TB9M003FG
Example of 1-Shunt Sensorless Vector Control

Description

This application note introduces an example of 1-shunt sensorless vector control using the TB9M003FG. The TB9M003FG is equipped with a Vector Engine (VE), which implements part of the vector control processing in hardware. The VE helps reduce the software processing load required for 1-shunt sensorless vector control.
By using the TB9M003FG together with our reference software, basic motor operation can be verified through parameter adjustment alone.

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1. Overview of Vector Control Using VE (Vector Engine)

1.1. Principle of Vector Control

This chapter provides an overview of vector control using our proprietary Vector Engine (VE).
In vector control, motor currents are decomposed into Id, the component contributing to magnetic flux generation, and Iq, the component contributing to torque generation.
These components are controlled independently, resulting in improved controllability and enabling highly efficient motor control.
Here, the d-axis and q-axis refer to coordinate axes that rotate synchronously with the rotor.

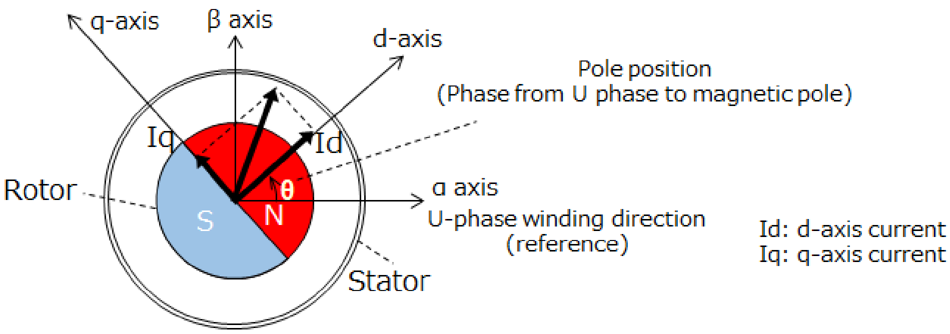

Figure 1.1 Coordinate Axes in Vector Control

1.2. Configuration of Vector Control

The configuration of vector control is shown below.
The VE installed in the TB9M003FG handles part of the vector control processing on behalf of the CPU.
Since the VE can freely select the arithmetic processing to execute from a set of predefined tasks, it enables various types of control in combination with the user's own software.

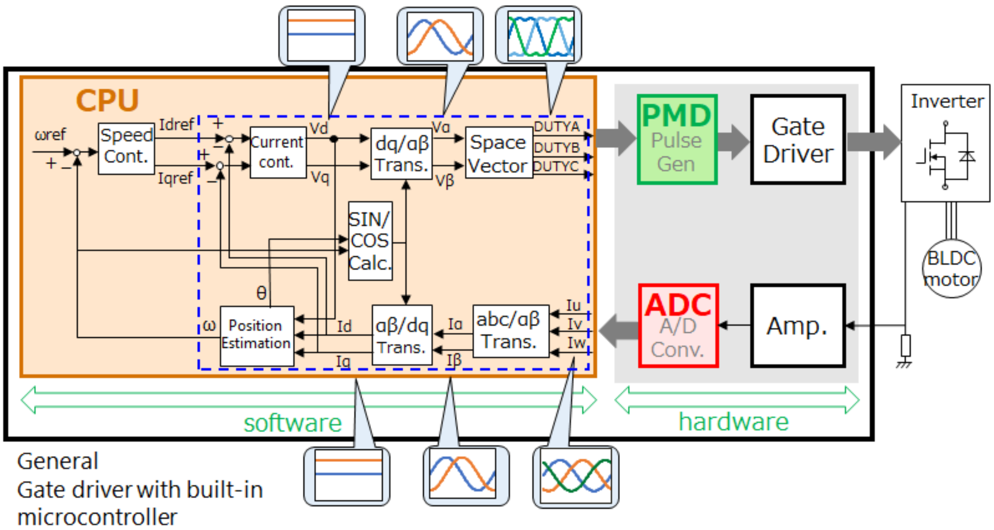

Figure 1.2 General block diagram for realizing FOC

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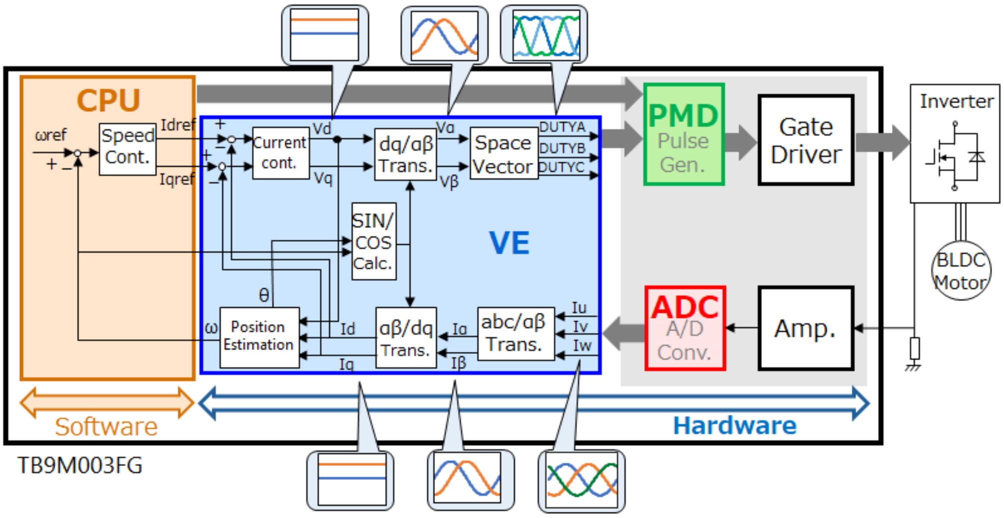

Figure 1.3 Block Diagram to Realize Vector Control Using the VE

1.3. Main Features of the VE

The features of the VE are as follows:
The TB9M003FG combines a low-cost CPU with slower processing and the VE, achieving both versatility and processing speed.
This configuration enables high-speed processing with a control cycle of 50 μs, even when using a low-cost CPU.

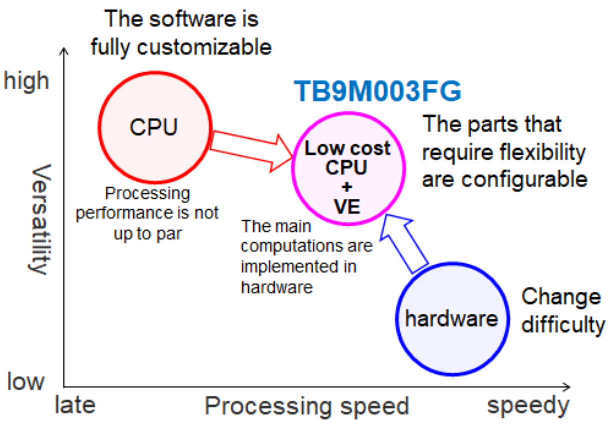

Figure 1.4 Features of VE

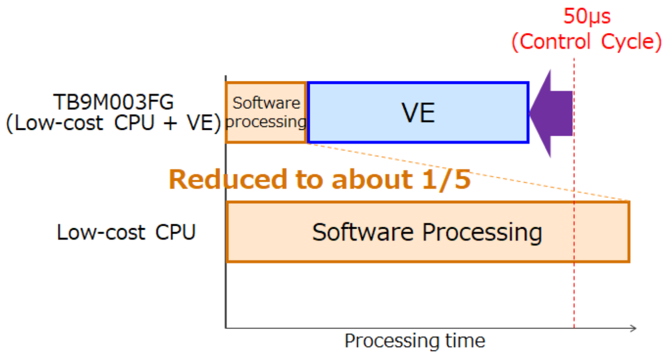

Figure 1.5 Comparison of processing time for motor control

1.4. VE Task

An example of the task execution flow in VE is shown below.
In VE, a series of arithmetic processing for vector control are organized into tasks.
Users can select tasks as needed. And since it is also possible to integrate the user's software, highly flexible motor control tailored to the application can be achieved.

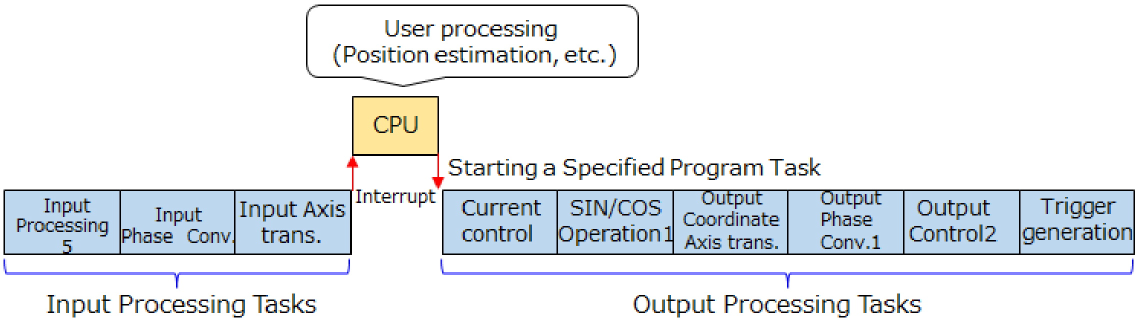

Figure 1.6 Example of Task Execution Processing Flow

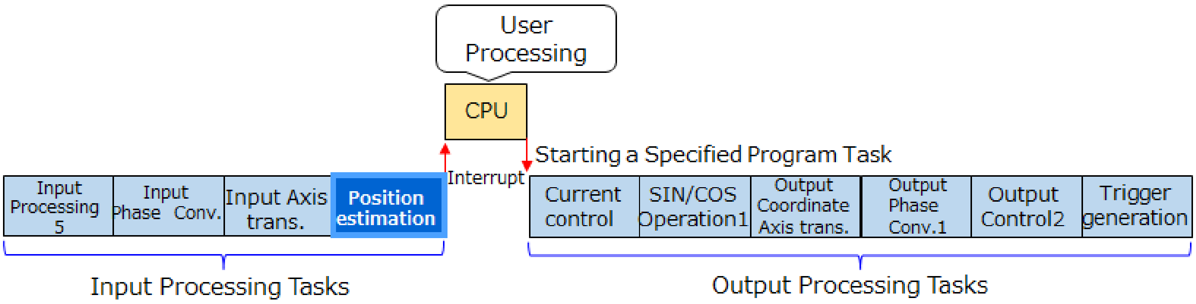

Figure 1.7 Example of Task Execution Processing Flow (Task Selection for Position Estimation)

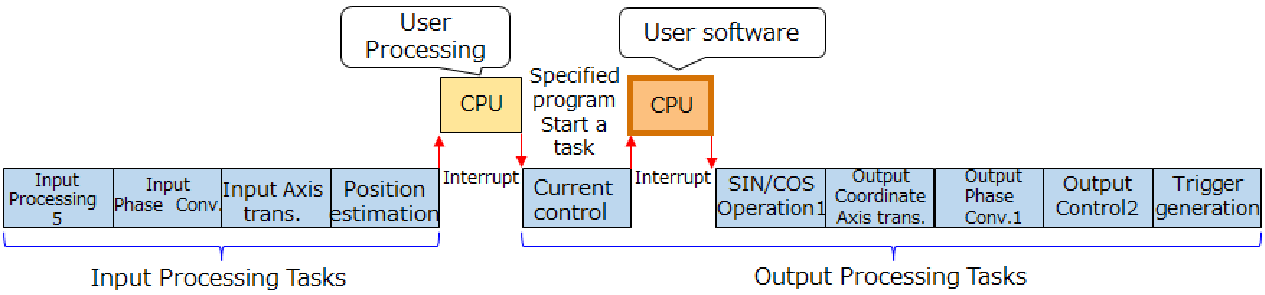

Figure 1.8 Example of Task Execution with User Software Integration

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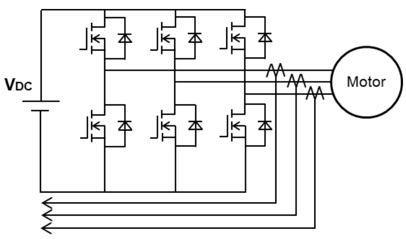
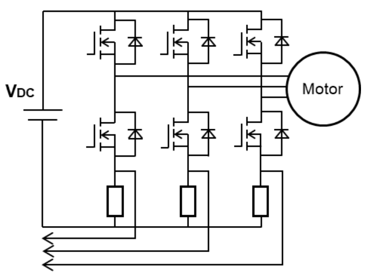
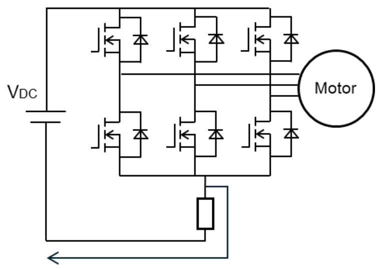
2. 1-Shunt Current Sensing

2.1. Current Sensing Method

This section explains the overview of current sensing.
Vector control requires information about motor current. The following methods are commonly used for current sensing. The TB9M003FG supports the 1-shunt method.

Table 2.1 Current Sensing Method

	Current Sensing Method	3-Shunts Method	1-Shunt Method
Current Sensing Method	Magnetically senses current	Measure the voltage at both ends of the shunt resistor, Getting the current	Similar to 3-shunts (Circuit configuration is 1/3 of 3-shunts)
Current Sensing Constraints	No constraints	Restricted (Only when overmodulated controlled)	Restricted (There is a period when current cannot be sensed)
Cost	High cost	Low cost	Low cost (1/3 of 3-shunts)
Circuit configuration (example)			

2.2. Shunt Method – Current Sensing Timing

The current sensing timing for the 3-shunt and 1-shunt methods is shown below.
To reconstruct the motor current from the voltage generated across the shunt resistor, it is necessary to sense the current of two phases within one PWM (Pulse Width Modulation) cycle. The current of the remaining one phase can be calculated based on the fact that the sum of the three-phase currents is zero.
In the 3-shunt method, the current sensing timing is always consistent.
On the other hand, since the 1-shunt method uses only one shunt resistor, the timing for current sensing must be adjusted accordingly.

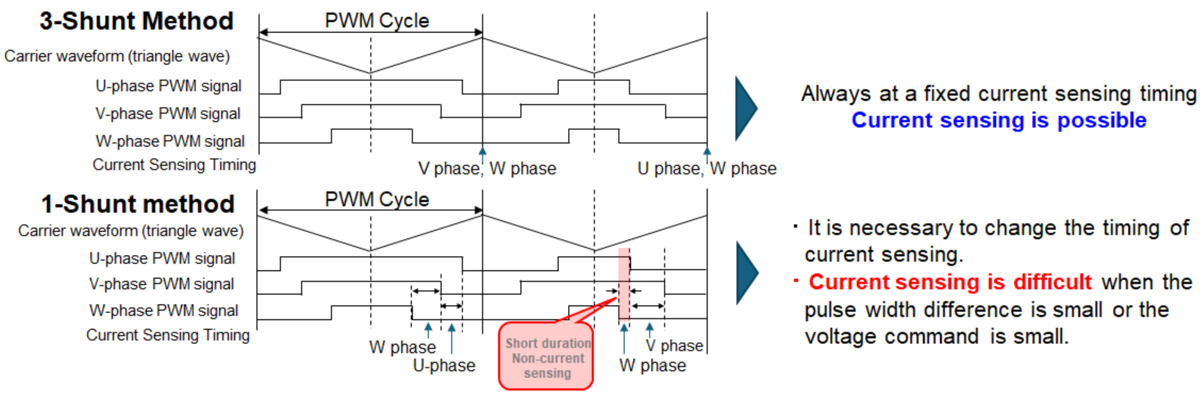


Figure 2.1 Switching Signals of Each Phase and Current Sensing Timing

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2.3. Issues with the 1-Shunt Method

The following describes the issues in current sensing using the 1-shunt method.
In the 1-shunt method, there are periods ((1) and (2)) during space vector modulation when current sensing is not possible.
During these periods, it becomes impossible to sense the two-phase currents required for vector control within a single PWM cycle.

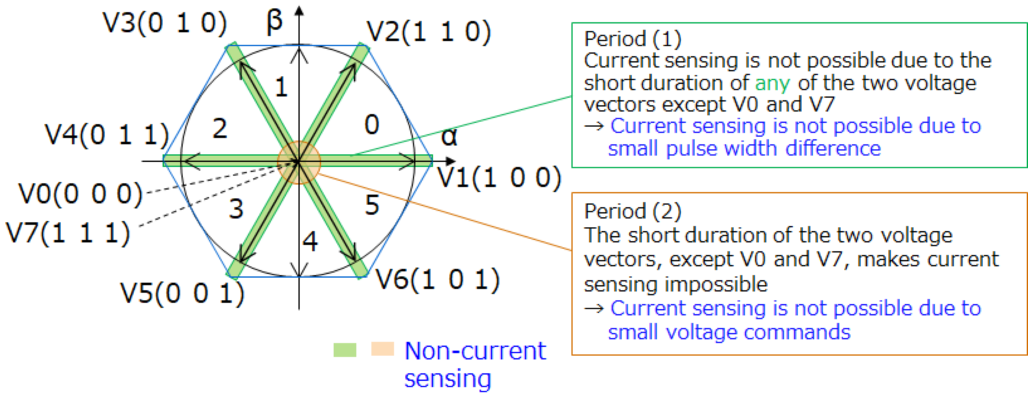

Figure 2.2 Spatial vector transformation method (definition of voltage vector V0 to V7, sector 0 to 5)

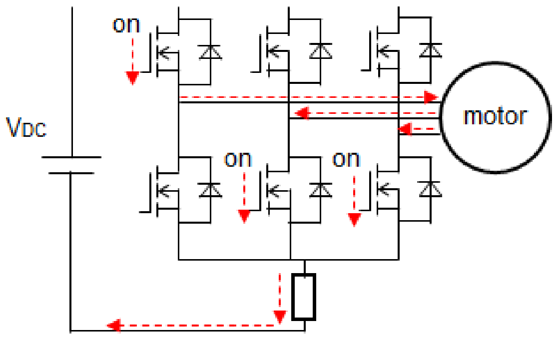

Figure 2.3 Current path in the case of V1

2.4. Overview of Shift PWM

This section explains the overview of Shift PWM.
In the 1-shunt method, to ensure a sufficient period for current sensing, VE is equipped with two types of Toshiba-original Shift PWM functions.
With **Shift 1 PWM**, the current sensing timing is automatically set by VE.
With **Shift 2 PWM**, the user sets a fixed current sensing timing. However, in the case of Shift 2 PWM, adjustments may be necessary depending on the motor and operating environment.

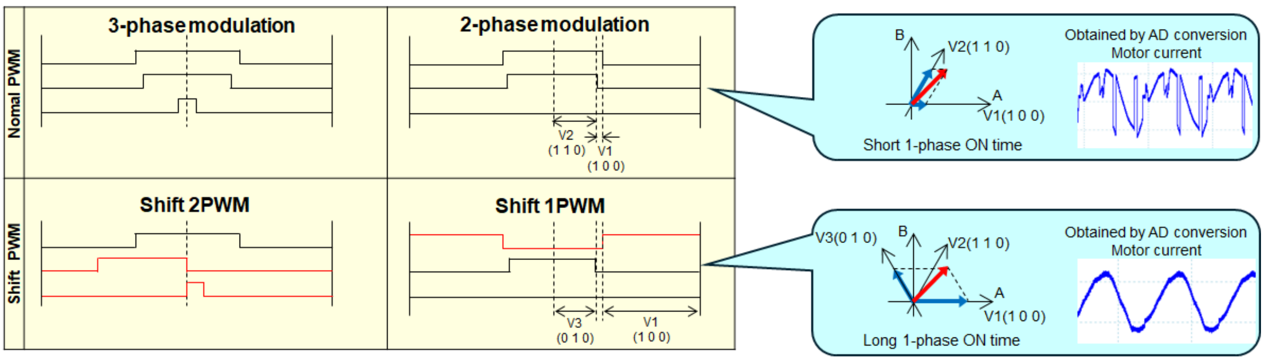

Figure 2.4 Normal PWM and Shift PWM

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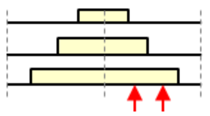
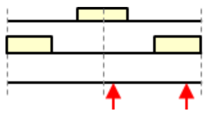
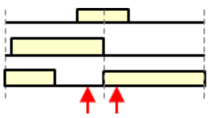
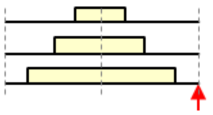
2.5. Current Sensing in 1-Shunt Method

The relationship between PWM mode and current sensing level is shown below.
The TB9M003FG supports only the 1-shunt method.
By configuring parameters related to the PWM mode, the system automatically switches to a PWM mode with a high current sensing rate, enabling 1-shunt sensorless vector control.

Table 2.2 Image of Current Sensing Levels for Each PWM Mode

Current Sensing Method	PWM Mode (↑ Current sensing timing)		Current Sensing Level (Modulation Index L ↔ H)				Remark
1-shunt	Normal		VL	L	M	H	The current sensing rate decreases at low and medium modulation rate.
	Shift 1		L	M	H	H	The current sensing rate decreases at low modulation rate.
	Shift 2		H	H	M	L	The current sensing rate decreases at medium and high modulation rate.
3-shunts	Normal		H	H	H	H	The current sensing rate is always 100%.

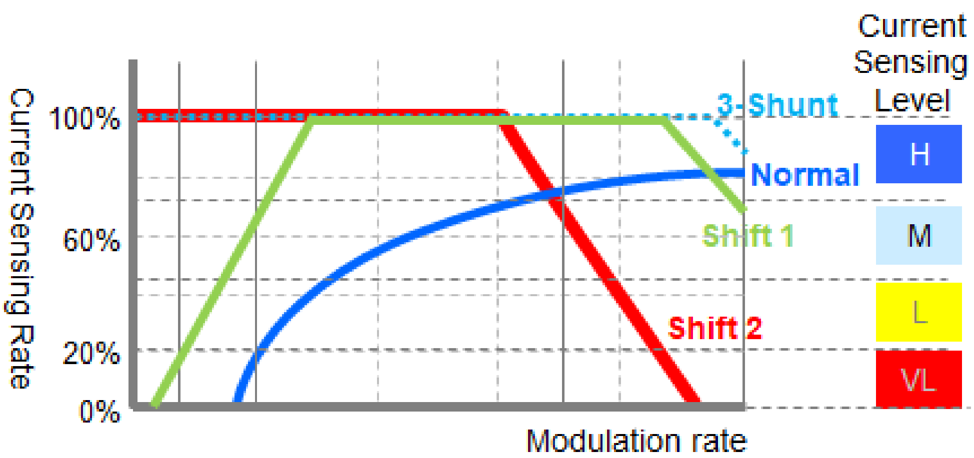


Figure 2.5 Relationship between PWM mode and current sensing rate

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2.6. Example of Operating Waveform

The following shows an example of operating waveforms for 1-shunt sensorless vector control using the TB9M003FG.

The waveforms illustrate the behavior when the speed command is varied (i.e., when the modulation index changes).By switching the PWM mode, current sensing is possible regardless of the modulation rate. The current error sensing flag indicates the period during which current sensing is not possible. Current sensed during this period is not used for control.

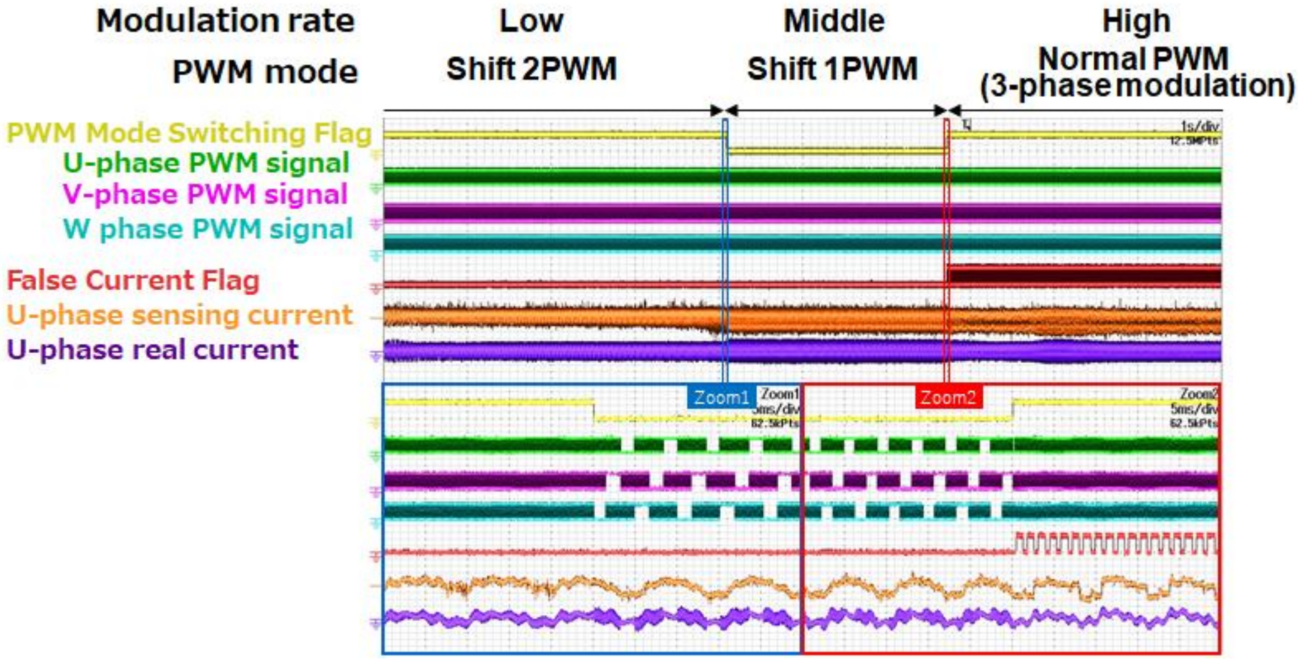

Figure 2.6　Operating waveform when changing PWM mode

Notes on Contents

1. **Block Diagrams**
   Some of the functional blocks, circuits, or constants in the block diagram may be omitted or simplified for explanatory purposes.

2. **Equivalent Circuits**
   The equivalent circuit diagrams may be simplified or some parts of them may be omitted for explanatory purposes.

IC Usage Considerations

Notes on Handling of Ics

(1) The absolute maximum ratings of a semiconductor device are a set of ratings that must not be exceeded, even for a moment.

(2) Use an appropriate power supply fuse to ensure that a large current does not continuously flow in case of over current and/or IC failure.

Points to Remember on Handling of ICs

(1) Over current Protection Circuit
Over current protection circuits (referred to as current limiter circuits) do not necessarily protect ICs under all circumstances. If the Over current protection circuits operate against the over current, clear the over current status immediately.

(2) Thermal Shutdown Circuit
Thermal shutdown circuits do not necessarily protect ICs under all circumstances. If the thermal shutdown circuits operate against the over temperature clears the heat generation status immediately.

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