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DsPIC33fj32mc204 Based Low Input Voltage AC Motor Driver Design and Implementation

*1Tolga Özer, 2Sinan Kıvrak and 3Yüksel Oğuz
1Afyon Kocatepe University Technology Faculty, Afyonkarahisar, Turkey
2Ankara Yıldırım Beyazıt University Faculty of Engineering and Natural Sciences, Ankara, Turkey
3Afyon Kocatepe University Technology Faculty, Afyonkarahisar, Turkey

Abstract

Asynchronous machines are commonly preferred at industrial systems. These kinds of machines present variable speed excitation systems due to their low cost, high durability. And they don't need to maintenance requirements and not contain brushes and collectors. But asynchronous machines, control are complex. Methods such as changing the number of poles, varying stator voltage or frequency are usually used to change the speed of the motor. Frequency changing ensures that the motor remains at the maximum torque value during speed control. For this reason, the voltage/frequency (V/f) ratio (or flux) is kept approximately constant. In this study, the speed of the asynchronous motor was controlled by changing the stator frequency. For this purpose, inverter and control circuits are designed and implemented at one PCB (Printed Circuit Board) card. SMT (Surface Mounted Technique) circuit technique was used at this work. A 3-phase variable frequency voltage was obtained by using an SMT designed inverter circuit with using MOSFET semiconductor elements. The power circuit is designed using 3 NPN type and 3 PNP type MOSFETs. The most important feature of this used circuit topology is reduce the number of independent power sources. The designed AC driver can be used for 12-18V input voltage range of three phase asynchronous motors. This study the AC driver is used for 90W asynchronous motor and drive at 12V and 18V variable input voltage values. The dsPIC33fj32mc204 microcontroller was used as a controller to achieve variable frequency and speed control.

Key words: Microcontroller, dsPIC, AC driver, Volts per Hertz control (V/f) method, SMT Card

1. Introduction

Asynchronous motors are generally preferred because of their advantages in industrial systems. In industrial systems, the motors are required to be controlled at different speeds so variable speed excitation systems are used in many industrial applications [1-4]. Despite advantages of asynchronous machines, control process is complex. Asynchronous motor speed control vector control method is applied because it gives better dynamic response in many studies. However scalar control method has a simple structure compared to vector control because of its easy to apply and low residual error [5]. For this reason, the control of voltage / frequency (V/f) constant in scalar control systems has a wide range of applications in industrial applications. For, computer or DSP (Digital Signal Processor) based hardware systems are widely used for experimental application but these systems are expensive. Microcontrollers have low cost and flexibility so they are preferred for industrial purposes [6]. For this reason, the dsPIC33fj32mc204 microcontroller is used for speed control of the asynchronous motor in the study. This controller can be used for three-phase asynchronous motor control applications.
In 2001, B.S. Cunha and others Produced Sinusoidal PWM (Pulse Width Modulation) signals.

*Corresponding author: Address: Afyon Kocatepe University Technology Faculty, Afyonkarahisar, Turkey. E-mail address: tolgaozzer@gmail.com

These signals produced by using a PIC microcontroller (PIC16C73A) and PWM signals used for drive an inverter. Designed inverter circuit controlled a single-phase asynchronous motor. PWM signals are produced by different amplitudes and frequencies. Simulation and experimental study of the system were performed at different loads and the change in speed was observed. [7]. In 2003, Rakesh Parekh from Microchip made some examples of the use of PIC16F7X7 microcontrollers in V/f control in 3-phase asynchronous motors. He stated that the used microcontroller had 3 PWM modules and explained using them to produce sinusoidal PWM signals for a 3-phase asynchronous motor [8]. In 2009, Abdulkadir Cakir and others were done a study using a PIC16F84 microcontroller related with 3-phase asynchronous motor constant V/f speed control [9]. In 2012 Sandip A. Waskar and others conducted simulation and experiment on speed control of dsPIC based SPWM controlled 3-phase asynchronous motor. The scalar control method, V/f ratio control, is implemented using fuzzy logic algorithm [10]. In 2014, Amogh Jain B. and Smt. S. Poornima were studied on dsPIC approach for the V/f control of three-phase induction motor. Speed control of motor is acquired with the accuracy of ±15rpm and 98% accuracy of speed control is recorded [11].
In this study, asynchronous motor drive design was performed by means of Proteus program. Designed driver can be used between 12-18V range. The PWM signals required for the three phases are obtained by the dsPIC33fj32mc204 microprocessor. During the implementation step, 24V, 90W and 1500 rpm characteristics a three-phase asynchronous motor was used. The V/f motor control technique has been successfully implemented in the speed and torque control of a three-phase asynchronous motor.

2. THREE-PHASE ASYNCHRONOUS MOTORS CONTROL

Asynchronous motors are preferred generally at industrial applications because they do not require much maintenance, their speed is not affected much by load changes, and their cost is low.

2.1. V/f Control of Asynchronous Motors

The change in the number of revolutions together with the increase or decrease of the load connected to the asynchronous motors has led to the need to control the motor's rotational momentum in industrial applications. By increasing the torque when the load increases and decreasing the torque when the load is reduced, the motor can be operated at constant speed. This torque control can be done by keeping the amplitude and frequency of the applied voltage on the asynchronous motor at a certain rate. The motor speed can be controlled by increasing or decreasing the motor frequency without deteriorating the voltage/frequency ratio. In addition, with the voltage/frequency ratio constant, the current drawn by the motor is also limited. The moment of the three-phase asynchronous motor is given in (1).

$$M = \frac{P_{mek}}{\omega_r} \tag{1}$$

In equation (1), M moment (Nm) is the output power of the P_{mek} motor (Watts), and ω_r is the angular velocity of the rotor (rad/s). Keeping the voltage and frequency ratio constant keeps the current constant. Thus, overcurrent is prevented from asynchronous motors under load, and more efficient operation is ensured.

3. MICROCONTROLLER

Microcontrollers commonly used at the industry application because of their low cost and high performance. Along with the use of microcontrollers instead of analog control elements in electronic circuit designs, it is possible to get rid of many circuit elements and hardware changes with the written algorithms. In recent years PIC and dsPIC microcontrollers generally used as a microcontroller at circuit applications.

3.1. dsPIC Microcontroller

The dsPIC microcontrollers, which combine the control features of microcontrollers with the computational and efficient operation of DSPs into an embedded system, were marketed by Microchip firm in 2005.

3.2. DsPIC33fj32mc204 Microcontroller

The dsPIC33fj32mc204 is a 16-bit microcontroller with a RISC architecture that was marketed and updated in 2005 by Microchip. Some technical features of dsPIC33fj32mc204 are presented in Table I.

TABLE I. Features of dsPIC33fj32mc204

MEMORY	MOTOR CONTROL PWM MODULE	ANALOG FEATURES
32 KB Flash	6 PWM output channels	10 bit analog-to-digital converter
2K SRAM	Run PWM outputs in independent or complementary mode	500 Ksps conversion rate
3 x 16 bit timer/ counter	3 "Duty Cycle" producers	9 analog input channels
	Dead time setting for complementary mode	

The dsPIC33fj32mc204 is mainly used in the drive of three-phase asynchronous motors, uninterruptible power supplies, brushless DC (BLDC) motors and switched reluctance motor drive circuits. The dsPIC's motor control PWM module and encoder module are designed to be used in these areas.

3.3. Motor Control PWM Module and Dead Time Module

Independent PWM signals are generally used for driving multi-phase motors such as asynchronous motors, BLDC motors at variable speeds. The PWM outputs can be used in stand-alone mode or in complementary mode. In complementary mode, the PWM output pairs are produced as opposed to each other and the switching of the upper and lower arms in the driver circuits with semiconductor switching can be done.

The PWM period of the motor control PWM module of the dsPIC microcontroller is calculated according to the formula in (2) [12].

$$PTPER = \frac{F_{cy}}{F_{PWM} \times (PTMR\ Prescaler)} - 1 \quad (2)$$

In equation (2), PTPER is the recorder where the period will be saved, F_{CY} is microcontroller clock frequency, F_{PWM} is the desired PWM frequency, and the PTMR prescaler is specified as the scale of the PWM timer.

When the motor control PWM module is used in the complementary mode, the dead time generator is designed to prevent the lower and upper semiconductor elements from being in the same conduction..The dead time calculation formula for the dsPIC motor control PWM module is given in (3).

$$DT = \frac{Dead\ Time}{Prescalevalue \times T_{cy}} \quad (3)$$

Equation (3) shows the Tcy is microcontroller time period, Dead time is the value of dead time as microseconds, Prescale value is the value of time period, and DT the value to be written to the dead time register.

4. IMPLEMENTATION OF VARIABLE VOLTAGE AND FREQUENCY AC DRIVE SYSTEM

4.1. System Overview

The basic block schematic of three-phase induction motor drive is shown in Fig.1. The system has DC source, three-phase full bridge inverter circuit, control circuit and three-phase asynchronous motors. In the proposed work the three-phase inverter designed. The three-phase inverter has 6 MOSFET switches. The inverter circuit output is applied to the three-phase induction motor. The asynchronous motor is controlled according to V/f control method. The speed of the motor is can be controlled via the control circuit potentiometer. Generated PWM signals which are used for controlling the MOSFETs are applied to each of the MOSFET gates through TLP250 optoisolator.

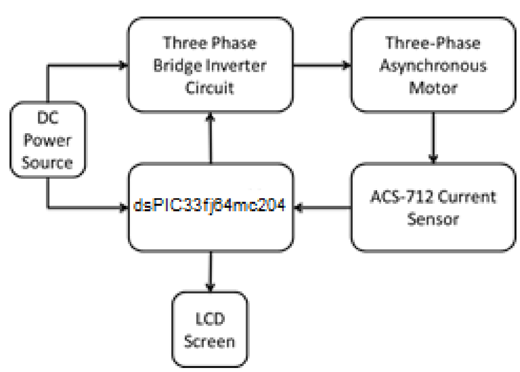


Figure 1. Block schematic of Three-Phase Asynchronous Motor Drive System

4.2. Power circuit and Control circuit design

The power circuit is designed using three NPN type and three PNP type MOSFETs. PNP type MOSFETs form the upper arm, and NPN type MOSFETs form the lower arm. These MOSFETs are driven by using TLP250 optoisolator. MOSFETs protected against surge voltages using 20V zener diodes between gate and source pins of MOSFETs. The ACS-712 current sensor is located on the inverter board. This prevents the motor from overheating when it overcurrents for a long time.
In this work Microchip's dsPIC33fj32mc204 digital signal controller is used. The control card is designed for applications requiring PWM signals. There is a potentiometer connected to analog input of the microcontroller. The speed of the motor can be changed by adjusting the V/f ratio through this potentiometer. In addition, the LCD connection to the control card can be performed with the removable and attachable LCD connection cable. Dead time is determined as 8.4us. PWM signal is adjusted at 5 kHz and microcontroller is operated at 80 Mhz with speed capacity with internal oscillator. Frequency change can be observed on the LCD screen by using potentiometer at 0-64Hz range. PTPER value can be calculated as (4).

$$3999 = \frac{20\ Mhz}{5\ kHz \times 1} - 1 \tag{4}$$

Dead Time value can be calculated as (5) 8.4 us.

$$63 = \frac{8.4\ us}{4 \times \left(\frac{1}{30\ Mhz}\right)} \tag{5}$$

4.4. PCB Design with Using SMT and Through Hole Technique

Healthy and long-term operation of designed circuits may vary according to the production type. It is also important that the designed circuit for continuous and long-term operation as well as its operation. Circuit components were classified based on their mounting style. There are two types mounting techniques at industrial designs for continuous and smoothly operation of electrical circuits. Through hole and surface mounting techniques are commonly used. SMT has helped significantly in solving the space problems that were commonly noticed with the Through Hole mounting. Also EMI (Electromagnetic Interference) effect can be decreased with using SMT.
The control and power circuit are printed on a single card after the circuit topology to be used has been determined. Thus, the motor driver system is turned into an industrial card. During this design phase, Proteus program was used. The ground of control and power parts are insulated from each other in order to prevent noise from coming from the power part to the control part so two parts combined with a thin line. Top of the PCB was designed as +18V source layer and bottom of the driver card was used as ground layer. SMT circuit components were used so compact card design had been made. Proteus circuit program was used for design process. Through hole and surface mounting techniques were used at this designed asynchronous motor driver card. Motor driver circuit Proteus program design can be seen at Figure 2. The motor driver circuit's front and back view is shown in Figure 2. Real-time designed PCB card can be seen at Figure 3. Complete three-Phase asynchronous motor driver system is given at Figure 4.

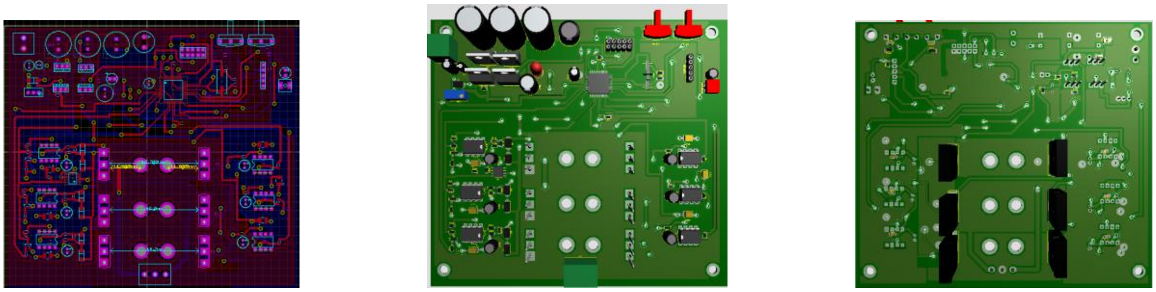


Figure 2. Designed Three-Phase Asynchronous Motor Driver Card at Proteus Program

Figure 3. Designed Three-Phase Asynchronous Motor Driver Card

Figure 4. Three-Phase Asynchronous Motor Driver System

5. Results

In this study the three-phase, 90 W asynchronous motor was operated at 12 and 18V input voltages with the designed asynchronous motor driver circuit. The stator windings of the ac motor were rewound so that the input voltage would be maximum 24 V. One of the phases drawn current was given at the bottom. Three phase voltage shapes were taken at 12V and only voltage shapes were taken at 18V operation. A power analyzer view of a drawn current from a first phase is given at Figure 5. It can be seen first phase drawn current 0.15A at 12V and no-load operation mode.

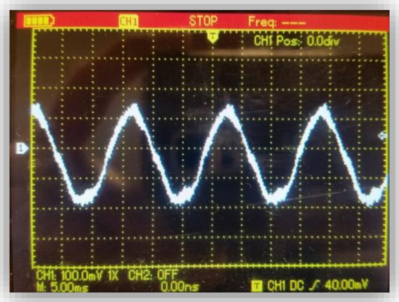
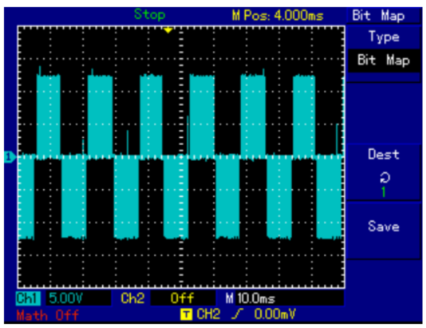
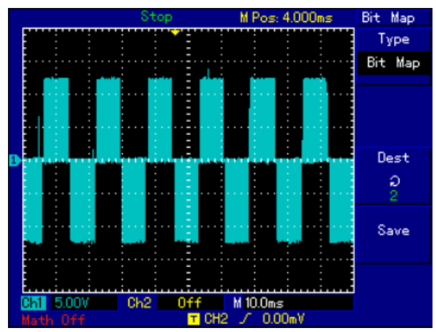


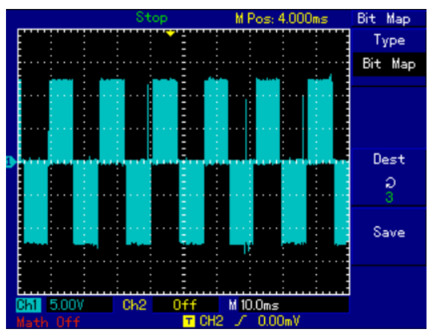
Figure 5. First Phase Drawn Current Shape (12V, 60Hz)



(a)



(b)



(c)

Figure 6. First, Second and Third Phase Voltage Shape (12V, 60Hz)

It can be seen respectively each phase voltage oscilloscope view at 12V asynchronous motor in case of no-load operation at Figure 6 (a) , Figure 6 (b) and Figure 6 (c) .

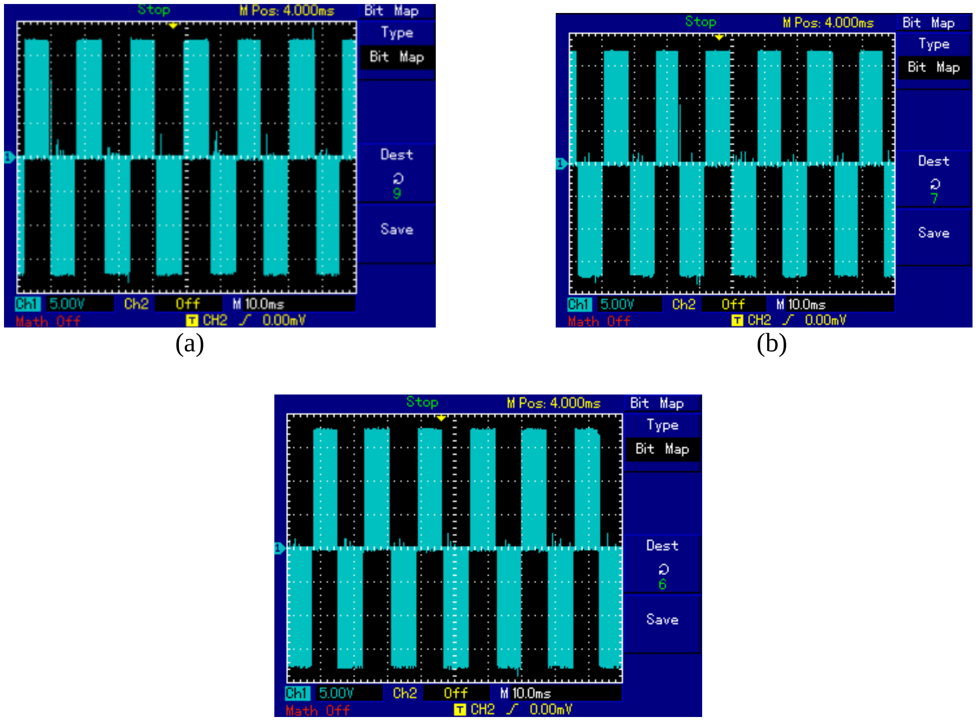


Figure 7. First, Second and Third Phase Voltage Shape (18V, 60Hz)

It can be seen respectively each phase voltage oscilloscope view at 18V asynchronous motor in case of no-load operation at Figure 7 (a) , Figure 7 (b) and Figure 7 (c) .

6. Discussion

According these results asynchronous motor driver has been successfully implemented. Signal outputs have been investigated at different voltage levels. It is understood that the driver is working properly at intervals of 12V and 18V, as a result of experimental results. The input voltage value can be pulled up to higher levels in future work. Hence different voltage ranges asynchronous motors can be controlled.

Conclusions

Asynchronous motor driver was designed successfully and tested between 12-18V input voltage ranges. At this driver circuit contained control and power circuit at the one card. So the designed driver card can be used in the industrial systems. The required PWM signals for the sinusoidal signals were produced by the dsPIC33fj32mc204 microprocessor. Three phase bridge inverter circuit topology was used in the study. In this topology, NPN type MOSFET switching semiconductor elements are used in the upper node and PNP sub-node. This reduces the number of different sources required for feeding the switching elements in the power circuit. Speed and torque control of 24V, 90W three-phase asynchronous motor with V/f motor control technique has been realized. Current and voltage oscilloscope screen views of the motor are obtained at 12V and 18V voltage values.

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References

[1] Ross, D., Theys, J. and Bowling, S., "Using the dsPIC for Vector Control of an ACIM", Microchip Application Note, 2007.
[2] Üstün, S. V. ve Demirtaş, M., "Optimal Tuning of PI Coefficients by Using Fuzzy-Genetic for V/f Controlled Induction Motor", Expert Systems with Applications, 34, 2714-2720, 2008.
[3] E. Ilten, "dsPIC Based Fractional Order Piλ Speed Control Of Induction Motor", Balikesir University Institute Of Science, 2013
[4] Demirtaş, M., "Alan Yönlendirmeli Asenkron Motorun Bulanık Kayan Kip ve Genetik Kayan Kip Konum Kontrolü", Doktora Tezi, Yıldız Teknik Üniversitesi Fen Bilimleri Enstitüsü, 2002.
[5] Suetake, M., da Silva, I. N. and Goedhel, A., "Embedded DSP-Based Compact Fuzzy System and Its Application for Induction-Motor V/f Speed Control", Transactions on Industrial Electronics, 58 (3), 2011.
[6] Üstün, S. V., "Asenkron Motorun DSP (Sayısal İşaret İşlemci) Temelli kontrolunda Yapay Sinir Ağları ve Genetik Algoritmalar Kullanılarak PI katsayılarının Optimizasyonu", Doktora Tezi, Yıldız Teknik Üniversitesi Fen Bilimleri Enstitüsü, 2001.
[7] Cunha, B. S., Camacho, J. R. and Bissochi, C. A., "Single-phase induction motor speed control through a PIC controlled sinusoidal PWM inverter-the mathematical model and various load conditions", IEEE Power Tech Proceedings, Porto, 2001.
[8] Parekh, R., "VF Control of 3-Phase Induction Motors Using PIC16F7X7 Microcontrollers", Microchip, 2003.
[9] Çakır, A., Çalış, H., Ayrılmış, A. and Kızıl, A., "3 Fazlı Asenkron Motorun Sabit V/f Oranlı Kapalı Döngü Hız Denetimi", 5. Uluslararası İleri Teknolojiler Sempozyumu (IATS'09), Karabük, Türkiye, 2009.
[10] Waskar, S. A., Bombale, U. L. and Sonawane, T. B., "dsPIC Based SPWM Controlled Three Phase Inverter Fed Induction Motor Drive", International Journal of Computer Applicaitons, 47 (16), 2012.
[11] Amogh Jain B. A., S. Poornima, "DsPIC based Fixed Speed Induction Motor Drive", IJRSI Journal, Volume I, Issue II, 2321 – 2705, July 2014
[12] "Motor Control PWM", Microchip dsPIC30F Family Reference Manual, 2005.