TB6575FNG Usage Considerations

The TB6575FNG provides sensorless commutation and PWM current control for 3-phase full-wave BLDC motors. It is for a fan motor. It can not be applied to the motor which changes the rotation direction between forward and reverse. Please confirm it can be applied to your motor or not by setting the IC because the sensorless drive is weak to a load change. It does not surely start. To start, consider the relation between FG pulse and Vsp and make the motor to detect the abnormal state and restart.

1. Power Supply Voltage

Power Supply Voltage Usage Range

Characteristic	Symbol	Operating Voltage Range	Unit
Power supply for control block	V_{DD}	4.5 to 5.5	V

2. Control Inputs (LA, CW/CCW, SEL_LAP, Fmax, Fst, OS and V_{SP})

(1) Input Method

When V_{DD} is switched off, the LA, CW/CCW, SEL_LAP, Fmax, Fst, OS, and VSP input signals should be open or low, until V_{DD} has settled.

3. Oscillation Circuit

(1) Operating Oscillation Range

Characteristic	Symbol	Operating Range	Unit
Oscillation frequency	f_{osc}	2 to 8	MHz

(2) Recommended Oscillator

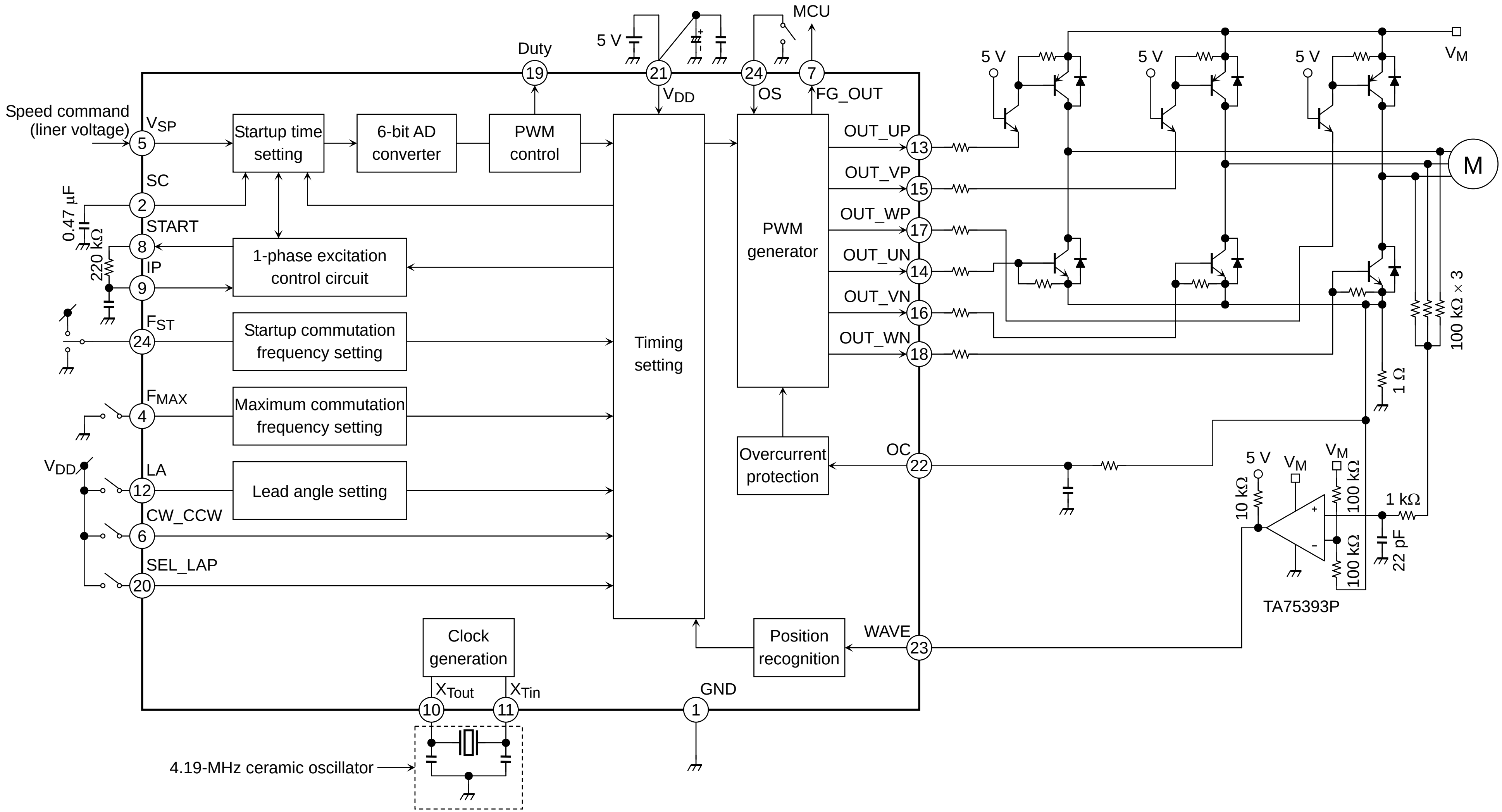
Ceramic Oscillator: 4.19 MHz

- FCR4.19MC5 (TDK Corporation)
- CSTLS4M19G56-B0 (Murata manufacturing Co. Ltd)

(3) Connection

Place the oscillator's GND as close as possible to the IC's S-GND pin.

4. Application Circuit (example for motor voltage of ≤ 30 V)



(1) Capacitors for Power Supply

Connect capacitors between V_{DD} and GND, and between V_M and GND as near the IC as possible.

Recommended Values

Characteristic	Recommended Value	Remarks
V_{DD} – GND	10 μF to 33 μF	Electrolytic capacitor
V_M – GND	0.001 μF to 0.22 μF	Ceramic capacitor

(2) Startup Setting

Please decide the value from the results of your evaluation because it depends on the motors.

Conditions of Toshiba's Evaluation

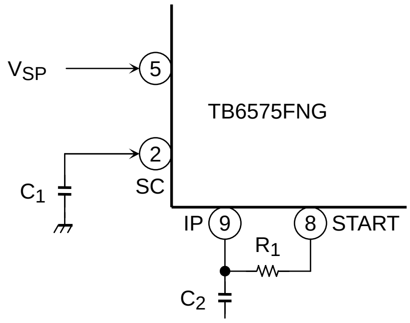
Characteristic	Value	Remarks
SC:C1	0.47 μF	Ceramic capacitor
START – IP:R1	220 kΩ	Resistor
IP:C2	1 μF	Ceramic capacitor

Our fan motor for evaluation operates under these conditions.

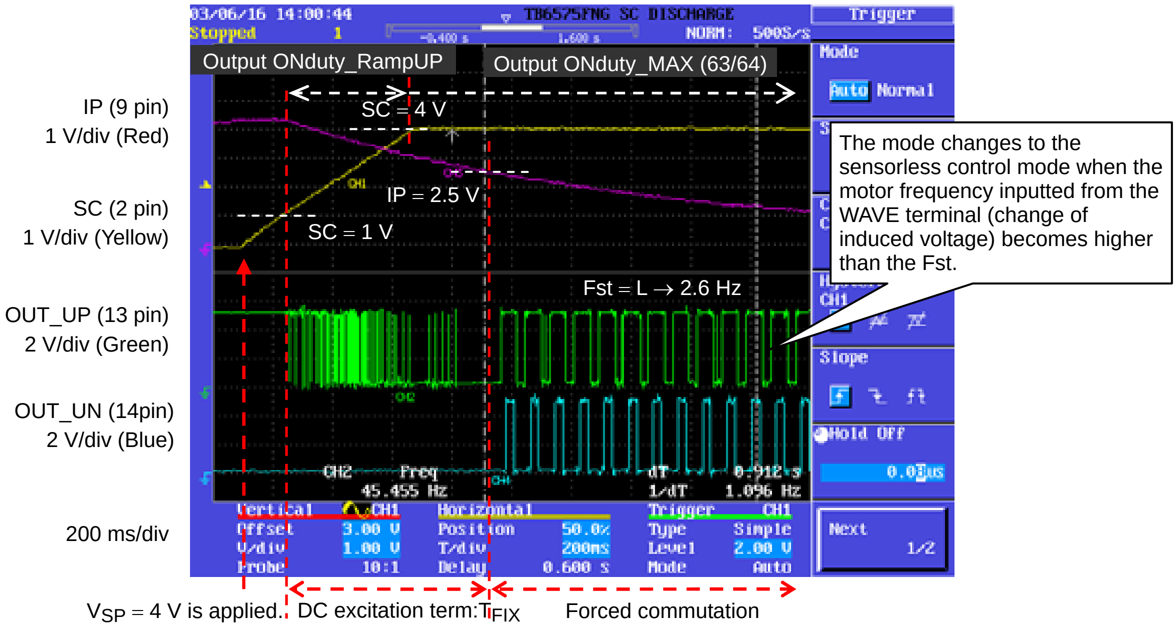
Output Operating Waveform of the TB6575FNG in Startup Mode (for reference)

The comparison of DC energization term is shown below when the capacitor C2 of 4.7 μF and 1 μF is adopted each. It is important to lock the rotor completely in the DC energization term. ON duty of output PWM in all modes is determined depending on the potential of SC terminal. Slope of SC terminal is determined by the capacitor C1 and the maximum potential is clamped by V_{SP}.

The most appropriate conditions for startup must be determined by doing an experiment by changing C1, C2, R1, Fst, and V_{SP}.

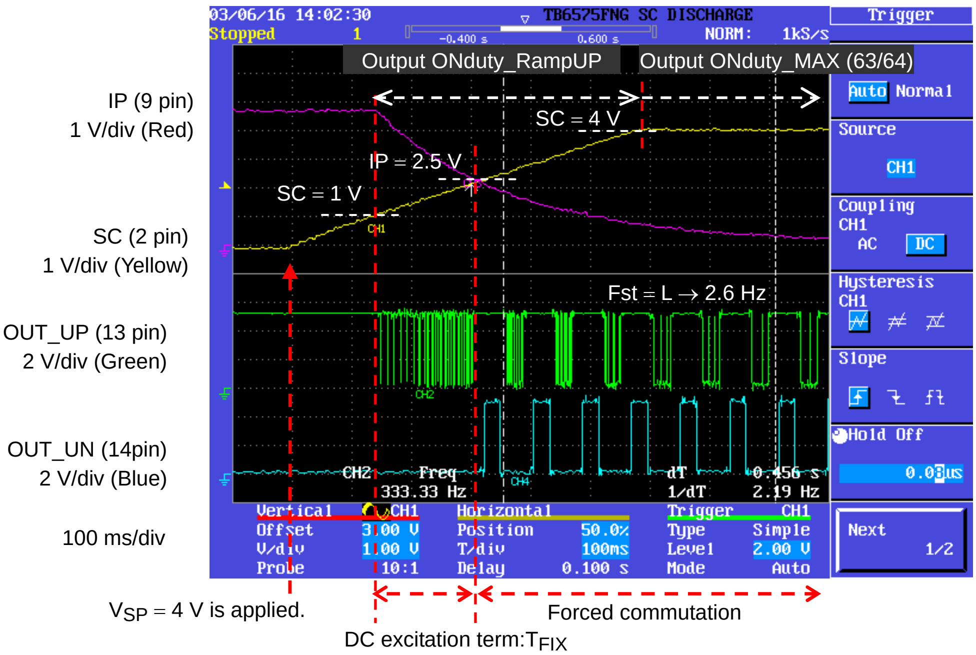


1. **Measurement condition: V_{DD} = 5.0 V, V_{SP} = 4.0 V, FST = "L", R1/C2 = 220 KΩ/4.7 μF**



T_{FIX} (typ.) = 0.69 × C2 × R1 (s) = 0.69 × 4.7 μF × 220 K = 0.71 (s)

2. **Measurement condition: V_{DD} = 5.0 V, V_{SP} = 4.0 V, FST = "L", R1/C2 = 220 KΩ/1.0 μF**



T_{FIX} (typ.) = 0.69 × C2 × R1 (s) = 0.69 × 1.0 μF × 220 K = 0.15 (s)

(3) Protection Filter for Input

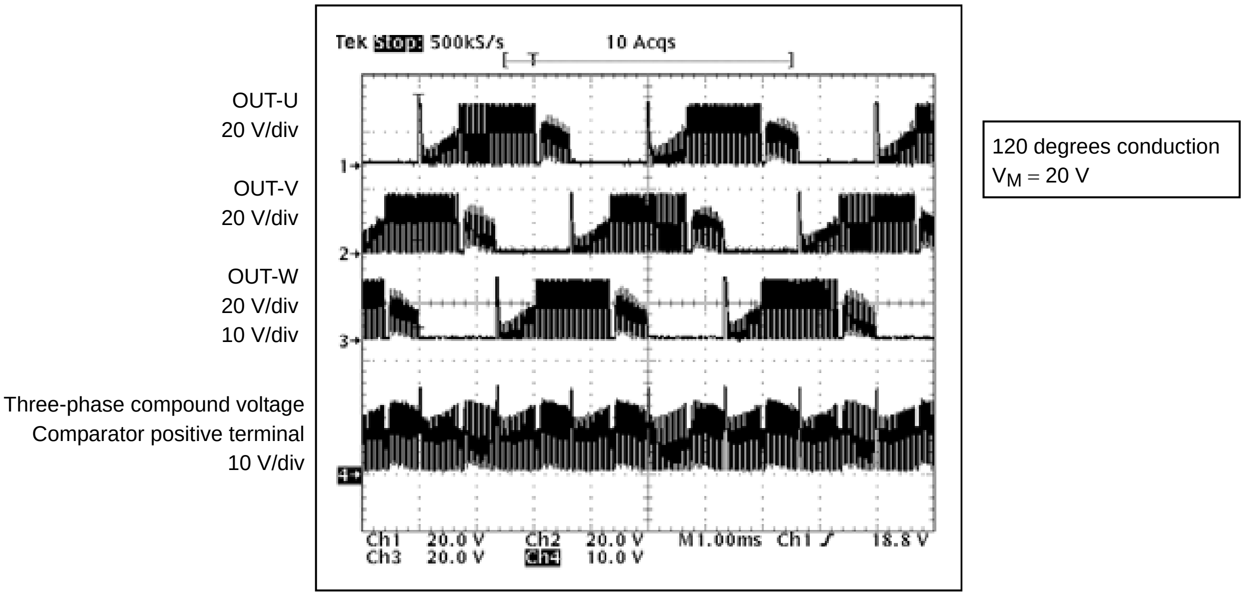
The input pins of over current protection and of position recognition have high impedance and are easily influenced by noise, so it has a possibility to cause a wrong operation. Please provide CR filter not to let it operate wrongly. Please decide the value of the filter from the noise frequency.

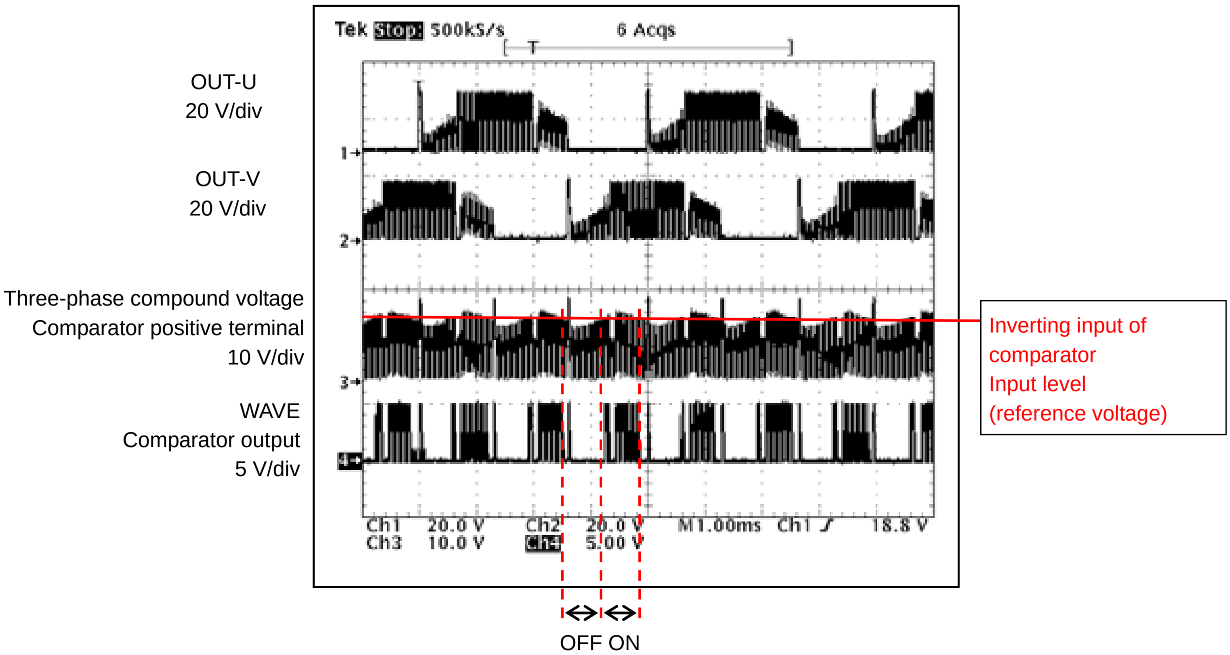
We recommend to set the capacity of 0.001 μF to 0.1 μF.

(4) Comparator

The standard voltage of inverting terminal is based on the middle voltage of VM and the voltage in front of the over current detective resistor that exists between output Tr and GND. A minute adjusting is needed depending on the conditions of noise and the motor because it detects the introducing voltage of OFF phase. VM is limited by withstand voltage of this comparator, so when you use it at more than 30 V, please refer “7. Level shift” written later.

TB6575FNG + MP6404 Driving Wave (for reference)





Inverting input of comparator (reference voltage) should be adjusted to make the ratio of OFF and ON for comparator output (WAVE terminal) 50% duty.

5. Lead angle controller

It can operate the driving signal electrically in the range of 7.5 to 15 degrees against introducing voltage. However, when it is in the DC excitation mode or in the forced commutation mode just after startup, it operates with zero degree.

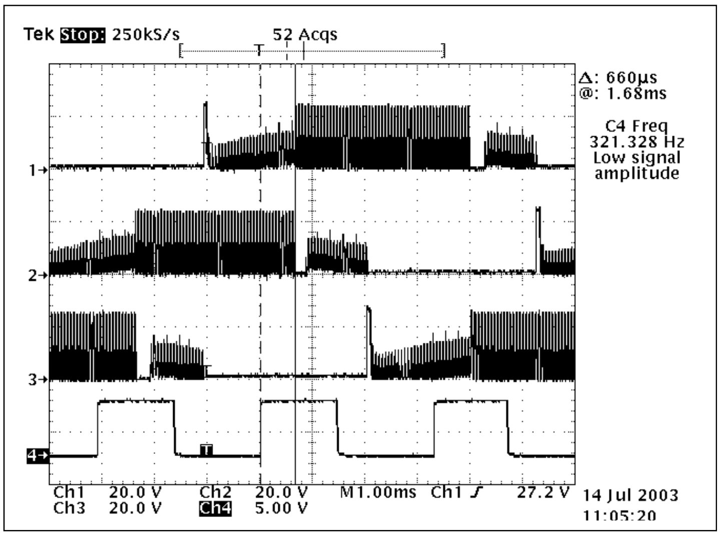
After it detects the introducing voltage and moves to the sensor less mode, it drives at the lead angle according to the LA pin.

LA	Lead Angle (°)
LOW or OPEN	7.5
HIGH	15

The setting of lead angle depends on the motor and the numbers of spin, so please decide it by doing experiments.

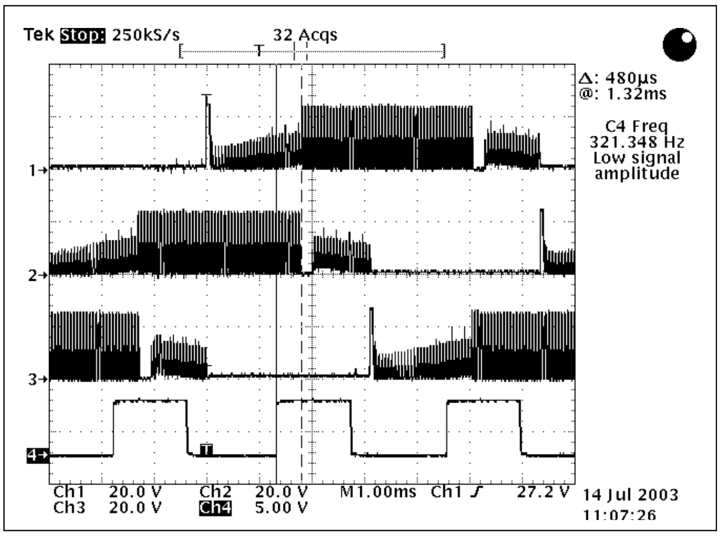
TB6575FNG + MP6404 Driving Wave (for reference)

OUT-U 20 V/div
OUT-V 20 V/div
OUT-W 20 V/div 10 V/div
FG 5 V/div



Lead angle: 7.5 degrees
120 degrees conduction
V_M = 24 V
V_{SP} = 2 V

OUT-U 20 V/div
OUT-V 20 V/div
OUT-W 20 V/div 10 V/div
FG 5 V/div



Lead angle: 15 degrees
120 degrees conduction
V_M = 24 V
V_{SP} = 2 V

6. Lap Conduction

During the lap conduction, it overlaps to other phases by starting the conduction from zero-cross to reduce the noise. This noise is produced in the changing of excitation that arises in the 120 degree conduction.

The term of overlap changes depends on the lead angle setting. When the lead angle is 7.5 degrees, it overlaps 22.5 degrees and when the lead angle is 15 degrees, it overlaps 15 degrees.

SEL_LAP	Conduction Method
HIGH or OPEN	120°
LOW	LAP

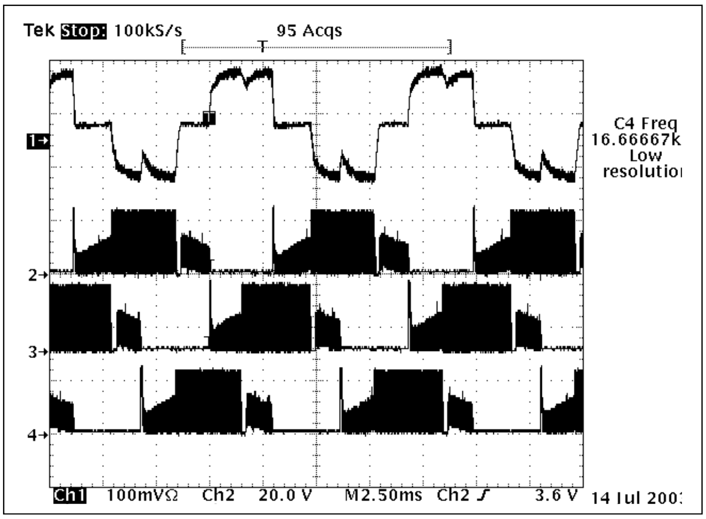
TB6575FNG + MP6404 Driving Wave (for reference)

U phase motor current 0.1 A/div

OUT-U 20 V/div

OUT-V 20 V/div

OUT-W 20 V/div 10 V/div



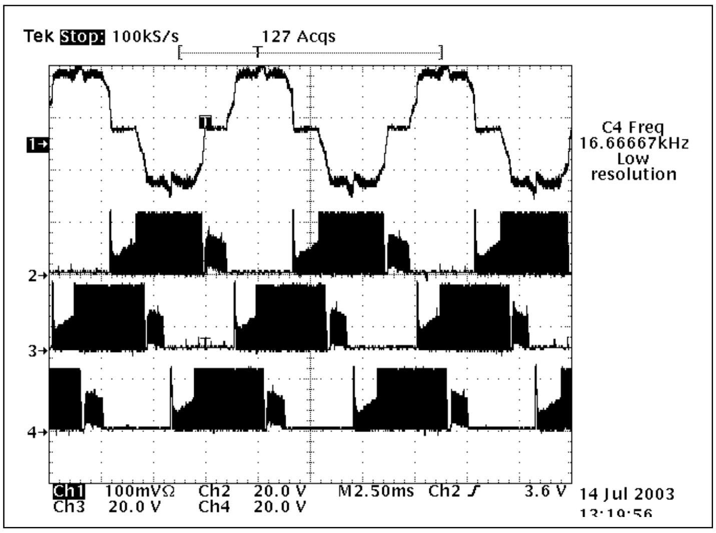
Lead angle: 7.5 degrees
120 degrees conduction
V_M = 24 V
V_{SP} = 2 V

U phase motor current 0.1 A/div

OUT-U 20 V/div

OUT-V 20 V/div

OUT-W 20 V/div 10 V/div



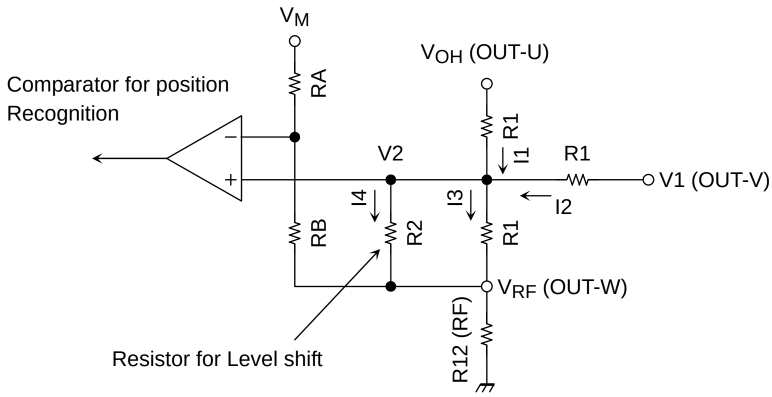
LAP conduction
V_M = 24 V
V_{SP} = 2 V

7. Level Shift

When you use the motor at higher than 30 V, please shift the input voltage of comparator by the mithod written below.

(1) Please put the standard voltage of GND side on the lower resistor (R12).
Please input the comparator for position recognition on R12, which is a resistor for a overcurrent detector, as a standard. Because the motor is influenced by R12's voltage reducing at startup and this reducing voltage should be canceled each other out.
When you put it on the GND, there is a possibility that it can not move to sesorless mode because of its errors.

(2) In calculation, please use the voltage in each phase that connects to the motor. Please do not use V_M.
V_M and the voltage to the motor are different.



It is a circuit diagram for calculation. Keep in mind that it differs that it is actual. Actual circuit is described in the section 8.

$I1 = (V_{OH} - V2)/R1$	Equation (1)
$I2 = (V1 - V2)/R1$	Equation (2)
$I3 = (V2 - V_{RF})/R1$	Equation (3)
$I4 = (V2 - V_{RF})/R2$	Equation (4)
$I1 + I2 = I3 + I4$	Equation (5)

When you substitute the equations (1), (2), (3), and (4) for (5),

$$(V_{OH} - V2)/R1 + (V1 - V2)/R1 = (V2 - V_{RF})/R1 + (V2 - V_{RF})/R2$$

From this equation,

$$V2 = (V_{OH} + V_{RF} + V1)/\ (3 + R1/R2) \qquad \text{Equation (6)}$$

In recognizing V1 as a middle point that is $((V_{OH} - V_{RF})/2 + V_{RF})$, Equation (6) becomes as follows:

$$V2\ (\text{middle point}) = \frac{3 \times R2 \times (V_{OH} + V_{RF})}{2 \times (3 \times R2 + R1)}$$

The standard voltage of the comparator is as follows:

$$V_A = (V_M - V_{RF}) \times \frac{RB}{RA + RB} + V_{RF}$$

If recognizing the middle point V2 as V_A,

$$(V_M - V_{RF}) \times \frac{RB}{RA + RB} + V_{RF} = \frac{3 \times R2 \times (V_{OH} + V_{RF})}{2 \times (3 \times R2 + R1)}$$

$$\frac{RB}{RA + RB} = \frac{1}{V_M + V_{RF}} \times \left\{ \frac{3 \times R2 \times (V_{OH} + V_{RF})}{2 \times (3 \times R2 + R1)} - V_{RF} \right\}$$

Ex.) If you substitute 40 V for V_M, 0.5 V for V_{RF}, 37 V for V_{OH}, 100 kΩ, for R1 and, 30 kΩ for R2, it is concluded that

RB/ (RA + RB) = 0.2070

That is RA: RB = 7930:2070

For example, when RB equals to 10 kΩ, RA becomes 38.3 kΩ.

8. Others

Position recognition

It recognizes the position by comparing the changes of introducing voltage of OFF phase and that of standard value which means postulating middle point.

When it recognizes the position recognizing signal in the IC, it masks opposite startup voltage. This opposite startup voltage equivalents to the Diode-ON time. This masking term changes according to the lead angle as follows;

In recognizing the term of masking after changing, the term written below is masked.

Lead Angle (°)	Masking Term (°)
7.5	22.5
15	30

When Diode-ON time is beyond the masking time written above, it may cause wrong operation and the motor may not work correctly.

In this case, you should change the setting of lead angle, improve the speed of output diode, change the applying conditions, or change the motor it self.

Maximum Commutation Frequency

If the commutation frequency set up with the FMAX terminal is exceeded, it is judged as the unusual state of a motor and an output is turned off. However, Maximum commutation frequency changes with setup of Forced commutation frequency (Fst terminal), cautions are required.

Commutation frequency means motor current frequency (1 electricity angle).

- Fst = Low

  F_{MAX} = High or Open, Maximum commutation frequency $f_{MX} = f_{XT} / (6 \times 2^{11})$
  F_{MAX} = Low, Maximum commutation frequency $f_{MX} = f_{XT} / (6 \times 2^{12})$

- Fst = High or Middle

  FMX = High or Open, Maximum commutation frequency $f_{MX} = f_{XT} / (6 \times 2^{8})$
  FMX = Low, Maximum commutation frequency f_{MX} $f_{XT} / (6 \times 2^{9})$

Note: FST = Low, FMAX = Low, since the number of rotations which becomes protection mode becomes low, cautions are required.

Ex.: fxt = 4.19 MHz, in 4pole motor
$f_{MX} = f_{XT} / (6 \times 2^{12}) = 4.19\ \text{MHz} / (6 \times 2^{12}) = 170.5\ \text{Hz}$
umber of rotations of a motor = (170.5 Hz/2) *60 (s) = 5115 rpm
Therefore, if the number of rotations of a motor is set to 5115 rpm, it will become protection mode.

Operation of Over Current Protection

When voltage of 0.5 V (typ.) or more is applied to OC terminal, output of upper-phase control (OUT_UP, OUT_VP, and OUT_WP) is halted.

The device is not destroyed because of the over current by applying the converted value of current and voltage. This value is set by the motor current detection resistance of the power steps. However, take care not to use this method regularly including startup. Set the current which does not flow in actual operation, and use this method to protect the IC only when the IC operation is in the abnormal state. The operation recovers on the next PWM cycle, so the over current flows at every PWM cycle when the power steps are under controlled. The voltage of 0.5 V or more is applied to OC terminal continuously, the output of the upper phase is halted. In case the over current is estimated to flow, protect the IC by detecting the abnormal state with another system.

The sensorless system of this IC estimates its position by detecting induced voltage (PWM) output. So, when the over current protection works, it cannot estimate the position because output (PWM) stops. As a result, motor has a possibility to become out of control and step-out. To avoid this risk, please recognize this over current protection as one of suggestions to avoid destroying the IC in abnormal state.

Control Method of V_{SP} Terminal in Startup

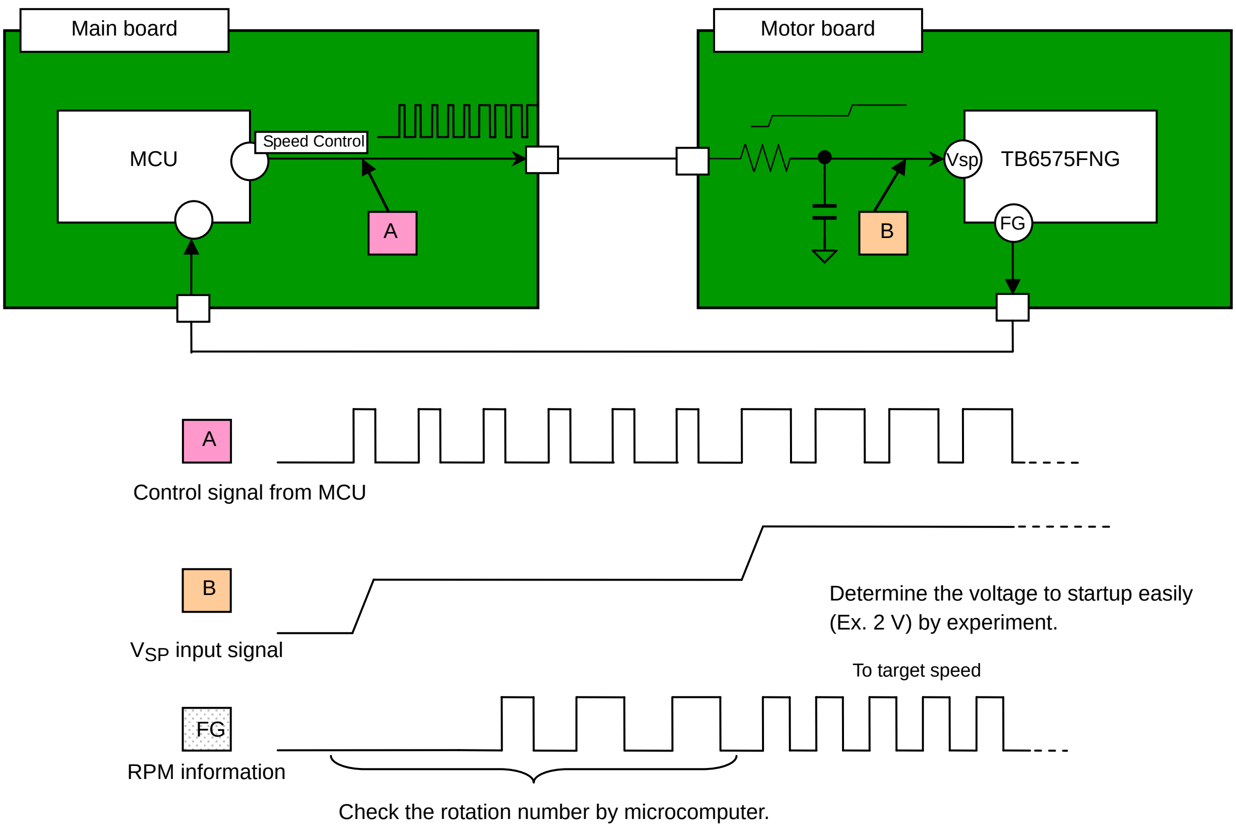
Though DC excitation time and forced commutation are adjusted by experiment, it is difficult to 100% startup because of other conditions including the load.

When the motor does not start, please re-start by checking the motor conditions with microcomputer. Find the best value of V_{SP} to start the motor by experiment and apply this V_{SP}. To judge whether the motor starts or not, use the microcomputer with FG pulse. When the rotation number corresponding to the V_{SP} is gained, change the V_{SP} to adjust to the target rotation number. Please check the relation between V_{SP} and FG with microcomputer regularly. In the case there is a problem of the condition, please turn on the power again after setting V_{SP} zero. If the rotation number is abnormal repeatedly, stop using the motor.

Step 1: Apply Vsp which is easy to startup.

Step 2: When the motor operates at the appropriate rotation number which corresponds to the V_{SP} of Step1, change the V_{SP} to gain the target rotation number.

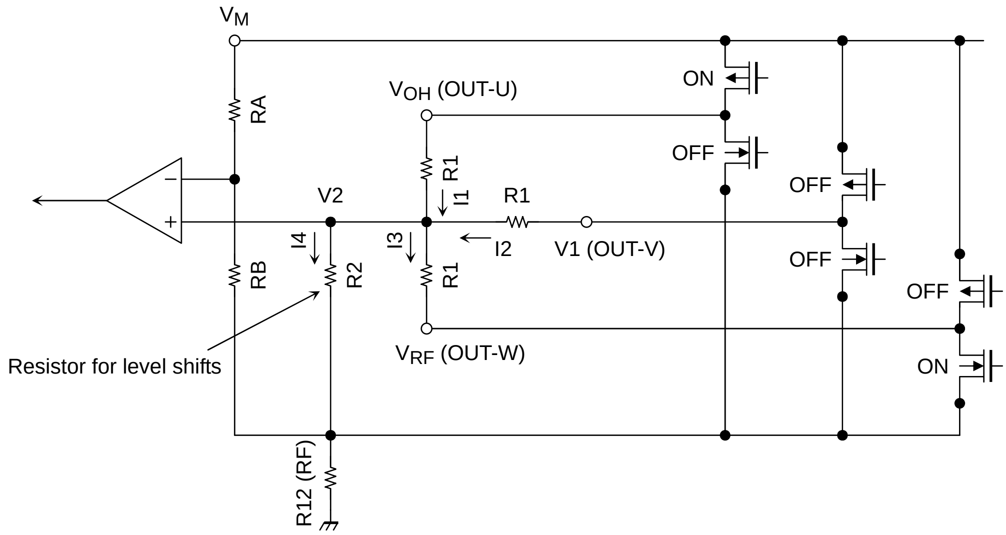
*: If you cannot have the rotation number which corresponds to the V_{SP} of Step1, lower the V_{SP} to 1 V and start again.



TB6575FNG Startup method

True circuit diagram (level shift)

The connection between the external circuit and the power device is shown below.



Induced voltage is supposed to generate under below conditions and output loss is ignored ($V_{OUT\text{-}W}$ is boarded upon V_{RF}.) in calculating.

OUT-W ... Low Side: ON
OUT-U ... High side: ON
OUT-V ... OFF (BEMF)

9. Q & A (For your reference)

(1) What is DC excitation term (TFIX)? How to determine the appropriate term?

Fix the rotor to the initial position. (In CW: the current direction is from U phase to V phase)
Time of fixing the rotor is necessary in this term.
Conform that the rotor is fixed completely by setting the long time. After that, shorten the fixing time as needed.
If the mode is changed to the forced commutation before fixing the rotor, the motor might not startup normally.

(2) What is forced commutation? How to determine the appropriate time?

Forced commutation mode operates the rotor forcedly and generates the induced voltage.
When the rotation number of the rotor exceeds the rating determined by Fst, the operation shifts to the normal mode. And so, setting the time is impossible.

(3) In startup, how to input V_{SP}?

Find the voltage which is easy to startup the motor operation. Then, apply the fixed voltage (Refer to page 10).
After that, conform that rotating number of FG pulse reaches within the rating (rotating number of V_{SP} conformed in the experiment). Change the V_{SP} to adjust the rotating number.

(4) In startup, the motor vibrates at first before rotating normally. How to startup the motor smoothly?

The motor vibrates a little at starting because the mode moves from DC exciting to forced commutation. However, it is possible to lighten up the vibration by rising V_{SP} slowly.

(5) In using the function of over current detection, how to calculate the value of resistance?

The resistance is determined from the formula below.
Detecting resistance R (Ω) = V_{OC} (0.5 (V))/I_{OUT} (A)

(Example) In the case current limit is set 1 A;
Spec. of V_{OC} : 0.46 to 0.54 V
R = 0.54 V/1 A = 0.54 Ω
In actual use, if resistance of 0.54 Ω is used,
V_{OC} (typ.) is 0.5 V and the current is limited at 0.93 A*.
*$I_{OUT(limit)}$ = 0.5 V/0.54 Ω = 0.93 A

Please set this function in order to stop the motor operation in abnormal state. Set the appropriate resistance not to operate this function in flowing rush current (ex. in startup).

RESTRICTIONS ON PRODUCT USE