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Computer based speed control application for universal motor

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ABSTRACT

In this study, speed control of alternative current (AC) universal motor is made in a computerized manner using PIC16F84A and PIC18F2550. AC universal motor speed control is realized by triggering the motor power circuit, triac with the phase angle control method by programming PIC16F84A. In the phase angle control method zero crossing points of AC line signal are detected by zero crossing detector and applied to the analog input of PIC16F84A. Zero crossing information applied to the microcontroller has provided phase control at a desired angle value in each alternance of the line. Motor speed control commands via computer are made by means of the control panel designed under Visual Basic 6.0 platform by using PIC18F2550 microcontroller based control card. Application results show that the speed control performed provides practical and easy control, is convenient, sensitive, and economic and also can immediately be adapted to different applications compared to the present analog control.

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1. Introduction

Use of the electric motors which provide substantial efficiency in conversion of electric energy into mechanical energy is increasing day by day. Since Universal Motors out of electric motors can operate both with Alternative Current (AC) and Direct Current (DC), they are used in most of the household appliances and power tools today. Universal motors are preferred due to the properties thereof such as having high start-up and turning moments, ability of being operated at high speeds and manufactured in small powers. The method used in the speed control of the universal motors substantially affects the motor efficiency. One of the important conditions to optimize the motor efficiency is to determine a proper speed control method. Phase angle control method is commonly used in speed control of the universal motors. This method provides performing the control of the universal motors in wide speed range. Microcontrollers are considerably used in the motor drive circuits designed by using phase angle control method.

In this study, speed control of the AC universal washer motor is performed through the control panel designed under Visual Basic 6.0 platform based on the microcontroller. The study is performed in two stages as application and simulation. In the application part, drive card and control card to control the drive card are designed for the speed control of the motor. In the control system, speed information received from the tacho generator coupled to the motor shaft is monitored with Visual Basic 6.0 program control panel and speed change of the motor is instantaneously monitored in the computer screen. In line with the commands given to the control card with the control panel designed triac trigger angles are changed by means of drive card PIC microcontroller, input voltage of the motor is adjusted and the control thereof in a wide speed range is provided. In the simulation part, on the other hand, simulation of all of the circuits in the application is made with ISIS program, which is the circuit drawing, simulation and analysis program of PROTEUS, speed analysis of the universal motor in various excitation conditions is performed.

2. Material and methods

2.1. Universal Motors

Universal motor is an AC series motor with stator and rotor magnetic bodies thereof being composed of sheet packages. When separately fed from AC and DC sources with the same efficient voltage, universal motors exhibit similar speed and power output characteristics. The most common usage areas of these motors are small power household, workplace machine and devices [1]. Universal motor has excellent properties. Compared to the induction motors, they are characterized with their high power regarding the size and weight thereof. Universal motor can be operated at a very good breakaway torque and extremely high speed (15 000-20 000 rpm) [2]. For a common use of the universal motor minimum energy consumption is very important. Therefore, universal motor high performance requirements have increasingly become important with a low-cost controller [3]. The best way of controlling the speed of a universal motor is to change the RMS value of the sinus function of AC input voltage. A higher RMS input voltage provides a higher motor speed [4]. Changing the RMS value of the sinus function of input voltage alternating current can simply be made using a triac serially connected AA source. Here, speed control can be performed adjusting the voltage applied to the motor by changing the triac firing angle [4]. In recent technology, power control is made with electronic circuits. Electronic control is preferred due to many advantages such as the elements being small in size, having a long life and providing computer control in automation [5]. In this study, BTA/BTB16-600B triac series is used as phase angle control power circuit element in the drive circuit. Triacs are semiconductor circuit elements which conduct bidirectional current, control high level load currents with small excitation current and operate at AC. Triac based power circuit is given in Fig. 1.

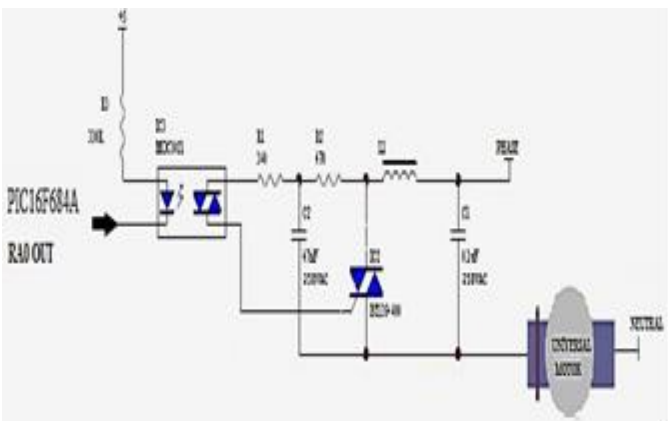


Figure 1. *Triac-based power circuit.*

Controller-based and speed-adjustable motor drives have also played an important role in the development of industrial automation [6].

Importance of the microcontrollers in the control of universal motors is increasing day by day. In the point of preferring the PIC microcontrollers, advantages of PICs compared to the other microcontrollers can be arranged as code efficiency, reliability, command set and speed [7]. The advantages provided by the computer programs in control systems are known to provide more professional control compared to the manual control systems. Computer program Visual Basic is a visual language having complex logics and forms which facilitate the designs of Windows compatible application. [8]. In this study, universal motor speed control is performed via computer. In line with the program written by forming necessary control elements with the use of drive card Visual Basic 6.0 program control panel, the control is performed. Control panel view of the designed control program is given in Fig. 2.

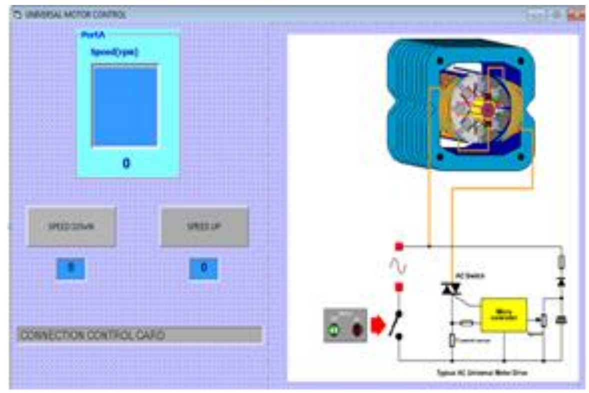


Figure 2. *Designed control panel.*

2.2. *Speed Control of Unıversal Motor*

The method used in the speed control of the universal motors substantially affects the motor efficiency. One of the important conditions to optimize the motor efficiency is to determine a proper speed control method. Motor drive systems designed depending on the speed control method affects the performance of the motor. Phase angle control method is commonly used in speed control of the universal motors. This method provides performing the control of the universal motors in wide speed range values. Microcontrollers are considerably used in the motor drive systems designed by using phase angle control method. Speed control of the universal motor connected to the AC source can simply be performed by using a triac connected to the motor in series. Speed control can be performed changing the voltage applied to the motor by changing the triac firing angle.

Varible Structure Systems (VSS) such as motor control, robotic manipulators and indefinite systems have an important place in the control of modern non-linear systems. However, there are some difficulties such as occurrence of numerous switches between the control bounds, which cannot be carried out by real controllers.

To overcome this problem, a thin boundary layer neighbouring the switching surface is introduced for smoothing out the control discontinuity [9].

In this study, speed control is made via computer using

PIC18F2550 based control card and PIC16F84A based drive card. It is cheaper to use PIC16F84A microcontroller for controlling the motor from the point of hardware [10]. Different reference frames can be used to model the motor: three phases frame (a,b,c), stationary frame (α,β) or synchronous frame (d,q). From the control point of view, the (d,q) reference frame is widely used [11]. Motor speed control is made using phase angle control in the drive system. Block diagram of the designed drive system is given in Fig. 3.

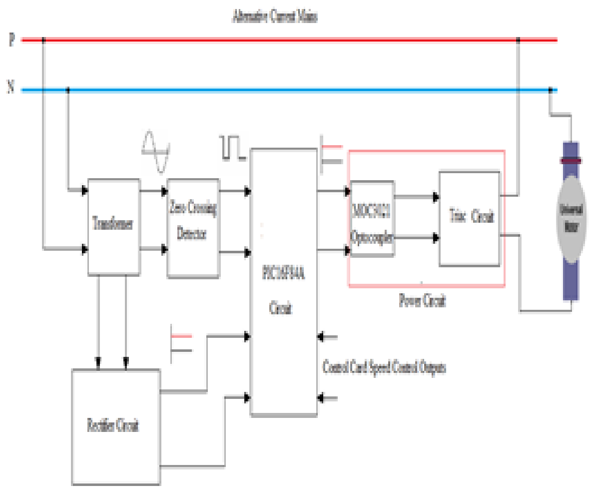


Figure 3. *Block diagram of the designed drive system*.

Zero crossing points of AC line should be detected in PIC based phase angle control systems. For this, a zero crossing detector is used in drive card. Zero crossing detector circuit used is given in Fig. 4.

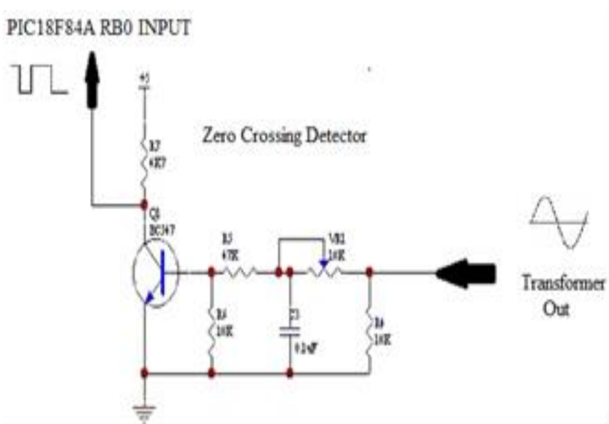


Figure 4. *Zero crossing detector circuit.*

In the speed control of universal motor application that proposed in this study, motor terminal voltage and triac terminal voltage changes are shown by oscilloscope measurements.

Oscilloscope probe connection of the voltage measurement of the universal motor excitation terminals and between A1-A2 terminals of triac in the drive circuit is given in Fig. 5.

Figure 5. *Oscilloscope probe connection.*

Various signals of the motor terminal voltage and the voltage between A1-A2 terminals of the triac monitored in the screen as a result of the measurements made with oscilloscope are given in figures 6, 7, 8 and 9.

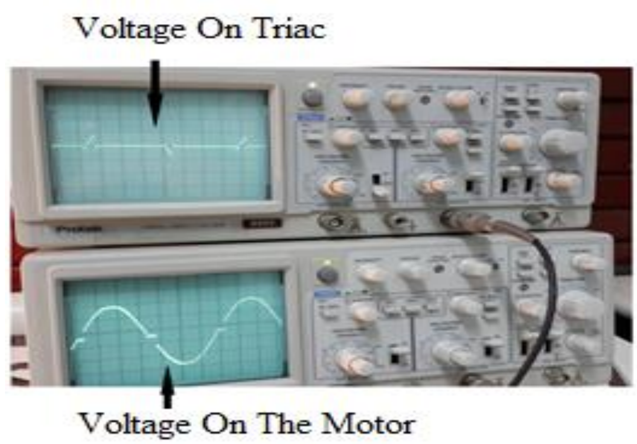


Figure 6. *Voltage between A1-A2 terminals of the triac and Motor terminal voltage when triac is triggered at the beginning of the alternance.*

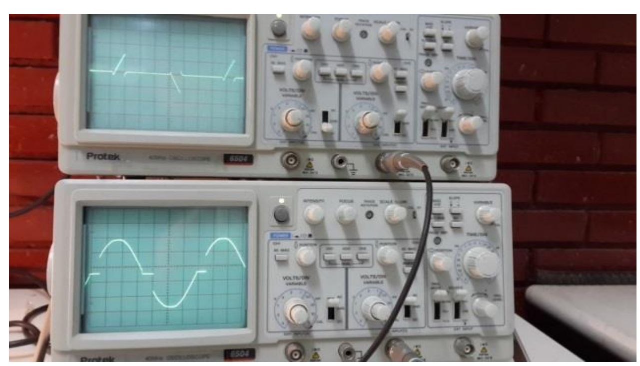


Figure 7. *Voltage between A1-A2 terminals of the triac and Motor*

terminal voltage when triac is triggered after 45o from beginning of the alternance.

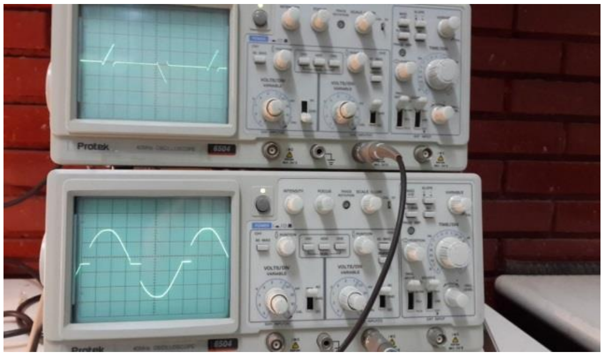


Figure 8. *Voltage between A1-A2 terminals of the triac and Motor terminal voltage when triac is triggered after 90o from beginning of the alternance.*

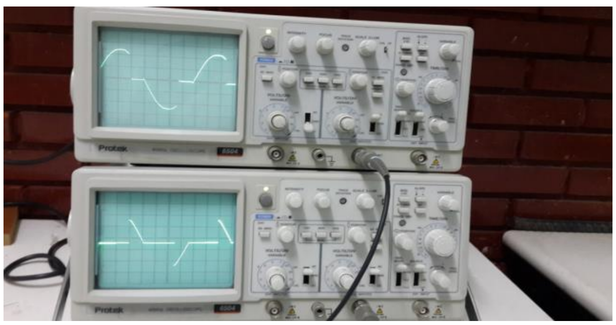


Figure 9. *Voltage between A1-A2 terminals of the triac and Motor terminal voltage when triac is triggered after 135o from beginning of the alternance.*

BTA16 triac used in the drive circuit is controlled with the phase angle control method and the voltage in the terminals of universal motor is adjusted as desired values and the speed control is performed. As long as the triac is not triggered, the current does not pass over the motor. While operating in AC voltage, triac is triggered at the start of each alternance and remains in transmission until the end of the alternance. However, in case triac is triggered toward the end of the alternance it will be cut until the time of triggering and a power loss occurs in the circuit. Triggering moment of the triac is adjusted with PIC16F84A and MOC3021 optocoupler in the circuit and efficient value of the voltage in the circuit is determined. As the triggering moment approaches to the end of alternance, power loss increases in the circuit and thus the motor speed will be reduced. As the triggering moment approaches to the start of alternance, however, a contrary situation is observed, transmission period of triac and accordingly motor speed increase [12].

2.3. Speed Control Sımulatıon of Unıversal Motor

In this study, universal motor speed control simulation is performed with ISIS PROTEUS program. Circuit diagram used in the simulation program is given in Fig. 10.

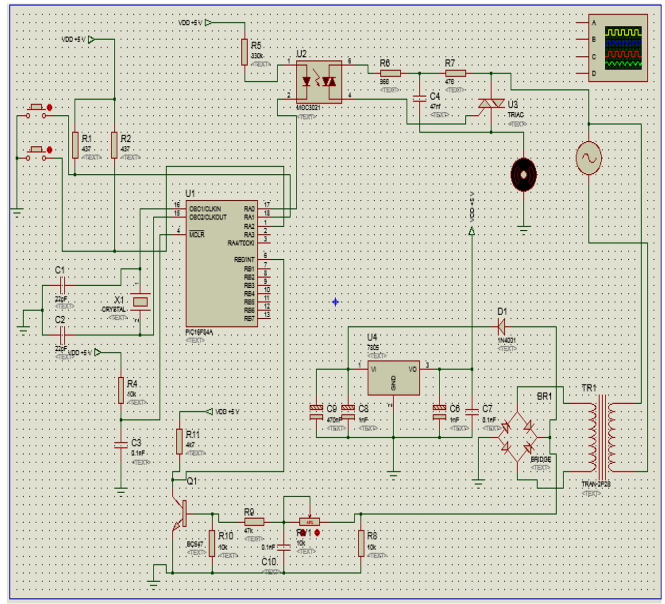


Figure 10. *Circuit diagram used in the simulation.*

In accordance with the commands given to the microcontroller in the simulation circuit of the drive card used in the application as seen in Fig. 10, line voltage, voltage of the load terminals and triac are measured by simulating the trigger pulse signal. In the simulation circuit, the load is controlled with the phase angle control method. Oscilloscope measurement in case of triggering the triac at the beginning of alternance based on the speed increase or speed decrease commands of the circuit line voltage simulated during zero crossing, line voltage signal, signal at the load terminals, triac gate signals are given in Fig. 11.

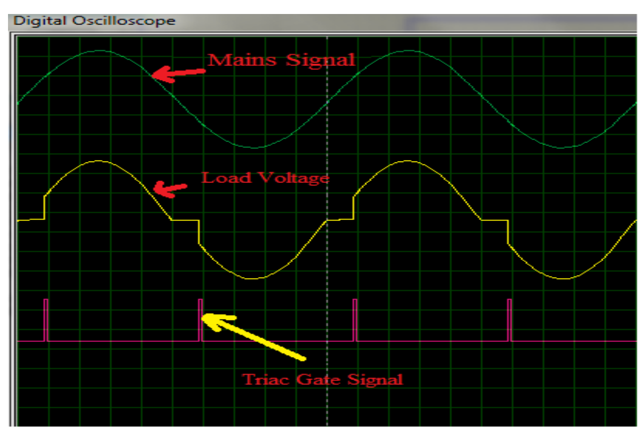


Figure 11. *Oscilloscope measurements when triac is triggered at the beginning of the alternance.*

Oscilloscope measurement in case of triggering the triac 45o after alternance started, line voltage signal, signal at the load terminals, triac gate signals are given in Fig. 12.

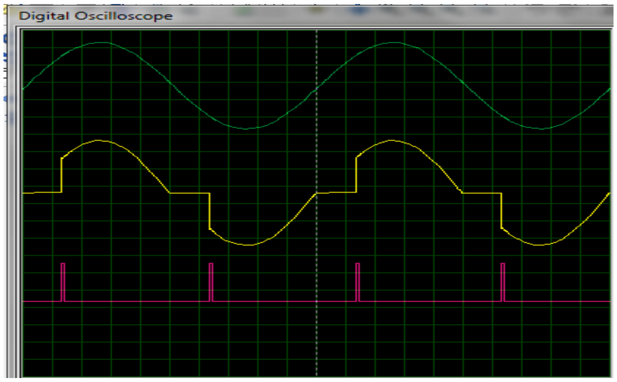


Figure 12 - *Oscilloscope measurements when triac is triggered after 45o from the beginning of the alternance.*

Oscilloscope measurement in case of triggering the triac 90o after alternance started, line voltage signal, signal at the load terminals, triac gate signals are given in Fig. 13.

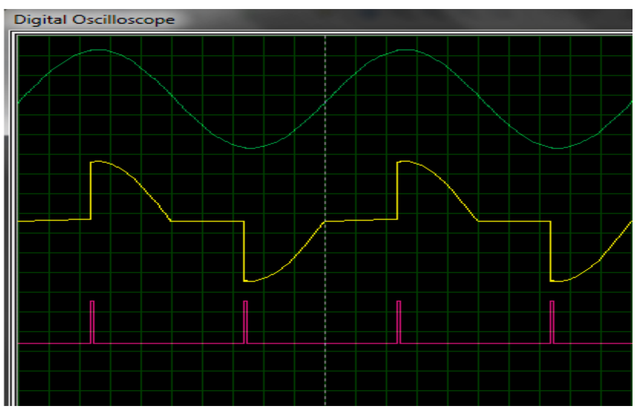


Figure 13 - *Oscilloscope measurements when triac is triggered after 90o from the beginning of the alternance.*

Oscilloscope measurement in case of triggering the triac 135o after alternance started, line voltage signal, signal at the load terminals, triac gate signals are given in Fig. 14.

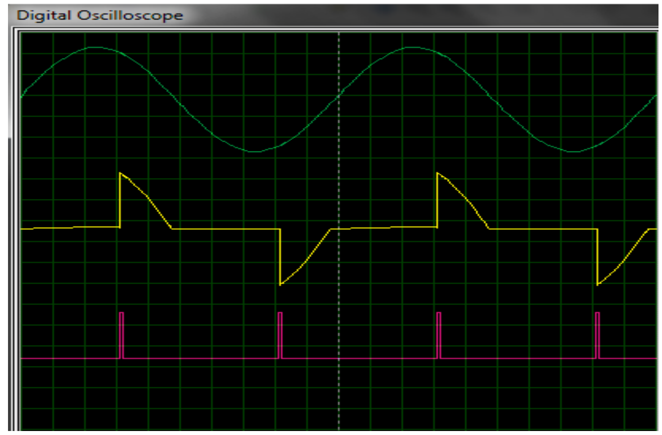


Figure 14 - *Oscilloscope measurements when triac is triggered after 135o from the beginning of the alternance.*

In this study, universal motor speed control is performed by means of Visual Basic 6.0 program. According with the program written by forming necessary control elements with the use of Visual Basic 6.0 program control panel, the control is performed. Control panel view of the designed control interface is given in Fig. 15.

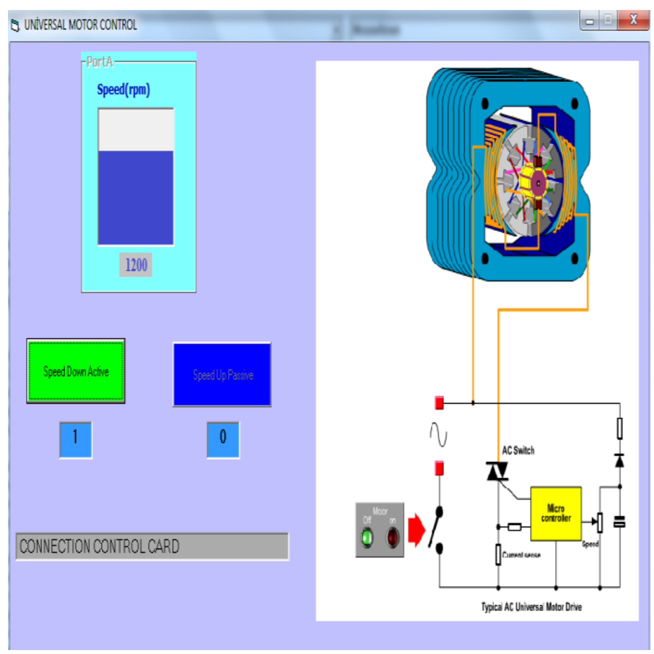
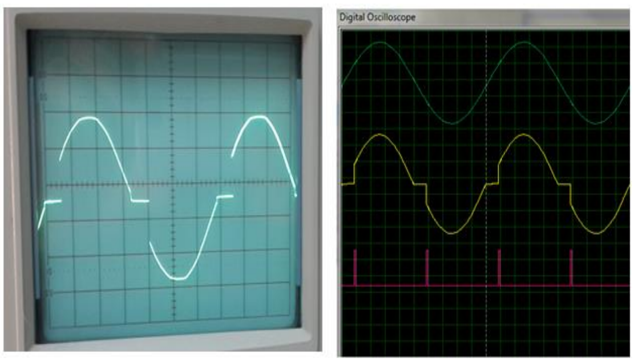


Figure 15 - *Control panel view of the designed control interface.*

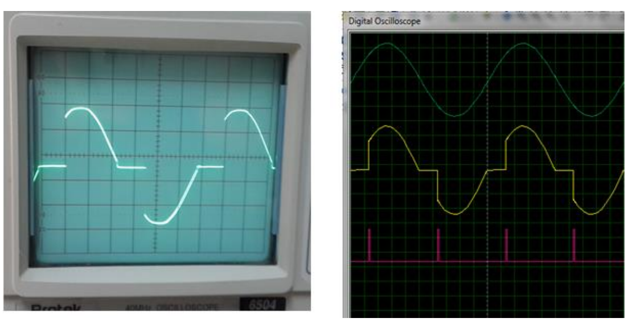
As seen in the control panel of the designed control program in figure 15, dashboard instantaneously indicating the speed information of the motor and control buttons reducing or increasing the motor speed are provided. Each function of the control buttons provided in the control panel is defined in different colors, thereby the position of the control buttons is visually understood better [13].

3. Results and discussions

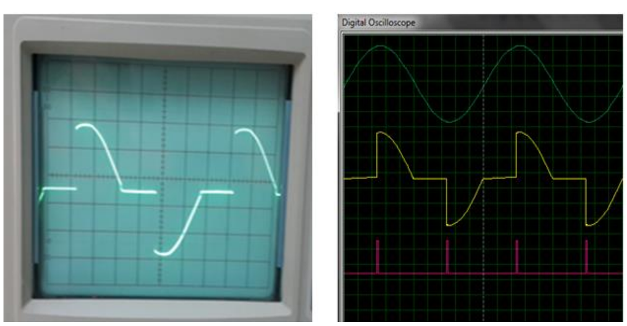
In this study, universal motor speed control is performed via computer with drive card, control card and control program designed. Universal motor speed control is performed with phase angle control method. In the phase angle control application made with the circuit designed as a result of this method, motor terminal voltage signal oscilloscope measurement is observed to be close to the oscilloscope motor terminal voltage signals of the circuit simulated. Comparison of the application and simulation signal examples of the motor terminal voltage is given in Fig. 16 (a,b,c and d).



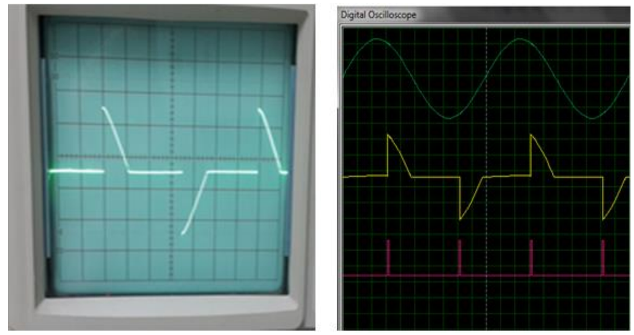
(a)



(b)



(c)



(d)

Figure 16 - *Comparison of the application and simulation of motor terminal voltage signals a) triac is triggered at the beginning of the alternance b) triac is triggered after 45o from the beginningof the alternance c) triac is triggered after 90o from the beginning of the alternance d) triac is triggered after 135º from the beginning of the alternance.*

As seen from the results of circuit application and simulation using PIC16F84A microcontroller and phase angle control method in the universal motor speed control, the motor is observed to have answered the commands given rapidly and be at desired values depending on the trigger angles in the motor terminal voltage measurements.

Control panel designed under Visual Basic 6.0 platform has provided the user with the opportunity of performing practical and easy control. Defining each function of each element provided in the control panel with colors and in writing, state of the functions are active or passive is provided visually in case of control. In this case, by facilitating the person controlling the control system to observe the relevant state of the system, a more professional control is provided. Moreover, while speed of the motor is controlled, motor speed information is indicated in the control panel and instant speed of the motor is known by the user, and thus in line with the motor speed information, the level of the control is provided to be known.

In this study, considering the method and circuit elements used, the cost can substantially be reduced as a faster control using less energy and less labor when compared to the manual control used in work and power tools is provided. When very big industrial systems are considered, this cost reduction may reach high rates and increase the profit rate.
With the study conducted, speed control of the universal motors, the use of which has significantly become common in the industrial applications is made with PIC 16F84 controller. It is shown that this and similar motor control applications can be made with PIC more simply and reliably.
Since this study provides incorporating more different systems, it has a developable structure. For instance, control

via internet can be developed to realize the objectives such as providing hand and power tools that can be controlled by mobile phones [14].

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