Available online at www.sciencedirect.com
ScienceDirect
IFAC-PapersOnLine 48-24 (2015) 039–042

Digital Synchronisation with Mains for the Purpose of the Phase Motion Control

Peter I. Yakimov

Technical University of Sofia, 1000 Sofia
Bulgaria (Tel: +359-2-965-3265; e-mail: pij@tu-sofia.bg).

Abstract: The induction or asynchronous motors are the most popular motors for industrial and consumer applications. Phase control is the most common form of thyristor or triac power control. The paper presents an approach for digital control of the ignition pulses generation using the possibilities of the enhanced capture timer module of the microcontrollers from the MC9S12D-Family. An algorithm for mains synchronization is proposed. Some fragments of code are presented. The practical implementation of the approach is explained.

Keywords: motion control, phase control, mains synchronisation, digital control, embedded systems.

1. INTRODUCTION

A large number of electric motors are in use everywhere in the human activities. AC induction machines are popular due to their simplicity, reliability and direct operation from an AC line voltage. Available voltage control methods include control by a transformer or by using electronic switches. The first method is not so easy to do with an AC speed control motor. In the second case the speed control is obtained by controlling the effective (RMS) value of the AC voltage applied to the motor. When the triac switch is connected between the AC power supply and the motor, the power flow can be controlled by varying the RMS of the AC voltage. This is called an AC voltage controller. There are two types of control normally used. On-off control - the triac switches connect the load to the AC source for a few cycles and then disconnect it for another few cycles of the source voltage. Alternately, the triac switches connect the load to the AC source for a moment in each half cycle of the AC voltage (50 or 60Hz) applied to the motor as it is mentioned by Shirahata.

Because of the wide spreading of the embedded control, the low prices of the microcontrollers and the permanent increase of their possibilities it is affordable to implement the digital control in the drives. According to Medina (2008) using microcontrollers in combination with the basic triac topology is cost-performance solution. Selection of an embedded microcontroller (MCU) for motor control applications requires to be considered multiple parameters. Nowadays, motor control applications are not dedicated drives for rotating machines but have become complex systems including several interfaces, real-time operating systems, high-performance peripherals and other elements.

Applications requiring the motor to operate with a required speed (pumps, fans, compressors, etc.) are speed controlled. The actual motor speed is maintained by a speed controller to reference speed command. The goal of this investigation is to propose an approach for AC motor control using microcontroller but this task has to be in addition to the main one and the others. It is emphasised on the tasks management and it is proposed the drive to be controlled by servicing interrupt requests but not in the main programme.

2. PROBLEM STATEMENT

Random phase triac drivers are designed to be phase controllable. They may be triggered at any phase angle within the AC sine wave. Phase control may be accomplished by an AC line zero cross detector and a variable pulse delay generator which is synchronised to the zero cross detector. The same task can be accomplished by a microprocessor which is synchronized to the AC zero crossing as it is described by Fairchildsemi (2014).

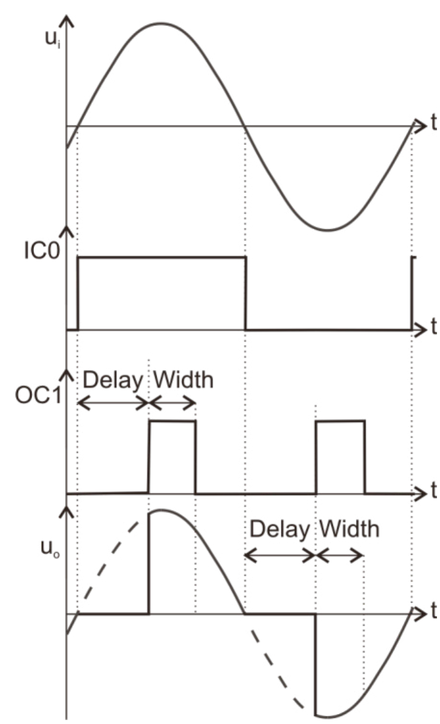

Fig. 1. Plot of the AC voltages and the control signals in the phase motion control.

10.1016/j.ifacol.2015.12.053

In Fig. 1 are presented the timing diagrams of the signals concerned by the processing. The signals u_i and u_o are respectively the input AC line voltage and the output voltage applied to the AC motor. It is shown that generally the rms value of the output voltage is less than the value of the input voltage and this is due to not applying the whole halves of the sine voltage. To synchronise the ignition pulses with the mains a zero cross detector is used and the signal *IC0* is shaped. The output pulses that are applied to the gate of the triac are labelled as *OC1*. The names of the square wave signals are chosen to be equal to the names of the corresponding channels of enhanced capture timer module of the microcontroller MC9S12A32 and their intended functions. *IC0* is an input signal and it is applied to the pin which serves as input capture for channel 0. Respectively *OC1* is an output signal which is produced by channel 1 serving as an output compare.

In phase control applications the driver is intended to be able to control each AC sine half wave from 0 to 180 degrees. Turn on at zero degrees means full power and turn on at 180 degree means zero power. This is not quite possible in reality because triac driver and triac have a fixed turn on time when activated at zero degrees. At a phase control angle close to 180 degrees the driver's turn on pulse at the trailing edge of the AC sine wave must be limited to end 200 microseconds before AC zero cross. This assures that the triac driver has time to switch off. Shorter times may cause loss of control at the following half cycle. The *Delay* time in Fig. 1 defines the phase angle after which the triac will turn on. The *Width* of the ignition pulse is chosen considering the requirement mentioned above.

3. IMPLEMENTATION OF THE DIGITAL SYNCHRONISATION

The project is based on the microcontroller of Freescale MC9S12A32. It is a 16-bit device composed of standard on-chip peripherals including a 16-bit central processing unit (HCS12 CPU), 32K bytes of Flash EEPROM, 4K bytes of RAM, 1K bytes of EEPROM, two asynchronous serial communications interfaces (SCI), one serial peripheral interfaces (SPI), an 8-channel IC/OC enhanced capture timer, one 8-channel, 10-bit analog-to-digital converters (ADC), an 8-channel pulse-width modulator (PWM). For the purpose of the digital synchronisation is used the enhanced capture timer module. Its basic features are: 16-Bit Buffer Register for four Input Capture (IC) channels, four 8-Bit Pulse Accumulators with 8-bit buffer registers associated with the four buffered IC channels which can be configured also as two 16-Bit Pulse Accumulators, 16-Bit Modulus Down-Counter with 4-bit Prescaler and four user selectable Delay Counters for input noise immunity increase. The module has 8 Input Capture, Output Compare (IC/OC) channels. When channels are selected as input capture by selecting the IOSn bit in TIOS register, they are called Input Capture (IC) channels. The software is organised in a way where the phase control is performed with servicing interrupt requests. This will save time and resources of MCU to execute the main programme. Some fragments of the assembly language code illustrating the operation of the digital synchronisation will be presented. First is the initialisation.

```
LDAA  #%10000000
STAA  $0046         ; TSCR1
LDAA  #%00000010    ; TIOS
STAA  $0040
LDAA  #%00000000    ;
STAA  $0048         ; TCTL1
LDAA  #%00001000
STAA  $0049         ; TCTL2
LDAA  #%00000000
STAA  $004A         ; TCTL3
LDAA  #%00000011    ; IC0 CAPTURE ON ANY EDGE
STAA  $004B         ; TCTL4
LDAA  #%00000001    ; TIER - IOC0 INTERRUPTS
STAA  $004C         ; REQUESTED
```

The first writing in Timer System Control Register 1 enables the timer and allows it to function normally. Next after the writing to the Timer Input Capture/Output Compare Select Register the intention of every channel is defined. Timer Channels can be configured as input capture channels or output compare channels. Writing 1 in a bit of this register configures the corresponding channel as output compare and writing 0 – respectively as input capture. So channel 0 will operate as input capture and channel 1 – as output compare. Initially after the writing in Timer Control Register 1/Timer Control Register 2 the output line OC1 is cleared to zero. After the writing in Timer Control Register 3/Timer Control Register 4 IC0 is forced to capture on any edge (rising or falling) and after the writing in Timer Interrupt Enable Register IC0 is enabled to request interrupts.

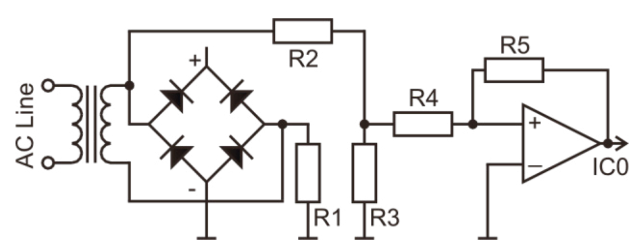

Fig. 2. Zero cross detector.

The zero cross detector which circuit diagram is depicted in Fig. 2 shapes square wave pulses which change their level when the input AC voltage crosses the zero line. As a source is used the system power supply unit and the terminals of the secondary winding of the transformer are loaded with the resistors R1, R2 and R3 in order to not produce parasitic pulses. The comparator produces square wave pulses as it is shown in Fig. 1 and its output is connected to IC0 pin of the microcontroller.

The flow chart of the routine which services the interrupt request causing by the zero cross detector is shown in Fig. 3. The routine uses two variables – DELAY which is two bytes long and LEVEL with one byte length. In DEALY is stored the value of the time representing the phase angle at which the triac switch will be turned on. In the presented project the bus frequency of the microcontroller is chosen to be 2MHz, so the time base is 0,5 microseconds. In this case if the mains frequency is 50Hz, the time that corresponds to 180 degrees will be 10 milliseconds and the maximum value which