and low voltage control part. Opto-coupler also performs the following two important functions:

- Increase the amplitude of PWM signal to desired level keeping the signal width and phase same.
- Manage the four separate grounds with respective PWM signal for the operation of power MOSFET.

The schematic of a single channel of opto-coupler part is shown if Fig. 5.

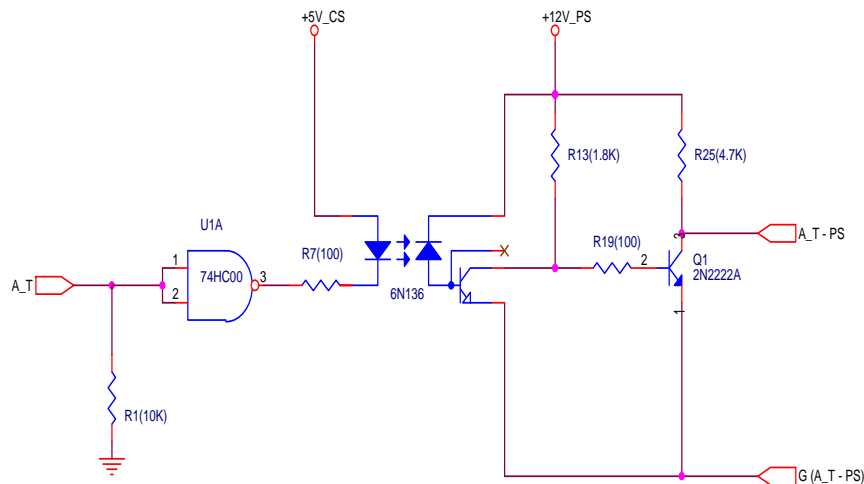


Fig. 5: Schematic of a single channel of Opto-coupler.

### 3.3 Control Part

The main component of the control part is the microcontroller MC3PHAC. The main objective of using microcontroller is to produce 3-phase PWM waveform. We can configure this microcontroller in two modes viz. host mode or computer mode and stand alone mode. In stand alone mode MC3PHAC can be controlled with switches and can be configured with variable resistors. But in host mode or computer mode we can control MC3PHAC with software and can configure it with the software. Also in computer mode we can easily measure the various values like actual speed, frequency, modulation index, bus voltage etc. directly. In this work we configure MC3PHAC as host mode or computer mode. The configuration of MC3PHAC in host mode is shown in Fig. 6.

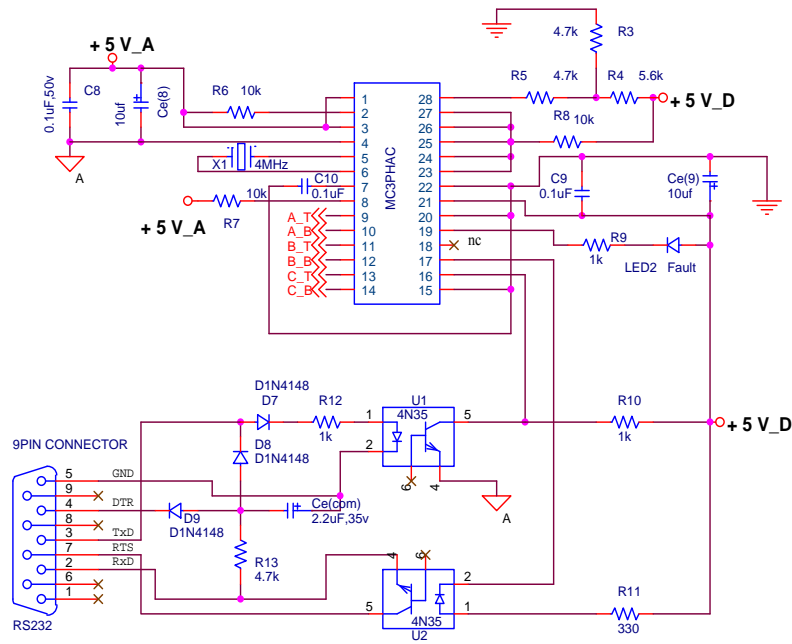


Fig. 6: Schematic of control part of inverter.

### 3.4 Computer Interface

The circuit shown in Fig. 7 is the schematic of a half duplex opto-isolated RS232 interface. The isolated terminal interface provides a margin of safety between the motor control system and a personal computer. To send data from a PC to the MC3PHA C microcontroller, it is necessary to satisfy the serial input of the MC3PHAC. In the idle condition, the serial input of the MC3PHAC must be at logic 1. To send data from MC3PHAC to PC's serial port input, it is necessary to satisfy the PC's receive data (RxD) input requirements. For the satisfy of the serial inputs of the MC3PHAC and the RxD input to the PC, transistors U1 and U2 are used.

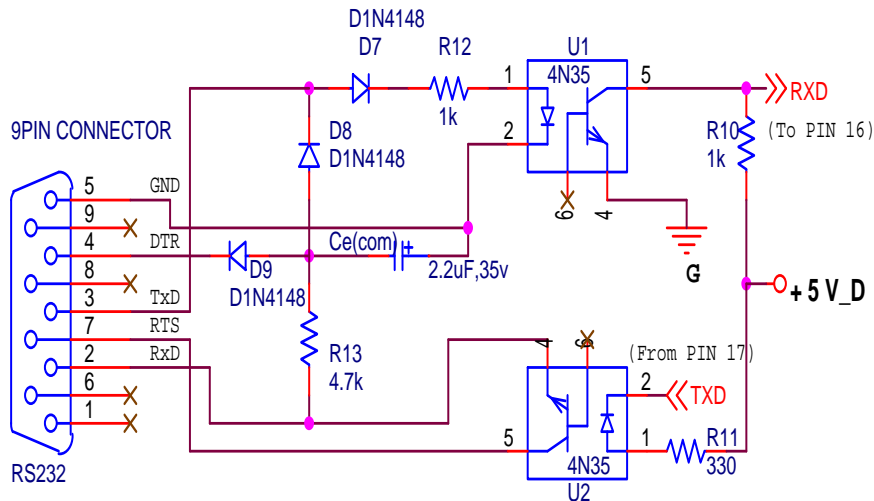


Fig. 7: Opto-isolated RS232 interface.

### 3.5 Power Supply for Control Part

The schematic for power supply to the control part is shown in Fig. 8. It is designed with a full wave bridge along with a 5 volts regulator IC MC7805. The specialty of this circuit is that we can get two type of power supply from this circuit. One is 5 volts digital power supply and another is 5 volts analog power supply. MC3PHAC is a mixed signal IC. It has an analog portion and a digital portion. Digital power supply is required for digital portion and analog power supply is required for analog portion, which include internal clock generation circuit, phase-look loop (PLL) and analog to digital converter. The digital power supply is labeled as +5V\_D and analog power supply is labeled as +5V\_A.

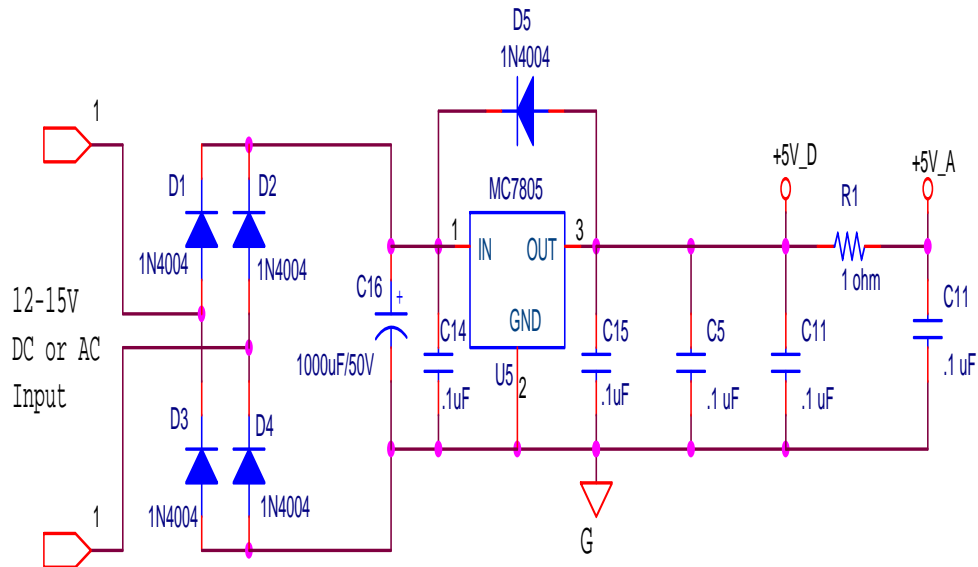


Fig. 8: Schematic for power supply circuit.

#### 4. RESULTS AND DISCUSIONS

In experiment, a three-phase 415 volts 1 H.P. squirrel case induction motor was used as the load. For controlling the proposed inverter in host mode or computer mode, special software called Free Master or PC master software was used. For controlling the MC3PHAC IC a special demo version of Free Master or PC master software called “MC3PHAC Motor Control Demo” was used. Almost all the functions required to control a three phase induction motor viz. start/stop, reverse/forward run, acceleration (Hz/sec), selection of base frequency, PWM frequency, actual frequency, dead time, modulation index etc. are available in this demo version. Additionally, a built in oscilloscope is available in this demo version.

The PWM signal and output voltage waveform of proposed inverter is shown in Fig. 9.

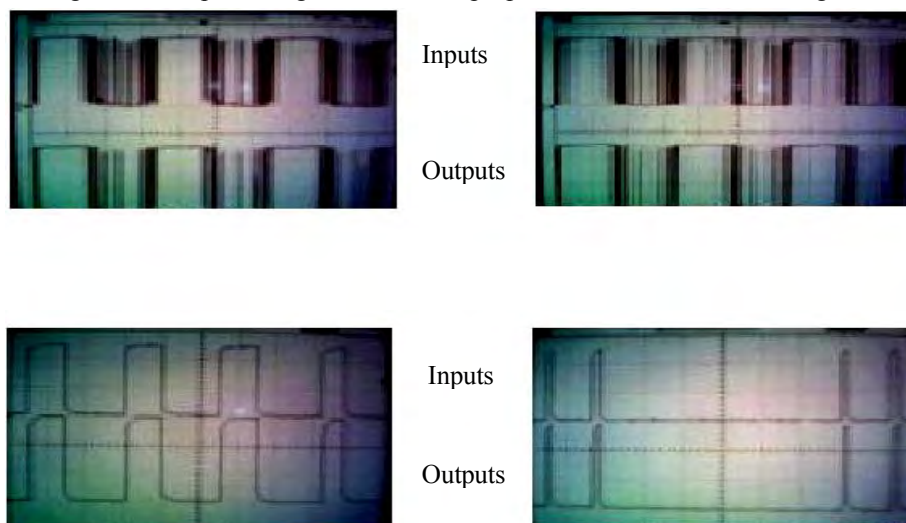


Fig. 9: PWM signal at the input and output of opto-coupler.

Some experimental results of the proposed inverter for speed control of induction motor are shown in Fig. 10. This oscilloscope shows the real time graphical representation of various quantities like actual frequency, commanded frequency, modulation index, bus voltage etc.

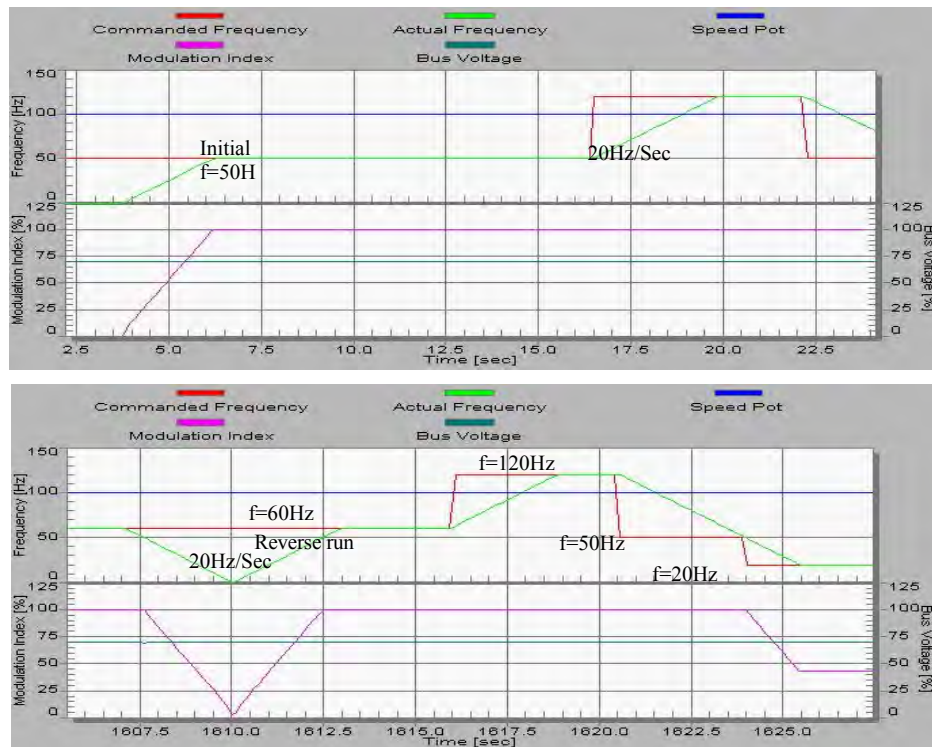


Fig. 10: Oscilloscope view of speed response of proposed inverter.

## 5. CONCLUSION

The main objective of this project work is to design and construct a three phase SPWM inverter controlled by microcontroller and necessary control circuit to run a three phase squirrel cage induction motor. From the theoretical and practical results the following conclusions can be made:

1. A good agreement between the experimental setup and theoretical model suggested that the constructed inverter is accurate enough.
2. Variation of frequency and thus the speed of the motor can be controlled smoothly; the frequency can set any value between 0 Hz to 127 Hz.
3. Motor acceleration or deceleration can be controlled from 0.5 Hz/Sec. to 128 Hz/Sec. and can change the direction of motor at any time.
4. The constructed inverter is equally applicable for 50 Hz and 60 Hz base frequency.
5. It is possible to change the modulation index and voltage boost both in online and off line therefore it is possible to control the output voltage.
6. PWM frequency can be changed at four presentable values viz. 5.3 KHz, 10.6 KHz, 15.9 KHz and 21.1 KHz and can be changed at any time.
7. It is possible to adjust PWM polarity and can adjust the dead time at any value between 0 to 31875 ns.
8. It is possible to monitor the dc bus voltage of the inverter.
9. There is the facility of resistive braking, fault monitoring etc. in the proposed circuit.

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