# Software implementation for ACIM motor control

Cristian Aghion[1], Ovidiu Ursaru[2], Mihai Lucanu[3]

**Abstract** – *Control circuits allow the performance increase of the power electronics converters through the implementation of advance control techniques. This paper describes the implementation of the DPWM-S4 technique on a microcontroller and compares the practical analysis results and the simulation results. The greatest advantage in using this command technique is the reduction by 1/3 of the power dissipated by the power transistors within a three-phase inverter.* 

***Keywords:*** *motor control, power electronics, microcontroller, algorithm*

DPWM-S4 → Discontinuous Pulse Width Modulation DPWM-S4 technique.
s4a, s4b and s4c → modulator signals of the DPWM-S4 technique.
$Q_A^+, Q_A^-, Q_B^+, Q_B^-, Q_C^+, Q_C^-$ → transistors from the power three-phase inverter.
C8051F120 → 100MIPS, 8-bit microcontroller from Silicon Laboratories.

## I. Introduction

In this paper, our aim is to describe the implementation of a modified reference wave on a microcontroller, using DPWM-S4 technique.

The DPWM-S4 [1] command technique was tested both practically and by SPICE simulation. This technique reduces by almost 1/3 the power dissipated by the power transistors, which constitutes its main advantage. The voltage and output currents frequency spectrum (as shown in simulation and in the practical experiment) at the output of a three-phase inverter controlled by this technique presents more harmonics than the spectrum obtained using other control techniques, such as Sinusoidal Pulse Width Modulation (SPWM) [2], Space Vector Modulation (SVM) [3].

The reduction of the power dissipated by the switching transistors is made possible by the low number of commutations in the same time frame. If the power dissipated by the transistors is lower, the transistor heat sink size is smaller for the same power delivered at the output by the three-phase inverter.

## II. Theoretical considerations

The main equations of the DPWM-S4 signal are presented in (1) and the mathematical representation is shown in Fig. 1.

$$s_4 = \begin{cases} \sqrt{3}m_a \cos\omega_m t + m_a \sin\omega_m t - 1; 0 \le \omega_m t \le \pi/3 \\ \sqrt{3}m_a \cos\omega_m t - m_a \sin\omega_m t + 1; \pi/3 \le \omega_m t \le 2\pi/3 \\ -1; 2\pi/3 \le \omega_m t \le \pi \\ \sqrt{3}m_a \cos\omega_m t - m_a \sin\omega_m t + 1; \pi \le \omega_m t \le 4\pi/3 \\ \sqrt{3}m_a \cos\omega_m t + m_a \sin\omega_m t - 1; 4\pi/3 \le \omega_m t \le 5\pi/3 \\ 1; 5\pi/3 \le \omega_m t \le 2\pi \end{cases} \quad (1)$$

Fig. 2 shows the waveforms of the modulator signals (s4a, s4b and s4c) obtained for the DPWM-S4 technique and the control signals for all six transistors within the power inverter.

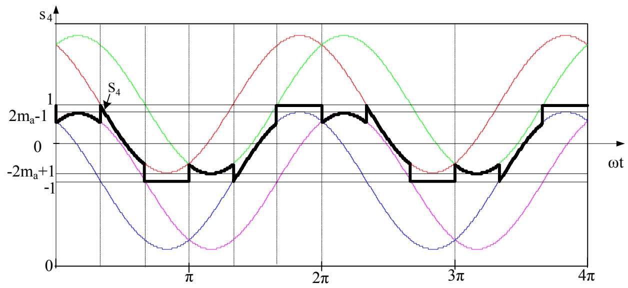


Fig. 1. The modulator signal DPWM-S4

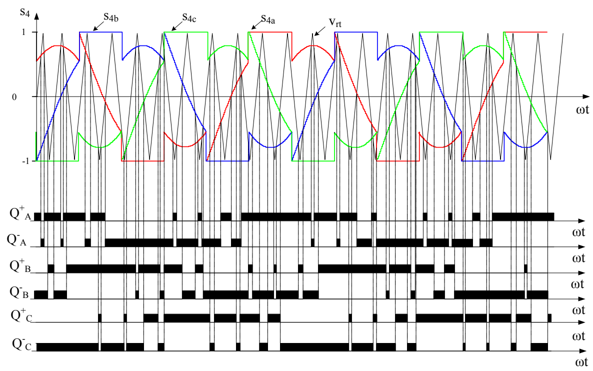


Fig. 2. Waveforms of the modulator and control signals for all six transistors

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## III. Control algorithm

The DPWM-S4 software takes into consideration equations (1) and is suited for C8051F120 microcontroller. The main flowchart of the control software is shown in Fig. 3(a). Fig. 3(b) shows the flowchart of the T3 Timer interruption (Service Routine Interruption), where the main equations are solved.

The first step is the microcontroller initialization (Input/Output Ports, ADC, PLL, Timers, PWM, etc.), the second step is the execution of the main software routine, written in C language, where the value of the Analog to Digital Converter (ADC) is continually read. This value is useful for the calculation of the magnitude of the modulator wave for the desired signal. The software also contains an interrupt routine 1 which appears at every 1ms because the Timer T3 surpasses itself. In this routine all three command signals are computed (with 120° phase-shift between them); there are three signals because it is necessary to command transistors $Q_A^+$, $Q_B^+$ and $Q_C^+$ , and for $Q_A^-$, $Q_B^-$ and $Q_C^-$ transistors, the command signals are obtained by the complementation of the original signals.

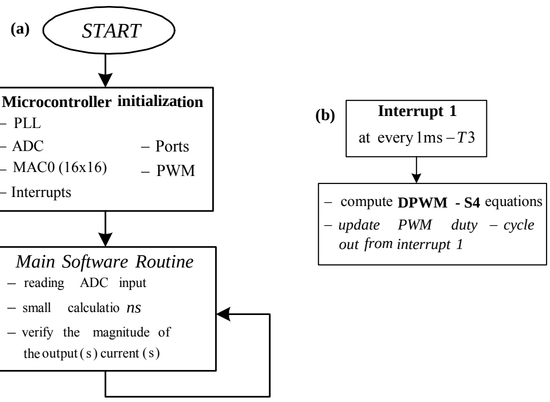


Fig. 3(a). Software control flowchart
Fig. 3(b). Flowchart of Interrupt 1

## IV. Software control

The command software is written in C language, applied to C8051F120 microcontroller. The software routine for the calculation of the DPWM-S4 signals is shown below. It should be taken into consideration that all these calculations are made in Interrupt 1 routine (having a lower priority), which is executed at every 1ms when Timer T3 surpasses itself. The necessary computing time is approximately 400µs, performance obtained using MAC 16x16 (Multiply and Accumulate) block.

```
void Timer3_ISR(void) interrupt 14
  {
    unsigned char SFRPAGE_SAVE = SFRPAGE;
    calc();
    SFRPAGE = TMR3_PAGE;
    TF3  = 0;
    SFRPAGE = SFRPAGE_SAVE;
  }

// Compute modulation signals S4
void calc(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 = s4(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 = s4(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 = s4(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 s4(float tr)
{
  float dpwm4;

  if(tr<=1.046 && tr>0)
    {
      dpwm4 = (sqr3*ma*cos(tr)+ma*sin(tr)) - 1;
    }
  if(tr<=2.093 && tr>1.046)
    {
      dpwm4 =(sqr3*ma*cos(tr)-ma*sin(tr)) + 1;
    }
  if(tr<=3.151 && tr>2.093)
    {
      dpwm4 =-1;
    }
  if(tr<=4.186 && tr>3.151)
    {
      dpwm4 = (sqr3*ma*cos(tr)+ma*sin(tr)) + 1;
    }
  if(tr<=5.233 && tr>4.186)
    {
      dpwm4 =(sqr3*ma*cos(tr)-ma*sin(tr)) - 1;
    }
  if(tr<=6.28 && tr>5.233)
    {
      dpwm4 =1;
    }
  if(tr<=1.046+6.28 && tr>0+6.28)
```

```
    {
      dpwm4 = (sqr3*ma*cos(tr)+ma*sin(tr)) - 1;
    }
  if(tr<=2.093+6.28 && tr>1.046+6.28)
    {
      dpwm4 = (sqr3*ma*cos(tr)-ma*sin(tr)) + 1;
    }
  if(tr<=3.151+6.28 && tr>2.093+6.28)
    {
      dpwm4 = - 1;
    }
  if(tr<=4.186+6.28 && tr>3.151+6.28)
    {
      dpwm4 = (sqr3*ma*cos(tr)+ma*sin(tr)) + 1;
    }
  if(tr<=5.233+6.28 && tr>4.186+6.28)
    {
      dpwm4 =(sqr3*ma*cos(tr)-ma*sin(tr)) - 1;
    }
  if(tr<=6.28+6.28 && tr>5.233+6.28)
    {
      dpwm4 =1;
    }

return dpwm4;
}
```

## V. Simulation and experimental results

After implementing the above software on the microcontroller, the signals s4a and s4b are obtained and shows in Fig. 4.

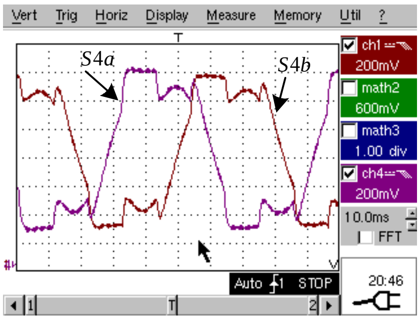


Fig. 4. Modulation signals s4a and s4b obtained by measurement

Fig. 5 shows the waveforms of the command signals for transistors within the three-phase inverter. It is important to mention that the modulation was a triangular modulation wave with 17.25KHz carrier frequency.

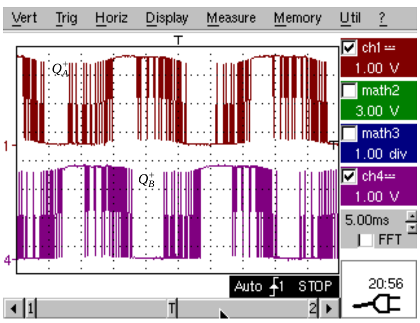


Fig. 5. Waveforms from the oscilloscope of the command signals for transistors.

Considering that the supply voltage of the three-phase is 305V and the output impedance is of 0.37 KW for the simulations and on the practical stand, we obtain the following.

Fig. 6 shows on the left side the line to line voltage between A and B phases read on the oscilloscope, and the harmonic content of this voltage is presented below. On the right side, is presented the line to line voltage between A and B phases, obtained by simulations, and the harmonic spectrum of the line to line voltage between A and B phases, obtained also by simulations.

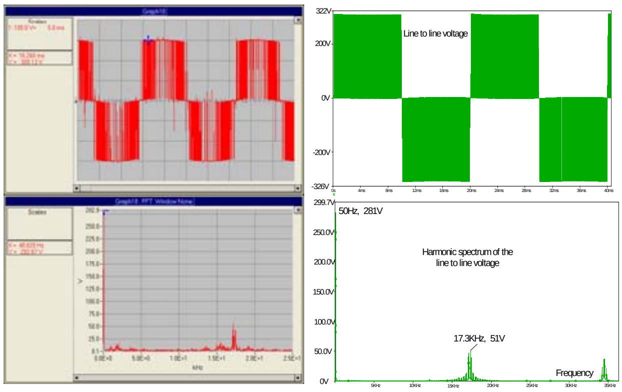


Fig. 6. – left side: waveforms and harmonic spectrum of the line to line voltage, obtained from oscilloscope
– right side: waveforms and harmonic spectrum of the line to line voltage, obtained by simulations

Fig. 7 shows on the left side the phase voltage A, read on the oscilloscope, and the harmonic content of this voltage is presented below. On the right side, is presented the phase voltage A, obtained by simulations, followed by the harmonic spectrum of the phase voltage A, obtained by simulations.

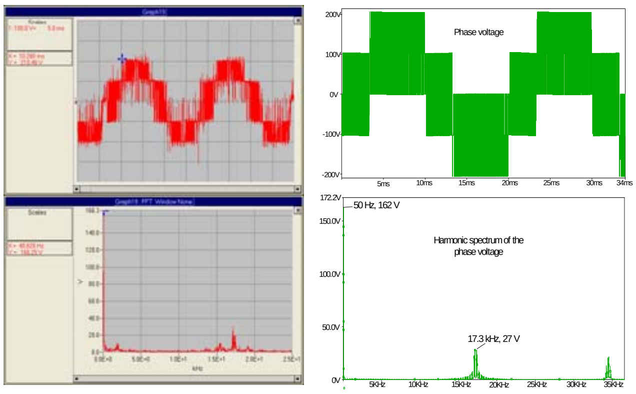


Fig. 7 – left side: waveforms and harmonic spectrum of the phase voltage A, obtained from oscilloscope.
– right side: waveforms and harmonic spectrum of the phase voltage A, obtained by simulations.

Fig. 8 shows on the left side the phase current A, read on the oscilloscope, and the harmonic content of this current is presented below. On the right side is presented the phase current A, obtained by simulations, followed by the harmonic spectrum of the phase current A, obtained by simulations.

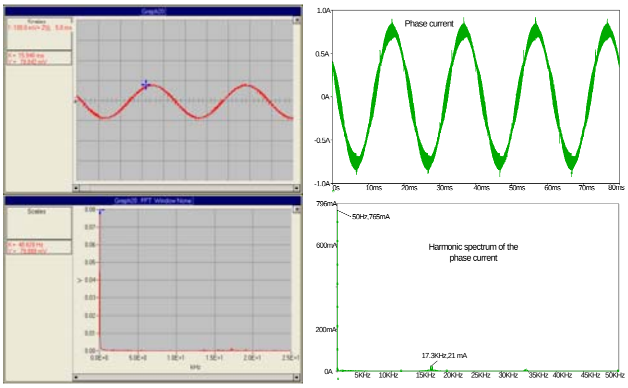


Fig. 8. – left side: waveforms and harmonic spectrum of the phase current A, obtained from oscilloscope
– right side: waveforms and harmonic spectrum of the phase current A, obtained by simulations.

Fig. 9 shows the practical circuit used for testing.

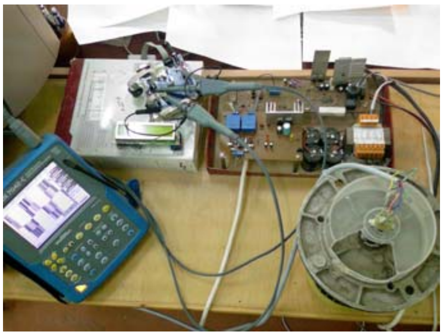

Fig. 9. Practical circuit contain: microcontroller, power three-phase inverter (made up with IRAMX16UP60A), 0,37KW motor, hall sensors for current measurements, LCD.

## VI. Conclusion

In this paper, we used a three-phase inverter command microcontroller in order to implement the DPWM-S4 algorithm. Nevertheless, it is obviously a high performance technique, which allows the reduction of the number of commutations of the power transistors within the three-phase inverter. Thus, the smaller power losses increase the efficiency of the inverter.

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