Space Vector Pulse Width Modulation MSS Software Implementation

User Guide

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SVPWM Theory

Introduction

Space Vector Pulse Width Modulation (SVPWM) is an improved technique for generating a fundamental sine wave that provides a higher voltage to the motor; lower total harmonic distortion, and controls the number of short pulses in the PWM waveform.

Sinusoidal PWM has the following drawbacks:

- **Lower output voltage**: A sinusoidal PWM drive cannot provide a line-line output voltage as high as the line supply.
- **Short Pulses**: The short pulses occur when the peak modulation signal is close to the peak carrier signal and contribute to inverter losses.

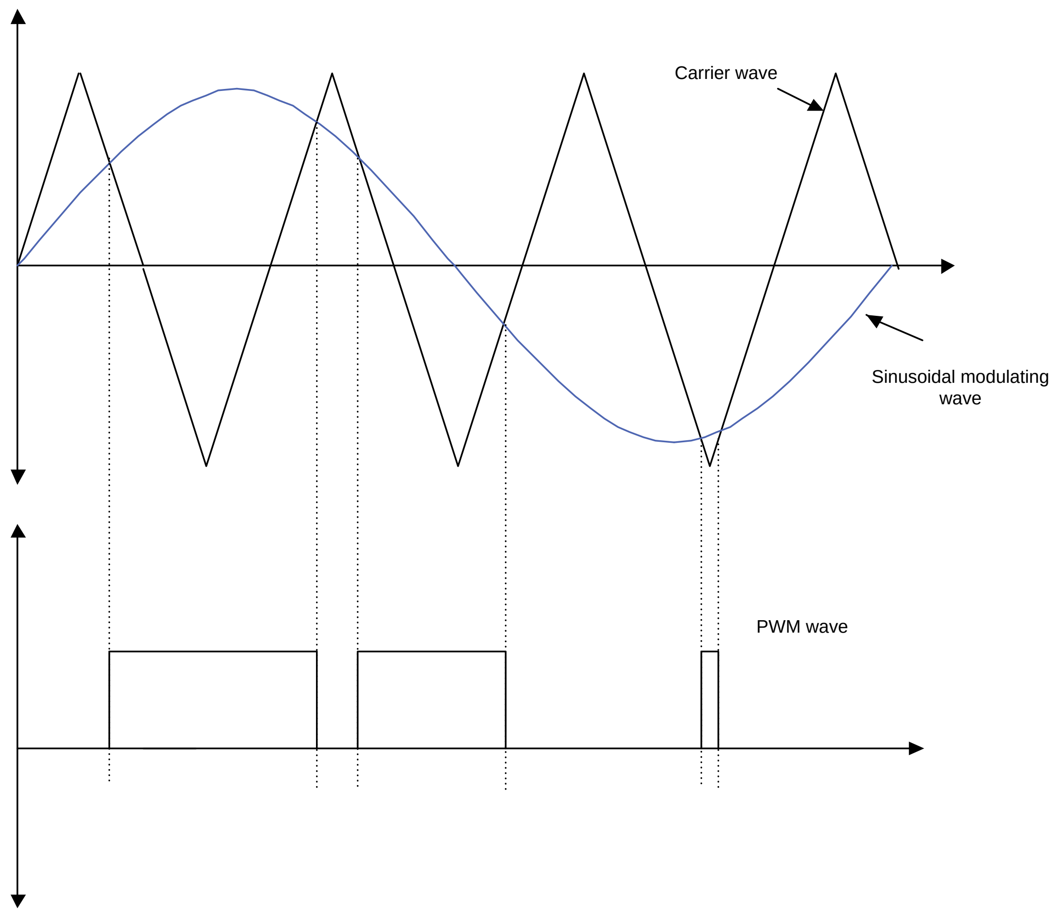

Figure 1 · Sinusoidal PWM Waveform

The strategy used in SVPWM technique is to modify the modulation of sine waves (input phase voltages) to increase the inverter voltage gain and also to reduce inverter losses.

The SVPWM implementation can be configured to use one of the following techniques:

1. MIN-MAX method
2. Direct injection of third harmonic

MIN-MAX Method

In the MIN-MAX method, the magnitude of a Common mode signal (vcm) is subtracted from all the three phase voltages.

$$v_{cm} = \frac{max(V_A, V_B, V_C) + min(V_A, V_B, V_C)}{2}$$

EQ1

The subtraction of the common mode voltage introduces a third harmonic component in the phase voltages. However, the line-to-line voltages are not affected because the same signal is subtracted from each phase voltage. The third harmonic component introduced by the common mode signal gives the following advantages:

- For a given modulation index, the peak modulation voltage is farther from the peak carrier voltage. Thus, the number of short pulses is minimized.
- Overmodulation is possible while keeping the peak of the carrier signal greater than the peak of the modulating signal. So, the line-to-line voltage would be same as the fundamental line-line supply voltage.

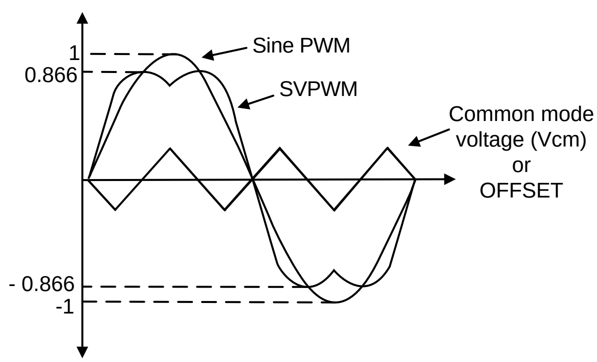

Figure 2 · SVPWM MIN-MAX Method

Direct Injection of Third Harmonic

The phase waveforms having no third harmonics can be generated by the addition of third harmonics in the sinusoidal reference waveform. Also, the voltage gain of the inverter can be improved by the addition of one-sixth of the third harmonic component of the phase voltage to the fundamental phase voltage. The addition of third harmonic component also improves the DC utilization of the inverter. The effect of addition of the third harmonic component is that it reduces the peak value of the resultant output voltage wave by a factor of 0.866 without any change in the fundamental input phase voltage as shown in EQ2.

The general equation for modulating wave in this method is:

$$V = k(\sin(wt) + \frac{1}{6}\sin(3 * wt))$$

EQ2

Where,

k is a factor to increase the amplitude of the modulating waveform

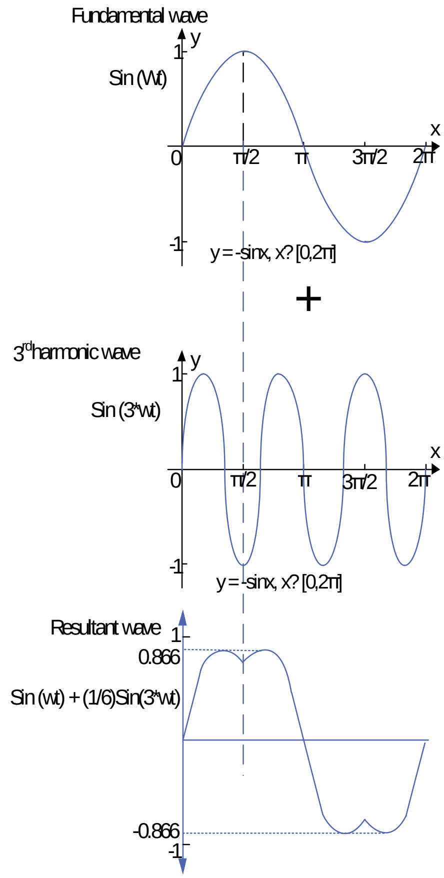

Figure 3 · Direct Injection of Third Harmonic Component

For example, if the output must be a unity peak value and the reduction in peak introduced by the block is 0.866, the factor k must be 1.155(k * 0.866 = 1; k=1/0.866). This implies that a 15.5 percent boost is introduced in the phase voltage, which results in better utilization of the DC bus.

API Type Definitions

This section lists the type definitions required to implement the MSS software libraries of SVPWM.

svpwm_minmax_type

Table 1 gives the type definition of svpwm_minmax_type.

Table 1 · svpwm_minmax_type

Name	svpwm_minmax_type	
Type	typedef struct { int32_t va; int32_t vb; int32_t vc; int32_t va3h; int32_t vb3h; int32_t vc3h; }svpwm_minmax_type;Input	
File	TypeDef.h	
Range	int32_t va;	This value refers to the phase A voltage.
	int32_t vb;	This value refers to the phase B voltage.
	int32_t vc;	This value refers to the phase C voltage.
	int32_t va3h;	This value refers to the third harmonic injected phase A voltage.
	int32_t vb3h;	This value refers to the third harmonic injected phase B voltage.
	int32_t vc3h;	This value refers to the third harmonic injected phase C voltage.

sine_3rdharmonic_inject_type

Table 2 gives the type definition of svpwm_minmax_type.

Table 2 · svpwm_minmax_type

<table>
<tr><td>Name</td><td colspan="2">sine_3rdharmonic_inject_type</td></tr>
<tr><td>Type</td><td colspan="2">typedef struct
{
int32_t voltage_magnitude;
int16_t sin_theta;
int16_t sin_three_theta;
int16_t sin_theta_minus120;
int16_t sin_three_theta_minus120;
int16_t sin_theta_plus120;
int16_t sin_three_theta_plus120;
int32_t va3h;
int32_t vb3h;
int32_t vc3h;
}svm_3rdharmonic_inject_type;</td></tr>
<tr><td>File</td><td colspan="2">TypeDef.h</td></tr>
<tr><td rowspan="10">Range</td><td>int32_t voltage_magnitude;</td><td>This value refers to the phase A voltage.</td></tr>
<tr><td>int16_t sin_theta;</td><td>This value refers to the sine value of the angle.</td></tr>
<tr><td>int16_t sin_three_theta</td><td>This value refers to the third harmonic sine value of the angle.</td></tr>
<tr><td>int16_t sin_theta_minus120;</td><td>This value refers to the sine value of the angle delayed by 120 degrees.</td></tr>
<tr><td>int16_t sin_three_theta_minus120;</td><td>This value refers to the third harmonic sine value of the angle delayed by 120 degrees.</td></tr>
<tr><td>int16_t sin_theta_plus120;</td><td>This value refers to the sine value of the angle advanced by 120 degrees.</td></tr>
<tr><td>int16_t sin_three_theta_plus120;</td><td>This value refers to the third harmonic sine value of the angle advanced by 120 degrees.</td></tr>
<tr><td>int32_t va3h;</td><td>This value refers to the third harmonic injected phase A voltage.</td></tr>
<tr><td>int32_t vb3h;</td><td>This value refers to the third harmonic injected phase B voltage.</td></tr>
<tr><td>int32_t vc3h;</td><td>This value refers to the third harmonic injected phase C voltage.</td></tr>
</table>

API Functions Description

In this section, the functions required to perform various tasks involved in implementing SVPWM are described.

SVPWM_MinMax_Lib_Calculate

Table 3 gives the description of SVPWM_MinMax_Lib_Calculate function which is used to calculate the voltage offset from the minimum and maximum values out of the given three phase voltages and computes the corresponding third harmonic value using the MIN-MAX method.

Table 3 · Specification of API SVPWM_MinMax_Lib_Calculate

Syntax	void SVPWM_MinMax_Lib_Calculate (svpwm_minmax_type *svpwm_ptr)
Re-entrancy	Re-entrant
Parameters (Inputs)	svpwm_ptr: Pointer to the SVPWM MinMax method structure
Parameters (output)	svpwm_ptr: Pointer to the SVPWM MinMax method structure
Return	None
Algorithm Description	$voltage\_offset = [MIN(va, vb, vc) + MAX(va, vb, vc)]/2$ $svpwm\_ptr \rightarrow va3h = 2/\sqrt{3} * (svpwm\_ptr \rightarrow va - voltage\_offset)$ $svpwm\_ptr \rightarrow vb3h = 2/\sqrt{3} * (svpwm\_ptr \rightarrow vb - voltage\_offset)$ $svpwm\_ptr \rightarrow vc3h = 2/\sqrt{3} * (svpwm\_ptr \rightarrow vc - voltage\_offset)$

Sine_3rdH_Inject_Lib_Calculate

Table 4 gives the description of Sine_3rdH_Inject_Lib_Calculate function which is used to generate sine voltages with direct addition of the third harmonic method.

Table 4 · Specification of API SVPWM_MinMax_Lib_Calculate

Syntax	void Sine_3rdH_Inject_Lib_Calculate (sine_3rdharmonic_inject_type * sine_3rdh_ptr)
Re-entrancy	Re-entrant
Parameters (Inputs)	sine_3rdh_ptr: Pointer to the sine plus third harmonic structure
Parameters (output)	sine_3rdh_ptr: Pointer to the sine plus third harmonic structure
Return	None
Algorithm Description	$V_a = Vm * [\sin(\theta) + \frac{\sin(3 * \theta)}{6}]$ $V_b = \frac{2}{\sqrt{3}} * Vm * \left[\sin(\theta - 120) + \frac{\sin\left(3 * (\theta - 120)\right)}{6}\right]$ $V_c = \frac{2}{\sqrt{3}} * Vm * \left[\sin(\theta + 120) + \frac{\sin\left(3 * (\theta + 120)\right)}{6}\right]$ Where, V_a = sine_3rdh_ptr→ va3h V_b = sine_3rdh_ptr→ vb3h

	V_c = sine_3rdh_ptr→ vc3h Vm = sine_3rdh_ptr→ voltage_magnitude $\text{Sin}(\theta)$ = sine_3rdh_ptr→ sin_theta $\text{Sin}(3\theta)$ = sine_3rdh_ptr→ sin_three_theta $\sin(\theta - 120)$ = sine_3rdh_ptr→ sin_theta_minus120 $\sin(3 *(\theta - 120))$ = sine_3rdh_ptr→ sin_three_theta_minus120 $\sin(\theta + 120)$ = sine_3rdh_ptr→ sin_theta_plus120 $\sin(3 *(\theta + 120))$ = sine_3rdh_ptr→ sin_three_theta_plus120

Sine_3rdH_Variable_Update

Table 5 gives the description of Sine_3rdH_Variable_Update function which is used to update different sine values for a particular reference phase angle (θ) and also magnitude of the third harmonic voltage.

Table 5 · Specification of API Sine_3rdH_Variable_Update

Syntax	void Sine_3rdH_Variable_Update(sine_3rdharmonic_inject_type *sine_3rdh_ptr int32_t voltage_magnitude int32_t sin_theta int32_t sin_three_theta int32_t sin_theta_minus120 int32_t sin_three_theta_minus120 int32_t sin_theta_plus120 int32_t sin_three_theta_plus120)
Re-entrancy	Re-entrant
Parameters (Inputs)	sine_3rdh_ptr: Pointer to the sine plus third harmonic structure
Parameters (output)	sine_3rdh_ptr: Pointer to the sine plus third harmonic structure
Return	None
Algorithm Description	sine_3rdh_ptr→ voltage_magnitude = voltage_magnitude sine_3rdh_ptr→ sin_theta = sin_theta sine_3rdh_ptr→ sin_three_theta = sin_three_theta sine_3rdh_ptr→ sin_theta_minus120 = sin_theta_minus120 sine_3rdh_ptr→ sin_three_theta_minus120 = sin_three_theta_minus120 sine_3rdh_ptr→ sin_theta_plus120 = sin_theta_plus120 sine_3rdh_ptr→ sin_three_theta_plus120 = sin_three_theta_plus120

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Fax, from anywhere in the world **408.643.6913**

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The technical support email address is soc_tech@microsemi.com.

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