Notes in use of TC78B043FNG/FTG

Outline

The TC78B043FTG/FNG are Sine Wave PWM drive controllers for 3-phase brushless motors.
The TC78B043FTG is encapsulated in a WQFN20 package, and the TC78B043FNG is encapsulated in a HTSSOP28 package.
And, they have built-in non-volatile memory (NVM), allowing various settings according to the characteristics and usage of the motor to be written to the NVM via SPI communication.
Additionally, the NVM in the TC78B043FNG has initial settings suitable for common motors, allowing driving a motor without writing via SPI communication. Furthermore, it is equipped with four pins: FGC pin, LATYPE pin, LAOFS pin, and LA pin. The voltage settings of these pins also allow adjustments of some parameters, such as motor lead angle control.
TC78B043FTG has no four pins: FGC pin, LATYPE pin, LAOFS pin, and LA pin. The NVM has no initial settings for motor control. Therefore, to control the motor, it is necessary to write settings to the NVM via SPI communication.

Table 1.1 Difference between TC78B043FTG and TC78B043FNG

Product name	TC78B043FTG	TC78B043FNG
Package	P-WQFN20-0303-0.50-002	P-HTSSOP28-0510-0.65-001
Initial value setting of NVM (Nonvolatile Memory)	Settings via SPI communication are required for the motor to rotate.	Settings that allow rotation depending on motor characteristics (When the motor does not rotate, it can be reconfigured via SPI communication according to the motor characteristics)
Terminal for rotation control adjustment for TC78B043FNG	None	5pin: FGC 6pin: LATYPE 8pin: LAOFS 9pin: LA

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Table of Contents

List of Figures

List of Tables

1. Example of Application Circuit

This product is a controller, so it is used in combination with a gate driver and FET (IGBT), or with an IPD (Intelligent Power Device) in which the gate driver and FET (IGBT) are integrated into a single package, to drive a motor.

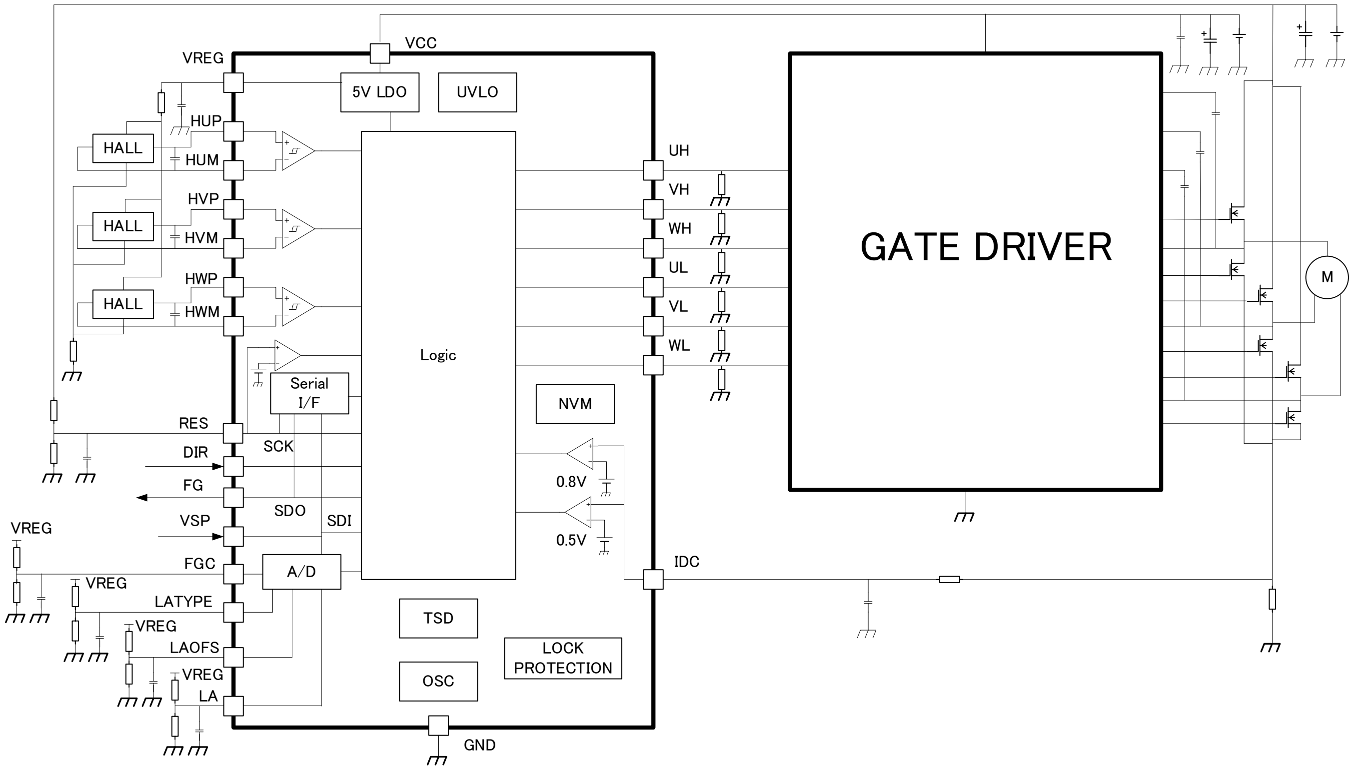


Fig. 1.1 TC78B043FNG Application Circuit Example

Note: The application circuit example has been partially omitted or simplified to explain the circuit.

2. E-PAD (Frame exposure area on the back of the package)

The E-PAD on the back of the package is connected to the internal IC chip, so please connect it to GND.

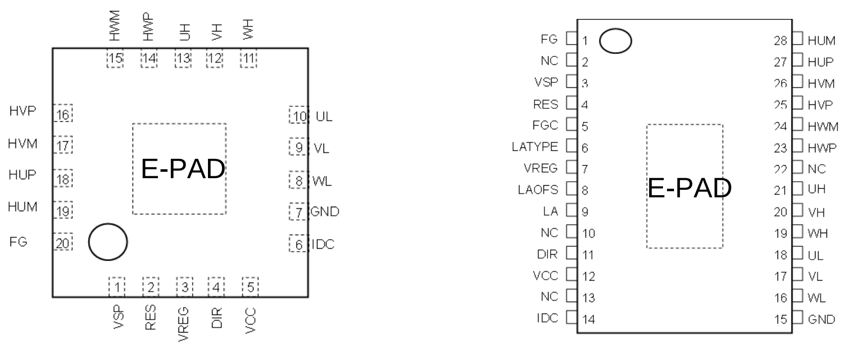


Fig. 2.1 E-PAD

3. Power Supply Voltage

To minimize noise and voltage fluctuations at the VCC terminal, connect ceramic capacitors or electrolytic capacitors between VCC and GND as close to the IC as possible, as needed. Connecting ceramic capacitors near the IC is effective in suppressing high-frequency power fluctuations and noise. If a sufficiently stable voltage can be obtained, it is possible to use only a ceramic capacitor alone, but please use it after thorough evaluation.

Table 3.1 VCC terminal capacitor

Item	Recommended usage range	Unit
Electrolytic capacitor	1 to 47	μF
Ceramic capacitor	0.001 to 2.2	μF

3.1. Absolute Maximum Ratings (Ta = 25 °C)

Table 3.2 Absolute Maximum Ratings (Ta = 25 °C unless otherwise specified)

Item	Symbol	Rating	Unit	Related pin and Remarks
Power suppy voltage	MVCC	25	V	VCC

The Absolute maximum ratings are specifications that must not be exceeded even momentarily. Exceeding the absolute maximum ratings may cause destruction, degradation, or damage to the device, and may also cause destruction, damage, or degradation to other than the device. Therefore, in designing the product, please pay attention not exceed the absolute maximum ratings under any operating conditions. In use of this device, please use it within the specified operating range.

3.2. Operating Range

Table 3.3 Operating Range (Ta= - 40 to 115 °C unless otherwise specified)

Item	Symbol	Min.	Typ.	Max.	Unit	Remarks
Power suppy voltage	VCCopr1	6	15	23	V	VCC
	VCCopr2	10.8	15	23	V	VCC VCC Supply Voltage Range at writing to NVM

4. VREG terminal

Please connect a ceramic capacitor between VREG and GND as close to the IC as possible, as needed, to minimize noise and voltage fluctuations on the VREG terminal.

Table 4.1 VREG terminal capacitor

Item	Recommended usage range	Unit
Ceramic capacitor	0.1 to 1	μF

5. Settings of Driving Waveform

For the startup of this device, either from the Forced Commutation of the Sin Wave Drive (180°Commutation) or from the Square Wave Drive (120°Commutation) can be selected.
In case of the Sine Wave Drive Startup, the motor is started to rotate by the Forced Commutation 1 Hz of the Sine Wave Drive, and when the rotation frequency exceeds the set value for switching, the driving waveform is switched to the Sine Wave Drive for Normal Rotation.
For the Square Wave Drive Startup, the driving waveform is switched to the Squire Wave Drive for Normal Rotation when the Hall Signal exceeds the Rotation Frequency of f = 1Hz. The Lead Angle value below the Rotation Frequency 1Hz is 0 °. And when the frequency exceeds 1Hz and the driving waveform is shifted to Normal Rotation, the Lead Angle value is shifted to the value set by the Lead Angle Function.

Also in Normal Rotation, either the Sine Wave Drive or the Square Wave Drive can be selected.
For the Sine Wave Drive during Normal Rotation, the Reset Method of the Hall Signal which generates the Sine Wave can be selected from 60 ° Reset, 360 ° Reset, 180 ° Reset, and 60 °/120 ° Reset. The reset method starts from the 60 ° Reset Method and shifted to the selected method when the Rotation Speed Fluctuation is settled within the set value.
When the Rotation Frequency Fluctuation exceeds the set value or falls below 1 Hz, the method is returned to the 60 ° Reset method.
For the Sine Wave Drive during Normal Rotation, by setting the number of averaging times, the Rotation Frequency Fluctuation is reduced, because the period of Hall Signal Input is averaged by that number of times with the set width.
For the Square Wave Drive, either 120 ° Commutation or 150 ° Commutation can be selected. And in 120 ° Commutation, the Lead Angle Control Valid/Invalid can be selected.

Table5.1 Settings of Driving Waveform

Register settings 2[15:12] PWM_MODE [3:0]	Inverted Hall Signal Input (Note)	At Rotation Startup	In Normal Rotation Non-inverted Hall Signal Input (Note)	Reset Method of Sine Wave Generation
0000	Square Wave Drive 120°Commutation (Lead Angle = 0° /With Refresh Operation)	Forced Commutation Sine Wave Drive: 60° Reset (Lead Angle=0°)	Sine Wave Drive (Lead Angle: Lead Angle setting)	60° Reset
0001				60°⇔360° Reset
0010				60°⇔180° Reset
0011				60°⇔60° / 120° Reset
0100		Square Wave Drive 120° Commutation (Lead Angle = 0° /With Refresh Operation		60 ° Reset
0101				60 °⇔360° Reset
0110				60 °⇔180° Reset
0111				60°⇔60° / 120° Reset
1000			Square Wave Drive150° Commutation (Lead Angle: Lead Angle setting / with no Refresh Operation)	-
1001			Square Wave Drive 120° Commutation (Lead Angle: Lead Angle setting / with no Refresh Operation)	-
1010			Square Wave Drive 120° Commutation (Lead Angle control Invalid, Lead Angle = 0°/ with Refresh Operation)	-
1011				-
1100				-
1101				-
1110				-
1111				-

Note: When the rotation direction is set to Forward Rotation and Hall Signals are input in the correct order, it is defined as the Non-inverted Hall Signal Input, and the motor is driven in Normal Rotation according to the setting. On the other hand, when the Hall Signals are input in the opposite order due to reverse wind, etc., this is defined as the Inverted Hall Signal Input, and in this case, the motor is driven in the Square Wave Drive 120° Commutation.
And when the rotation direction is set to Reverse Rotation, the motor is driven in Normal Rotation when Hall Signals are input in the reverse order, and the motor is driven in the Square Wave Drive 120° Commutation when Hall Signals are input in the positive order.
The Refresh Operation is to turn ON the Low-side Commutation Signals at a fixed cycle (carrier cycle). The ON duty is approximately 8%.

Table5.2 Settings of Rotation Frequency to switch from Forced Commutation

Resister settings 6[1:0] START_FREQ [1:0]	Rotation Frequency to switch from Forced Commutation ［Hz］
00	2
01	4
10	5
11	8

Table5.3 Settings of Rotation Frequency Fluctuation Figure to switch Sine Wave Reset Method

Resister settings 6[3:2] SIN_SW_RATIO[1:0]	Rotation Frequency Fluctuation Figure to switch Sine Wave Reset method ［%］
00	6.25
01	12.5
10	25
11	37.5

Table5.4 Settings of Averaging Times Number in Sine Wave Drive

Resister settings 6[5:4] AVE_SEL[1:0]	Averaging Times Number ［times］
00	2
01	4
10	8
11	Invalid

5.1. Settings of Driving Waveform at Rotation Startup

Forced commutation sine wave drive may improve vibration and noise at startup through sine wave drive. Depending on the characteristics of the motor and the load, if the motor cannot rotate or start with forced commutation sine wave drive, it may be possible to start with the setting of square wave drive 120° energization, so please evaluate thoroughly before setting.

5.2. Settings of Driving Waveform in Normal Rotation

Sine wave drive may improve vibration and noise compared to square wave drive. Depending on the characteristics and load of the motor, square wave drive with 150° conduction or 120° conduction may allow the motor to rotate more smoothly than sine wave drive, so please make settings after thorough evaluation.

5.3. Reset Method of Sine Wave Generation

The sine wave generation reset method includes 60° reset, 180° reset, 360° reset, and 60°/120° reset methods. Depending on the characteristics of the motor, it may be possible to improve distortion, vibration, and noise in motor rotation, so please set after thorough evaluation.

Table5.5 Characteristics of the sine wave generation reset method

Reset Method of Sine Wave Generation	Characteristics
60° Reset	The 60° reset method is a control method that uses the standard three-phase Hall signals. The motor can rotate in response to acceleration and deceleration. If the Hall signals are not uniform across the three phases due to misalignment of the Hall element PCB mounting position, it may cause distortion in motor rotation, leading to vibration and noise.
60°⇔360° Reset	The 360° reset method is a control method that uses the falling edge of the U-phase Hall signal. If there is misalignment in the PCB mounting position of the Hall elements in each of the three phases, which affects motor rotation distortion, vibration, or noise, this control method—using only the U-phase falling edge for control—may have an improvement effect. However, compared to the 60° reset, the responsiveness during acceleration and deceleration decreases, increasing the likelihood of motor step-out, and similar issues.
60°⇔180° Reset	The 180° reset method is a control method that uses the rising and falling edges of the U-phase Hall signal. If there is misalignment in the PCB mounting position of the Hall elements in each of the three phases, which affects motor rotation distortion, vibration, or noise, this control method—using only the U-phase for control—may have a potential improvement effect. However, compared to the 60° reset, the responsiveness during acceleration and deceleration decreases, increasing the possibility of motor step-out, but the responsiveness is higher than with the 360° reset.
60°⇔60° / 120° Reset	3The 360° reset method is a control method that uses U-phase and V-phase hall signals. If there is a misalignment in the PCB mounting position of the hall element, such as in the W-phase, and there is distortion, vibration, or noise in the motor rotation, this control method, which controls with U-phase and V-phase, may have an improvement effect. However, compared to the 60° reset, the responsiveness during acceleration and deceleration decreases, so the possibility of motor step-out becomes higher.

5.4. Settings of Acceleration

The acceleration setting at startup allows the motor to gradually accelerate and rotate by increasing the output Duty according to the SS duty change limit setting ratio, and the acceleration setting during steady operation allows the motor to gradually accelerate and rotate by increasing the output Duty according to the UP duty change limit setting ratio. By setting the acceleration, sudden increases in motor rotation and motor output current during startup or acceleration can be suppressed, enabling control in a state where the current limiting function does not operate, which may improve motor vibration and noise. However, since the motor gradually accelerates due to the acceleration setting, the rotational speed during startup and acceleration will decrease, so please set it after sufficient evaluation.

5.5. Settings of Deceleration

The deceleration setting can gradually slow down the motor by reducing the output Duty according to the DWN duty change limit setting ratio.
However, depending on the motor characteristics and deceleration settings, the output Duty during energization may become lower than the induced voltage of the motor's rotational state, which can cause a large motor output current (brake current) to flow. Therefore, please ensure that the output stage FET and other components do not exceed their absolute maximum rated output current by thoroughly evaluating before setting. Additionally, since the motor output current (brake current) may regenerate to the power supply side, causing the power supply voltage to rise, please ensure that the output stage FET and other components do not exceed their absolute maximum rated voltage by thoroughly evaluating before setting.

5.6. Settings of Stopping Sequence

The stopping sequence allows the motor to gradually decelerate and stop by reducing the output Duty according to the deceleration setting ratio, without any stop sound when the output is OFF. However, depending on the motor characteristics and deceleration settings, the output Duty during energization may become lower than the induced voltage of the motor's rotational state, which can cause a large motor output current (brake current) to flow. Therefore, please ensure thorough evaluation before use so that the output stage FET and other components do not exceed their absolute maximum rated output current. Additionally, since the motor output current (brake current) may regenerate to the power supply side, causing the power supply voltage to rise, please ensure thorough evaluation and settings so that the output stage FET and other components do not exceed their absolute maximum rated voltage.

5.7. Settings of Initial Output Duty in returning from Idle Rotation

When the motor resumes rotation from idling, it begins to rotate by determining the initial output duty based on the set reference frequency. After that, the output duty increases or decreases according to the acceleration and deceleration settings of the speed command input value. Therefore, set the reference frequency and the motor’s maximum rotational speed to match as closely as possible. If the reference frequency and the motor’s maximum rotational speed do not match, it may cause fluctuations in the motor’s rotation or output current at the moment the motor resumes rotation from idling, so please make settings after thorough evaluation.

5.8. Settings of Lead Angle Function

Lead angle is a function to match the phase of conduction with the phase of the motor induced voltage, and when the phases are aligned, efficiency increases. Additionally, there is a possibility that vibration and noise may be improved.
Since the phase of the motor induced voltage changes depending on motor characteristics, load, and rotation speed, the lead angle value (phase of conduction) is adjusted so that the phases match. When the phases are aligned by adjusting the lead angle value, the motor output current value becomes lower for the same rotation speed, so please set the lead angle value after sufficient evaluation.
Also, the speed command value for lead angle setting (SPD: internal speed command value) is linked with the speed command setting of the VSP terminal.

For example, when the VSP terminal analog voltage input is set to A mode, the output ON duty changes with 512 resolutions between 2.1V and 5.4V, and the SPD for lead angle setting also changes according to the setting with 512 resolution. In other words, the output ON duty and lead angle SPD setting change in conjunction at (5.4V-2.1V)/512 resolution

5.9. Example of Drive Waveform

Conditions
Motor power supply voltage＝140V
Settings of Rotation Frequency Fluctuation Figure to switch Sine Wave Reset Method=37.5%
Settings of Averaging Times Number in Sine Wave Drive=2 times

5.9.1. Sine Wave Drive 60° Reset
SPD=128, LA=0,10,20,30

Note: The oscilloscope's filter function makes it easy to display the two-phase modulated waveform of sine wave drive.

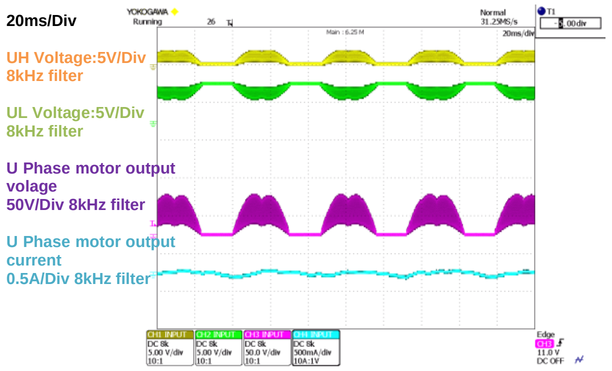


Fig. 5.1 Sine Wave Drive 60° Reset
SPD=128,LA=0(Lead angle=0°)

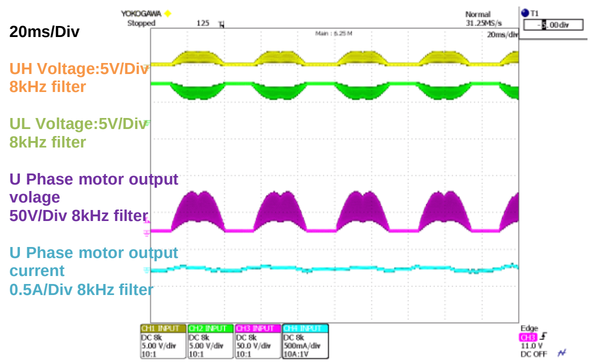


Fig. 5.2 Sine Wave Drive 60° Reset
SPD=128,LA=10(Lead angle =4.7°)

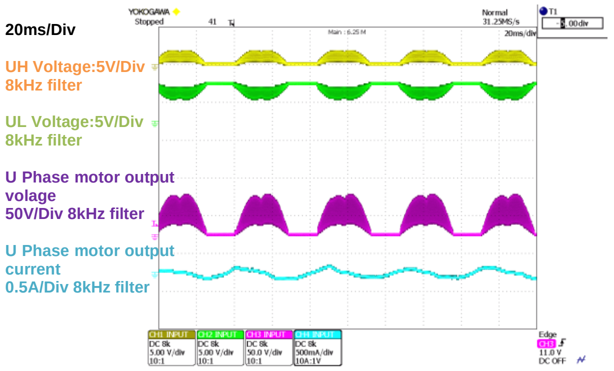


Fig. 5.3 Sine Wave Drive 60° Reset
SPD=128,LA=20(Lead angle =9.4°)

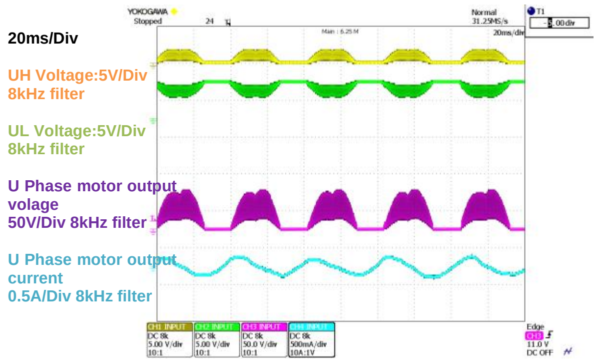


Fig. 5.4 Sine Wave Drive 60° Reset
SPD=128,LA=30(Lead angle =14.1°)

5.9.2. Sine Wave Drive 60° Reset
SPD=256, LA=0,10,20,30

Note: The oscilloscope's filter function makes it easy to display the two-phase modulated waveform of sine wave drive.

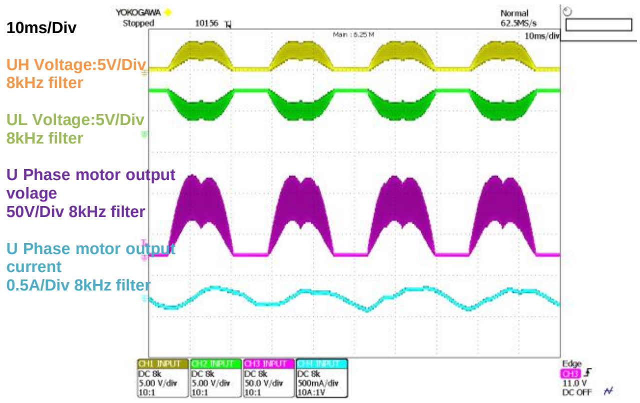


Fig. 5.5 Sine Wave Drive 60° Reset

SPD=256,LA=0(Lead angle =0°)

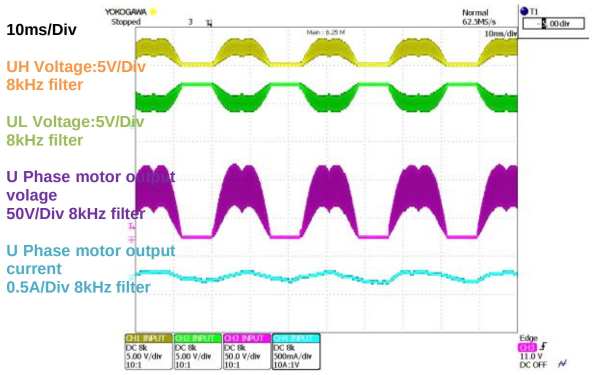


Fig. 5.6 Sine Wave Drive 60° Reset

SPD=256,LA=10(Lead angle =4.7°)

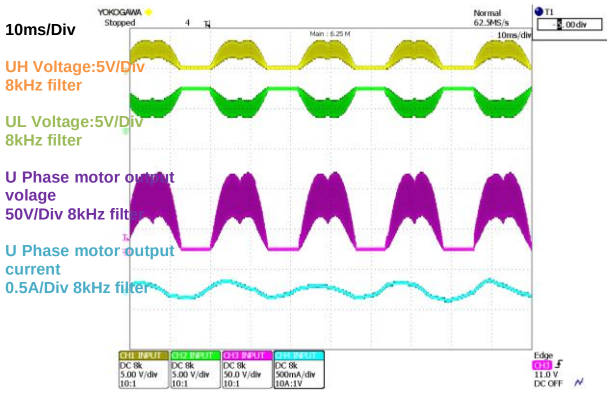


Fig. 5.7 Sine Wave Drive 60° Reset

SPD=256,LA=20(Lead angle =9.4°)

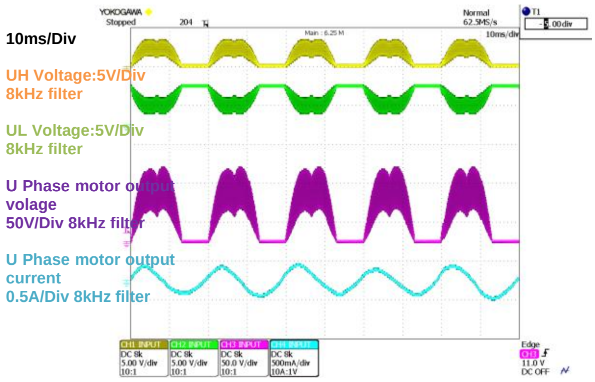


Fig. 5.8 Sine Wave Drive 60° Reset

SPD=256,LA=30(Lead angle =14.1°)

5.9.3. Sine Wave Drive 60° Reset
SPD=384, LA=0,10,20,30

Note: The oscilloscope's filter function makes it easy to display the two-phase modulated waveform of sine wave drive.

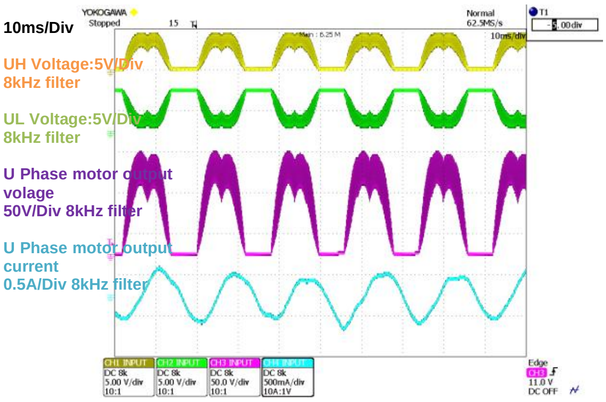


Fig. 5.9 Sine Wave Drive 60° Reset
SPD=384,LA=0(Lead angle =0°)

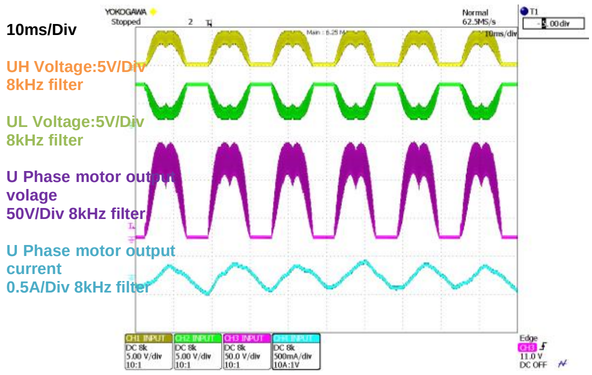


Fig. 5.10 Sine Wave Drive 60° Reset
SPD=384,LA=10(Lead angle =4.7°)

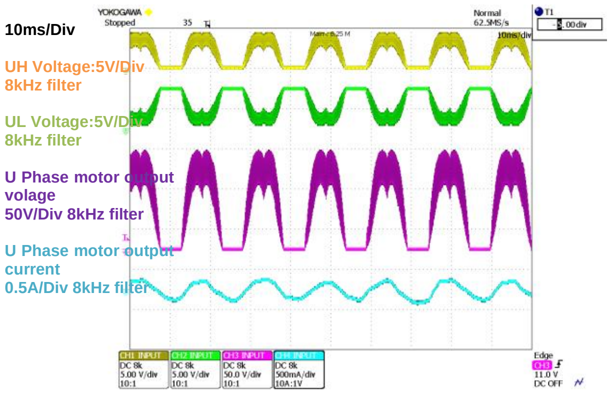


Fig. 5.11 Sine Wave Drive 60° Reset
SPD=384,LA=20(Lead angle =9.4°)

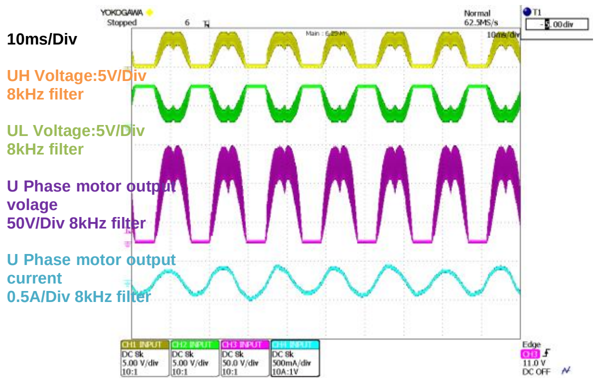


Fig. 5.12 Sine Wave Drive 60° Reset
SPD=384,LA=30(Lead angle =14.1°)

5.9.4. Sine Wave Drive 60° Reset
SPD=512, LA=0,10,20,30

Note: The oscilloscope's filter function makes it easy to display the two-phase modulated waveform of sine wave drive.

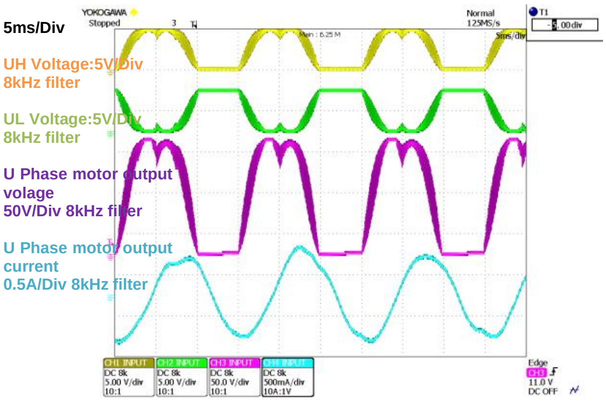


Fig. 5.13 Sine Wave Drive 60° Reset
SPD=512,LA=0(Lead angle =0°)

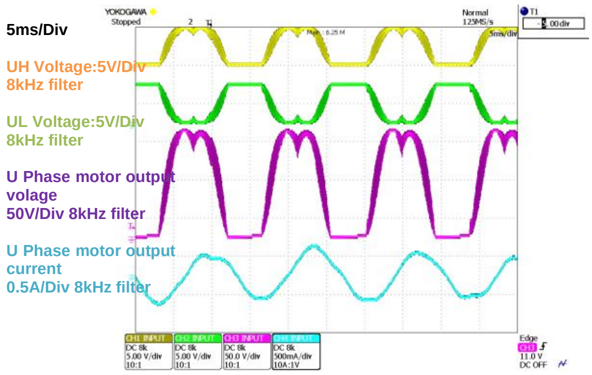


Fig. 5.14 Sine Wave Drive 60° Reset
SPD=512,LA=10(Lead angle =4.7°)

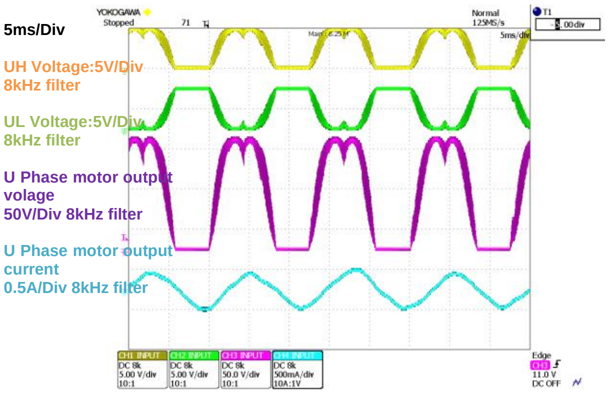


Fig. 5.15 Sine Wave Drive 60° Reset
SPD=512,LA=20(Lead angle =9.4°)

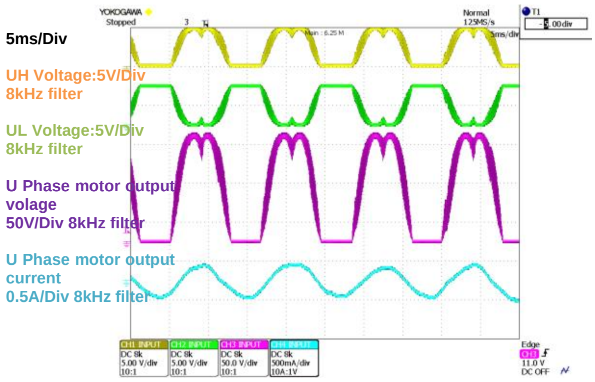


Fig. 5.16 Sine Wave Drive 60° Reset
SPD=512,LA=30(Lead angle =14.1°)

5.9.5. Square Wave Drive 150° Commutation
SPD=128, LA=0,10,20,30

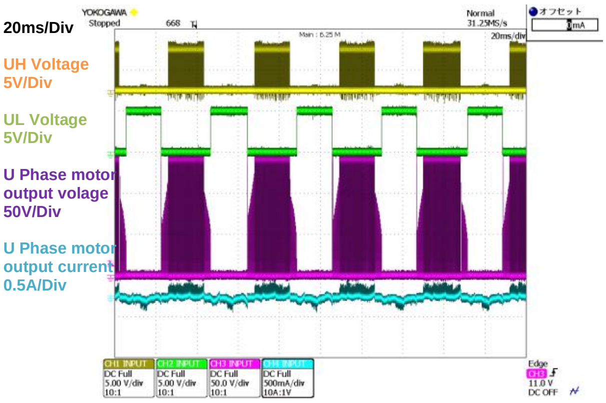


Fig. 5.17 Square Wave Drive 150° Commutation
SPD=128,LA=0(Lead angle =0°)

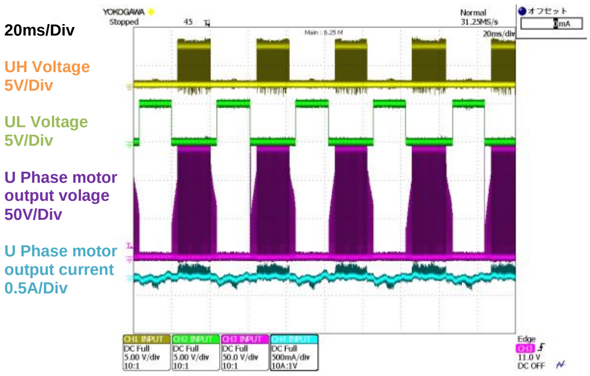


Fig. 5.18 Square Wave Drive 150° Commutation
SPD=128,LA=10(Lead angle =4.7°)

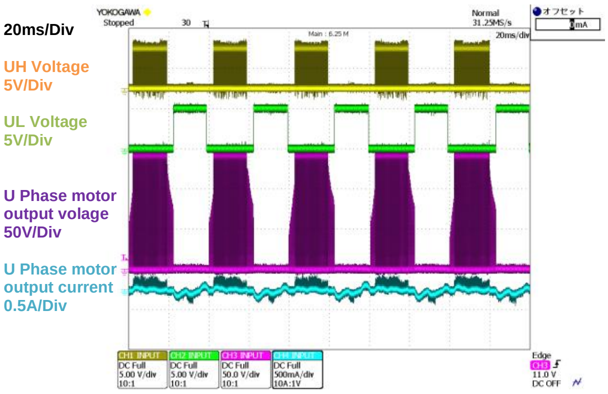


Fig. 5.19 Square Wave Drive 150° Commutation
SPD=128,LA=20(Lead angle =9.4°)

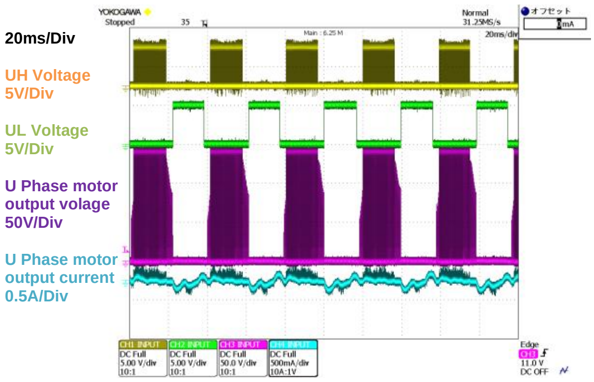


Fig. 5.20 Square Wave Drive 150° Commutation
SPD=128,LA=30(Lead angle =14.1°)

5.9.6. Square Wave Drive 150° Commutation SPD=256, LA=0,10,20,30

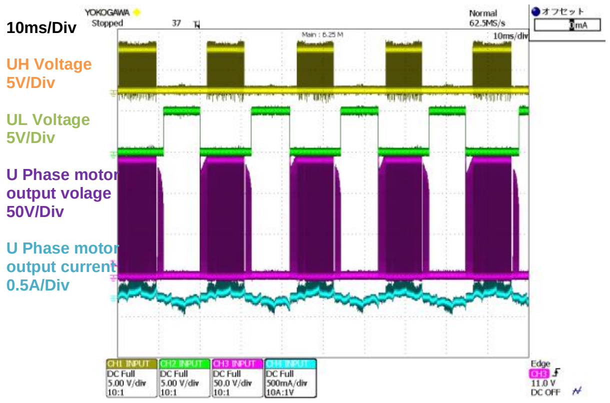


Fig. 5.21 Square Wave Drive 150° Commutation
SPD=256,LA=0(Lead angle =0°)

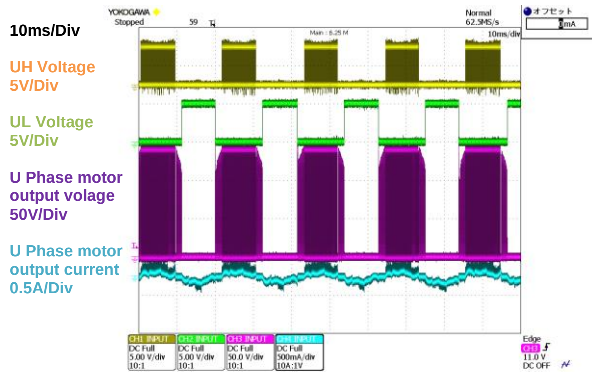


Fig. 5.22 Square Wave Drive 150° Commutation
SPD=256,LA=10(Lead angle =4.7°)

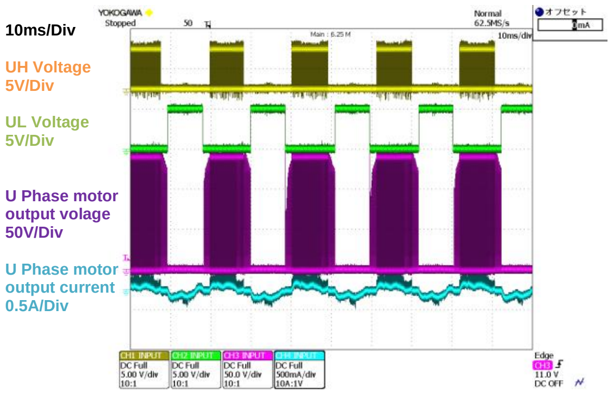


Fig. 5.23 Square Wave Drive 150° Commutation
SPD=256,LA=20(Lead angle =9.4°)

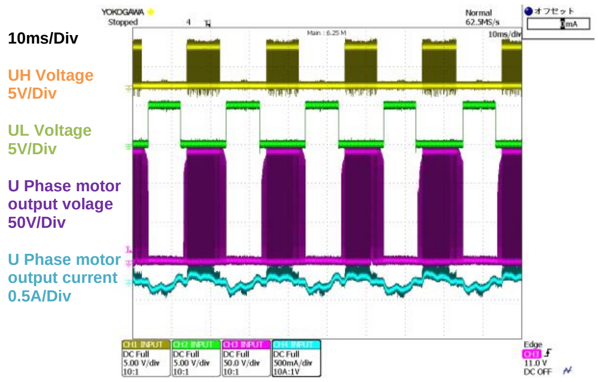


Fig. 5.24 Square Wave Drive 150° Commutation
SPD=256,LA=30(Lead angle =14.1°)

5.9.7. Square Wave Drive 150° Commutation SPD=384, LA=0,10,20,30

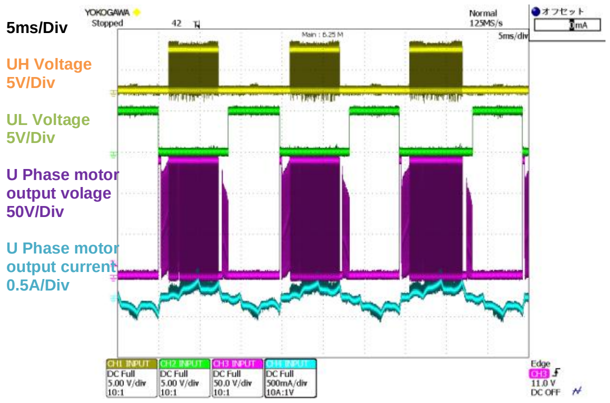


Fig. 5.25 Square Wave Drive 150° Commutation SPD=384,LA=0(Lead angle =0°)

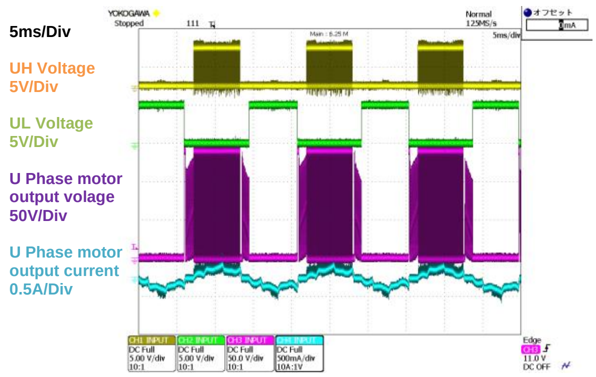


Fig. 5.26 Square Wave Drive 150° Commutation SPD=384,LA=10(Lead angle =4.7°)

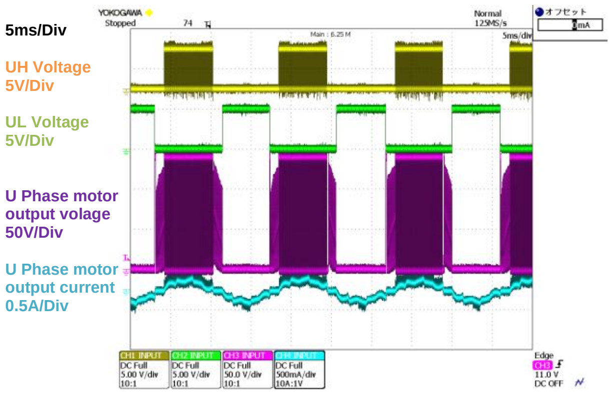


Fig. 5.27 Square Wave Drive 150° Commutation SPD=384,LA=20(Lead angle =9.4°)

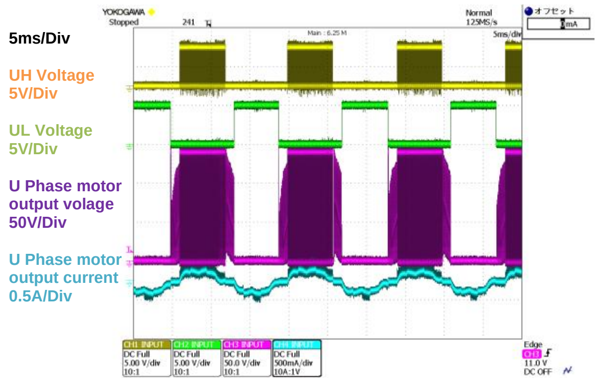


Fig. 5.28 Square Wave Drive 150° Commutation SPD=384,LA=30(Lead angle =14.1°)

5.9.8. Square Wave Drive 150° Commutation SPD=512, LA=0,10,20,30

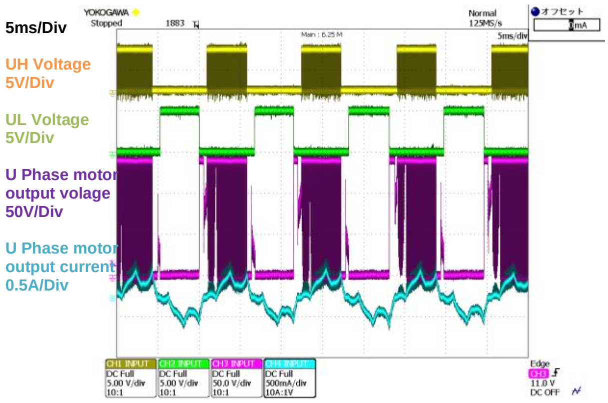


Fig. 5.29 Square Wave Drive 150° Commutation
SPD=512,LA=0(Lead angle =0°)

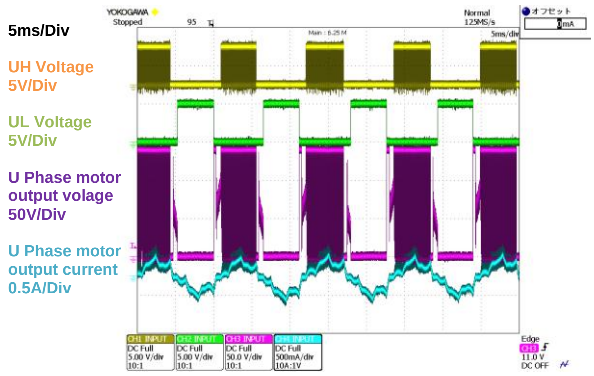


Fig. 5.30 Square Wave Drive 150° Commutation
SPD=512,LA=10(Lead angle =4.7°)

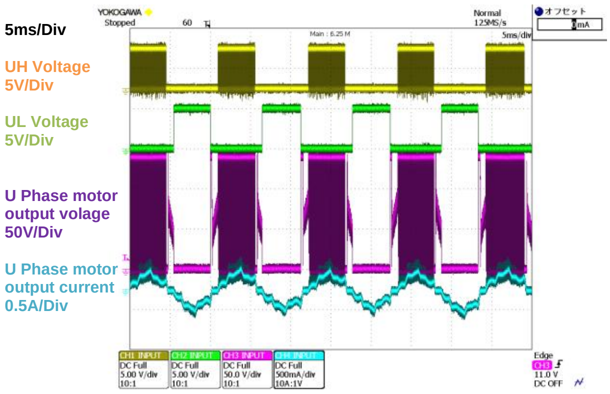


Fig. 5.31 Square Wave Drive 150° Commutation
SPD=512,LA=20(Lead angle =9.4°)

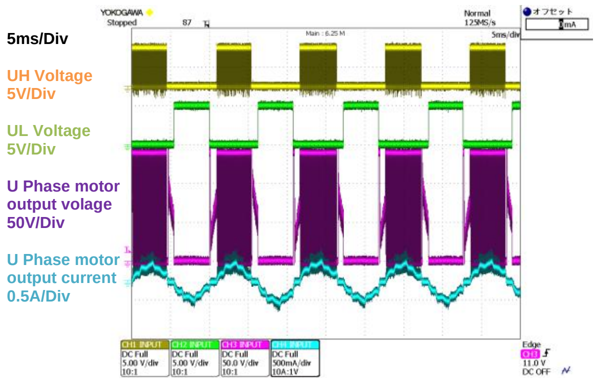


Fig. 5.32 Square Wave Drive 150° Commutation
SPD=512,LA=30(Lead angle =14.1°)

5.9.9. Square Wave Drive 120° Commutation (with no Refresh Operation) SPD=128, LA=0,10,20,30

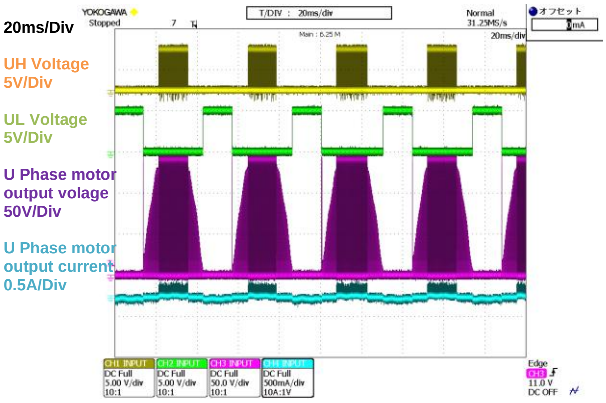


Fig. 5.33 Square Wave Drive 120° Commutation SPD=128,LA=0(Lead angle =0°)

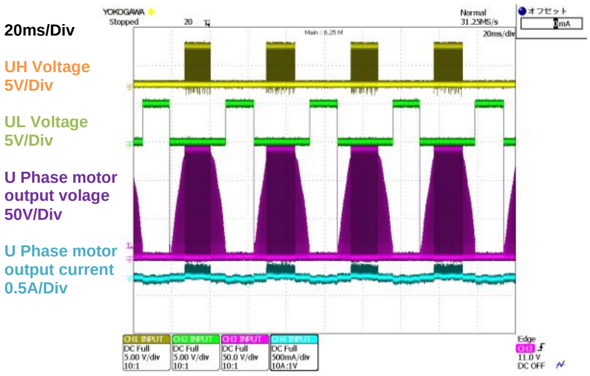


Fig. 5.34 Square Wave Drive 120° Commutation SPD=128,LA=10(Lead angle =4.7°)

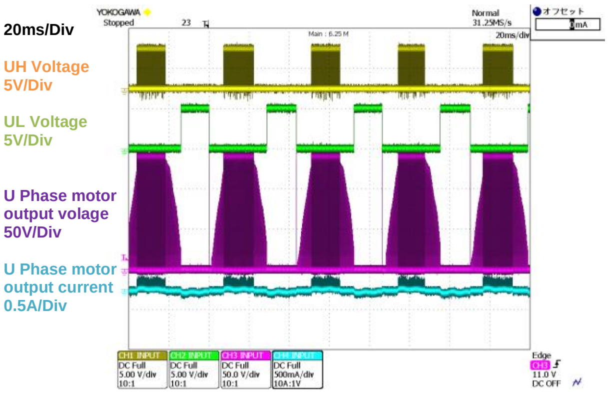


Fig. 5.35 Square Wave Drive 120° Commutation SPD=128,LA=20(Lead angle =9.4°)

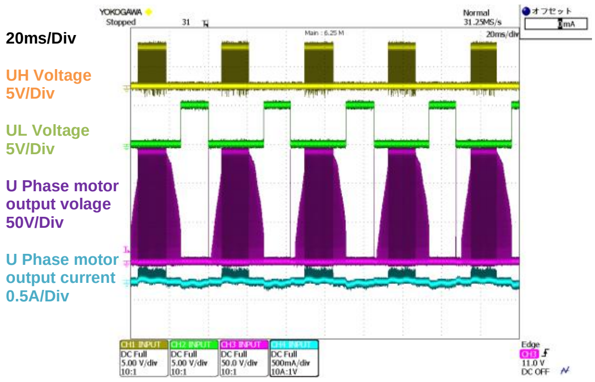


Fig. 5.36 Square Wave Drive 120° Commutation SPD=128,LA=30(Lead angle =14.1°)

5.9.10. Square Wave Drive 120° Commutation (with no Refresh Operation)
SPD=256, LA=0,10,20,30

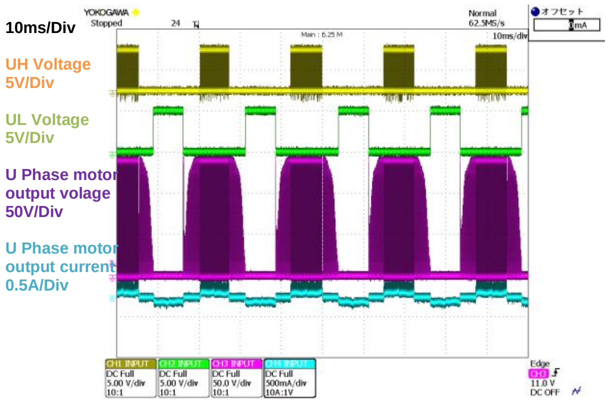


Fig. 5.37 Square Wave Drive 120° Commutation SPD=256,LA=0(Lead angle =0°)

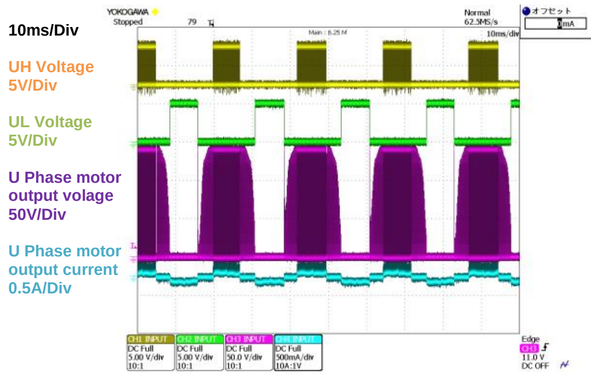


Fig. 5.38 Square Wave Drive 120° Commutation SPD=256,LA=10(Lead angle =4.7°)

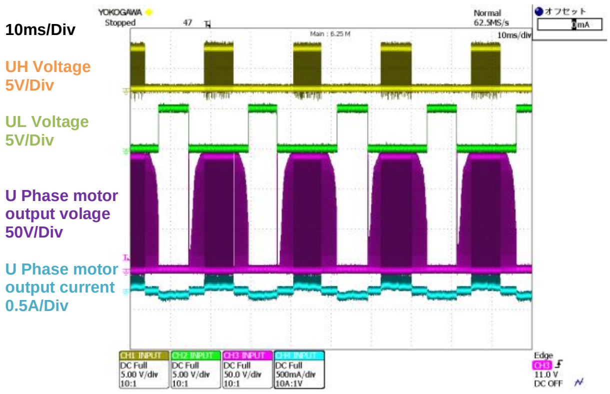


Fig. 5.39 Square Wave Drive 120° Commutation SPD=256,LA=20(Lead angle =9.4°)

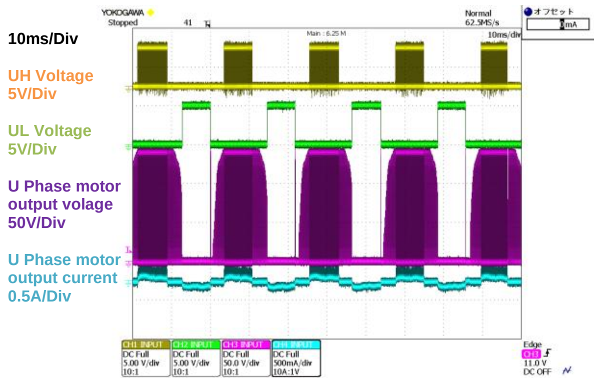


Fig. 5.40 Square Wave Drive 120° Commutation SPD=256,LA=30(Lead angle =14.1°)

5.9.11. Square Wave Drive 120° Commutation (with no Refresh Operation) SPD=384, LA=0,10,20,30

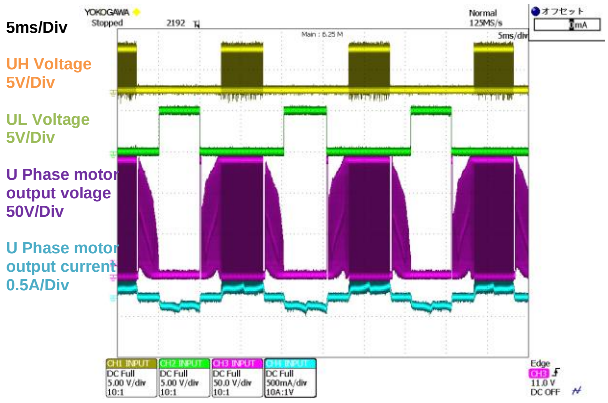


Fig. 5.41 Square Wave Drive 120° Commutation

SPD=384,LA=0(Lead angle =0°)

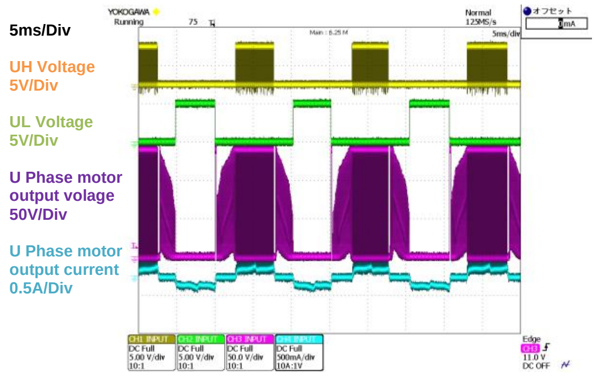


Fig. 5.42 Square Wave Drive 120° Commutation

SPD=384,LA=10(Lead angle =4.7°)

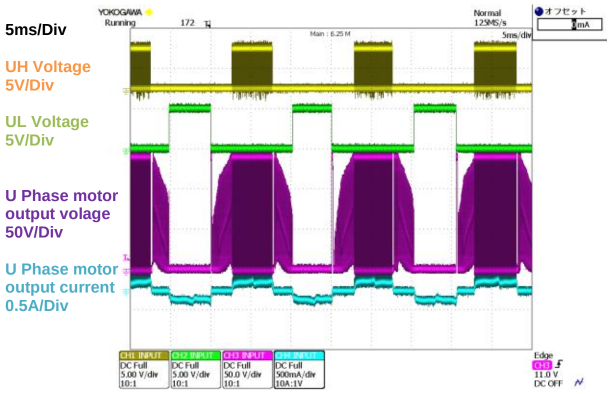


Fig. 5.43 Square Wave Drive 120° Commutation

SPD=384,LA=20(Lead angle =9.4°)

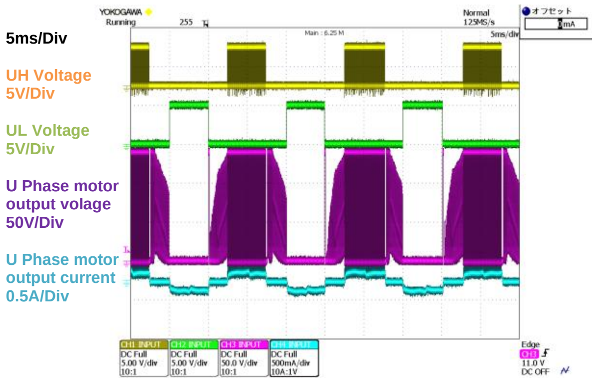


Fig. 5.44 Square Wave Drive 120° Commutation

SPD=384,LA=30(Lead angle =14.1°)

5.9.12. Square Wave Drive 120° Commutation (with no Refresh Operation)
SPD=512, LA=0,10,20,30

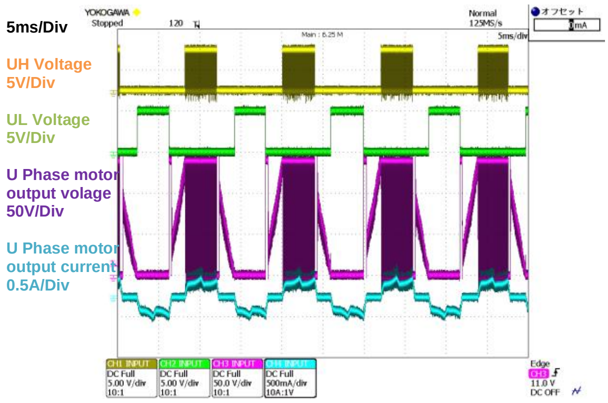


Fig. 5.45 Square Wave Drive 120° Commutation
SPD=512,LA=0(Lead angle =0°)

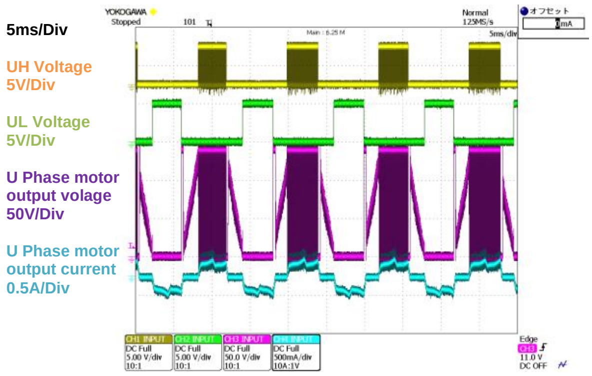


Fig. 5.46 Square Wave Drive 120° Commutation
SPD=512,LA=10(Lead angle =4.7°)

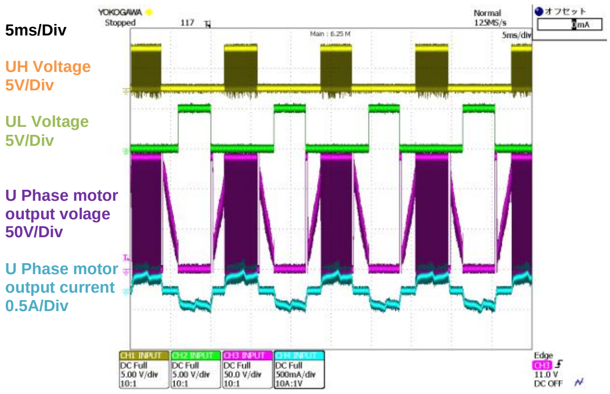


Fig. 5.47 Square Wave Drive 120° Commutation
SPD=512,LA=20(Lead angle =9.4°)

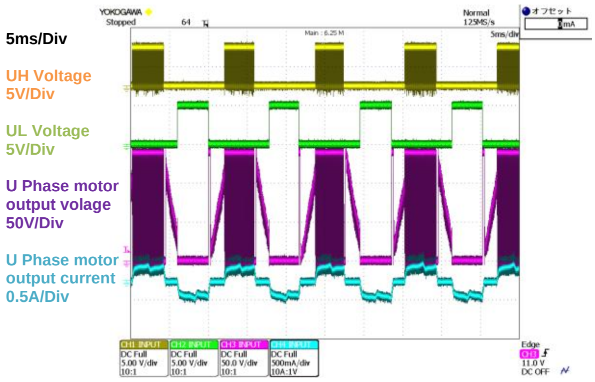


Fig. 5.48 Square Wave Drive 120° Commutation
SPD=512,LA=30(Lead angle =14.1°)

5.9.13. Square Wave Drive 120° Commutation (with Refresh Operation)
SPD=128, 256, 384, 512, LA=0

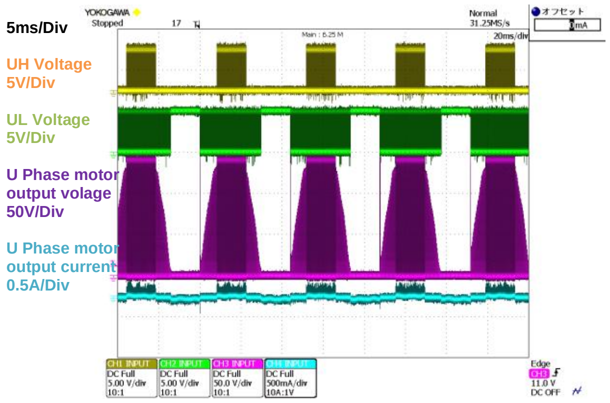


Fig. 5.49 Square Wave Drive 120° Commutation SPD=128, (with Refresh Operation)

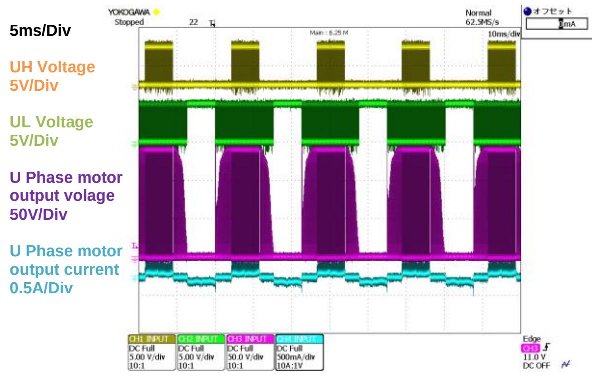


Fig. 5.50 Square Wave Drive 120° Commutation SPD=256, (with Refresh Operation)

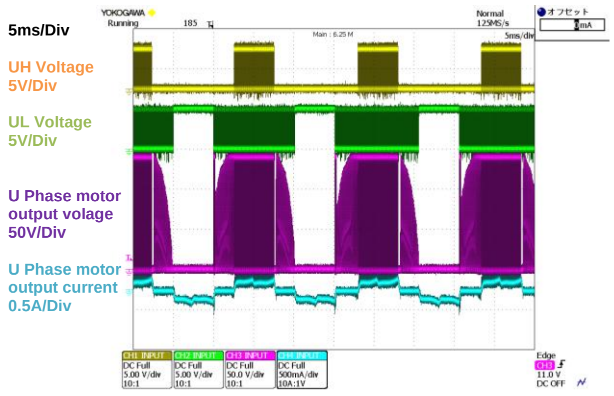


Fig. 5.51 Square Wave Drive 120° Commutation SPD=384, (with Refresh Operation)

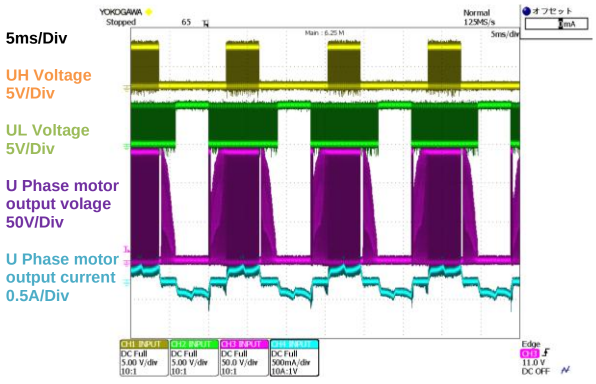


Fig. 5.52 Square Wave Drive 120° Commutation SPD=512, (with Refresh Operation)

5.9.14. At Rotation Startup (SPD=0 to 256)

Sine Wave Drive, Square Wave Drive 120° Commutation
Settings of Rotation Frequency to switch from Forced Commutation=2Hz
SS duty change limit = UP duty change limit = 4/8, 10/8

Note: The oscilloscope's filter function makes it easy to display the two-phase modulated waveform of sine wave drive.

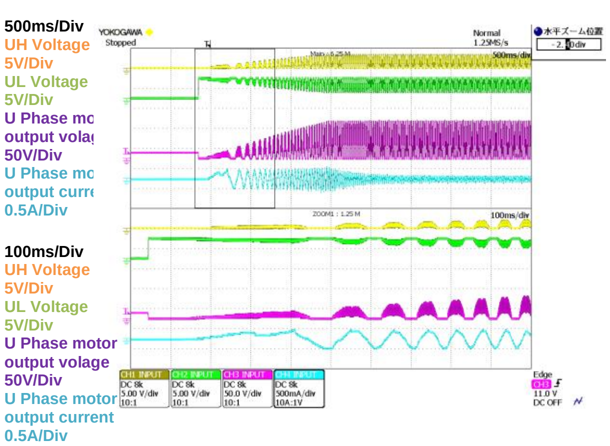


Fig. 5.53 At Rotation Startup, Sine Wave Drive

SS duty change limit = UP duty change limit = 4/8

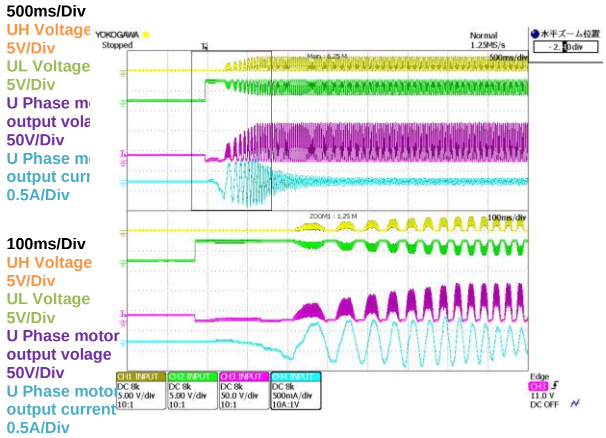


Fig. 5.54 At Rotation Startup, Sine Wave Drive

SS duty change limit = UP duty change limit = 10/8

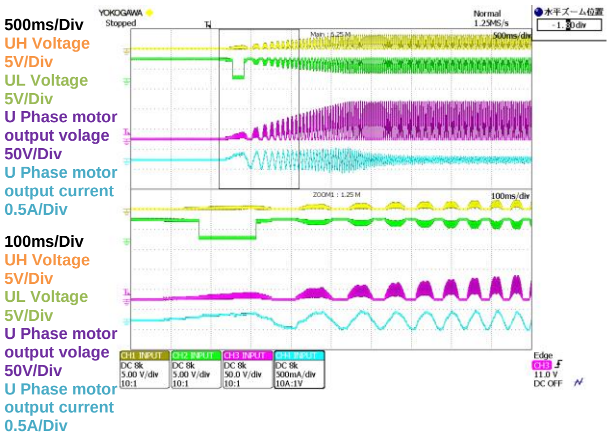


Fig. 5.55 At Rotation Startup

Square Wave Drive 120° Commutation

SS duty change limit = UP duty change limit = 4/8

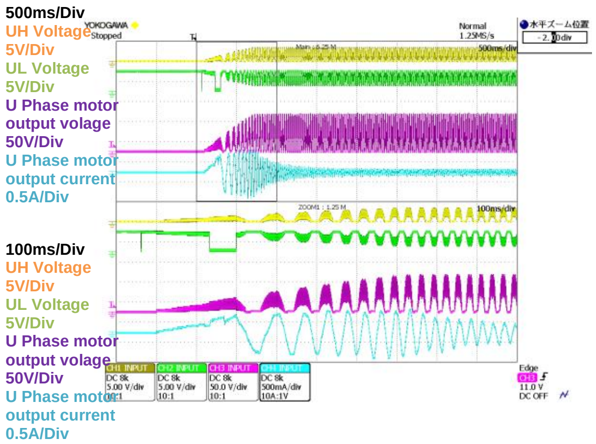


Fig. 5.56 At Rotation Startup,

Square Wave Drive 120° Commutation

SS duty change limit = UP duty change limit = 10/8

5.9.15. When rotation stops (SPD=256 to 0)
Sine Wave Drive
Stopping Sequence: Valid, Invalid

Note: The oscilloscope's filter function makes it easy to display the two-phase modulated waveform of sine wave drive.

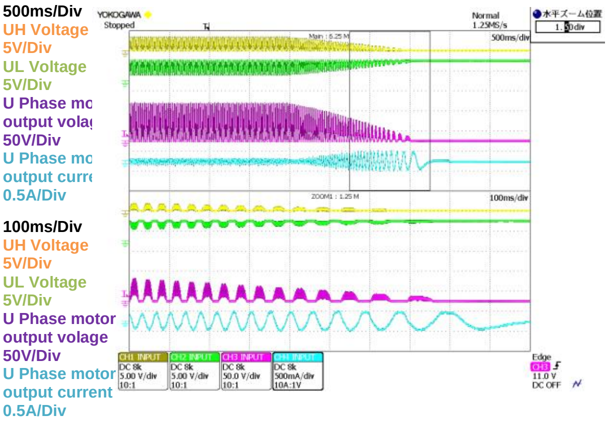


Fig. 5.57 Stopping Sequence: Valid

DWN duty change limit = 4/8

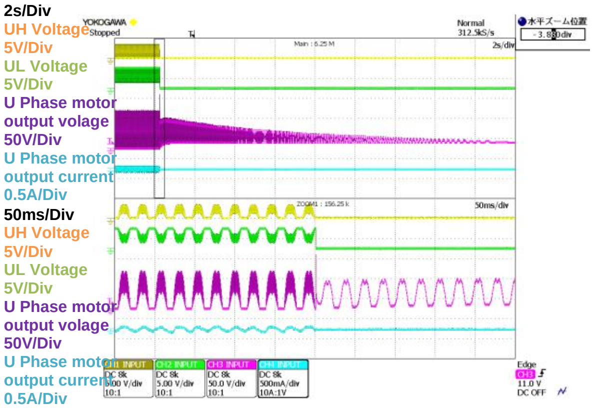


Fig. 5.58 Stopping Sequence: Invalid

DWN duty change limit = 4/8

6. Hall signal settings

6.1. Hall signal input

For the motor to rotate, it is necessary to input the signals to this IC that switches conduction using the hall signals. When rotating the motor forward with a sine wave, please arrange the hall elements so that the hall signals are input with the timing shown in Fig.6.1 relative to the motor's Back-EMF. If the hall signals are input with the timing shown in Fig.6.2, the motor will rotate in reverse or with a square wave, so please review the connection of the hall signal input.

Note: When the rotation direction is set to Forward Rotation and Hall Signals are input in the correct order, it is defined as the Non-inverted Hall Signal Input, and the motor is driven in Normal Rotation according to the setting. On the other hand, when the Hall Signals are input in the opposite order due to reverse wind, etc., this is defined as the Inverted Hall Signal Input, and in this case, the motor is driven in the Square Wave Drive 120° Commutation.
And when the rotation direction is set to Reverse Rotation, the motor is driven in Normal Rotation when Hall Signals are input in the reverse order, and the motor is driven in the Square Wave Drive 120° Commutation when Hall Signals are input in the positive order.

For example, if the motor is set to operate in sine wave drive mode but is actually operating in square wave drive, it is possible that the rotation direction of the motor and the input order of the Hall signals do not match.

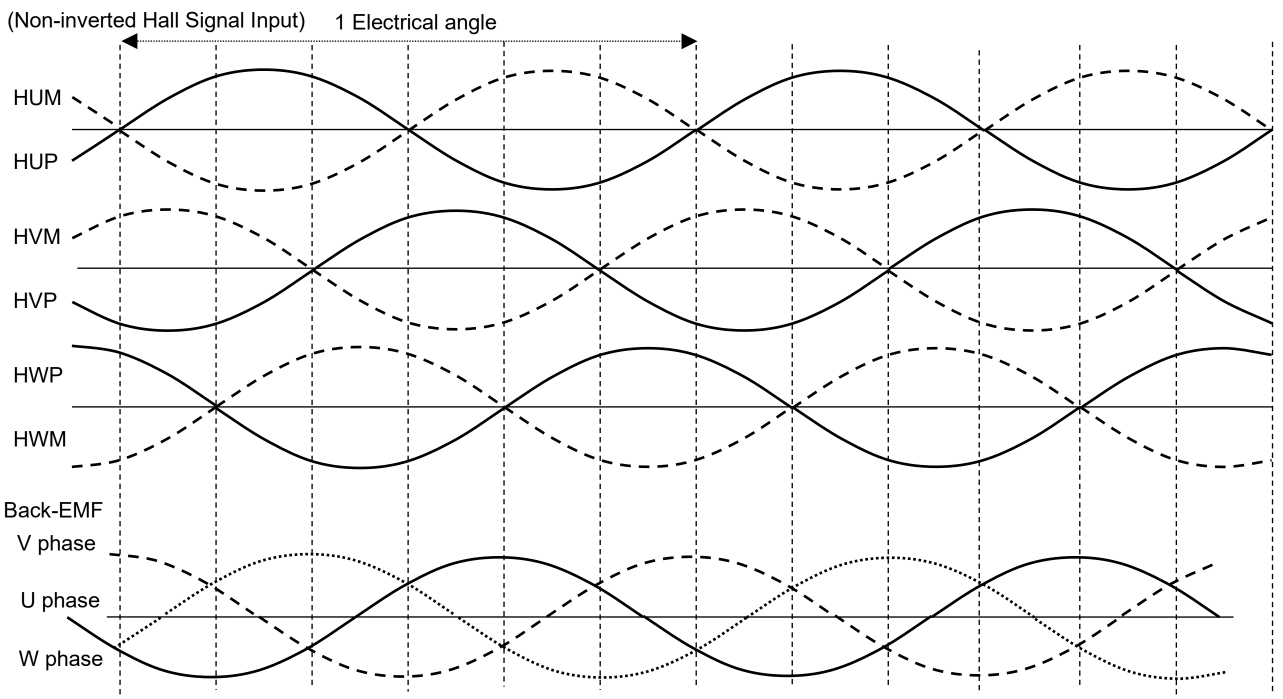


Fig. 6.1 Non-inverted Hall signal input

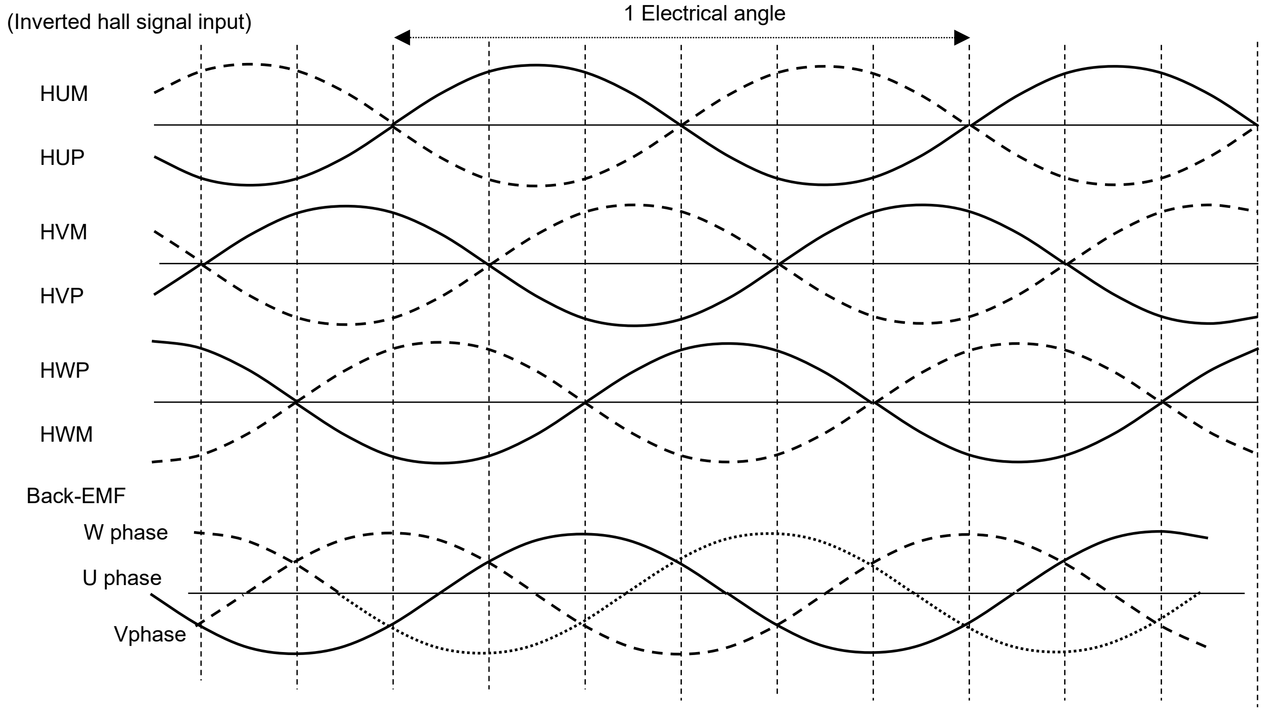
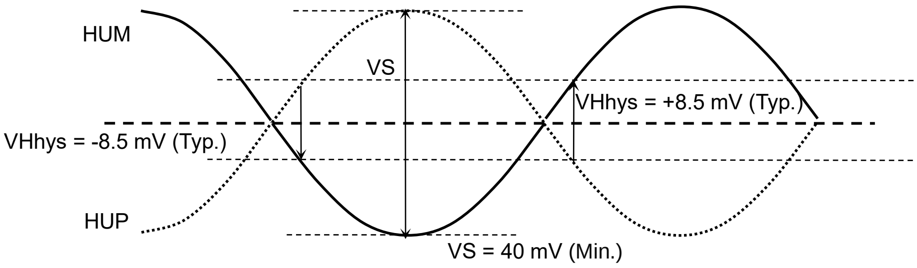


Fig. 6.2 Inverted Hall signal input

6.1.1. Hall element input

When inputting the Hall signals with the Hall elements, the common-mode voltage range of this IC is VW = 0.2 ~ 3.5 V. Additionally, the input hysteresis is VHhys = 8.5 mV (typical), and Vs is 40 mVpp or higher. Please adjust the resistance values of R1a and Ra2 so that they fall within this range. Also, since the Hall signal input terminals have high impedance and are susceptible to noise, connect noise suppression capacitors C1a, C2a, and Ca3 in the range of approximately 100pF to 1μF to prevent malfunction due to noise.



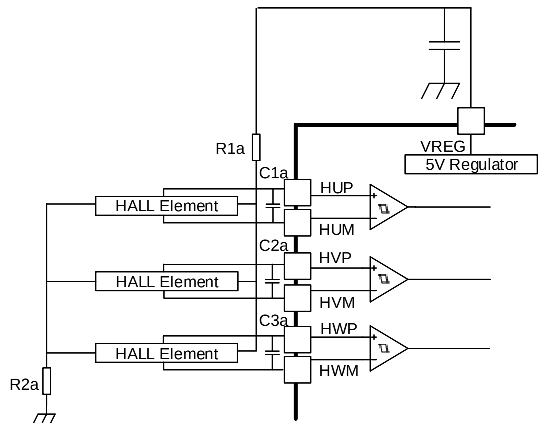


Fig. 6.3 Hall element input example

6.1.2. Hall IC Input

When inputting the Hall signals with the Hall ICs, fix one side of the Hall input terminal to a voltage that is approximately half the amplitude of the Hall IC signal, and connect the Hall IC signal to the other Hall input terminal.

As shown in Fig.6.4, set one side of the Hall input terminal to VREG/2 voltage using R4b and R5b, and input a Hall IC signal amplitude of 0V to 5V (VREG terminal voltage) to the other Hall input terminal. Also, since the Hall signal input terminal has high impedance and is susceptible to noise, connect a noise removal low-pass filter to prevent malfunction due to noise. Adjust the low-pass filter with R1b, R2b, R3b: 1kΩ to 100kΩ, and C1b, C2b, C3b: 100pF to 1μF to remove noise.

If the output structure of the Hall IC is push-pull, it will be as shown in Fig.6.4, but if the output structure of the Hall IC is open-drain/open-collector, connect a pull-up to the VREG terminal as shown with R6c, R7c, and R8c in Fig.6.5.

If the timing phase of the Hall input signal is inverted, it is possible to restore the phase to normal by connecting the VREG/2 voltage to the HUP, HVP, HWP terminals instead of the HUM, HVM, HWM terminals, and inputting the Hall signal to the HUM, HVM, HWM terminals instead of the HUP, HVP, HWP terminals, swapping the connections accordingly.

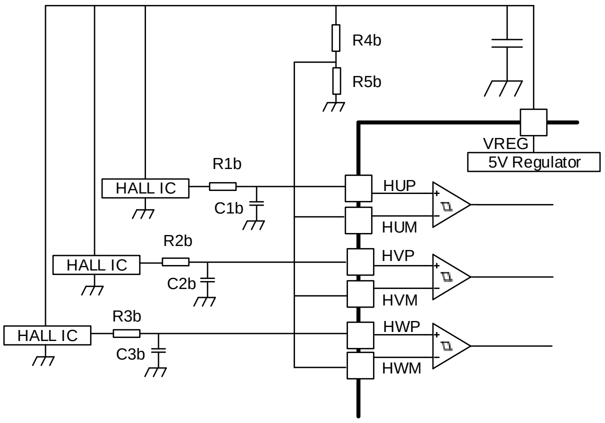


Fig. 6.4 Hall IC Input Example (for Hall IC Output Push-Pull Type)

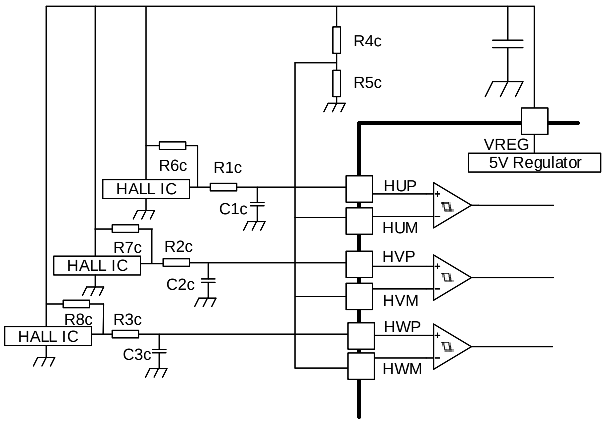


Fig. 6.5 Hall IC Input Example (For Hall IC Output Open Drain/Open Collector)

7. Terminal Settings

7.1. Serial Interface (SPI) Communication Settings

The SCK, SDI, and SDO of SPI communication are shared with the RES terminal, VSP terminal, and FG terminal, so when configuring with SPI communication, please connect and configure with each terminal.

Table7.1 SPI Communication Settings

Terminal name	SPI Communication
RES terminal	SCK
VSP terminal	SDI
FG terminal	SDO

7.2. RES terminal (SPI: SCK)

When the Input Signal level RES = High, the Commutation Signal Outputs are set to Low, and after setting RES = Low it is released for each carrier frequency to restarts. The polarity of the input can also be switched. When a Speed Command is input in Stop State, after 1.5 msec. of Refresh Operation driving signals are output to restart.
On the other hand, when a Speed Command is input in Rotation State, immediate driving signals are output to restart.

As the Internal Counter is still operating during the reset input, the FG signal is kept outputting.
And the RES pin can be used for monitoring the Motor Power Supply Voltage by attenuating the motor power supply voltage with a resistor divider and inputting it to this pin.
In addition, the RES pin is used as a role of the SCK for the Serial Interface Communication.
The Failure Detection Input Function can be turned ON/OFF by setting the register.

Table7.2 Setting of Polarity at RES pin

Register settings 10[5] RES_INV	Settings of Input at RES pin	Failure State All Commutation Output = Low	Normal Operation
0	Non-inverted Input	High	Low (OPEN)
1	Inverted Input	Low (OPEN)	High

Table7.3 Settings of Failure Detection Input Function Valid/Invalid

Settings of register 10[4] RES_ON	State
0	Normal Operation
1	Failure State All Commutation Output = Low

7.3. VSP terminal（SPI:SDI）

The setting of Speed Command is selected from the settings in the table below.
In addition, the VSP terminal is used as a role of the SDI for the Serial Interface Communication.

Table7.4 Settings of Speed Command

Register settings 6[15:13] TRQ_SEL [2:0]	Settings of Speed Command
000	Analog Voltage Input to VSP pin: A Mode
001	Analog Voltage Input to VSP pin: B Mode
010	Analog Voltage Input to VSP pin: Velocity Curve Mode
011	PWM Duty Input VSP pin: Low active Velocity Curve Mode
100	PWM Duty Input (High active) to VSP pin: Velocity Curve Mode
101	SPI Communication Input: Velocity Curve Mode
110	-
111	-

7.3.1. Refresh Operation

Refresh operation refers to turning ON the lower conduction signal at a fixed cycle (carrier cycle) of approximately 8% ON duty. By including the refresh operation before the output stage conduction starts, voltage is supplied to the gate of the high-side FET (IGBT) in the output stage, enabling motor operation from the moment conduction begins.

7.3.2. High-voltage Input to VSP pin Operation Mode

When the Input Voltage to the VSP pin is set to 7.75 V < VSP ≦ 10 V, “High-voltage Input to VSP pin Operation Mode” is selected, and the Motor Outgoing Test Mode or the Commutation Output Low can be selected with the register. (When the Input Voltage exceed 10 V, what is outside range of the VSP Operating Input Voltage, “High-voltage Input to VSP pin Operation Mode” is selected.)

In the Motor Outgoing Test Mode, the Sine Wave Drive operates with zero Lead Angle and the Output ON Duty is maintained at the maximum value. Even though the Sine Wave Generation Method is changed to another reset method, the Sine Wave 60° Reset remains set.

"High-voltage Input to VSP pin Operation Mode" Valid or Invalid can also be selected with the register. The register can also be used to select "High-voltage Input to VSP pin Operation Mode" Valid or Invalid. When the register is set to Invalid, the maximum value in the Speed Command is maintained. The settings of the Lead Angle and the Sine Wave Generation Method are kept unchanged.

Please set the configuration after considering what kind of operation should be performed when the VSP terminal voltage becomes high.

Table7.5 Settings of High-voltage Input to VSP pin Operation Mode

Register settings 11[5] SHIP_CHG	High-voltage Input to VSP pin Operation Mode
0	Motor Outgoing Test Mode ・Sine Wave 60° Reset ・Zero Lead Angle ・Output ON Duty maximum value
1	Commutation Output all Low (Motor Output OFF)

Table7.6 Settings of High-voltage Input to VSP pin Operation Mode Valid/Invalid

Register settings 11[6] SHIP_MASK	High-voltage Input to VSP pin Operation Mode
0	Valid
1	Invalid

7.4. FG terminal (SPI:SDO)

The Output Signal at the FG pin can be selected as shown below.
The Output Structure at the FG pin can also be selected.
The FG pin also plays the role of SDO for Serial Communication, but it can be selected to output the FG Function Signal even during the Serial Communication with the register settings.

Note:
・As for the FG function, no Rotation Pulse Signal is output for rotation below 1 Hz, except for the 3 ppr and 1 ppr settings.
・When the FG pin is set as an open drain output and a pull-up resistor is connected to a separate external power supply without using the VREG pin, voltage may be supplied from the separate external power supply to the power supply of this device via the FG pin. Even though a voltage is supplied from the FG pin, this device is not abnormally controlled as long as the FG pin is used within the specification range. But please note that this phenomenon may occur.

Table7.7 Selection of Output Signal Functions in Serial Communication at FG terminal

Register settings 1[15] SR_FG	Output Signal at FG pin
0	SDO Function
1	FG Function

Table7.8 Selection of Output Structure at FG terminal

Register settings 11[4] FG_OD	Selection of Output Structure at FG pin
0	Push-pull Output
1	Open Drain Output

Table7.9 Settings of Functions at FG terminal

Register settings 10[3:0] FG_SEL	Poles	2	4	6	8	10	12	14	16
	Pole pairs	1	2	3	4	5	6	7	8
	ppr	Pulse per revolution							
0000	3.00	3.00	6.00	9.00	**12.00**	15.00	18.00	21.00	24.00
0001	2.40	2.40	4.80	7.20	9.60	**12.00**	14.40	16.80	19.20
0010	2.00	2.00	4.00	6.00	8.00	10.00	**12.00**	14.00	16.00
0011	1.71	1.71	3.43	5.14	6.86	8.57	10.29	**12.00**	13.71
0100	1.50	1.50	3.00	4.50	6.00	7.50	9.00	10.50	**12.00**
0101	1.00	1.00	2.00	3.00	**4.00**	5.00	6.00	7.00	8.00
0110	0.80	0.80	1.60	2.40	3.20	**4.00**	4.80	5.60	6.40
0111	0.67	0.67	1.33	2.00	2.67	3.33	**4.00**	4.67	5.33
1000	0.57	0.57	1.14	1.71	2.29	2.86	3.43	**4.00**	4.57
1001	0.50	0.50	1.00	1.50	2.00	2.50	3.00	3.50	**4.00**
1010	Failure Detection Signal								
1011									
1100									
1101									
1110									
1111									

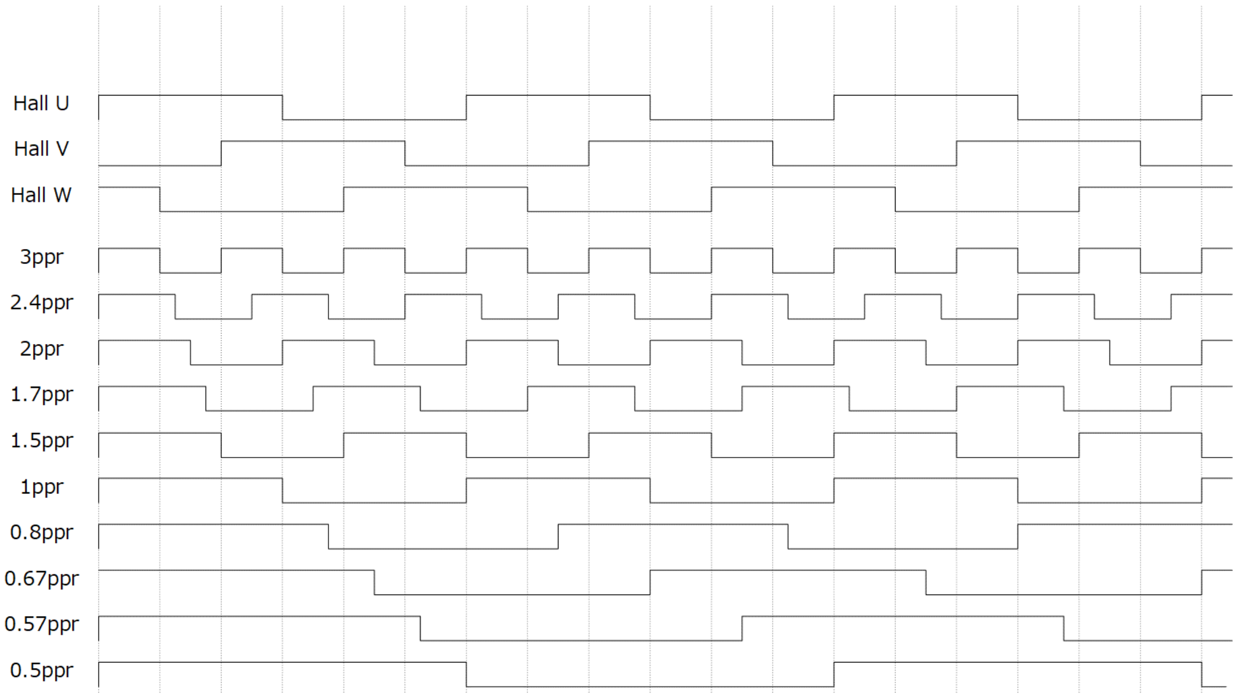


Fig. 7.1 Timing Chart of Rotation Pulse Signal at FG terminal

7.5. DIR terminal

By setting the registers, the DIR pin can be switched to the following functional pin.
The forward/reverse rotation can be set with the rotation direction input.
The short brake can be set with the short brake input.
As for the Failure Detection Input, the Failure Stare and the Normal Operation can be switched in the same way as the RES pin.
(However, the timing for releasing the Failure State is not the carrier frequency timing as with the RES Pin does, but an immediate release to the Normal operation.)
The Rotation Direction Input, the Short Brake input, and the Failure Detection Input can also be set with the registers.

Note:
・Do not set the voltage to the DIR pin to 6.5 V or higher, which is outside range of the Operating Input Voltage, because the device is switched to the Test Mode.
・During short brake state, the short brake condition is prioritized over SPD=0 and Refresh Operation.

Table7.10 Setting of Functions at DIR terminal

Register settings		Settings of input operation at DIR pin	Input voltage to DIR pin	State of Operation
12[2:1] DIR_SEL [1:0]	12[0] DIR_INV			
00	0	Non-inverted Input of Rotation Direction	HIGH	Reverse Rotation
			LOW/OPEN	Forward Rotation
	1	Inverted Input of Rotation Direction	HIGH	Forward Rotation
			LOW/OPEN	Reverse Rotation
01	0	Non-inverted Input of Forward Rotation	HIGH	Forward Rotation
			LOW/OPEN	Normal Operation
	1	Inverted Input of Short Brake	HIGH	Normal Operation
			LOW/OPEN	Forward Rotation
10	0	Non-inverted Input of Failure Detection	HIGH	Failure State: Motor Output OFF (Commutation Output = All Low)
			LOW/OPEN	Normal Operation
	1	Inverted Input of Failure Detection	HIGH	Normal Operation
			LOW/OPEN	Failure State: Motor Output OFF (Commutation Output = All Low)
11	0	Register Settings	-	Note
	1			

Note:
The functions of the rotation direction input and short brake input that are not specified in the input operation settings at the DIR pin are the register settings.
As for the Failure Detection Input, either the register settings or the Failure Detection Input at the RES pin can be used to switch to the Failure State.

Table7.11 Register Settings of Rotation Direction Input

Register 12[4] DIR	Rotation Direction
0	Forward Rotation
1	Reverse Rotation

Table7.12 Register Settings of Short Break Input

Register 12[3] BRK_ON	Short Break
0	Normal Operation
1	Short Break

Table7.13 Register Settings of Failure Detection Input at DIR terminal

Register 12[5] RES	Failure Detection Input
0	Normal Operation
1	Failure State

7.6. FGC, LATYPE, LAOFS, LA terminal (Parameter setting terminals for TC78B043FNG, TC78B043FTG has no terminals)

In the TC78B043FNG, the control that enables a specific motor to rotate has already been written to NVM as the initial setting. And by adjusting each register setting from the 4 pins (LA, FGC, LATYPE, LAOFS), the motor can be rotated by this Initial Setting without setting registers via SPI Communication.
When the default setting is insufficient to rotate the motor and a readjustment of the register setting is required, the readjustment can be performed via SPI Communication.

Note: In the case of the TC78B043FTG (WQFN20), the registers of the four pins (LA pin, FGC pin, LATYPE pin, and LAOFS pin) are set Invalid. Please do not set them Valid, because the setting state is undefined when they set Valid.

Each terminal setting can be configured using resistor voltage division as in the application circuit example, and it is also possible to connect a capacitor as a countermeasure to prevent terminal voltage fluctuations due to noise.

7.7. Setting of output terminals (UH, VH, WH, UL, VL, WL)

It is also possible to connect a pull-down resistor to the output terminal, as shown in the application circuit example, so that the gate driver does not malfunction due to noise when this IC is powered off.

7.8. IDC terminal

There is a function for Current limiting when the IDC terminal exceeds 0.5V (Typ.), and a function for Over-current detection when it exceeds 0.8V (Typ.).

When the output current detection resistor value is set to 0.2 Ω,
Current limiting function operates at 0.5V/0.2Ω = 2.5A.
Over-current detection operates at 0.8V/0.2Ω = 4A.

Therefore, when both the current limiting function and overcurrent detection are enabled, the current limiting function operates before overcurrent detection, so the IDC terminal voltage does not reach 0.8V and overcurrent detection does not operate. However, in cases such as output short-circuit, the IDC terminal voltage instantaneously reaches 0.8V, so overcurrent detection operates and turns off the motor output.

Additionally, the IDC terminal has a built-in low-pass filter of 200 kΩ and 5 pF at the input. If affected by noise, it is also possible to take countermeasures by adding an external resistor and capacitor low-pass filter.

8. Failure Detection Function

Current Limiting Function, Over-current Detection, Thermal Shutdown Detection, Failure Detection Input Function, Position Detection Signal Failure Function, Lead Angle Limiting at High RPM Function, and Motor Lock Protection Function are built in.
By setting the register, the Output Signal of the Failure Detection at the FG pin can be selected.
And the polarity of the Output Signal is also selectable.
In addition, after the Failure Detection is operated, the Failure Detection Output Signal continues to output the Failure State until the Failure Status is released, regardless of the Latch Mode or Automatic Recovery Mode.

8.1. Settings of Lead Angle Limiting at High RPM Function

If the motor speed increases excessively during no load or similar conditions, you can set a limit to restrict the speed. The limiting function includes "Lead angle 0°" and "motor output OFF". When set to "Lead angle 0°", after high-speed detection, Lead angle is controlled to decrease by 1 step at a time down to 0°, causing the speed to decrease. The effectiveness of this function depends on motor characteristics and load characteristics, so please evaluate thoroughly before setting.

9. Settings of Oscillation Frequency

You can select PWM frequency, dead time, and other frequencies or times, but since the original oscillation frequency will be changed, all frequencies and times controlled based on that oscillation frequency will also change, so please make sure to evaluate thoroughly before setting.

10. Register, NVM (Nonvolatile Memory) settings

The initial values of the NVM at product shipment differ between TC78B043FTG (WQFN20) and TC78B043FNG (HTSSOP28). The NVM built into the TC78B043FNG is programmed with initial settings suitable for General Motors, so motor operation is possible without using SPI communication. Furthermore, four terminals—FGC terminal, LATYPE terminal, LAOFS terminal, and LA terminal—are provided, allowing adjustment of some parameters such as motor lead angle control by setting the terminal voltages.
The TC78B043FTG does not have the four terminals: FGC terminal, LATYPE terminal, LAOFS terminal, and LA terminal, and the initial motor control settings are not programmed into the NVM. Therefore, when performing motor control, it is necessary to write settings to the NVM using SPI communication.
Please refer to the datasheet for the initial value settings of the NVM. If you wish to change any functions from the initial values, it is also possible to rewrite the NVM using SPI communication.

Notes on Contents

1. Block Diagrams

Some of the functional blocks, circuits, or constants in the block diagram may be omitted or simplified or explanatory purposes.

2. Input / Output Equivalent Circuit

The equivalent circuit diagrams may be simplified for explanatory purposes.

3. Timing Charts

Timing charts may be simplified for explanatory purposes.

4. Application Circuits

The application circuits shown in this document are provided for reference purposes only. Thorough evaluation is required, especially at the mass production design stage. Providing these application circuit examples does not grant a license for industrial property rights.

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. Do not exceed any of these ratings. Exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion.

(2) Do not insert devices in the wrong orientation or incorrectly.
Make sure that the positive and negative terminals of power supplies are connected properly. Otherwise, the current or power consumption may exceed the absolute maximum rating, and exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion. In addition, do not use any device that is applied the current with inserting in the wrong orientation or incorrectly even just one time.

(3) 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. The IC will fully break down when used under conditions that exceed its absolute maximum ratings, when the wiring is routed improperly or when an abnormal pulse noise occurs from the wiring or load, causing a large current to continuously flow and the breakdown can lead smoke or ignition. To minimize the effects of the flow of a large current in case of breakdown, appropriate settings, such as fuse capacity, fusing time and insertion circuit location, are required.

(4) If your design includes an inductive load such as a motor coil, incorporate a protection circuit into the design to prevent device malfunction or breakdown caused by the current resulting from the inrush current at power ON or the negative current resulting from the back electromotive force at power OFF. IC breakdown may cause injury, smoke or ignition. Use a stable power supply with ICs with built-in protection functions. If the power supply is unstable, the protection function may not operate, causing IC breakdown. IC breakdown may cause injury, smoke or ignition.

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.
Depending on the method of use and usage conditions, such as exceeding absolute maximum ratings can cause the over current protection circuit to not operate properly or IC breakdown before operation. In addition, depending on the method of use and usage conditions, if over current continues to flow for a long time after operation, the IC may generate heat resulting in breakdown.

(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, clear the heat generation status immediately.
Depending on the method of use and usage conditions, such as exceeding absolute maximum ratings can cause the thermal shutdown circuit to not operate properly or IC breakdown before operation.

(3) Heat Radiation Design

In using an IC with large current flow such as power amp, regulator or driver, please design the device so that heat is appropriately radiated, not to exceed the specified junction temperature (Tj) at any time and condition. These ICs generate heat even during normal use. An inadequate IC heat radiation design can lead to decrease in IC life, deterioration of IC characteristics or IC breakdown. In addition, please design the device taking into considerate the effect of IC heat radiation with peripheral components.

(4) Back-EMF

When a motor reverses the rotation direction, stops or slows down abruptly, a current flow back to the motor’s power supply due to the effect of back-EMF. If the current sink capability of the power supply is small, the device’s motor power supply and output pins might be exposed to conditions beyond absolute maximum ratings. To avoid this problem, take the effect of back-EMF into consideration in system design.

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