Notes in use of TB67S579FTG

Overview

TB67S579FTG is a PWM chopper-type, 2-phase bipolar stepping motor driver with a built-in clock-in decoder, supporting 40 V / 2.0 A operation. It features the Advanced Current Detect System (ACDS), enabling PWM constant-current control without external current-sense resistors. Additionally, as part of its Advanced Micro-stepping Technology, it incorporates three functions: Active Gain Control (AGC2), Automatic Wave Generation System (AWGS), and Continuous Micro-stepping, which together provide highly efficient motor driving with low vibration and low noise.

Note: The contents described in the application note are reference for evaluating the product. Therefore, the contents described cannot be guaranteed. As for the detailed materials, please check the data sheet.

Contents

1. Power supply voltage

1.1. Operating range of Power supply voltage

In use of TB67S579FTG, voltage supply to the VM pin and the VREF pin is required. Even though the absolute maximum rating of the VM power supply voltage is 40V (in active), please use within the operating range: 4.5 to 34 V. The slew rate at power on should be used 0.05 V / μs or less as a guideline.

The VREF pin should be used within the operating range: 0 to 3.6 V.

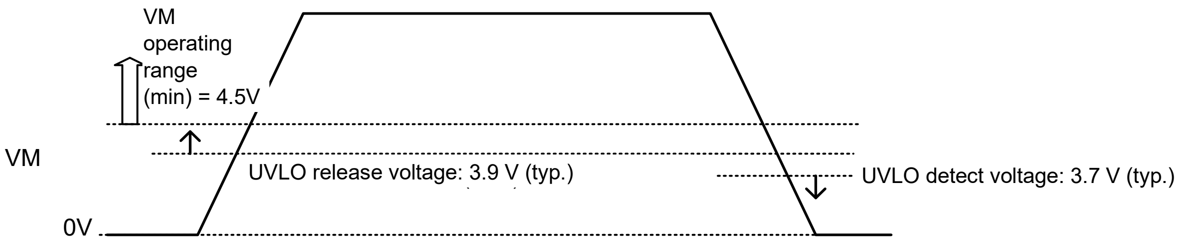


Figure 1.1 VM operating range and UVLO threshold

1.2. Sequence of power supply

Owing to the built-in regulator a single power supply drive is realized in this device. And owing to the built-in low power supply voltage detection (UVLO) malfunctions at low power supply voltage can be prevented.

When the voltage of VM is unstable at turning power on / off (transient area), it is recommended to turn off the motor operation. Please start motor operation by switching the input signal after the power supply voltage becomes stable. And likewise, it is recommended to turn off the power supply after the motor has stopped completely.

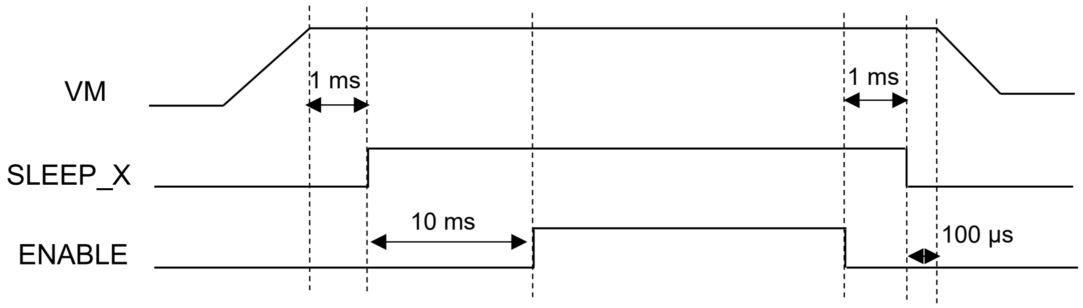


Figure 1.2 Timing chart of VM voltage, SLEEP_X, and ENABLE signals

2. Output current

Please use this device within the operating range of the motor current: 1.8 A or less (per phase). And the maximum current value that can be used actually is limited by application conditions (ambient environment temperature, the board wiring, heat dissipation path, etc.). Please set the optimum current value within the range that does not exceed the allowable power dissipation under operating environment after thermal calculation and actual evaluation.

3. Control input

This device is configured that no electromotive force by the signal input is generated, even though the logic input signal is input during the VM voltage is not supplied. However, it is recommended to set the input signals to a low level before the power supply is turned on. As the logic input signal is specified as VIN (H) = 2.0 V (min) and VIN (L) = 0.8 V (max), this device can be also controlled with input signal of the 3.3 V system. Pull-down resistors of 100 kΩ (typ.) are integrated.

3.1. Function description

3.1.1. Function of the SLEEP_X

By setting the device to sleep and then setting it to normal operation mode again, it is possible to wake up from the output forced OFF state due to the operation of the overtemperature detection circuit (TSD) and the overcurrent detection circuit (ISD). By setting SLEEP_X = Low, the sleep mode is entered after 100 μs. After entering SLEEP_X=High, normal operation is returned to 10 ms (max).

table 3.1.1 SLEEP_X Function

SLEEP_X	Function
L	Sleep Mode (Charge Pump Stop, VCC Reg Stop)
H	Normal operation

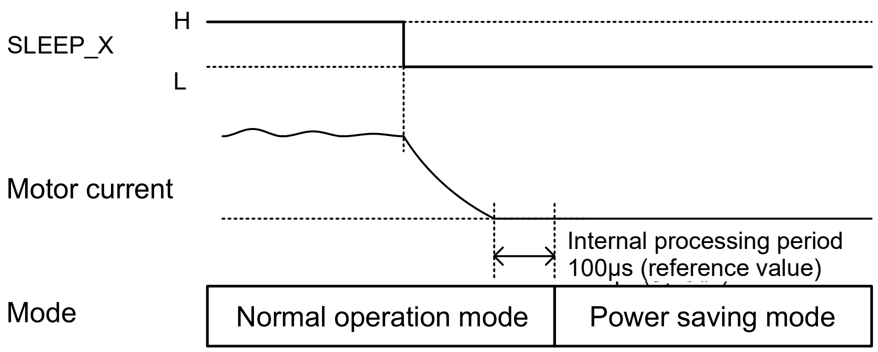


Figure 3.1 SLEEP_X Timing

Note: Please control the SLEEP_X pin from a logic signal such as the MCU. In particular, when pull - up to a power supply such as 5 V or 3.3 V through a resistor, please adjust the rise time of the signal to less than 0.1ms.

3.1.2. CLK Function

For each CLK, one electric angle advances. The signal is reflected at the rising edge.

table 3.1.2 CLK Function

CLK	Function
↑	Take the next step with rising edge
↓	- (Preserve previous state)

3.1.3. ENABLE Function

Switches the stepping motor drive ON/OFF. Normal constant current control is started by turning on the motor drive, and setting it to OFF turns off the MOSFET and the output is high impedance.

table 3.1.3 ENABLE Function

ENABLE	Function
H	Output MOSFET Operation: ON (Normal Operation)
L	Output MOSFET operation: OFF (operation stopped, high impedance)

3.1.4. CW_CCW Function

Switch the direction of rotation of the stepper motor.

table 3.1.4 CW_CCW Function

CW_CCW	Function
H	Forward Rotation (CW)
L	Reversal (CCW)

3.1.5. DMODE0, DMODE1, and DMODE2 Function

Switch the step resolution.
The step resolution can be switched during motor operation. After switching, the mode changes on the next rising edge of the external CLK. After the switch, the electrical angle moves to the nearest position in the direction of rotation.

table 3.1.5 DMODE Function

DMODE0	DMODE1	DMODE2	Function
L	L	L	Full Step
L	L	H	Half Step (A)
L	H	L	Half Step (b)
L	H	H	1 / 4 Step
H	L	L	1 / 8 Step
H	L	H	1 / 16 Step
H	H	L	1 / 32 Step
H	H	H	1 / 32 Step

3.1.6. Selectable Mixed Decay Function

Selectable Mixed Decay is a function that allows the amount of current regeneration during the current regeneration period to be adjusted by terminals.
Mixed decay control itself is achieved by switching between three controls: Charge, Slow, and Fast. The DECAY pin allows this constant current control to be selected from four settings. This pin function is enabled when the ADMD pin = L. If this setting is switched during constant current operation, the setting after switching will be reflected from the next chopping cycle. This function is disabled when Active gain control and Continuous Micro-stepping are selected. When Active gain control and Continuous Micro-stepping are set, the sequence is basically Charge ⇒ Slow, and Fast is turned on only when forced discharge is required.

table 3.1.6 Selectable Mixed Decay Function

DECAY2	DECAY1	Function
L	L	Mixed Decay
L	H	Slow Decay only
H	L	Fast Decay only
H	H	Advanced Dynamic Mixed Decay

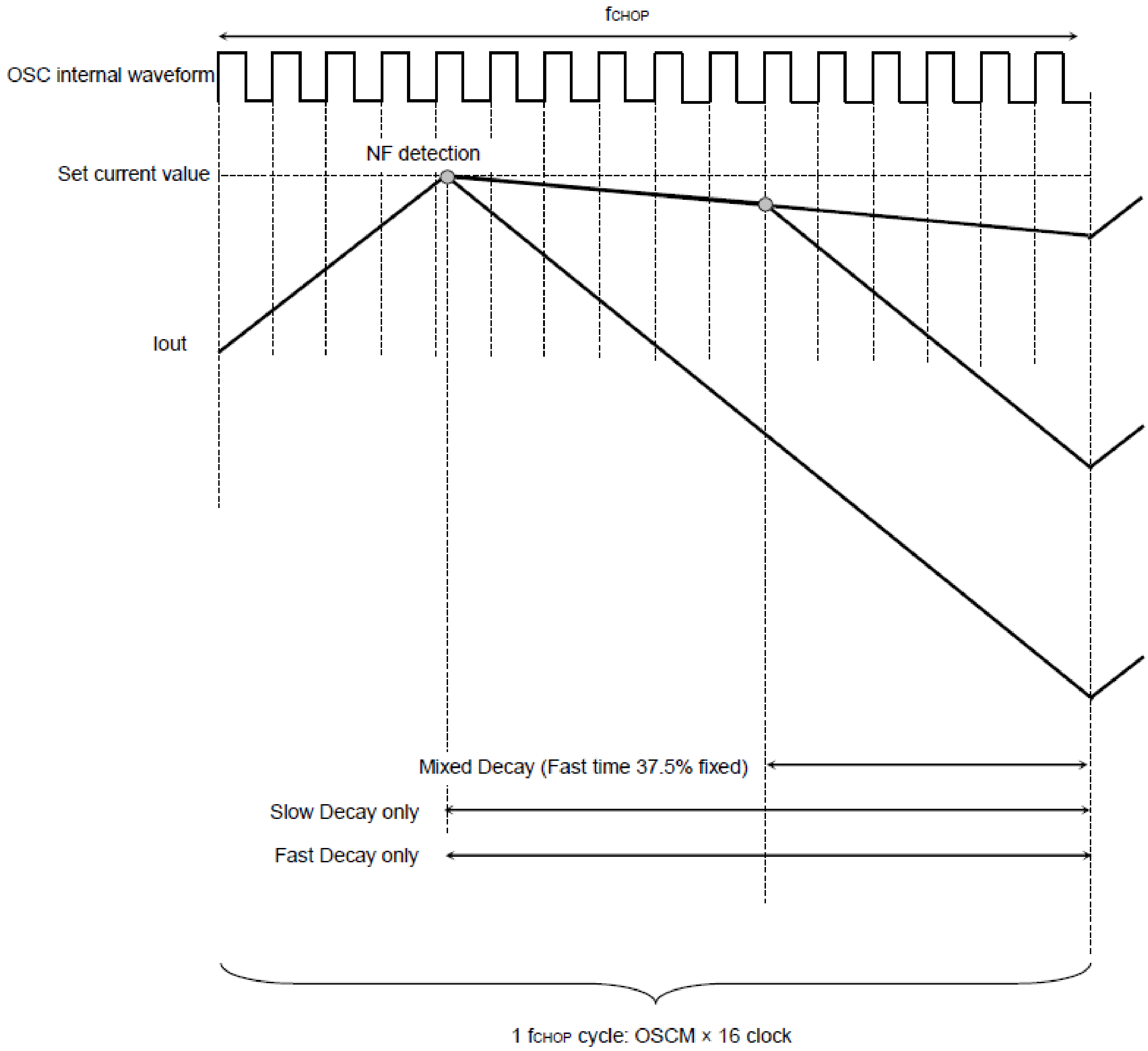


Figure 3.2 Mixed Decay Timing

Note: The timing chart is partially omitted or simplified to explain functions and operation.

3.1.7. ADMD (Advanced Dynamic Mixed Decay) function

The Advanced Dynamic Mixed Decay monitors both the current which flows from the power supply to the motor, and the current which regenerates from the motor to the power supply. The Advanced Dynamic Mixed Decay also controls constant current PWM.The basic sequence of the Advanced Dynamic Mixed Decay is as follows.

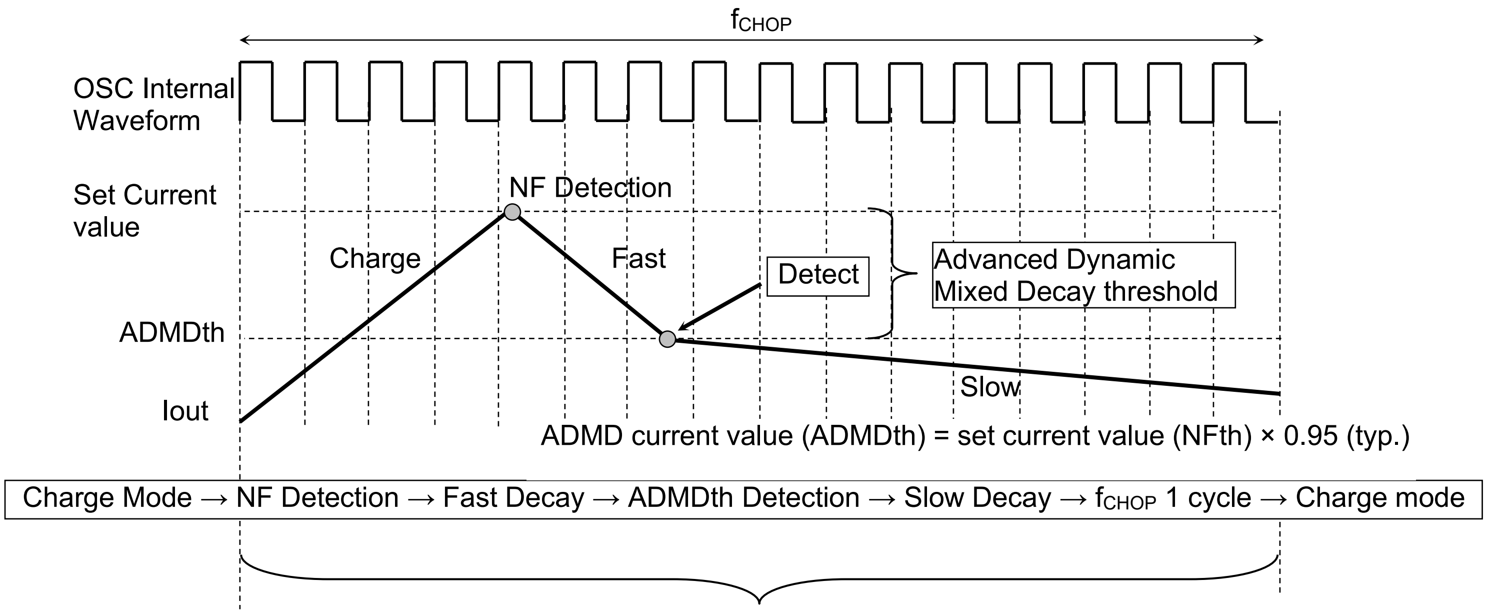


Figure 3.3 ADMD timing chart

Note: Timing charts may be simplified for explanatory purpose.
Note: The values in the timing chart are reference values.

Each filter is attached in order to avoid current-detection error caused by the external noise, etc. (Shown in below figure.)
L value of the motor to be used is small, and when the current value reaches ADMDth (ADMD current value) within the ADMDtblank period, it changes to Slow operation after progress during the ADMDtblank. In this case, the ADMD current value (ADMDth) becomes smaller than "the set current value (NFth) x 0.95 (typ.).

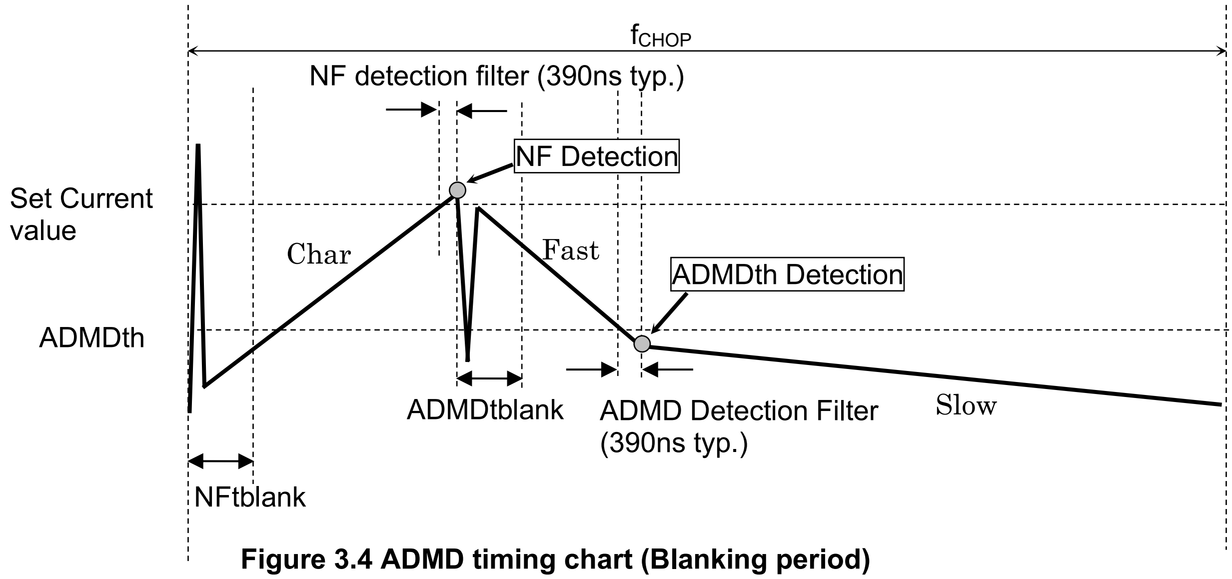


Figure 3.4 ADMD timing chart (Blanking period)

Note: Each tblank time is set in the CTBLANK setting, etc.
Note: Timing charts may be simplified for explanatory purpose.
Note: The values in the timing chart are reference values.

3.1.8. RESET_X Function

The internal electrical horn can be initialized.

table 3.1.8.1 RESET_X Function

RESET_X	Function
H	Normal operation
L	Electric Angular Initialization

The current of each phase when RESET is applied is as follows. (e.g. in microstepping operation)

table 3.1.8.2 Phase current at RESET

Excitation mode	Phase A current	Phase B current	Initial Electric Angle
Full Step	100%	100%	45°
Half Step (A)	100%	100%	45°
Half Step (b)	71%	71%	45°
1 / 4 Step	71%	71%	45°
1 / 8 Step	71%	71%	45°
1 / 16 Step	71%	71%	45°
1 / 32 Step	71%	71%	45°

Note: When using AWGS and Continuous Micro-stepping, each phase is fixed at 71% at RESET.
The above table is for normal μStep. Even if the mode is switched during RESET, the current value changes in sync with the control signal.

3.1.9. MO function

MO is a function to confirm the internal electric angle. Please connect the output of the MO pin to the potential of 3.3 V or 5 V with a pull-up resistor of 10 k to 100 kΩ.

table 3.1.9 MO function

MO	Function
H (Pull-up)	Other than the initial electrical angle
L	The initial electrical angle

3.1.10. LO (Error Detection Flag Output) function

The LO function is a function that outputs an external signal when the error detection function is activated. To restore the LO pin, the VM power is turned back on or the SLEEP_X pin is used to restore normal operation. (When in TSD auto-recovery mode, it is synchronized to TSD.))
Since it is an open-drain terminal, when using the function, the outputs of the LO0, LO1, and LO2 terminals should be connected to a potential of 3.3 V or 5 V with a pull-up resistor of 10 k to 100 kΩ. Normally, the LO0 pin level is Hi-Z (the internal MOSFET is OFF). When an error detection function (over-temperature (TSD), over-current (ISD), etc.) is activated, the pin level is set to L (internal MOSFET is turned on). If the error detection is canceled by re-cycling the VM power cycle or sleep mode, the LO pin will return to the "normal state (normal operation)" again. If the LO pin is not used, set the pin to open or GND. In addition, it is possible to identify the detected error condition by checking the LO1 and 2 pin states. If multiple errors are detected at the same time, the one with the highest priority is prioritized and output. (Error priority: ISD>TSD>OPD>STD)

table 3.1.10 LO Function

LO0	LO1	LO2	Function	
H (during pull-up)	H (during pull-up)	H (during pull-up)	Normal (Normal Operation)	Priority: High
L	H (during pull-up)	H (during pull-up)	ISD (Motor Power Stop)	
L	H (during pull-up)	L	TSD (Motor Output Stop)	
L	L	H (during pull-up)	Output open (motor output operation continued)	
L	L	L	Stall (motor output operation continued)	Priority: Low

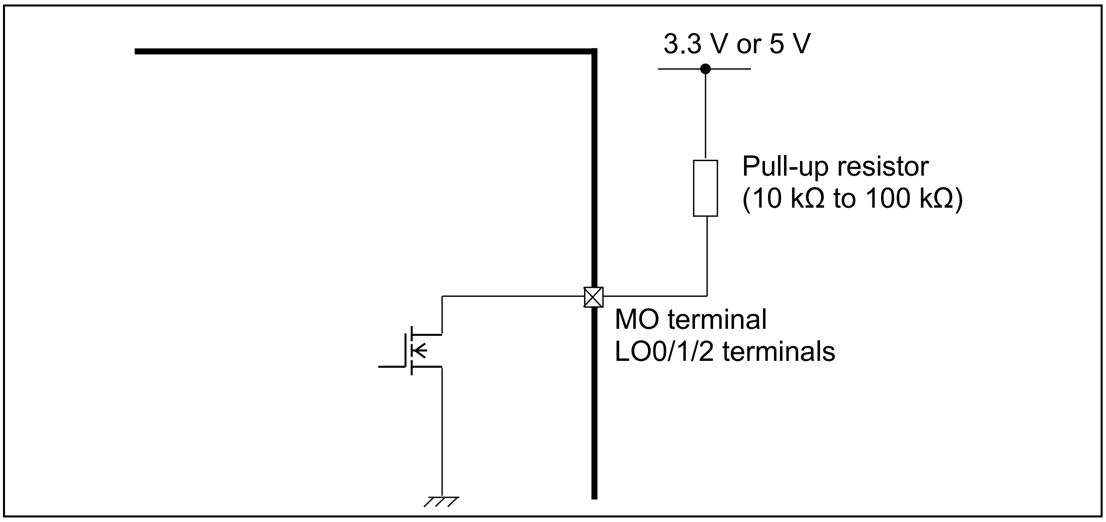


Figure 7.1.10 LO Function

Note: Equivalent circuits may be omitted or simplified in order to explain the circuit.

3.1.11. Output Open Detection Function

When the motor output is Open, it is a function that detects it as an error.
Even when a motor is connected, when the difference between the set current set by VREF and the actual current is large (when VREF is large and at high rpm), or when the required rotation speed is high for VREF, where the current fluctuation in one electric angle is less than a certain level (at high rotation when Vref is small). Error detection also works. Therefore, please evaluate carefully before setting VREF when using it.

3.2. Automatic Wave Generation System (AWGS) function

AWGS is a function that realizes a pseudo-sine wave even with the input CLK of Full step. In a normal μStep, if the rotational speed is to be maintained at the same rate as during Full step, the CLK frequency must be increased according to the number of steps. By using this function, TB67S579FTG automatically completes the input CLK, so that μStep operation is possible even with the same CLK as the two-phase excitation. AWGS can be switched from any μStep state. When AWGS is selected, the 1/32 Step operation is forced.

table 3.2 Automatic Wave Generation System (AWGS) function

AWGS	Function
L	Normal μStep operation
H	Automatic Wave Generation System (AWGS) operation (1/32 Step)

Note: AWGS operation requires 2 clk spare clks. After the Mode setting is set to Full step, 2CLK works with Full step , after AWGS is set.

[Normal μStep (Full Step)]

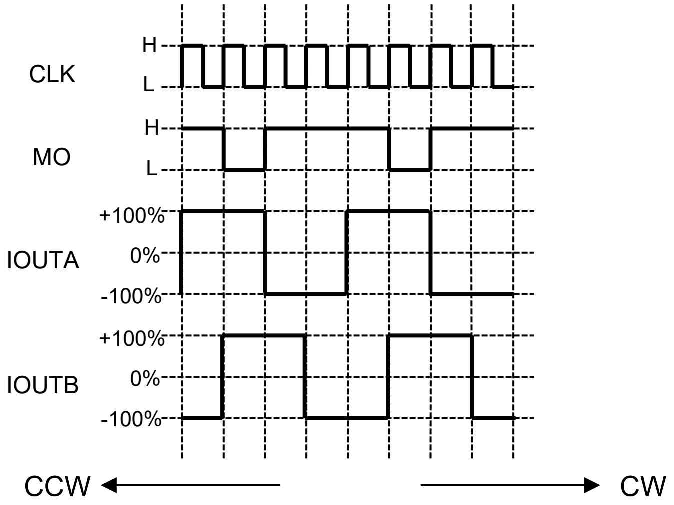


Figure 3.2.1 Normal μStep (Full Step)

[AWGS (1/32): Full step mode]

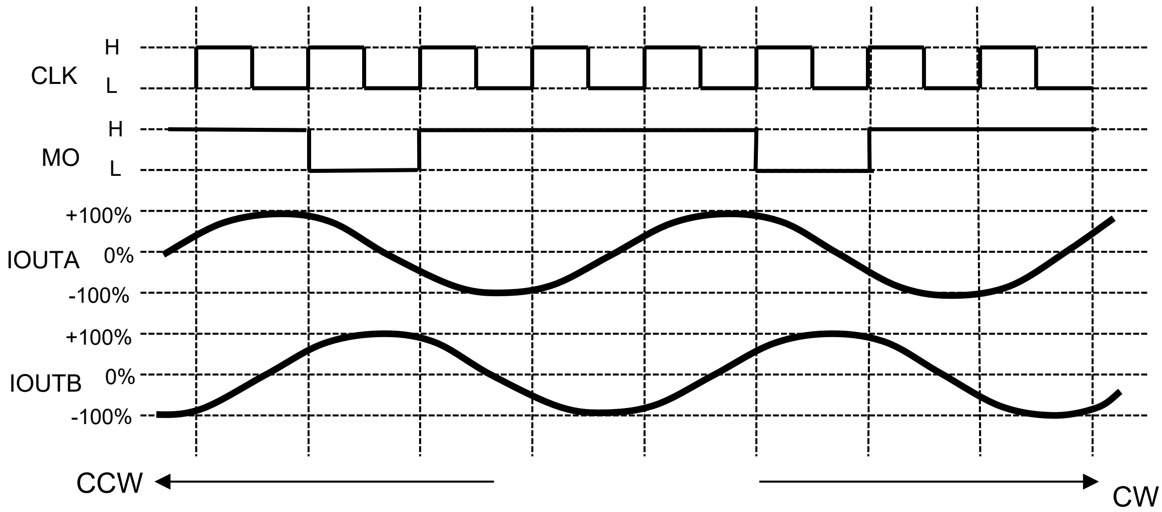


Figure 3.2.2 AWGS (Full step mode)

Note: The MO output is the terminal waveform in the pull up state. The width of the MO at AWGS is output as a width synchronized to the external CLK, similar to the μStep mode.

Note: Timing charts may be simplified for explanatory purpose.

3.3. Active gain control function

3.3.1. Active gain control configuration function

The AGC_ON pin allows the active gain control function to be switched on and off. In the case of H, it is ON, and in the case of L, it is OFF. When the active gain control is ON, TB67S579FTG gradually reduces the motor current according to the load torque, up to the current set by the VREF pin. The lower limit of the attenuation current is the current value set at the VSP_MIN pin. When the active gain control is OFF, the motor current is the current value set by the VREF pin.

table 3.3.1 Active gain control configuration function

AGC_ON pin input	Function
L	AGC: OFF
H	AGC: ON

3.3.2. Active gain control automatic time setting function

When using Active gain Control, it is possible to choose whether to use the internal settings as a condition necessary for operation or to automatically determine and set them by TB67S579FTG. Set to the internal automatic measurement mode, and automatic measurement starts after 84 ms when the output current is energized by 600 mA or more when ENABLE = H and RESET_X = L are energized. However, it is valid only once from the time the power is turned on. If the automatic measurement mode is selected, increase the VREF voltage.

table 3.3.2 Active gain control automatic time setting function

AGC_AUTO	Function
L	Internal Configuration Mode
H	Internal automatic measurement mode

3.3.3. tblank setting function for charge (CTBALNK pin)

Depending on the motor characteristics (L value and R value), the current breakthrough during charging may be large, and the constant current control may be disturbed.
Therefore, it is possible to change the tbank settings for the Charge period.
The tblank time changes depending on the voltage value input to the CTBLANK pin.

Example: If CTBLANK=1V is entered, the tbank time for the charge period is 1.875 µs. The setting changes in 0.156 V steps.

Note: For the CTBLANK and STBLANK settings, set the sum of the Charge and Slow dead zone times to be longer than the dead zone time of ISD (1.25 µs (typical)). If it is shorter than the ISD dead zone time, ISD may not be detected. The operating range is 0 to 2.49 V. If 2.5 V or higher is applied, the IC’s internal settings will become active. The internal IC settings can be configured via serial control.

table 3.3.3 tblank setting function for charge

Val	tblank time [µs]	Val	tblank time [µs]
0	0.000	8	2.500
1	0.313	9	2.813
2	0.625	10	3.125
3	0.938	11	3.438
4	1.250	12	3.750
5	1.563	13	4.063
6	1.875	14	4.375
7	2.188	15	4.688

3.3.4. tblank setting function for Slow (STBLANK pin)

Set the tblank time of Slow by setting this terminal. The tblank time changes depending on the voltage value input to the STBLANK pin.

Example: If STBLANK = 1 V is entered, the tbank time for the slow period is 2.188 μs. The setting changes in 0.156V steps. The operating range is 0 to 2.49 V. If 2.5 V or higher is applied, the IC's internal settings will become active. The internal IC settings can be configured via serial control.
Note: For the CTBLANK and STBLANK settings, set the sum of the Charge and Slow dead zone times to be longer than the dead zone time of ISD (1.25 μs (typical)). If it is shorter than the ISD dead zone time, ISD may not be detected.

table 3.3.4 TBLANK Configuration Function for Slow

Val	tblank time [μs]	Val	tblank time [μs]
0	0.313	8	2.813
1	0.625	9	3.125
2	0.938	10	3.438
3	1.250	11	3.750
4	1.563	12	4.063
5	1.875	13	4.375
6	2.188	14	4.688
7	2.500	15	5.000

3.3.5. tblank setting function for motor M connection (MTBLANK terminal)

Due to the influence of the M-coupling of the motor, the AGC operation may become unstable. It is possible to improve stability by adjusting the Blank time by setting this terminal. The tblank time changes depending on the voltage value input to the MTBLANK pin.

Example: If MTBLANK = 1 V is entered, the tbank time is 1.875 μs. The setting changes in 0.156 V steps. The operating range is 0 to 2.49 V. If 2.5 V or higher is applied, the IC's internal settings will become active. The internal IC settings can be configured via serial control.

table 3.3.5 tblank setting function for motor M

Val	tblank time [μs]	Val	tblank time [μs]
0	0.000	8	2.500
1	0.313	9	2.813
2	0.625	10	3.125
3	0.938	11	3.438
4	1.250	12	3.750
5	1.563	13	4.063
6	1.875	14	4.375
7	2.188	15	4.688

3.3.6. NF Detection Hysteresis Setting Function (NFHYS Pin)

The output current is pierced from the NF point. In addition, the decay of the slow current decreases as the output current decreases, and it operates at a level that cannot be adjusted by tblank time alone. Due to the influence of the induced voltage generated during motor drive, the current may be lifted during the slow period. In order to stabilize the control, the NF is equipped with a function to have Hys.

Note: If NF_HYS = 1 V is entered, Val = 1. The setting changes in 0.625 V steps. The operating range is 0 to 2.49 V. If 2.5 V or higher is applied, the IC's internal settings will become active. The internal IC settings can be configured via serial control.

table 3.3.6 NF Detection Hysteresis Setting Function

Val	NF_HYS settings	remarks
0	0	No change
1	1	Modified to match slow_hys fuse
2	2	Changing the slow_hys to match the DAC value
3	3	Changing the slow_hys to match the DAC value
4	Serial Registers	Uses Serial Registers

3.3.7. Motor Phase Delay Setting Function (TARGET_ANGLE Pin)

Set the delay tolerance of the motor. This terminal can be used to adjust the extent to which the motor phase delay in AGC operation is tolerated. If it is set to an area that is not PWM controlled, the motor will go out of step. The voltage value input to the TARGET_ANGLE pin changes the target phase. The amount of change is 1.406 [°], which can be set in 64 steps from 0 ~ 88.594 [°].

Note: The setting changes in 0.039V steps. The operating range is 0 to 2.49 V. If 2.5 V or higher is applied, the IC's internal settings will become active. The internal IC settings can be configured via serial control.

3.3.8. Active Gain Control Control Gain Setting Function (ACG_KP Pin, AGC_KI Pin)

This function adjusts the control gain for the influence of current pulse flow and load response during AGC operation. When you want to suppress the current pulse flow, lower the gain by using this setting terminal. If you want to increase the load response, increase the gain. The control gain changes depending on the voltage value input to the KP and KI pins. The amount of change is 8 [A/°], and 64 steps can be set from 0 ~ 504 [A/°].

Note: The setting changes in 0.039V steps. The operating range is 0 to 2.49 V. If 2.5 V or higher is applied, the IC's internal settings will become active. The internal IC settings can be configured via serial control.

3.3.9. Active Gain Control Attenuation Setting Function (VSP_MIN Pin)

In AGC operation, when the load is light and torque is not required, the output current is attenuated, but if the damping is too much, the motor may go out of step. To prevent this, it is possible to set a lower limit for current decay in AGC operation. The lower limit of attenuation changes depending on the voltage value input to the VSP_MIN terminal.

Note: If the VSP_MIN is the VSP_MIN > VREF pin input voltage, the value of the VREF pin is valid.

Note: The setting changes in 0.156V steps. The operating range is 0 to 2.49 V. If 2.5 V or higher is applied, the IC's internal settings will become active. The internal IC settings can be configured via serial control.

table 3.3.9 Active Gain Control Attenuation Configuration Function

Val	Lower current limit [A]	Val	Lower current limit [A]
0	0	8	1.001
1	0.125	9	1.126
2	0.250	10	1.251
3	0.375	11	1.376
4	0.500	12	1.501
5	0.626	13	1.627
6	0.751	14	1.752
7	0.876	15	1.877

3.3.10. Active Gain Control OFF Setting Function at Low Speed (FREQ_MIN Pin)

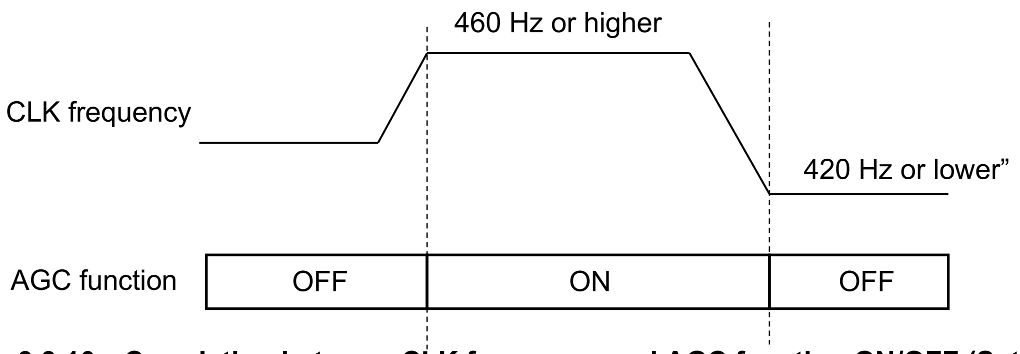
It is set to turn off AGC at low speeds. In the AGC system, the induced voltage is detected and the current control is switched. Since the induced voltage cannot be detected normally at low speed of the motor, this function sets the frequency to turn off the AGC function at low speed. Since there is a Hys for switching, the setting frequency is shown in the table below. The frequency at which the AGC is turned off changes depending on the voltage value input to the FREQ_MIN pin.

Example: When FREQ_MIN = 1 V is input, Val = 6, and AGC is turned off when the rotation speed of the motor is 420 to 460 Hz or less.

Note: The setting changes in 0.156 V steps. The operating range is 0 to 2.49 V. If 2.5 V or higher is applied, the IC's internal settings will become active. The internal IC settings can be configured via serial control.

table 3.3.10 Low Speed Active Gain Control OFF Setting Function

Val	Frequency [Hz]	Val	Frequency [Hz]	Val	Frequency [Hz]
0	1	6	420 to 460	12	840 to 920
1	66 to 88	7	488 to 536	13	920 to 996
2	140 to 152	8	560 to 616	14	967 to 1084
3	208 to 228	9	624 to 696	15	1038 to 1162
4	280 to 304	10	696 to 772	-	-
5	348 to 384	11	772 to 840	-	-



Figuar 3.3.10 Correlation between CLK frequency and AGC function ON/OFF (Setting: Val = 6)

3.3.11. Active Gain Control Zero-Cross Localization Time Setting Function (AGC_TIME Pin)

It is possible to set the time to specify the zero-crossing position with this terminal. This is a function to set the slow time of zero crossing. If AGC_AUTO = H and the automatic measurement mode is used, no setting is required. Depending on the voltage value input to the AGC_TIME terminal, the slow time of zero-crossing changes. The amount of change is 0.625 μs, and 512 steps can be set from 0 to 319.375 μs.

Note: The setting changes in 0.005 V steps. The operating range is 0 to 2.49 V. If 2.5 V or higher is applied, the IC’s internal settings will become active. The internal IC settings can be configured via serial control.

3.4. Continuous Micro-stepping Function

3.4.1. Continuous Micro-stepping Configuration Function

To set the Continuous Micro-stepping operation, set AGC_ON = H, AWGS = H, ADMD = L. Continuous Micro-stepping can be configured. While the normal μStep changes the motor current in a step-like manner so that it becomes a pseudo-sine wave, the IC automatically completes the step clock and continuously changes the motor current so that it becomes a sine wave. Compared to μStep drive, it has the effect of reducing vibration during motor drive. It can only be set when ENABLE = L. If you select it, be sure to set it to ENABLE = L. When switching from other excitation operations to Continuous Micro-stepping, or when switching from it to other excitation operations, changes to settings during output operation will not be reflected. In addition, if the ADMD pin is switched during operation other than Continuous Micro-stepping (chopping operation), the setting will be reflected at the next Charge timing.

table 3.4.1 Continuous Micro-stepping Configuration Function

AGC_ON	AWGS	ADMD	AGC_AUTO	Function
L	L	L	x	Normal μStep
L	L	H	x	Auto Decay Mode (Charge⇒Slow⇒Charge (Fast))
L	H	L	x	AWGS Operation
L	H	H	x	AWGS Operation (Auto Decay Mode)
H	L	L	x	Normal μStep
H	L	H	L	AGC Operation
H	L	H	H	AGC operation (internal automatic measurement mode)
H	H	L	x	Continuous Micro-stepping
H	H	H	L	AGC ＋ AWGS
H	H	H	H	AGC + AWGS (Internal Automatic Measurement Mode)

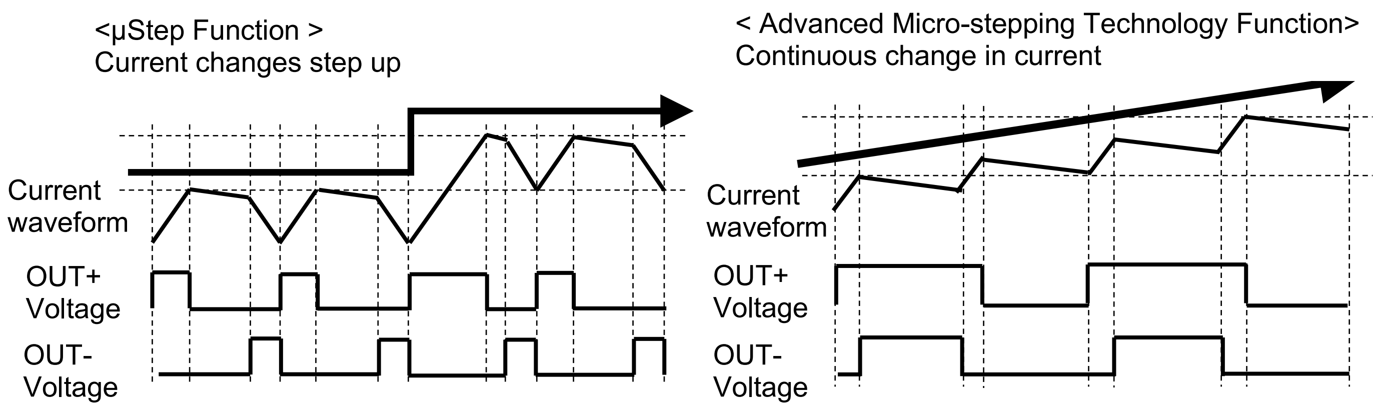


Figure 3.4.1 μStep and Continuous Micro-stepping

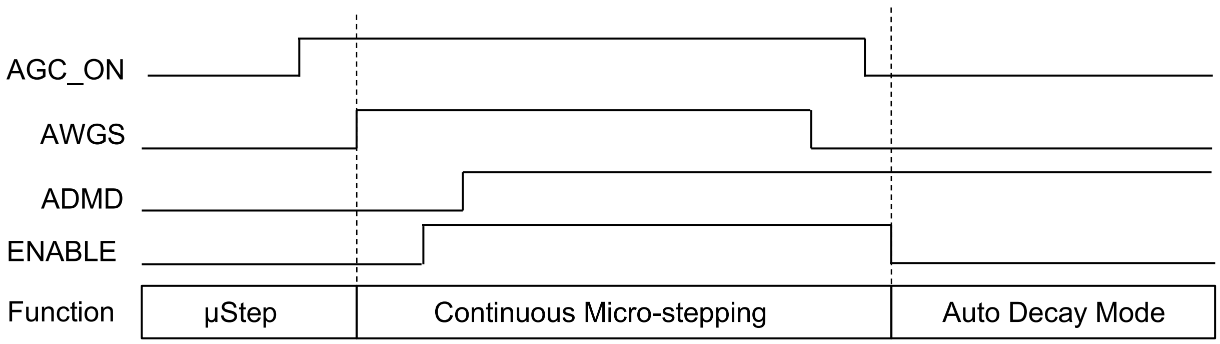


図 3.4.2 Correlation between Continuous Micro-stepping settings and ENABLE

3.4.2. Continuous Micro-stepping Control Gain Setting Function (KPKI_NANO Pin)

During Continuous Micro-stepping operation, the operation may become unstable due to load fluctuations and induced voltages. Therefore, it becomes a function to adjust the control gain. The control gain changes depending on the voltage value input to the KPKI_NANO terminal. Depending on the input voltage to this pin, 10 settings can be made as a combination. The setting changes in 0.313V steps. The operating range is 0 to 2.49 V. If 2.5 V or higher is applied, the IC's internal settings will become active. The internal IC settings can be configured via serial control.

table 3.4.2 Continuous Micro-stepping Control Gain Setting Function

Val	Kp	Ki
0	128	160
1	128	304
2	128	608
3	256	160
4	256	304
5	256	608
6	512	160
7	512	304
8	512	608
9	IC Internal Settings (Kp_nano×2^4)	IC Internal Settings (Ki_nano×2^4)

3.4.3. AGC_OUT Function

A reference signal that controls the output current during AGC operation is output from the AGC_ OUT pin. By monitoring this pin, it is possible to check the state of increase or decrease in output current without observing the output current. In addition, the serial setting (m_dac_sel) changes the signal output to the AGC_OUT pin. If the detection position is selected in the serial setting, the rotor phase of the motor is output during AGC operation. When torque command output is selected, the AGC_OUT terminal voltage = 0.75 V × output current.When position signal output is selected, the AGC_OUT terminal voltage = 0.0166 V × electrical angle.

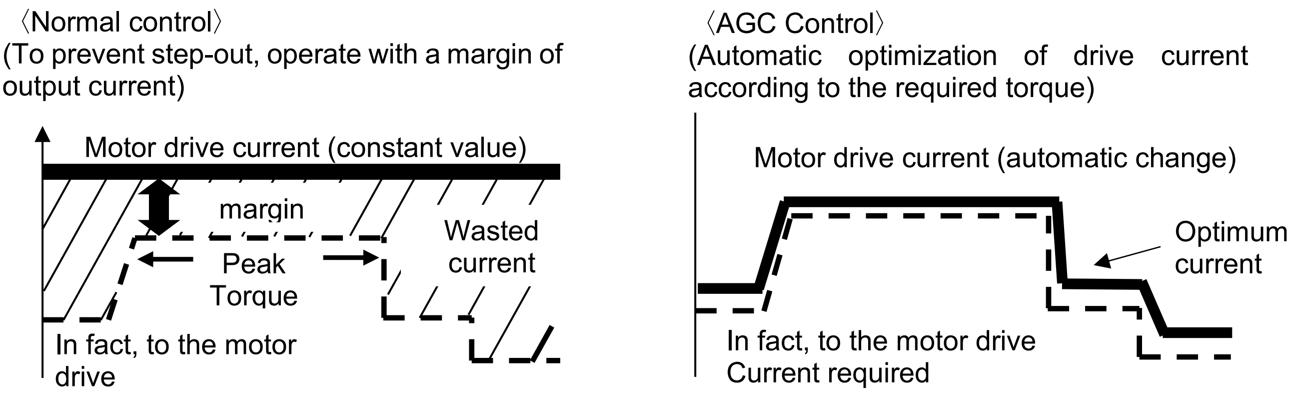


Figure 3.4.3 Normal and AGC Control

3.5. Serial Input Control

External terminal settings required for AGC operation and Continuous Micro-stepping operation can be set with a 2-wire serial with 2 terminals of SERIAL_IN and SERIAL_CLK. The commands that can be set in serial are as follows. In addition, the SERIAL_IN is also a terminal for output serial data. It has a format similar to I2C, but does not have an acknowledge bit. Communication starts in the start condition (SERIAL_CLK = SERIAL_IN down edge during H) and ends communication in the stop condition (SERIAL_IN up edge during SERIAL_CLK = H). If the VM < 5 V, the SERIAL_IN control voltage should be less than or equal to the VM. If you want to enable the value changed in the serial settings, enter a 5 V input (VREG level) to each parameter pin such as CTBLANK. When inputting a voltage from a different power supply other than the VREG pin output to each parameter pin, be sure to enter a voltage that can keep 2.5 V or higher. Also, connect to GND when not in use.

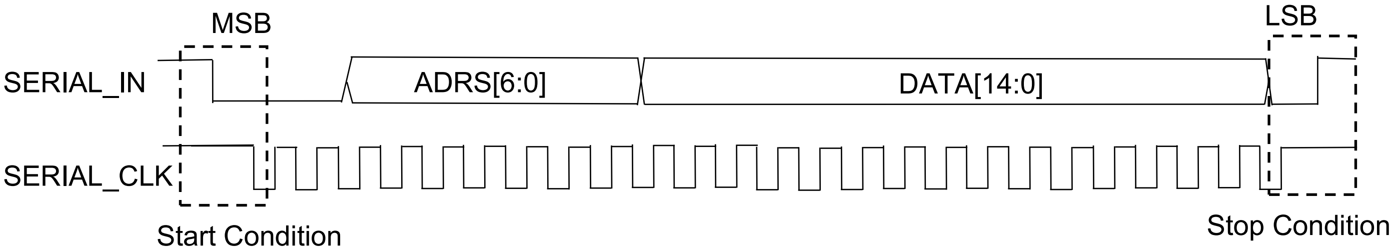


Figure 3.5 Serial Format

table 3.5 Register Map

Addr [6:0]	データ幅														
	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
0															
1				tsd_err_clear	isd_err_clear	stall_err_clear	open_err_clear				crc_err	tsd_lat	isd_lat	stall_det	open_det
2												Ctblank			
3												Stblank			
4												Ftblank			
5												Mtblank			
6												vsp_min			
7														nf_hys	
8												Freq_min			
9													calib_wait		
10							Agc_time								
11										ki					
12										kp					
13										target_angle					
14										Err_delta					
15										ki_nano					
16										Kp_nano					
17														ODET_NANO	
18														wait_nano	
19													ad_wait_nano		
20													boost_sel		
21															RS
22															TSD_Auto
23								dummy						odet_mask	m_dac_sel

3.5.1. Address 1

Clear each abnormal condition (TSD, ISD, Stall, Open).

table 3.5.1 Address 1

DATA Bit				Function
D11	D10	D9	D8	
tsd_err_clear	isd_err_clear	stall_err_clear	open_err_clear	
0	0	0	0	Initial value
-	-	-	1	OPEN Error Clearing
-	-	1	-	Clear Stall Errors
-	1	-	-	ISD Error Clearing
1	-	-	-	TSD Error Clearing

3.5.2. Address 2

Depending on the motor characteristics (L value and R value), the current breakthrough during charging may be large, and the constant current control may be disturbed.
Therefore, it is possible to change the tbank settings for the Charge period.

table 3.5.2 Address 2

DATA Bit				Function
D3	D2	D1	D0	
Ctblank				tblank time [μs]
0	1	0	0	Initial value (1.406)
0	0	0	0	0.156
0	0	0	1	0.469
0	0	1	0	0.781
0	0	1	1	1.094
0	1	0	0	1.406
0	1	0	1	1.719
0	1	1	0	2.031
0	1	1	1	2.344
1	0	0	0	2.656
1	0	0	1	2.969
1	0	1	0	3.281
1	0	1	1	3.594
1	1	0	0	3.906
1	1	0	1	4.219
1	1	1	0	4.531
1	1	1	1	4.844

3.5.3. Address 3

Set the tblank time of SLOW.

table 3.5.3 Address 3

DATA Bit				Function
D3	D2	D1	D0	
Stblank				tblank time [μs]
0	1	0	0	Initial value (1.563)
0	0	0	0	0.313
0	0	0	1	0.625
0	0	1	0	0.938
0	0	1	1	1.250
0	1	0	0	1.563
0	1	0	1	1.875
0	1	1	0	2.188
0	1	1	1	2.500
1	0	0	0	2.813
1	0	0	1	3.125
1	0	1	0	3.438
1	0	1	1	3.750
1	1	0	0	4.063
1	1	0	1	4.375
1	1	1	0	4.688
1	1	1	1	5.000

3.5.4. Address 4

Set the tblank time during Fast.

table 3.5.4 Address 4

DATA Bit				Function
D3	D2	D1	D0	
Ftblank				tblank time [μs]
0	1	0	0	Initial value (1.406)
0	0	0	0	0.156
0	0	0	1	0.469
0	0	1	0	0.781
0	0	1	1	1.094
0	1	0	0	1.406
0	1	0	1	1.719
0	1	1	0	2.031
0	1	1	1	2.344
1	0	0	0	2.656
1	0	0	1	2.969
1	0	1	0	3.281
1	0	1	1	3.594
1	1	0	0	3.906
1	1	0	1	4.219
1	1	1	0	4.531
1	1	1	1	4.844

3.5.5. Address 5

Due to the influence of the M-coupling of the motor, the AGC operation may become unstable. It is possible to increase stability by adjusting the Blank time with this setting.

table 3.5.5 Address 5

DATA Bit				Function
D3	D2	D1	D0	
Mtblank				tblank time [μs]
0	0	1	1	Initial value (0.938)
0	0	0	0	0.000
0	0	0	1	0.313
0	0	1	0	0.625
0	0	1	1	0.938
0	1	0	0	1.250
0	1	0	1	1.563
0	1	1	0	1.875
0	1	1	1	2.188
1	0	0	0	2.500
1	0	0	1	2.813
1	0	1	0	3.125
1	0	1	1	3.438
1	1	0	0	3.750
1	1	0	1	4.063
1	1	1	0	4.375
1	1	1	1	4.688

3.5.6. Address 6

In AGC operation, when the load is light and torque is not required, the output current is attenuated, but if the damping is too much, the motor may go out of step. To prevent this, it is possible to set a lower limit for current decay in AGC operation.

table 3.5.6 Address 6

DATA Bit				Function
D3	D2	D1	D0	
vsp_min				Lower current limit [A]
0	0	1	0	Initial value (0.250)
0	0	0	0	0
0	0	0	1	0.125
0	0	1	0	0.250
0	0	1	1	0.375
0	1	0	0	0.500
0	1	0	1	0.626
0	1	1	0	0.751
0	1	1	1	0.876
1	0	0	0	1.001
1	0	0	1	1.126
1	0	1	0	1.251
1	0	1	1	1.376
1	1	0	0	1.501
1	1	0	1	1.627
1	1	1	0	1.752
1	1	1	1	1.877

3.5.7. Address 7

The output current is pierced from the NF point. In addition, the decay of the slow current decreases as the output current decreases, and it operates at a level that cannot be adjusted by tblank time alone. Due to the influence of the induced voltage generated during motor drive, the current may be lifted during the slow period. In order to stabilize the control, the NF is equipped with a function to have Hys.

table 3.5.7 Address 7

DATA Bit		Function
D1	D0	
nf_hys		
0	1	Initial value
0	0	No change
0	1	Internal settings
1	0	With the magnitude of the Ustep command value The amount of change changes
1	1	

3.5.8. Address 8

It is set to turn off AGC at low speeds. In the AGC system, the induced voltage is detected and the current control is switched. Since the induced voltage cannot be detected normally at low speed of the motor, this function sets the frequency to turn off the AGC function at low speed. Since there is a Hys for switching, the setting frequency is shown in the table below.

table 3.5.8 Address 8

DATA Bit				Function
D3	D2	D1	D0	
Freq_min				Frequency [Hz]
0	0	0	1	Initial value (66 to 88)
0	0	0	0	1
0	0	0	1	66 to 88
0	0	1	0	140 to 152
0	0	1	1	208 to 228
0	1	0	0	280 to 304
0	1	0	1	348 to 384
0	1	1	0	420 to 460
0	1	1	1	488 to 536
1	0	0	0	560 to 616
1	0	0	1	624 to 696
1	0	1	0	696 to 772
1	0	1	1	772 to 840
1	1	0	0	840 to 920
1	1	0	1	920 to 996
1	1	1	0	967 to 1084
1	1	1	1	1038 to 1162

3.5.9. Address 9

Set the wait time for agc_auto detection.

table 3.5.9 Address9

DATA Bit			Function
D2	D1	D0	
nf_hys			Wait time [ms]
1	0	0	Initial value (80.00 to 80.04)
0	0	0	5.00 to 5.04
0	0	1	10.00 to 10.04
0	1	0	20.00 to 20.04
0	1	1	40.00 to 40.04
1	0	0	80.00 to 80.04
1	0	1	100.00 to 100.04
1	1	0	120.00 to120.04
1	1	1	160.00 to160.04

3.5.10. Address 10

It is possible to set the time to determine the zero-crossing position. This is a function to set the slow time of zero crossing. The amount of change is 0.625 μs, and 512 steps can be set from 0 to 319.375 μs.

table 3.5.10 Address 10

DATA Bit									Function
D8	D7	D6	D5	D4	D3	D2	D1	D0	
Agc_time									Zero Crossing Slow Time [Hz]
0	0	0	1	1	0	0	1	0	Initial value (31.25)
0	0	0	0	0	0	0	0	0	0.000
0	0	0	0	0	0	0	0	1	0.625
0	0	0	0	0	0	0	1	0	1.250
0	0	0	0	0	0	0	1	1	1.875
0	0	0	0	0	0	1	0	0	2.500
⋮									
1	1	1	1	1	1	0	0	1	315.625
1	1	1	1	1	1	0	1	0	316.250
1	1	1	1	1	1	0	1	1	316.875
1	1	1	1	1	1	1	0	0	317.500
1	1	1	1	1	1	1	0	1	318.125
1	1	1	1	1	1	1	1	0	318.750
1	1	1	1	1	1	1	1	1	319.375

3.5.11. Address 11

This function adjusts the control gain for the influence of current pulse flow and load response during AGC operation. When you want to suppress the current pulse flow, lower the gain by using this setting terminal. If you want to increase the load response, increase the gain. The amount of change is 8 [A/°], and 64 steps can be set from 0 to 504 [A/°].

table 3.5.11 Address 11

DATA Bit						Function
D5	D4	D3	D2	D1	D0	
Ki						A/°
0	1	0	0	0	0	Initial value (128)
0	0	0	0	0	0	0
0	0	0	0	0	1	8
0	0	0	0	1	0	16
0	0	0	0	1	1	24
0	0	0	1	0	0	32
⋮						
1	1	1	0	0	1	456
1	1	1	0	1	0	464
1	1	1	0	1	1	472
1	1	1	1	0	0	480
1	1	1	1	0	1	488
1	1	1	1	1	0	496
1	1	1	1	1	1	504

3.5.12. Address 12

This function adjusts the control gain for the influence of current pulse flow and load response during AGC operation. When you want to suppress the current pulse flow, lower the gain by using this setting terminal. If you want to increase the load response, increase the gain. The amount of change is 8 [A/°], and 64 steps can be set from 0 to 504 [A/°].

table 3.5.12 Address 12

DATA Bit						Function
D5	D4	D3	D2	D1	D0	
Kp						A/°
1	1	1	1	1	1	Initial value (504)
0	0	0	0	0	0	0
0	0	0	0	0	1	8
0	0	0	0	1	0	16
0	0	0	0	1	1	24
0	0	0	1	0	0	32
・ ・ ・						
1	1	1	0	0	1	456
1	1	1	0	1	0	464
1	1	1	0	1	1	472
1	1	1	1	0	0	480
1	1	1	1	0	1	488
1	1	1	1	1	0	496
1	1	1	1	1	1	504

3.5.13. Address 13

Set the delay tolerance of the motor. This terminal can be used to adjust the extent to which the motor phase delay in AGC operation is tolerated. If it is set to an area that is not PWM controlled, the motor will go out of step. The voltage value input to the TARGET_ANGLE pin changes the target phase. The amount of change is 1.406 [°], which can be set in 64 steps from 0 to 88.578 [°].

table 3.5.13 Address13

DATA Bit						Function
D5	D4	D3	D2	D1	D0	
target_angle						Target electric angle [°]
1	0	1	0	1	0	Initial value (59.052)
0	0	0	0	0	0	0
0	0	0	0	0	1	1.406
0	0	0	0	1	0	2.812
0	0	0	0	1	1	4.218
0	0	0	1	0	0	5.624
・ ・ ・						
1	1	1	0	0	1	80.142
1	1	1	0	1	0	81.548
1	1	1	0	1	1	82.954
1	1	1	1	0	0	84.360
1	1	1	1	0	1	85.766
1	1	1	1	1	0	87.172
1	1	1	1	1	1	88.578

3.5.14. Address 14

Sets the error for the differential electric angle of zero-crossing detection. The amount of change is 1.406 [°], which can be set in 64 steps from 0 to 88.578 [°].

table 3.5.14 Address 14

DATA Bit						Function
D5	D4	D3	D2	D1	D0	
Err_delta						Differential electric angle [°]
1	1	0	0	0	0	Initial value (67.488)
0	0	0	0	0	0	0
0	0	0	0	0	1	1.406
0	0	0	0	1	0	2.812
0	0	0	0	1	1	4.218
0	0	0	1	0	0	5.624
· · ·						
1	1	1	0	0	1	80.142
1	1	1	0	1	0	81.548
1	1	1	0	1	1	82.954
1	1	1	1	0	0	84.360
1	1	1	1	0	1	85.766
1	1	1	1	1	0	87.172
1	1	1	1	1	1	88.578

3.5.15. Address 15

During Continuous Micro-stepping operation, the operation may become unstable due to load fluctuations and induced voltages. Therefore, it becomes a function to adjust the control gain.

table 3.5.15 Address15

DATA Bit						Function
D5	D4	D3	D2	D1	D0	
ki_nano						Continuous Micro-stepping ki [%/A]
0	0	1	0	1	0	Initial value (160)
0	0	0	0	0	0	0
0	0	0	0	0	1	16
0	0	0	0	1	0	32
0	0	0	0	1	1	48
0	0	0	1	0	0	64
· · ·						
1	1	1	0	0	1	912.000
1	1	1	0	1	0	928.000
1	1	1	0	1	1	944.000
1	1	1	1	0	0	960.000
1	1	1	1	0	1	976.000
1	1	1	1	1	0	992.000
1	1	1	1	1	1	1008.000

3.5.16. Address 16

During Continuous Micro-stepping operation, the operation may become unstable due to load fluctuations and induced voltages. Therefore, it becomes a function to adjust the control gain.

table 3.5.16 Address16

DATA Bit						Function
D5	D4	D3	D2	D1	D0	
kp_nano						Continuous Micro-stepping kp [%/A]
0	0	1	0	0	0	Initial value (128)
0	0	0	0	0	0	0
0	0	0	0	0	1	16
0	0	0	0	1	0	32
0	0	0	0	1	1	48
0	0	0	1	0	0	64
・ ・ ・						
1	1	1	0	0	1	912.000
1	1	1	0	1	0	928.000
1	1	1	0	1	1	944.000
1	1	1	1	0	0	960.000
1	1	1	1	0	1	976.000
1	1	1	1	1	0	992.000
1	1	1	1	1	1	1008.000

3.5.17. Address 17

Set the open detection width for the Continuous Micro-stepping.

table 3.5.17 Address17

DATA Bit		Function
D1	D0	
odet_nano		Detection Width Count
0	0	Initial value (9 (9 / set current value*511))
0	0	9 (9 / set current value*511)
0	1	5 (Minimum current: 5 / Set current value*511)
1	0	18 (Minimum current: 18 / Set current value*511)
1	1	27 (Minimum current: 27 / Set current value*511)

3.5.18. Address 18

Sets the waiting time until the start of SW control at the time of Continuous Micro-stepping.

table 3.5.18 Address18

DATA Bit		Function
D1	D0	
wait_nano		Wait time [μs]
1	0	Initial value (0.47)
0	0	0.00
0	1	0.23
1	0	0.47
1	1	0.78

3.5.19. Address 19

Set the waiting time before AD conversion at the time of Continuous Micro-stepping.

table 3.5.19 Address19

DATA Bit			Function
D2	D1	D0	
ad_wait_nano			Wait time [μs]
0	0	0	Initial value (0.23)
0	0	0	0.23
0	0	1	0.47
0	1	0	0.78
0	1	1	1.25
1	0	0	1.48
1	0	1	1.72
1	1	0	1.95
1	1	1	2.27

3.5.20. Address 20

Set the boost. Depending on the setting, the differential setting value of the electric angle in the error count during AGC operation changes.

table 3.5.20 Address20

<table>
<tr><th colspan="3">DATA Bit</th><th colspan="9">Function</th></tr>
<tr><th>D2</th><th>D1</th><th>D0</th><th colspan="9">Number of consecutive errors</th></tr>
<tr><th colspan="3">boost_sel</th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th></tr>
<tr><td>0</td><td>0</td><td>0</td><td colspan="9">Initial value (2047)</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td colspan="9">1023</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td colspan="9">2047</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td colspan="9">4095</td></tr>
<tr><td>0</td><td>1</td><td>1</td><td colspan="3">1023</td><td colspan="6">8191</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td colspan="2">1023</td><td colspan="7">4095</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td colspan="2">2047</td><td colspan="7">4095</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1023</td><td>2047</td><td colspan="5">4095</td><td colspan="2">8191</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1023</td><td colspan="2">2047</td><td colspan="4">4095</td><td colspan="2">8191</td></tr>
</table>

3.5.21. Address 21

Select internal RS mode and external RS resistance mode. External RS mode only works for normal μStep operation.

table 3.5.21 Address 21

DATA Bit D0 RS	Function
0	Initial value (Internal RS Mode)
0	Internal RS Mode
1	External RS Resistor Mode

3.5.22. Address 22

Select the auto-return/latch mode for the TSD function. Automatic recovery is automatically restored depending on the temperature state. In latch mode, once a TSD is detected, the output remains in a stopped state.

table 3.5.22 Address22

DATA Bit D0 TSD_Auto	Function
1	Initial value (latch)
0	Automatic recovery
1	latch

3.5.23. Address 23

The m_dac_sel selects the signal to be output from the AGC_OUT terminal. odet_mask is a mask function for open detection. When open detection is disabled, no error is output from the LO pin.

table 3.5.23 Address 23 (D0)

DATA Bit D0 m_dac_sel	Function
0	Initial value (Torque command output (0.75 V × Output Current))
0	Torque command output (0.75 V × Output Current)
1	Detection position signal output (0.0166 V × Electrical Angle)

table 3.5.24 Address 23 (D1)

DATA Bit D1 odet_mask	Function
0	Initial value (Open Detection Enabled)
0	Open Detection Enabled
1	Open Detection Disabled

4. Constant current control

4.1. The calculation formula of current value setting

The set current value during constant-current PWM control can be determined by setting the reference voltage (VREF).

The set current value (IOUT) can be calculated by the following equation:

IOUT = VREF × 0.556
Example: If VREF = 2.0 V, IOUT = 1.11 A.

In RS mode, the set current value can be determined by the reference voltage (VREF) and an external RS resistor.

The set current value (IOUT) can be calculated by the following equation:

IOUT = VREF / RS / 5
Example: If VREF = 2.0 V and RS resistance = 0.22 Ω, IOUT = 1.82 A.

Note: For external RS resistors, please meet the RS resistor value of 0.4 > Iout × RS.

4.2. Correction of output setting current

When using this IC under conditions other than IOUT = 1.0 A errors due to circuit offset can be reduced by using a correction coefficient.
If you use the current value below, you can reduce the current error by inputting the voltage obtained by multiplying the VREF obtained by the above calculation formula by the correction coefficient below.

Example: When using the 0.2 A setting, the VREF voltage becomes 0.36 V. By applying the correction factor of 0.864 shown below to 0.36 V,
0.36 × 0.864 = 0.311 V, the VREF voltage can be corrected.
Note: The correction factor is a reference value for RS-less mode.

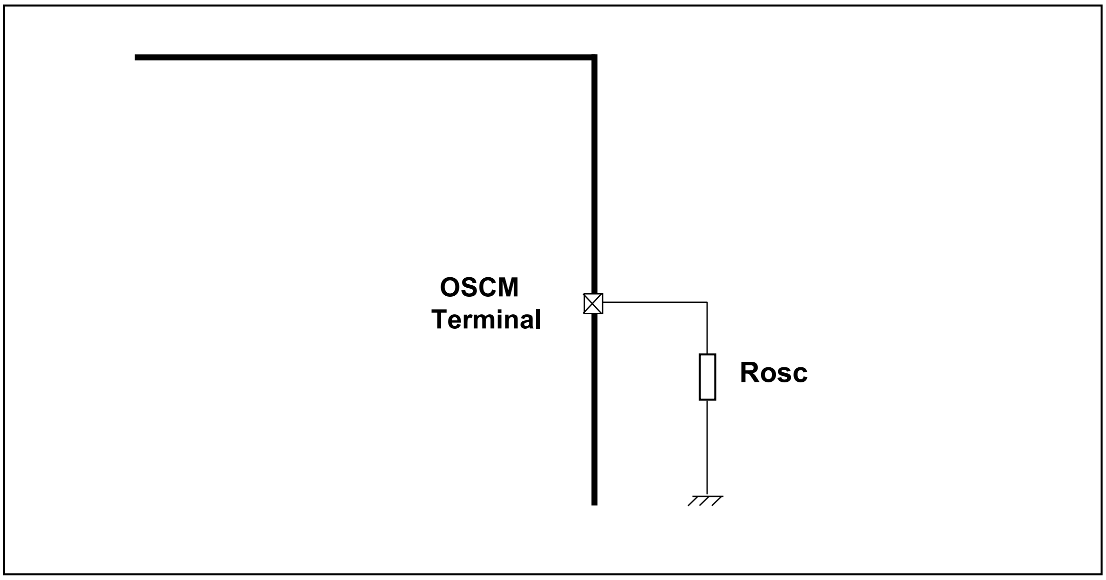
Table 4.2 VREF correction factor

IOUT(A)	Correction factor
0.2	0.864
0.5	0.988
1.0	1.00
1.5	1.001
2.0	1.013

Note: The above values are reference values and are not guaranteed values.

4.3. OSCM Oscillation Frequency and Chopping Frequency

The chopping frequency of the constant current control of the motor current can be set by the resistor ROSC connected to the OSCM pin. It can also be used at a fixed chopping frequency without any external components on the OSCM pin.



Note: Equivalent circuits may be omitted or simplified in order to explain the circuit.

Figure 4.3 OSCM pin equivalent circuit

The chopping frequency (fchop) can be calculated using the following formula:
In general, it is recommended to set the frequency range from 40 kHz to 100 kHz based on a frequency of about 70 kHz.

fchop = foscm / 16
foscm =1/(α×Rosc＋β） [MHz] α = 1.7×10 ^ -5、β = 0.0285
Example: foscm = 1.2 MHz (typ.), fchop = 75 kHz (typ.), when Rosc = 47 kΩ

When the OSCM pin is open or shorted to GND, the IC operates at the automatically generated frequencies fOSCM2 = 800 kHz (typical) and fchop = 50 kHz (typical). Constant current waveform when the chopping frequency is changed.

4.4. Constant current waveform when the chopping frequency is changed.

It is generally recommended to set and use a chopping frequency (f_{CHOP}) of approximately 70 kHz as a typical value. And when the chopping frequency is increased from the typical one, the ripple of a motor current can be reduced and the waveform quality is improved. But on the other hand, as the number of choppings is increased, switching loss also increases and heat generation increases. When the waveform quality is prioritized, increase the chopping frequency, and when the heat generation is concerned, decrease the chopping frequency.

Example 1: When chopping frequency (fchop) = 100 kHz

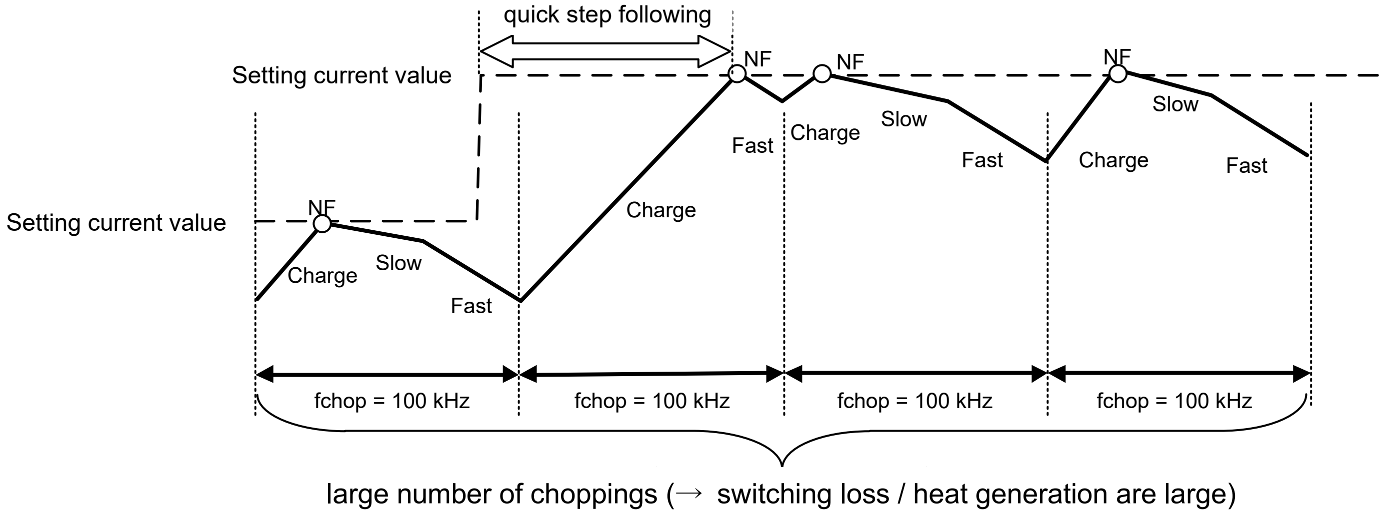


Figure 4.4.1 Constant current waveform (when fchop = 100 kHz)

Example 2: When chopping frequency (f_{chop}) = 50 kHz

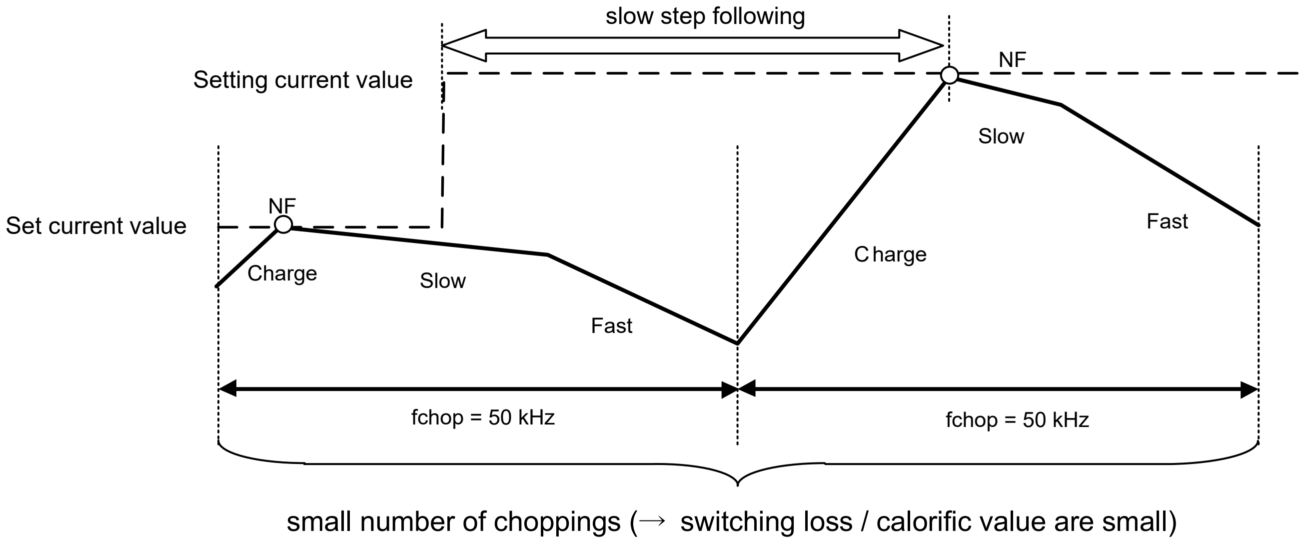


Figure 4.4.2 Constant current waveform (when fchop = 50 kHz)

5. Active Gain Control(AGC) Setting

5.1. Active Gain Control (AGC) setting flow

When using Active Gain Control (AGC), please refer to the following configuration flow and perform the necessary settings.

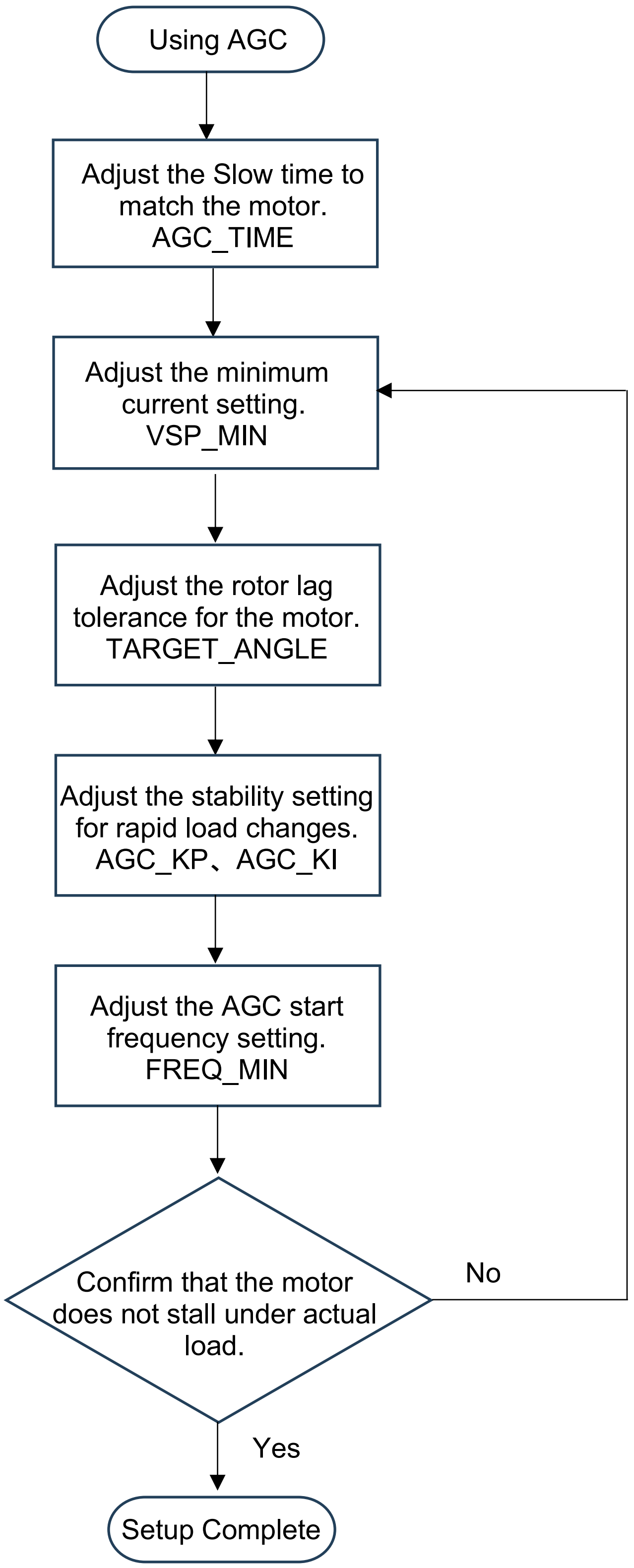


Figure 5.1 Active Gain Control (AGC) setting flow

5.2. AGC_TIME setting

There are three ways to set AGC_TIME:

1. By actual measurement
2. By using the AGC_AUTO function
3. By calculation

5.2.1. By actual measurement

1. Apply power with ADMD pin = H, RESET_X = L, and ENABLE = H so that TB67S579FTG in the reset state.
2. Confirm that sufficient current is flowing and that the PWM pattern is Charge → Slow → Charge (as shown in the figure, with no PWM applied to the negative terminal side).
3. Measure the Slow time. (Example: 36.3 μs in the figure)
4. Enter a value close to the measured Slow time via the pin or serial interface.

For pin input: :

Conversion gain：320 μs / 2.5 V,

Input voltage = 36.3 μs × 2.5 / 320 μs ≒ 0.28 V

For serial input：

Conversion gain：0.625 μs × LSB
Input voltage = 36.3 μs / 0.625 μs ≒ 58

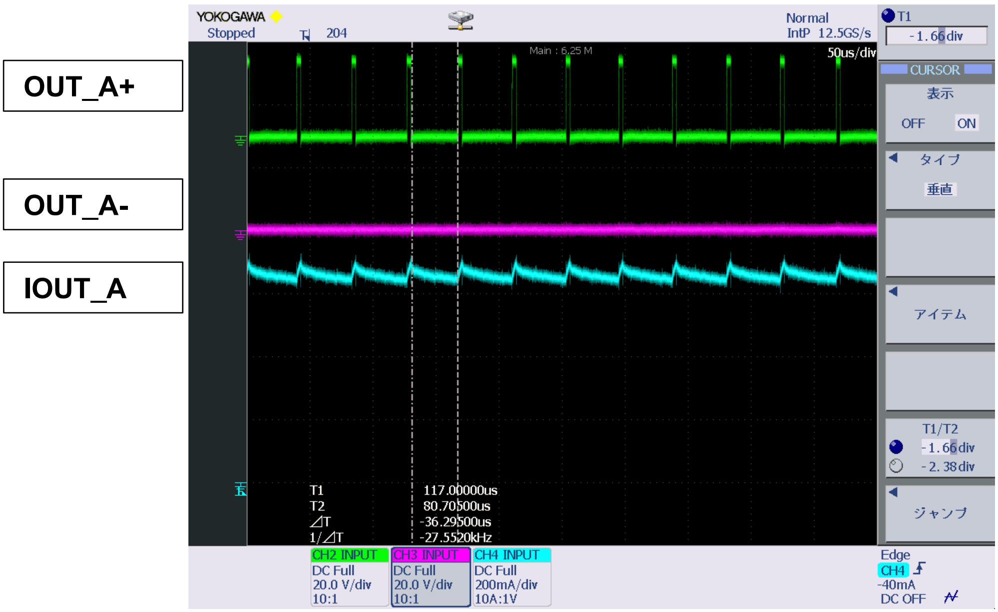


Figure 5.2.1 Motor output wave

5.2.2. By using the AGC_AUTO function

1. Input with ADMD = H, RESET_X = L, AGC_AUTO = H, and AGC_ON = H.
2. Set Vref to a voltage where sufficient current flows.
3. Apply power with ENABLE = H for at least 160 ms.

ADR:9 allows selection from 5 ms to 160 ms. If 160 ms cannot be applied, please adjust accordingly.

Note 1: In automatic learning mode, if the current is too low and causes the fast state during automatic measurement, proper learning cannot be achieved. Therefore, ensure that sufficient current flows.

Note 2: The learning time is 160 ms excluding the time required for the current to reach the constant-current value, so please take into account the time needed to reach the constant-current level.

5.2.3. By calculation

1. Measure the motor constants L and R.
   Since the L value varies with frequency, it is recommended to measure it at the PWM frequency used during normal current operation.
2. If the wiring impedance to the motor cannot be ignored compared to the motor constants, please take it into consideration.
3. Calculation formula:
   AGC_TIME ≈ L / (R + wiring resistance + 0.6) × 0.05

Example:

Motor inductance L = 2.2 mH @ 30 kHz
Motor resistance R = 1.8 Ω
Motor wiring = 0.7 Ω
AGC_TIME = 2.2 mH / (1.8 + 0.7 + 0.6) × 0.05 = 35.4 μs
As with actual motor measurement, set the above value via the pin or serial interface.

5.3. VSP_MIN setting

1. After connecting to the actual operating environment, set the current to a value higher than the level at which stable operation is possible even under no-load conditions.
2. If there are large sudden load changes, increase the set current above the value in step 1 so that the current recovery becomes faster.

For pin input
Conversion gain：1.87 A / 2.5 V　（16step）

For serial input
Conversion gain：0.125 A / LSB

5.4. TARGET_ANGLE setting

1. TARGET_ANGLE sets the allowable rotor lag.
   Because regions without PWM cannot be measured, you must set a value smaller than 75° for Half step and 82.5° for 1 / 4 Step.
   For step modes other than Full step, please set the value within the PWM region according to the step mode.
2. Set ADMD = H, AGC_ON = H, ENABLE = H, and set VREF to the normal operating voltage.
3. Configure Serial: ADR = 23, DO = 1.
4. Monitor AGC_OUT at the rotational speed where you intend to use AGC.
   (The figure shows the case where position detection is operating normally.)
5. Under maximum load, reduce TARGET_ANGLE so that AGC_OUT becomes < 1.5 V.
   (For sudden load changes, adjust in conjunction with AGC_KP and AGC_KI.)

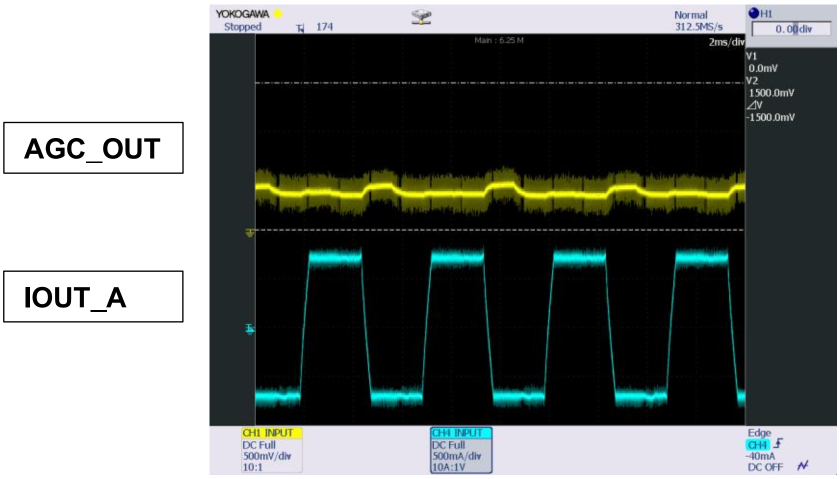


Figure 5.4　AGC_OUT and motor output

5.5. AGC_KP、AGC_KI setting

Since AGC_KP and AGC_KI are PI control gains, they are provided only as reference settings. Please configure them considering the required response to sudden load changes and current stability.
If step-out occurs under sudden load changes, increase AGC_KP and AGC_KI.
If step-out still occurs even after increasing these values, also adjust by reducing TARGET_ANGLE or increasing VSP_MIN as needed.

5.6. FREQ_MIN setting

・If the AGC_OUT output is near 0 V when checking TARGET_ANGLE, it is likely that the induced voltage at the current rotational speed is insufficient.
・If a state including 0 V is observed as shown in the figure, increase the FREQ_MIN setting until the condition is resolved at a higher rotational speed.

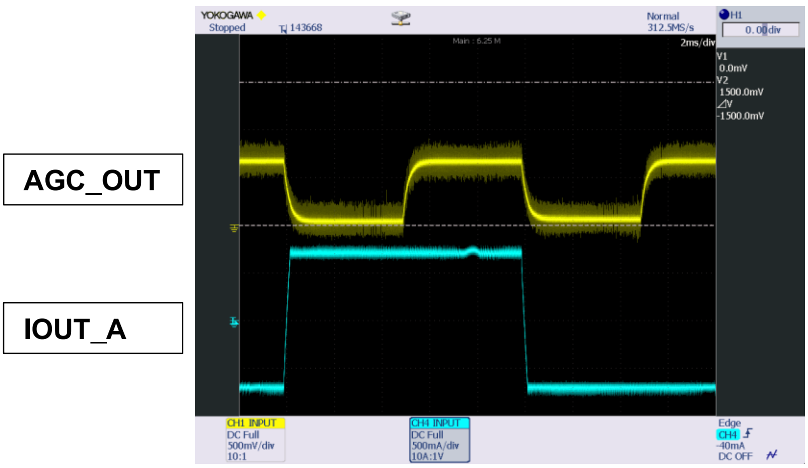


Figure 5.6　AGC_OUT and motor output

6. Fault detection circuit

・Over-temperature detection circuit (TSD)　(Latch mode)

When the junction temperature of the device reaches 160 °C (typ.), the internal detection circuit starts operation and latches the output section to OFF state. A dead band time of 5 μs (typ.) is provided internally to avoid false detection caused by noise from the outside. After the TSD operation, it can be canceled by turning the power on again or setting the standby mode. As the TSD is a function that detects when the device overheats abnormally, please avoid utilizing this function aggressively.

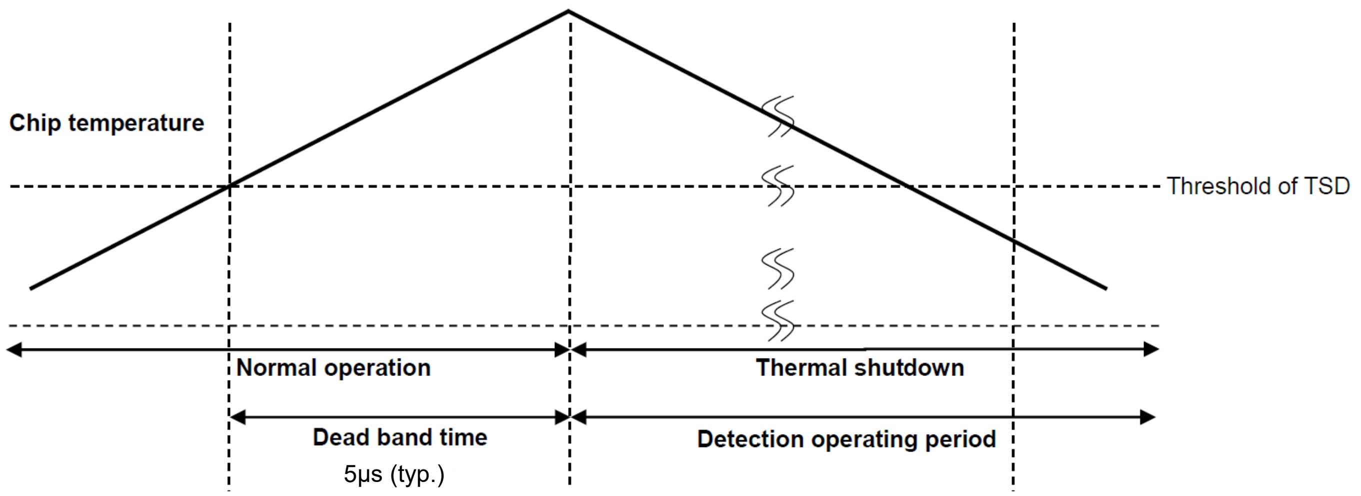


Figure 6.1 TSD operation (Latch mode)

Note: The above time widths are not a guaranteed value, but a reference value.

・Over-temperature detection circuit (TSD)　(Auto-recovery mode)

When the junction temperature of the device reaches 160 °C (typ.), the internal detection circuit starts operation and the output section to OFF state. A dead band time of 5 μs (typ.) is provided internally to avoid false detection caused by noise from the outside. After the TSD operation, it is automatically released when the junction temperature falls to 130 °C (typ.) or below.As the TSD is a function that detects when the device overheats abnormally, please avoid utilizing this function aggressively.

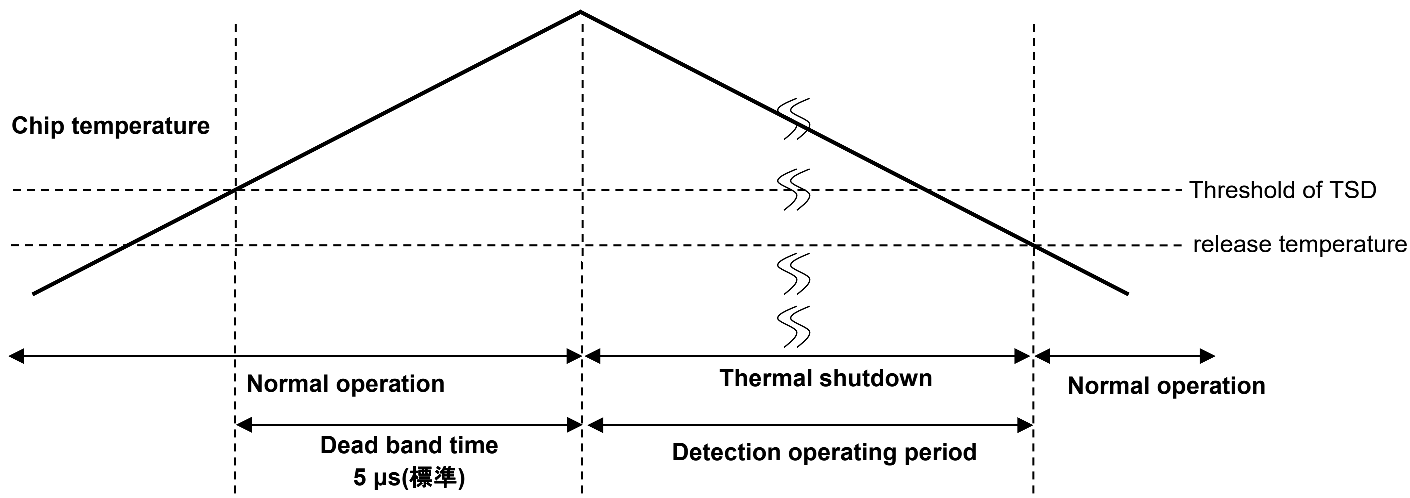


Figure 6.2 TSD operation　(Auto-recovery mode)

Note: The above time widths are not a guaranteed value, but a reference value.

· Low voltage detection circuit (UVLO)

When the voltage applied to the VM pin reaches 3.7 V (typ.) or less, the internal detection circuit starts operation and puts the output section off state. After the UVLO operation, it is canceled by setting the voltage applied to the VM pin to 3.9 V (typ.) or higher.

· Over-current detection circuit (ISD)

When a current exceeding the specified value flows through the motor output, the internal detection circuit starts operation and latches the output section to OFF state. A dead zone period of 1.25 μs (typ.) is provided internally to avoid malfunctions caused by switching, etc. After the ISD operation, it can be canceled by turning the power on again or setting the standby mode.

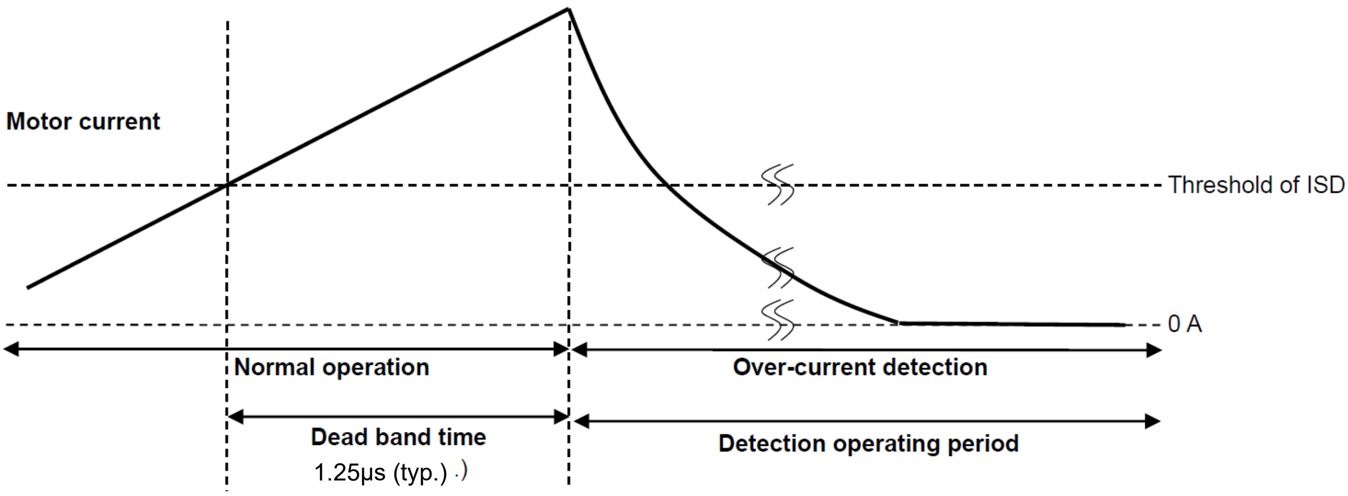


Figure 6.3 ISD operation

Note: The above time widths are not a guaranteed value, but a reference value.

7. Power consumption of the device

The power consumed by the IC can be roughly divided into two parts: the power consumed by the transistor in the output section and the power consumed by the logic section.

7.1. Power Consumption of Power Transistors

The power of the output section is consumed by the transistors above and below the H-bridge.

The power of the transistor section of one H-bridge can be expressed by the following equation:

$P\ (out) = \ Iout\ (A) \times VDS\ (V) = \ Iout\ (A)^2 \times Ron\ (\Omega)$ ....(1)

When a full step operation is performed and the output current waveform becomes a perfect square waveform, the average power consumption of the output is as follows It can be calculated.

Assuming Ron =0.6Ω, Iout (peak : Max) = 1.0 A, and VM = 24 V, the calculation is as follows.
$P\ (out) = 2\ (Tr) \times 1.0\ (A)^2 \times 0.6(\Omega)$ ....(2)
$= 1.2(W)$

7.2. Power Consumption of Logic and IM System

The power consumption of the logic and IM systems is calculated separately during operation and stoppage.

I (IM3) =10.5mA (typ.) : Operating
I (IM2) =7.5mA (typ.) : Stop
I (IM1) =0.03μA (typ.) : Standby

The output system is connected to the VM (24V). (Output system: The current consumed by the circuit connected to the VM and the output stage are
The sum of the currents dissipated by switching)

Power consumption can be estimated as follows:

$P\ (IM3) = 24\ (V) \times 0.0105(A)$ ....(3)
$=0.252(W)$

7.3. Power Consumption

From the results of 1 and 2, the overall power consumption P can be calculated as follows:

$P = P\ (out) + P\ (IM3) = 1.452(W).$

In addition, the power consumption for one axis during standby is as follows.

$P\ (Standby) = 24\ (V) \times 0.03\ (\mu A) = 0.72\ (\mu W)$

Regarding the thermal design of the board, etc., it should be set with a margin after sufficient mounting evaluation.

In addition, in actual motor operation, the average current will be lower than the calculated value due to the transition time of the current step and the ripple caused by constant current PWM. However, referring to the above calculated values, please perform the thermal design of the board, etc. with a margin after a sufficient evaluation of the assembled board.

8. Application circuit example

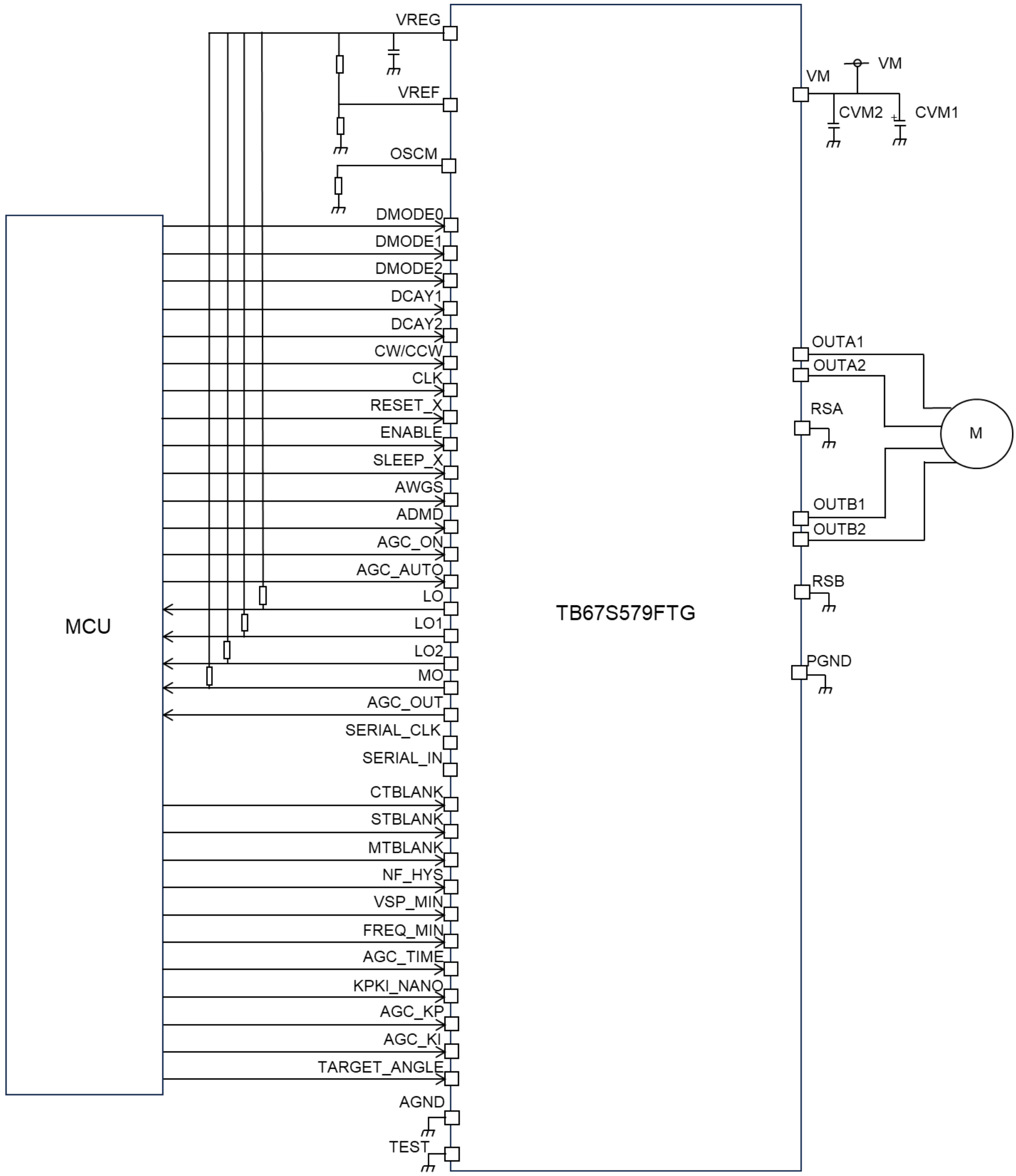


Figure 8 Application circuit example

Note: The application circuit example may be simplified or some parts of them may be omitted for explanatory purposes.

8.1. Capacitor for power supply pins

Please connect a capacitor with an appropriate value to each pin for stabilizing the power supply voltage applied to the device and rejecting noises. And it is recommended to connect the capacitor as close to the device as possible. In particular, locating a ceramic capacitor close to the device is effective in suppressing fluctuations of high-frequency power supply and noise.

Table 8.1 Recommended values of capacitor at power supply pins

Item	Parts	Typical value	Recommended value range
Between VM and GND	Electrolytic capacitor	100 μF	47 to 100 μF
	Ceramic capacitor	0.1 μF	0.01 to 1 μF
Between VREG and GND	Ceramic capacitor	0.1 μF	0.01 to 1 μF
Between VREF and GND	Ceramic capacitor	0.1 μF	0.01 to 1 μF

Note: Please consider connecting a capacitor between VREF and GND in accordance with application and environment.

Note: It is also possible to omit each part or use a capacitor other than the recommended value depending on the motor load conditions and PCB pattern layout.

8.2. Wiring pattern for power supply / GND

In this device, a large current is assumed to flow through PCB patterns especially of VM, AGND, PGND_x, OUT_x +, OUT_x-, or RSx (x = A or B)). Please secure a sufficient wiring pattern in order not to be affected by the wiring impedance, etc. As TB67S579FTG is surface mount package type, it is extremely important to dissipate heat from the heat sink on the back side of the package to the GND pattern of the board. Therefore, please design pattern in sufficient consideration of the thermal design.

8.3. Fuse

Please insert an appropriate fuse into the power supply line before use in order to prevent a continue large current flow in the event of an over-current or the device failure. The device may be destroyed caused by usage exceeding the absolute maximum rating, incorrect wiring, and abnormal pulse noise induced by wiring or load. As a result, a continues large current flow through the device might lead to smoke or ignition. Assuming a large current inflow and outflow cause by the device destruction, appropriate settings of fuse such as capacity, blow time, and insertion circuit location are required to minimize the effects.

In this device, the over-current detection circuit (ISD) that detects when an excessive current flows through the outputs and turns the outputs off is a built-in, but it is not guaranteed that the device is protected under all conditions. Please release the over-current state immediately after the fault detection circuit operates. Depending on the usage and conditions such as exceeding the absolute maximum ratings, the over-current detection circuit may not operate normally or the device may be damaged before the ISD operates. In addition, when over-current continues to flow, the device may be destroyed caused by heat generation depending on the usage and conditions. A secondary destruction is concerned when the over-current state continues, and non-operation of the ISD is concerned depending on the output load conditions because a dead zone period is provided in order to prevent malfunction caused by noise.

As a conclusion, considering the case of emergency please use a fuse in the power supply to prevent abnormal state form continuing.

9. PCBA design dimensions for reference

P-VQFN48-0707-0.50-006 Unit: mm

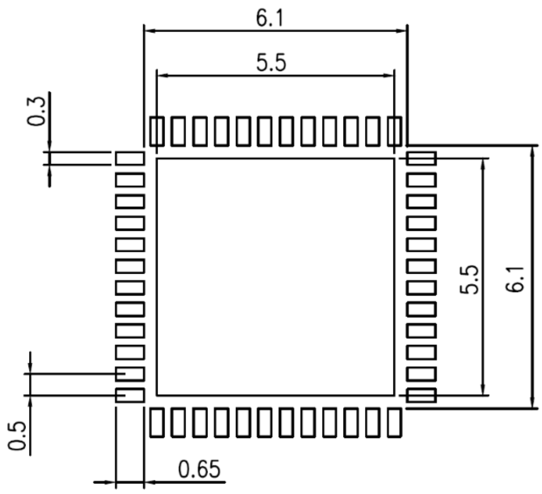


Figure 9 PCBA design dimensions for reference

Notes

- All linear dimensions are given in millimeters unless otherwise specified.
- This drawing is based on JEITA ET-7501 Level3 and should be treated as a reference only.
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Note on Contents

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

2. **Equivalent Circuit**
   The equivalent circuit may be partially omitted or simplified to explain the circuit.

3. **Timing Charts**
   Timing charts may be simplified for explanatory purposes.

4. **Application Circuit Example**
   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

Over-current detection circuit

Over-current detection 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.

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.

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.

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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