TC78B011FTG

Precautions for Use

Overview

The TC78B011FTG is a sensorless PWM predriver IC for 3-phase brushless motors. Motor speed can be controlled by selecting among the PWM Duty cycle, analog voltage, and I^{2}C. Non-volatile memory (NVM) is implemented and it can set according to the motors and directions for use. It also realizes closed loop speed control function without an external microcomputer. TC78B011FTG is used with 6 external N-ch power MOSFETs, to drive motors of which the output range is wide.

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1. Setting Method

1.1. VM Power Supply Voltage Settings

If necessary, connect ceramic capacitors or electrolytic capacitors between the VM and GND as close to the IC as possible to reduce noise and fluctuations at the VM terminal. In particular, using ceramic capacitors in parallel with electrolytic capacitors and connecting them near the IC is effective in suppressing high-frequency power supply voltage fluctuations and noise.

Table 1.1 Power Supply Voltage Operating Range of VM Terminals

Item	Symbol	Min.	Standard	Max.	Unit	Remarks
VM power-supply voltage 1	$V_{M(opr1)}$	9	14.8	27	V	—
VM power-supply voltage 2	$V_{M(opr2)}$	5.5	—	9	V	The variation in electrical characteristics is large, and the electrical characteristics are not guaranteed. Please be careful.
VM Power-supply voltage 3	$V_{M(opr3)}$	10.8	14.8	27	V	VM power supply voltage range when writing to NVM.

- Note: The absolute maximum rating of the VM terminal is 30V. The absolute maximum rating is a standard that must not be exceeded even momentarily.

If the absolute maximum rating is exceeded, the IC may be destroyed, deteriorate, or be damaged, and there is a risk of destruction, deterioration, or damage to components other than the IC. Be sure to perform design so that the absolute maximum rating is not exceeded under any operating conditions.

Please use within the described operating range.

Table 1.2 VM Terminal Capacitators

Item	Recommended Usage Range	Unit
Electrolytic capacitor	10 to 1000	μF
Ceramic capacitors	0.01 to 1	μF

- Note: This is only a reference value, and the appropriate capacitance value will change depending on the motor current. Therefore, use a capacitor value that reduces power supply voltage fluctuations and noise even if it is out of the recommended range.

1.2. VREG Terminal Settings

If necessary, connect a ceramic capacitor between VREG and GND as close to the IC as possible to reduce noise and voltage fluctuations at the VREG terminal.

Table 1.3 VREG Terminal Capacitators

Item	Recommended Value	Unit
Ceramic capacitors	0.1 to 1	μF

1.3. Startup Settings

The sensorless startup method using this product is to first perform initial position detection using DC excitation. After that, the motor is synchronized and rotated by 120° forced commutation to generate the induced voltage of the motor. The rotation position of the motor is detected from the induced voltage and it is rotated by sine-wave without a sensor.

In addition, the success or failure of startup is determined by the DC excitation time, forced commutation frequency, and output Duty (output current limit and Duty at soft start) settings. However, the settings depend on the characteristics and load of the motor, so check them in actual operation and set them so that the rotor can be started from any position.

Also, if there is a dead zone at a specific position of the motor and position detection is not possible with the second DC excitation, the first DC excitation is used. Exclude that position so that the initial position is determined by the second DC excitation. If there is no such position, it is not necessary to use the first DC excitation.

In addition, when FG_ON=0, the FG signal is output when shifting to sensorless control, and when FG_ON=1, it is output when the forced commutation frequency is above the set value.

1.4. Brake Sequence

You can set the brake sequence as the state after the power is turned on or standby is released. In the brake sequence, the state of the output stage can also be set to the short brake, so if the motor is idling when the power is turned on or standby is released, the motor can be started from the stopped state. If you do not need to take such measures, there is no need to set the brake sequence.
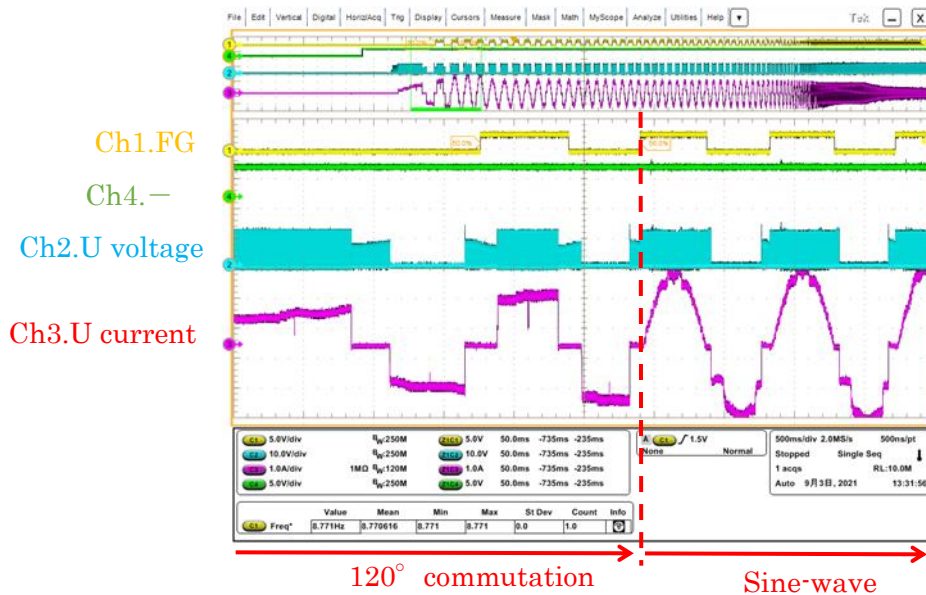

Figure 1.1 Motor operating waveform at startup

1.5. Idling Detection

This product does not perform the control of DC excitation and forced commutation when the motor is started from the idling state (the motor is using (forward rotation), and it rotates with sensorless control from the beginning.

    However, even if the motor is not idling, if the motor is vibrating due to an external factor, the position detection comparator may react and falsely detect it as an idling state. In such cases, set the hysteresis voltage so that the position detection comparator does not react. However, setting the hysteresis voltage makes it impossible to detect low-speed idling.

    For example, when the power supply voltage is 15 V, the maximum rotation speed is 3000 rpm, and the hysteresis voltage of the position detection comparator is ±100 mV (absolute value 200 mV), 3000 rpm / 200 mV / 15 V = 40 rpm, so rotation speeds of about 40 rpm or less are not detected as idling. The startup sequence starts with DC excitation in the same startup sequence as when stopped.

    Please note that if the motor is idling in the opposite direction, the startup sequence will start with DC excitation in the same starting sequence as when it was stopped.

    Also, please note that regardless of the hysteresis voltage setting, if the idling speed is less than or equal to the detection time in the table below, the startup sequence starts with DC excitation in the same way as when idling.

Table 1.4 Forced Commutation Frequency

Resistor Settings 21[1:0] FST	Electrical Angular Frequency	Idling Detection Time (Electrical Angular Frequency)
00	1.6 Hz	200 ms (5 Hz)
01	3.2 Hz	100 ms (10 Hz)
10	6.4 Hz	50ms (20 Hz)
11	12.8 Hz	25 ms (40 Hz)

1.6. Accelerating/Decelerating

In sensorless step, the acceleration/deceleration of the motor is controlled by limiting the amount of fluctuation in the Duty change.

The speed control is set by the Duty change limit and the Duty up time.

The time of the output Duty to reach the input value can be expressed by the following formula.

Output Duty time to reach input value = SPD input setting x Update time / (Duty change)

For example, if the following conditions are set,

When the SPD input (speed command) is input from 0% to 100% (full Duty, 512), SPD input setting = 512

DUTYCHG LIMIT: 001 setting, Duty change = 2/8

DUTY_UP_TIME: 0 setting, Duty up time = 2.7 ms

The output Duty time to reach input value = 512 x 2.7 ms / (2/8) = 5.5296 s

The output Duty changes by 2/8 every 2.7 ms, meaning it takes 5.5296 s to reach full Duty.

1.7. Position Detection

In position detection of the sensorless control of this product, the induced voltage (Back-EMF) of the motor is detected at the output PWM timing in the output OFF section.

After starting with forced commutation of 120° commutations, IC moves to the sine wave commutation. when driving the sine wave, in order to detect the rotation position from the rising zero cross of U back-EMF, the position detection period is output OFF.

Therefore, the accuracy of position detection changes depending on the output PWM frequency, so it is recommended to set the output PWM frequency as 100 times or more than the rotation frequency (the frequency of 1 electrical angle).

However, if the output PWM frequency is set high when the rotation speed is slow, the induced voltage may not be detected because the induced voltage is small and the pulse time of the output PWM is short. Also, if the output PWM frequency is set low when the rotation speed is high, the number of output PWM pulses is small compared to the rotation speed, so position detection may shift.

For example, if the output PWM frequency = 23.4 kHz and the rotation frequency of 1 electrical angle = 234 Hz, then 23.4 kHz / 234 Hz = 100, so set the output PWM frequency = 23.4 kHz up to the rotation frequency of 1 electric angle = 234 Hz. For rotation frequencies (to 469 Hz) that exceed 234 Hz, set output PWM frequency = 46.9 kHz.

Depending on the characteristics of the motor and the characteristics of the external FET, the pulse width for detecting the induced voltage of the output PWM may not be sufficient due to the slew rate and ringing when the output PWM is switched, so the position of the motor may not be detected and unable to be used. In particular, there is a high possibility that a motor with a large L value, a high maximum rotation speed, and a large output current cannot be used.
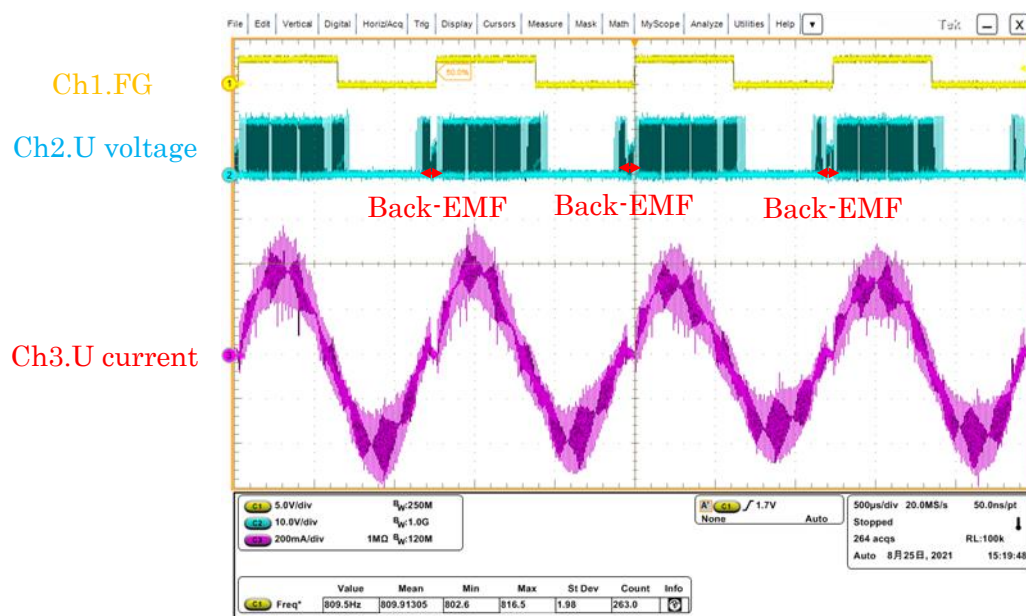
Figure 1.2 Induced voltage (Back-EMF) waveform of motor operation

1.8. Maximum Rotation Speed

Abnormality detection of the maximum rotation frequency can be set as shown in the table below, but please set it with a margin of about 10% from the set value in consideration of the tolerance of this IC. In addition, it is recommended that the maximum applicable frequency of the motor is about 2.7 kHz from the abnormality detection setting of the maximum rotation frequency and the output PWM frequency.
For example, in the case of a 4-pole pair motor, the upper limit of the motor speed = 2.7 kHz x 60 s / 4-pole pair = 40.5 krpm is a guideline for the maximum applicable motor speed.

Table 1.5   Abnormality Detection Setting of the Maximum Rotation Frequency

Resistor Settings 21[3:2] FMAX	Maximum Rotation Frequency
00	0.75 kHz
01	1.5 kHz
10	3 kHz
11	Unavailable

1.9. Closed loop

Increasing the values of Kp and Ki will shorten the time to reach the target rotation speed, but may cause overshooting or vibration, so check it in actual operation before setting them.
Also, Kp and Ki are dependent on each other, so changing one can affect the other as well.

1.10. Output PWM Frequency

To evaluate the initial setting, it is recommended to set the FPWM register as 111 (23.4 kHz to 187.5 kHz). However, as in the position detection of this product, detection is at the timing of the output PWM frequency, the position detection timing changes depending on the PWM frequency due to the influence of the motor rotation speed and the characteristics of the FET in the output stage. In the worst case, position detection may not be possible. In addition, the ripple of the output current may change and the efficiency may change, so check and set it on the actual machine.

1.11. Lead Angle Settings

Depending on the characteristics of the motor, efficiency and noise will change depending on lead angle setting, so check and set with the actual machine.
In the case of the following motor operation settings, the motor operation sound with 142.5° commutation / Lead angle 0° / With soft switching is the quietest.
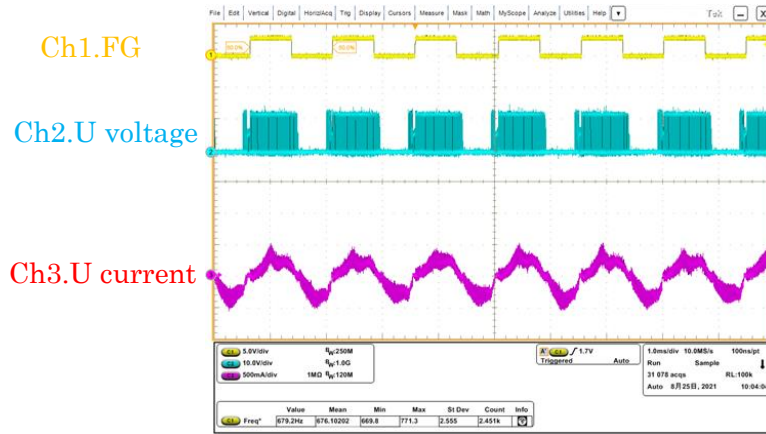
Figure 1.3 Lead angle 0° motor operating waveform
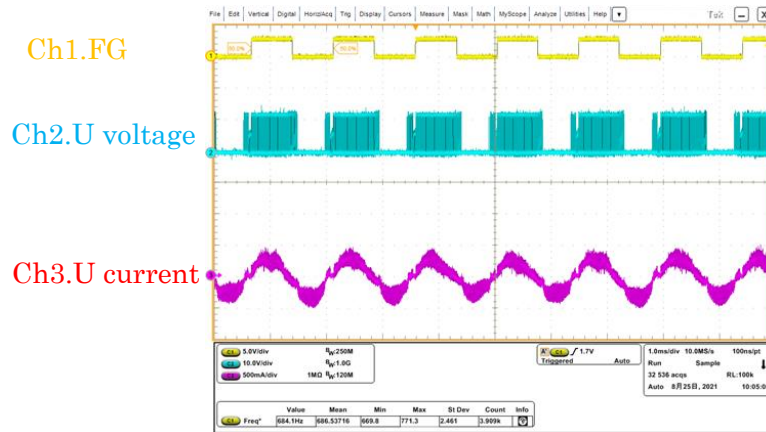
Figure 1.4 Lead angle 7.5° motor operating waveform
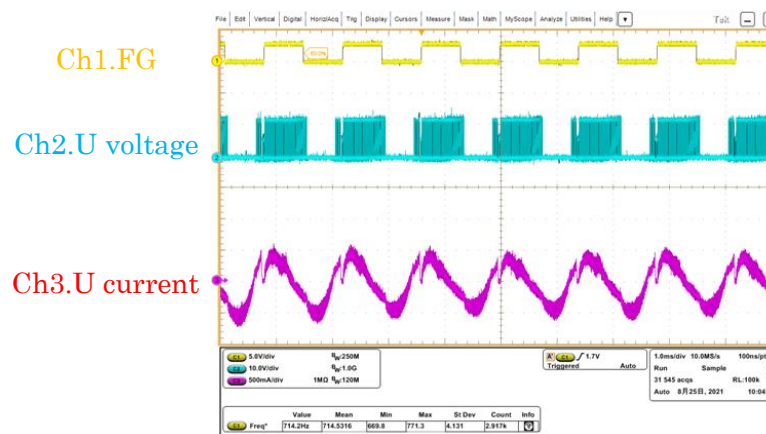
Figure 1.5 Lead angle 15° motor operating waveform

Notes on Contents

(1) Block Diagrams

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

(2) Equivalent Circuits

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

(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] 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.

[3] 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.

[4] 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.

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) 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.

(3) 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.

RESTRICTIONS ON PRODUCT USE

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