

A Microprocessor - Based Waveform Control System for Pulsewidth Modulated Inverter.

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A complete design of microprocessor - based control circuit for a three - phase PWM inverter is presented. The Z - 80 microprocessor is used, and a flowchart and control signal hardware are provided. Practical problems for controlling the PWM inverter waveform using various ICs and devices are discussed, and modifications to the basic program are indicated. The basic control philosophy developed can be extended to the entire class of various PWM converter systems.

I . Introduction

Pulse width modulation of a six - step inverter can be accomplished in different ways. We can recognize three distinct switching strategies. The first and the one which has been most widely used because of its ease of implementation using analogue techniques are based on “natural” sampling techniques. A switching strategy, referred to as “regular” sampling, is considered to have number of advantages when implemented using microprocessor techniques. The third approach uses the so - called “optimal” PWM switching strategies which are based on the minimization of certain performance criteria ; for example, elimination or minimization of particular harmonics or the minimization of harmonic current distortion, peak current, torque ripple etc.

The following research is concerned with an investigation of a microprocessor implementation associated with the regular sampling method.

II . Survey of Variable Speed Drive Functions

Fig.1 provides an overview of a possible microprocessor control hierarchy and distinguishes some of speed drive systems. Only a small number of the functions shown could be performed by a single microprocessor. For a more complicated system, where several of the functions are to be performed, a multi - processor arrangement must be considered, with each microprocessor performing a different function.

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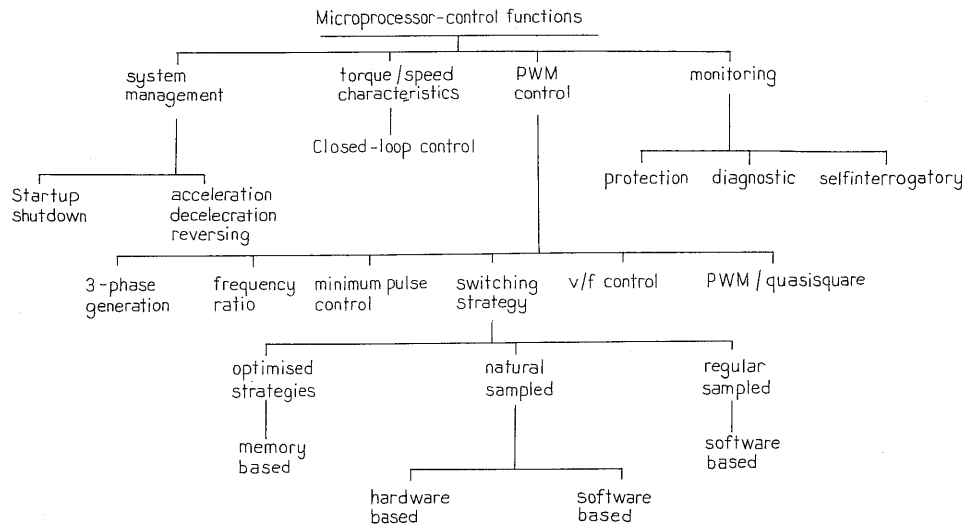


Fig. 1 Microprocessor - control hierarchy.

III. Switching Strategy

The heart of any PWM inverter control scheme is the switching strategy used to generate the switching edges of the PWM control waveform.

Regular sampling techniques can be implemented using current microprocessor technology, and is likely to form the basis of most microprocessor controlled PWM inverters.

IV. Microprocessor Based Regular Sampled PWM

A practical implementation illustrating the general features of this mode of sampling is shown in Fig. 2.

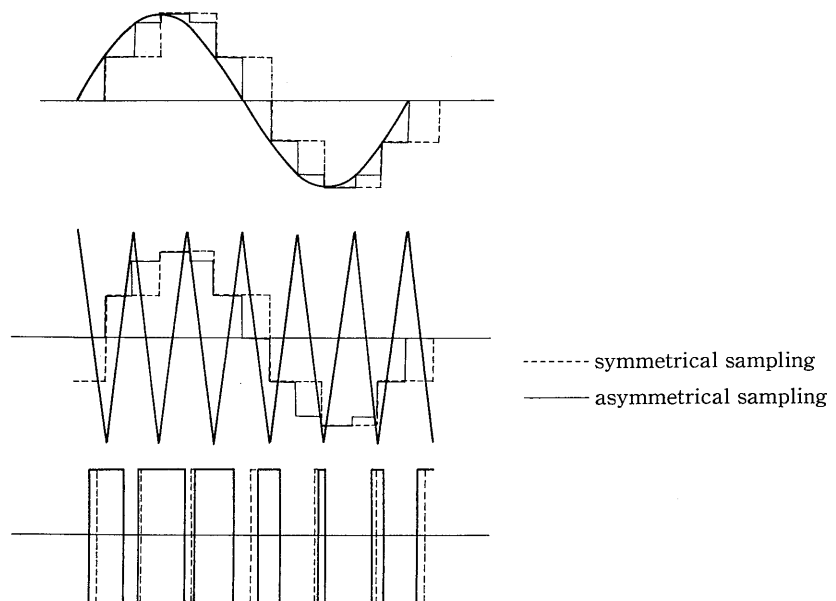


Fig. 2 Symmetric and asymmetric regular sampled PWM.

The sinusoidal modulating wave is sampled at regular interval corresponding to the positive peaks of the synchronized carrier wave. The sample and hold circuit maintains a constant level until the next sample is taken. This process results in a stepped, or amplitude modulated, version of the reference waveform. This stepped waveform is compared with the triangular carrier, and the points of intersection determine the inverter switching instants.

The generation of a single pulse, using the symmetric regular sampling process is illustrated in Fig. 3.

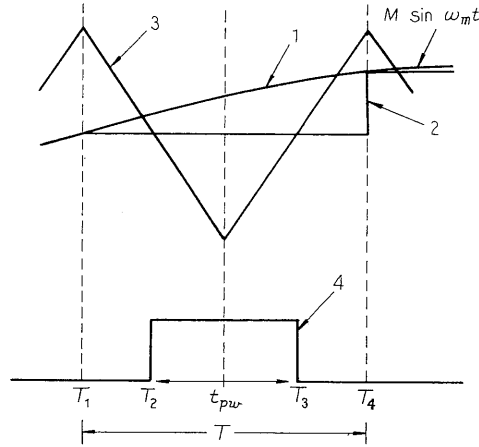


Fig. 3 Single pulse generated by regular symmetric sampling.

1 reference modulation signal, 2 sample - hold modulation signal, 3 carrier signal, 4 PWM waveform.

As a result of this process, the modulating wave has a constant amplitude while each sample is being taken, and consequently the widths of the pulses are proportional to the amplitude of the modulating wave at uniformly spaced sampling times.

It is therefore an important characteristic of regular sampling that the sampling positions and sampled values can be defined unambiguously, such the pulses produced are predictable both in width and position.

It is possible to derive a simple trigonometric function to calculate the pulse widths.

With reference to Fig. 3, the width of pulse may be defined as :

$$t_{pw} = (1 + M * \sin(\omega_m * T_1)) * T/2 \quad (1)$$

M : modulation index

T : time period of carrier signal

ω_m : angular frequency of modulation signal

T_1 : sample instant

This equation can be used to calculate the pulse widths directly.

An alternative and more efficient approach can be used for application where constant volts per cycle (constant flux) characteristics are required.

The duration of an individual voltage pulse in the modulated line to line voltage is proportional to the modulation index, M , and the periodic time of the reference wave, $1 / F_m$. Thus, the pulse duration, T_p , is proportional to M / F_m . If the reference wave amplitude is varied linearly with frequency, then M / F_m is constant and the pulse duration is independant of frequency.

In this case, the modulating frequency and modulation depth are linearly related by the equation $M = K * F_m$, and therefore, for a fixed frequency ratio P , the pulse width equation can be expressed in the form :

$$t_{pw} = T/2 + K * \sin(\omega_m * T_1) / 2P \quad (2)$$

$$P = \omega_c / \omega_m$$

The first term of this equation represents the unmodulated carrier frequency pulse, and the second term is constant for a particular frequency ratio. It is only necessary to calculate the degree of modulation at each switching instant, and to store these in memory.

V . Hardware and Software Based System

The efficient approach involves the use of Eq. (2) to calculate the pulse width angles directly, and then to output these angles using a three phase timer, as shown in Fig. 4.

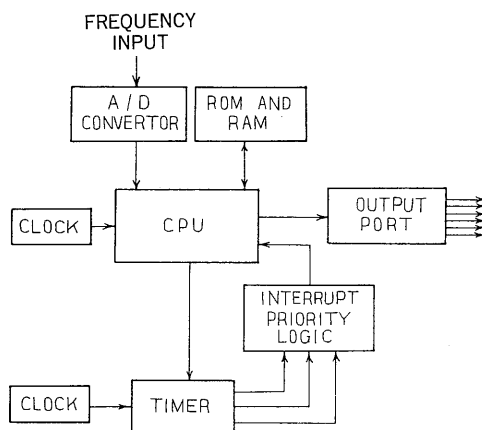


Fig. 4 Hardware for microprocessor - based regular sampled PWM.

The use of this timer allows a flexible program structure to be used, and so minimizes computation time. Assuming that the pulse width angles for the three phases have been calculated, then these may be converted to a time period using a timer. Each of the three counters of the timer is loaded with the appropriate value, each counter corresponding to one of the three phases.

When one of the counter completes the appropriate time period, it generates an interrupt signal. In order that the microprocessor can identify the source of the interrupt signal, and to avoid the

ambiguity which could arise if two interrupt signals were generated at the same time, interrupt priority logic circuitry is required as shown in Fig. 4.

Six signals are generated by the output port, corresponding to the six power devices in the inverter. Typical pulses for the three phases are illustrated in Fig. 5.

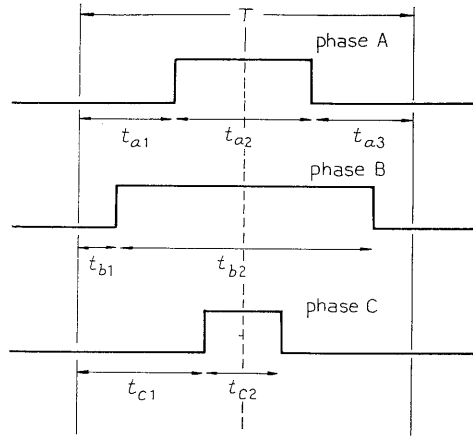


Fig. 5 3 - phase PWM waveform.

The pulse widths for the three phases must be calculated in advance. At the start of the carrier period, times t_{a1} , t_{b1} , and t_{c1} are loaded into the three counters. As each counter completes its period, the appropriate outputs are changed and the times corresponding to the pulses are loaded into the counters. In order to define the end of a carrier period, it is only necessary to load time t_{a3} into the first counter when the next interrupt is generated by that counter.

The timer and its associated circuitry may be regarded as being equivalent to the triangular wave generator and comparator. Loading a value into a counter corresponds to the output of suitable scaled version of the sampled modulation wave. The counting down process is equivalent to the changing magnitude of the triangular wave ; and when the time period is completed, the modulating wave may be regarded as having the same value.

VI. Microprocessor Calculation of Pulse Widths

The calculation for the pulse widths is based on the following equation.

$$\begin{aligned} t_{pw} &= T/2 + K * \sin(\omega_m * t_1)/2P \\ &= T/2 + K * \sin(\theta_1)/2P \end{aligned}$$

t_{pw} : width of modulating signal

M : modulation index

T : time period of carrier signal

P : frequency ratio

θ_1 : sample angle

For example, a frequency ratio of 9 and the following parameters are used.

$$M = 0.8$$

$$F_m = 50 \text{ Hz}$$

VIII. Functional Block Diagram - Hardware

The block diagram of the signal generator hardware is shown in Fig. 6. The microcomputer used is the Z-80 from Zilog. For developmental purposes, a single board microcomputer from Taiheiyoh Kogyo was used.

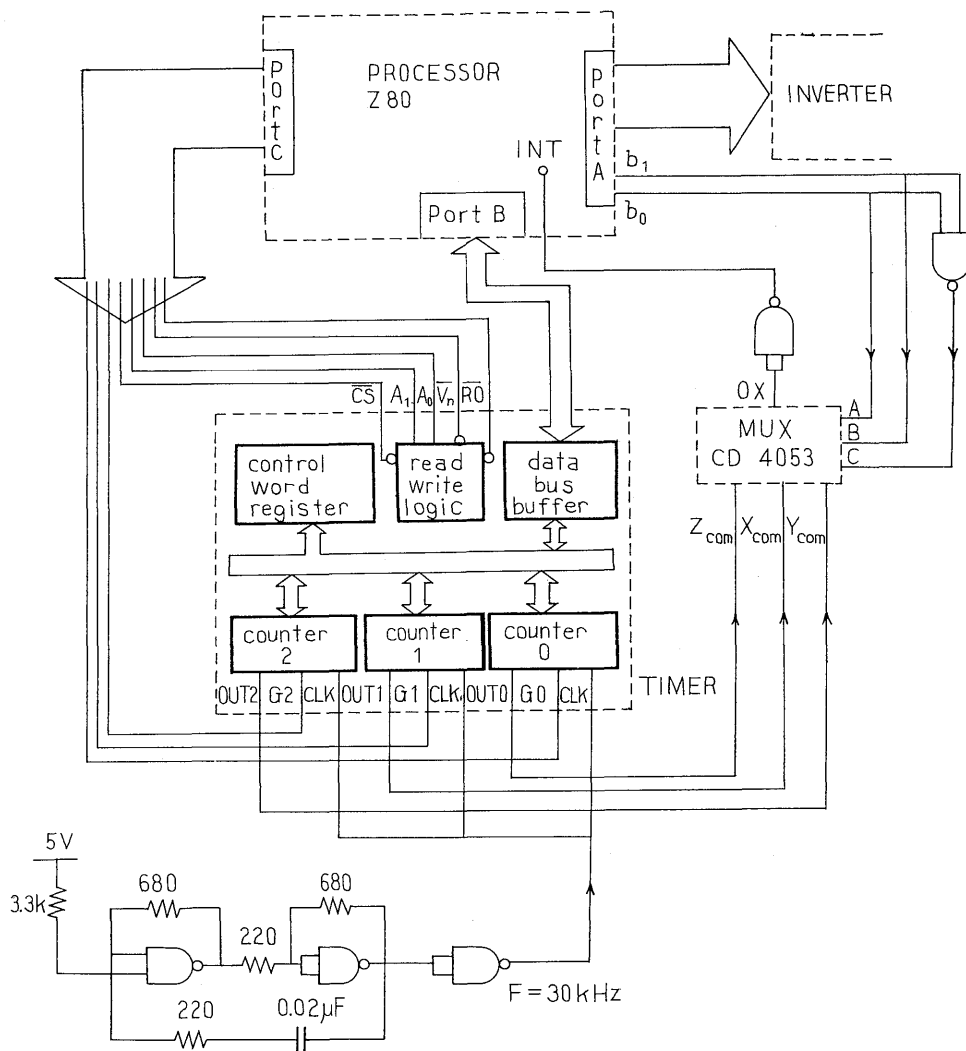


Fig. 6 Functional block diagram of PWM control signal generator hardware.

The system timing controller is M8254 from Intel which is driven by the astable multivibrator of 30kHz from 7400. This chip has five 16-bit timer-counters. Each timer-counter can operate in various modes which can be selected independently. In our case, timers 1, 2, and 3 have been selected for phase A, B, and C.

VIII. Functional Block Diagram - Software

The software of the generator is designed as an interrupt driven multitasking system. The functional block diagram of the microcomputer software is presented in Fig. 7. The main program consists of three functional blocks: (1) initialization, (2) control computations, (3) background.

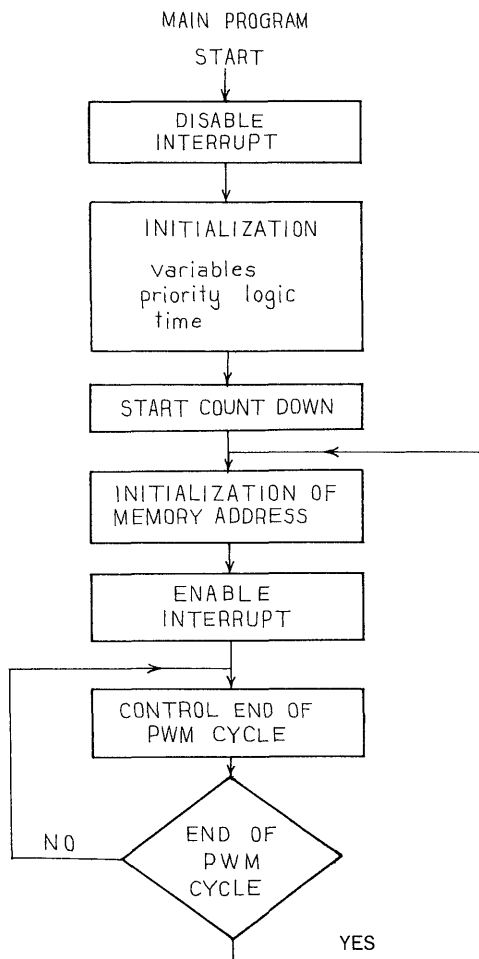


Fig. 7 Functional block diagram of PWM control signal generator software.

During initialization, the hardware timers (Fig. 6) are set in the proper mode of operation, and the software variables are set to their initial values.

During control computation, the command inputs are acquired by the microcomputer, and the values of variables which determined the frequency and the amplitude of the generated PWM signal fundamental are computed. The results of the computations are loaded into one of the two banks

of some registers each, which form a "rotating buffer" used to supply data to the pulse generation routine. The control computation routine is repeated every 60° of the reference signal.

During the background task, the program is in a loop waiting for the next interrupt and checking the status of flag which determines the destination of the next jump.

IX. PWM Signal Generation Algorithm

The arrival of an interrupt from the system timer initiates the pulse generation routine. During this routine, the PWM signal generation algorithm is executed. The functional block diagram of the interrupt program is presented in Fig. 8. The computational algorithm implemented in the signal generator takes into account following previously mentioned facts.

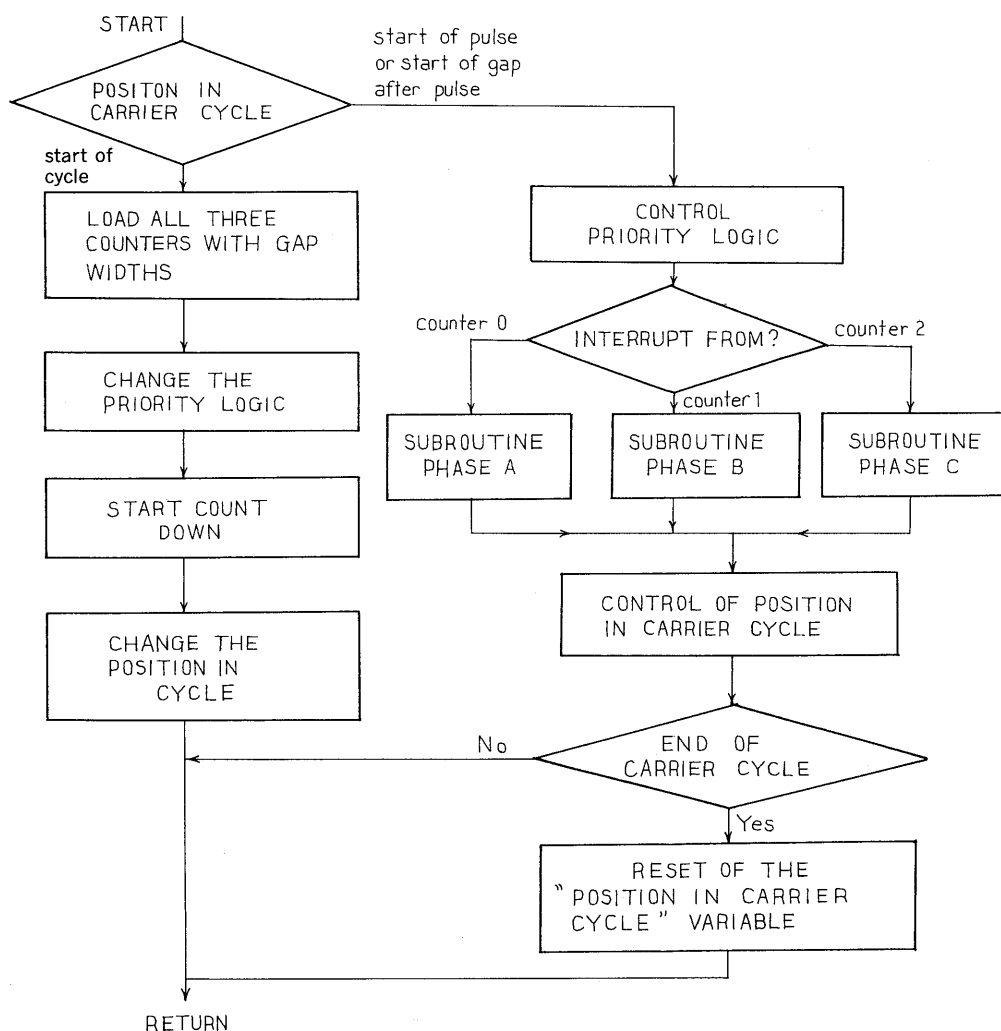


Fig. 8 Interrupt program.

There is an even integer number per each 60° interval of the reference signal. At any moment in time, all three process types are taking place in the signal phases. The order of following of processes and the order of changes of signal polarities are determined only by the direction of rotation.

Since there is only one switching point per each interval, this interval has been selected as the system sampling interval. As a example for the phase A, a simplified flowchart of this routine is shown in Fig. 9. The others also can be shown like this figure.

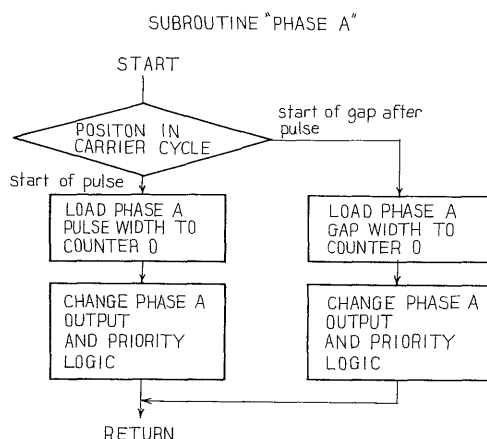


Fig. 9 PWM signal generation program.

X. Conclusion

In this program, the two devices in an inverter leg are switched simultaneously. In fact, the devices must always be switched alternatively, with a brief interval between the turning off of one device and the turning on of the other. Firing signals which result in simultaneous conduction of both devices will cause a "shoot - through" fault that short circuits the DC supply.

The results presented in this section were obtained using a Z80 microprocessor to provide the PWM base drive control for a 3 - phase inverter.

The microprocessor hardware configuration used is based on the implementation shown in section VII, using a 500KHz clock.

A microcomputer - based signal generator has been built. It has reduced hardware parts and all the flexibility resulting from software implementation of most of its functions. In spite of the limited precision of computations possible with an eight bit microcomputer, the harmonic contents of the generated PWM signal is comparatively low. The PWM signal generator was also used as a component of control system for an ac motor.

Acknowledgment

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