

SOFTWARE CONTROL USED FOR AC MOTORS

BY

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Abstract. With a view to obtain higher performances regarding the harmonic content of voltage and load current, we use a modern modulation strategy that is also intended to modify the ratio between the fundamental magnitude voltage from the inverter output and the power supply value. There are various modulation techniques that use exact mathematic equations for turning on the transistors within the power converter. In this paper we present the results obtained using the DPWM-S5 modulation technique for circuit control, through simulation and through practical implementation.

Key words: microcontroller; PWM technique; inverter; power supply; software.

1. Introduction

The Discontinuous Pulse Width Modulation S5 (DPWM-S5 – Hava, 1998) modulation technique uses mathematic equations to control the turning on of the transistors within the three-phase inverter, as shown in eqs. (1). The performances achieved are comparable with those obtained by Sinusoidal Pulse

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Width Modulation (SPWM – Ursaru *et al.*, 2009), Space Vector Modulation (SVM – Bose, 1987). However, DPWM-S5 has an important advantage: it reduces the number of commutations in an output voltage period. Out of four conduction intervals, in two intervals the transistors within the inverter are in continuous conduction and in the other two there are switching moments; this also results from eqs. (1). The reduced number of commutations in an output voltage period means diminished power losses on the power transistors, which leads to less heating and, therefore, the use of smaller heat-sinks for these transistors.

2. Theoretical Considerations

The basic eqs. for modulating signal s_5 are the following:

$$s_5 = \begin{cases} \sqrt{3}m_a \cos w_m t + m_a \sin w_m t - 1, & 0 \leq w_m t \leq 2p / 3; \\ -1, & 2p / 3 \leq w_m t \leq p; \\ -1, & p \leq w_m t \leq 4p / 3; \\ \sqrt{3}m_a \cos w_m t + m_a \sin w_m t - 1, & 4p / 3 \leq w_m t \leq 2p, \end{cases} \quad (1)$$

its waveform being represented in Fig. 1.

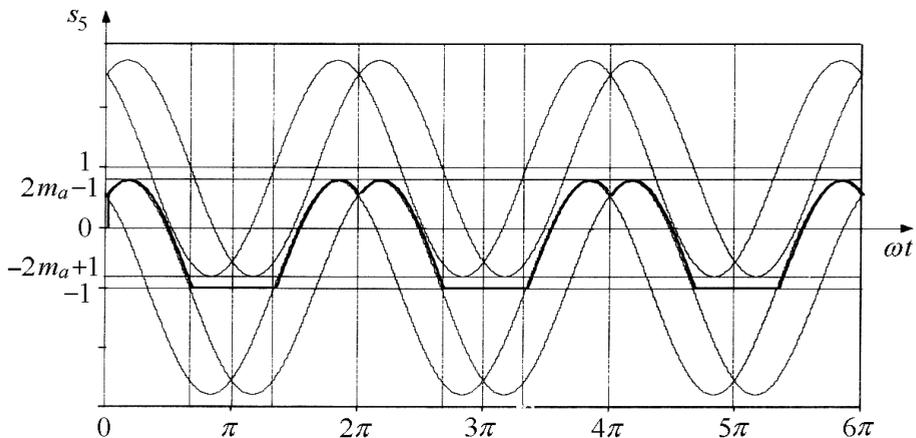


Fig. 1 – The modulator signal DPWM-S5.

Fig. 2 illustrates the waveforms of the modulator signals (s_{5a} , s_{5b} and s_{5c}) obtained for the DPWM-S5 technique and the control signals for the transistors within the three-phase inverter.

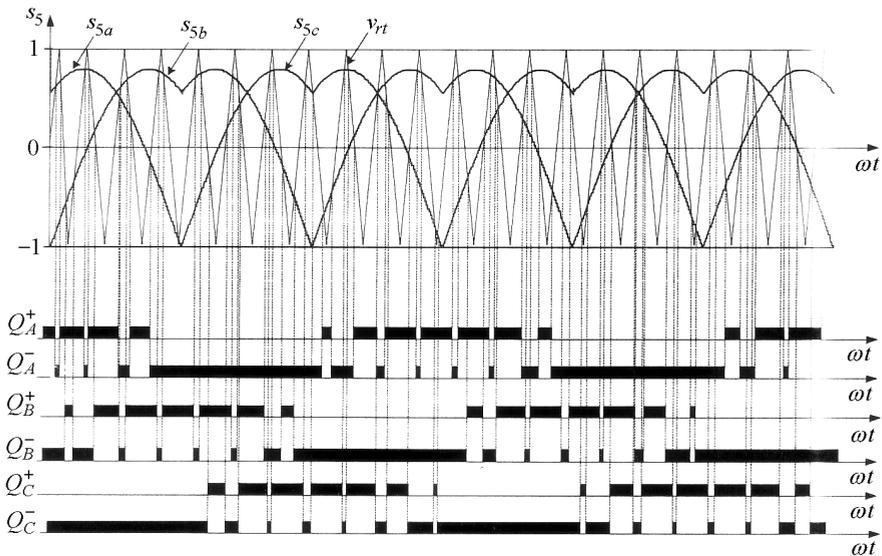


Fig. 2 – Waveforms of the modulator and control signals for all six transistors.

Fig. 3 shows the power inverter that will be controlled by DPWM-S5 signal.

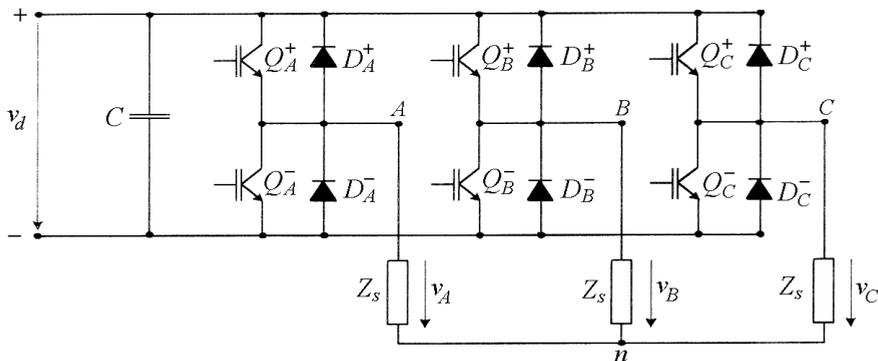


Fig. 3 – Power inverter architecture.

3. Control Algorithm

With the view to apply the control technique DPWM-S5, we used the C8051F120 microcontroller and we implemented the flowcharts presented in Figs. 4 *a* and 4 *b*. Fig. 4 *a* shows the main flowchart and Fig. 4 *b* presents the flowchart of the interruption routine required by timer $T3$.

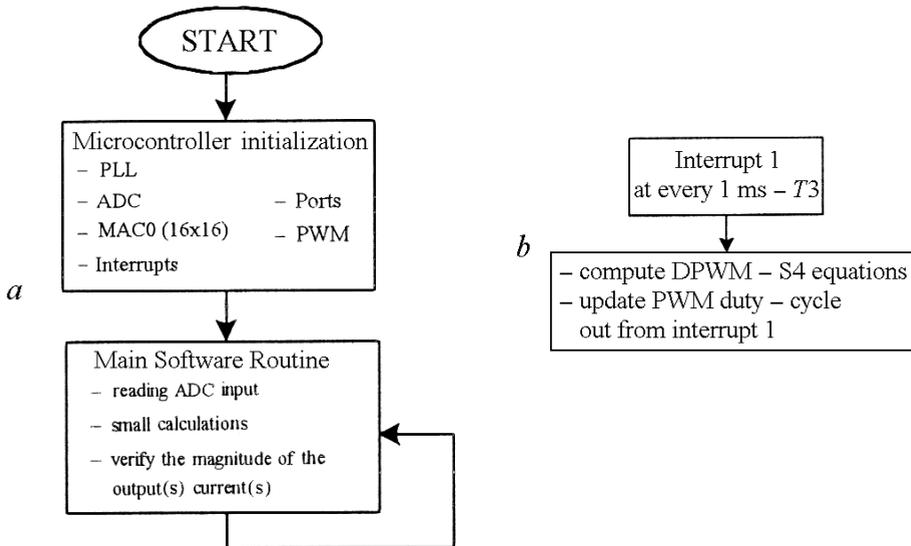


Fig. 4 – Software control flowchart (a); flowchart of Interrupt 1 (b).

After the microcontroller initialization (Timers, ADC, Output Ports, PWM block, PLL block, etc.), the main program is run. The switching moments for the six transistors within the three-phase inverter are calculated in interruption routine 1 of timer $T3$ every millisecond. More precisely, switching moments are calculated for transistors Q_A^+ , Q_B^+ and Q_C^+ , and control signals for transistors Q_A^- , Q_B^- and Q_C^- will be obtained by complementing the signals corresponding to transistors Q_A^+ , Q_B^+ and Q_C^+ ; this is carried out by the practical circuit. We must point out that the six transistors (Q_A^+ , Q_A^- , Q_B^+ , Q_B^- , Q_C^+ and Q_C^-) are grouped so that the “+” transistors are placed in the upper part of the three-phase transistor and the “-“ transistors in the lower part.

4. Control Software

The control software is written in C language, using the development environment provided by Silicon Laboratories. The most important code fragment for obtaining modulating signals, s_{5a} , s_{5b} and s_{5c} , is given below. This partial code is run every millisecond (time is measured by timer $T3$ based on interruptions). Although this microcontroller works on 8 bits, due to its work speed (100 MIPS) and to the MAC 16×16 block; all equations are calculated in a time less than 300 μ s.

```

void Timer3_ISR(void) interrupt 14
{
    unsigned char SFRPAGE_SAVE = SFRPAGE;
    s5();
    SFRPAGE = TMR3_PAGE;
    TF3 = 0;
    SFRPAGE = SFRPAGE_SAVE;
}
// Compute modulation signals S5
void s5(void)
{
    signed char s;           // signed sine
    unsigned char o;        // output value
    unsigned int p;         // 16 bit //product
    unsigned char SFRPAGE_SAVE = SFRPAGE;
    float f0, f1, f2, tr0, tr1, tr2;
    Sum += (freq << 6);
    q0 = (Sum >> 8);
    tr0 = (q0/40.6);
    if(!reverse)
    {
        tr1 = tr0 + xx1;
        tr2 = tr0 + xx2;
    }
    else
    {
        tr2 = tr0 + xx1;
        tr1 = tr0 + xx2;
    }
    SFRPAGE = PCA0_PAGE;
    f0 = s5abc(tr0);
    s = f0*0x7F;
    p = amplitude * (signed int)s;
//multiply by v
    o = p>>8; // throw away low byte
    o += 0x80; // center sinewave at 50%
    PCA0CPH0 = o;
    f1 = s5abc(tr1);
    s = f1*0x7F;
    p = amplitude * (signed int)s;
//multiply by v
    o = p>>8; // throw away low byte
    o += 0x80; // center sinewave at 50%
    PCA0CPH1 = o;
    f2 = s5abc(tr2);
    s = f2*0x7F;
    p = amplitude * (signed int)s;
//multiply by v
    o = p>>8; // throw away low byte
    o += 0x80; // center sinewave at 50%
    PCA0CPH2 = o;
    SFRPAGE = SFRPAGE_SAVE;
}

```

```

}
//-----
float s5abc(float tr)
{
    float dpwm5;
    if(tr<=2.093 && tr>0)
    {
        dpwm5=1-(sqr3*ma*cos(tr)+ma*sin(tr));
    }
    if(tr<=3.14 && tr>2.093)
    {
        dpwm5 = 1;
    }
    if(tr<=4.18 && tr>3.14)
    {
        dpwm5 = 1;
    }
    if(tr<=6.28 && tr>4.18)
    {
        dpwm5=1-(sqr3*ma*cos(tr)-ma*sin(tr));
    }
    return dpwm5;
}

```

5. Simulation and Experimental Results

After implementing the above software on the microcontroller, the signals s_{5a} and s_{5b} are obtained and represented in Fig. 5.

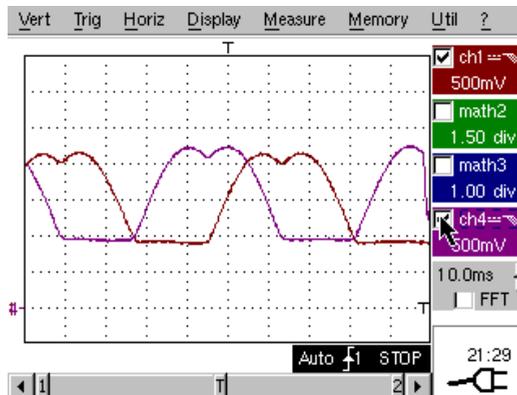


Fig. 5 – Modulation signals s_{5a} and s_{5b} obtained by measurement.

Fig. 6 shows the waveforms of the command signals for transistors within the three-phase inverter. The carrier frequency used in the program to modulate signals s_{5a} , s_{5b} and s_{5c} is of 17.25 kHz.



Fig. 6 – Waveforms from the oscilloscope of the command signals for Q_A^+ and Q_B^+ transistors.

Fig. 7 shows waveforms between phases A and B of the line voltage; on the left side these waveforms are read on the oscilloscope, and on the right side, they are obtained by simulations. The harmonic content is presented underneath.

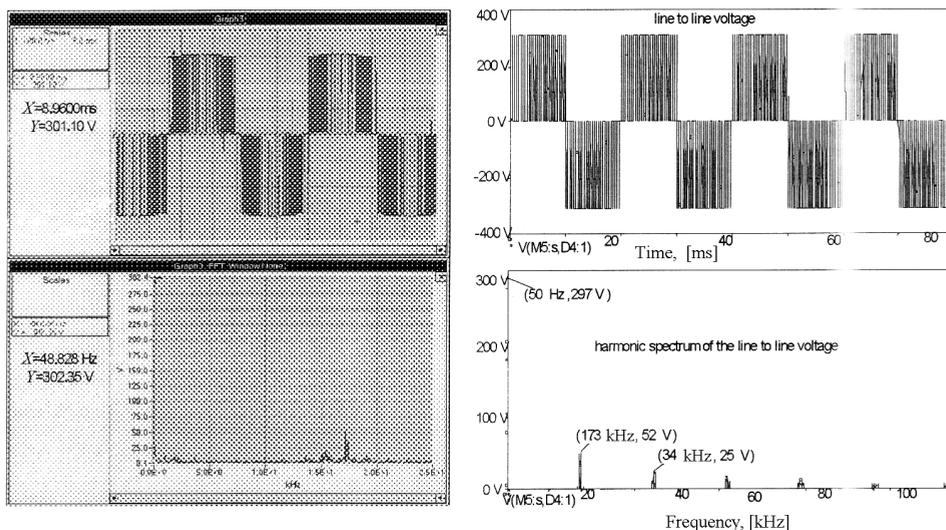


Fig. 7 – Waveforms and harmonic spectrum of the line to line voltage, obtained from oscilloscope (a); waveforms and harmonic spectrum of the line to line voltage, obtained by simulations (b).

The supply power of the three-phase inverter is 310 V. As load current we used a 0.37 kW three-phase motor.

As shown in Fig. 7, the amplitude of the line voltage fundamental for the practical circuit is 302 V, and the simulation value is 297 V.

Fig. 8 shows the waveform of the voltage between phase A and the virtual neutral point. In Fig. 8 *a* the waveform is read on the oscilloscope, and in Fig. 8 *b* it is obtained by simulation. The harmonic content is presented underneath.

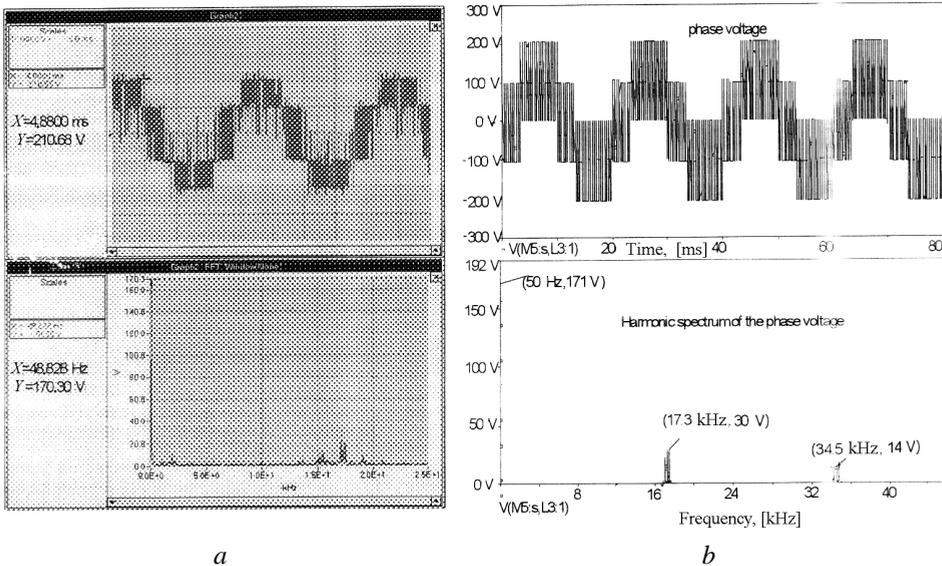


Fig. 8 – Waveforms and harmonic spectrum of the phase voltage A, obtained from oscilloscope (*a*); waveforms and harmonic spectrum of the phase voltage A, obtained by simulations (*b*).

As shown in Fig. 8, the amplitude of the phase voltage fundamental for the practical circuit is 170.3 V, and the simulation value is 171 V.

6. Conclusions

This paper presents the implementation of DPWM-S5 equations on a microcontroller and compares theoretical simulation results with results obtained from practical measurements. As compared to the Space Vector Modulation control technique, the performances of this technique are slightly lower, but power losses on the transistors within the inverter are significantly smaller. This control technique is adequate for cases where a low harmonic content is not necessarily a requirement, but where the inverter needs to work with increased efficiency.

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CONTROL SOFTWARE FOLOSIT PENTRU COMANDA MOTOARELOR DE CURENT ALTERNATIV

(Rezumat)

Se prezintă modul de implementare al semnalului DPWM-S5 pe un microcontroler, după care se analizează rezultatele și se compară cu cele obținute în urma simulărilor folosind programul SPICE. Microcontrolerul folosit este C8051F120 produs de compania Silicon Laboratories, ce controlează un inverter trifazat bazat pe puntea IRAMX16UP60A. Ca sarcină pentru inverterul trifazat s-a folosit un motor asincron trifazat cu trei perechi de poli, de 0,37 KW, iar frecvența de comutație a semnalului PWM este de 17,25 kHz.

UPLOADING USER PROGRAMS FROM PERSONAL COMPUTER AND RUNNING THEM ON DEVELOPMENT SYSTEMS EQUIPPED WITH 8051 FAMILY MICROCONTROLLERS

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Abstract. The paper describes the hardware structure of a development system equipped with an 8051 family microcontroller either with or without internal program memory, used for testing various applications. The system is connected to a personal computer through a serial interface. The user programs are edited, assembled and simulated on personal computer. The paper also details how to load user programs into the volatile memory of the development system and how to run them. Along with the other commands of the monitor software it is executed a real-time checking of the user program performing.

Key words: development systems; 8051 family microcontroller; program memory; data memory; monitor program; uploading and running user programs.

1. Introduction

The basic structure of a development system equipped with an 8051 family microcontroller is represented in Fig. 1, the acronyms standing for: CC – clock circuit; IC – initialization circuit; PSC – power supply circuit; LD-RS232

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