TC78B041FNG/TC78B042FTG

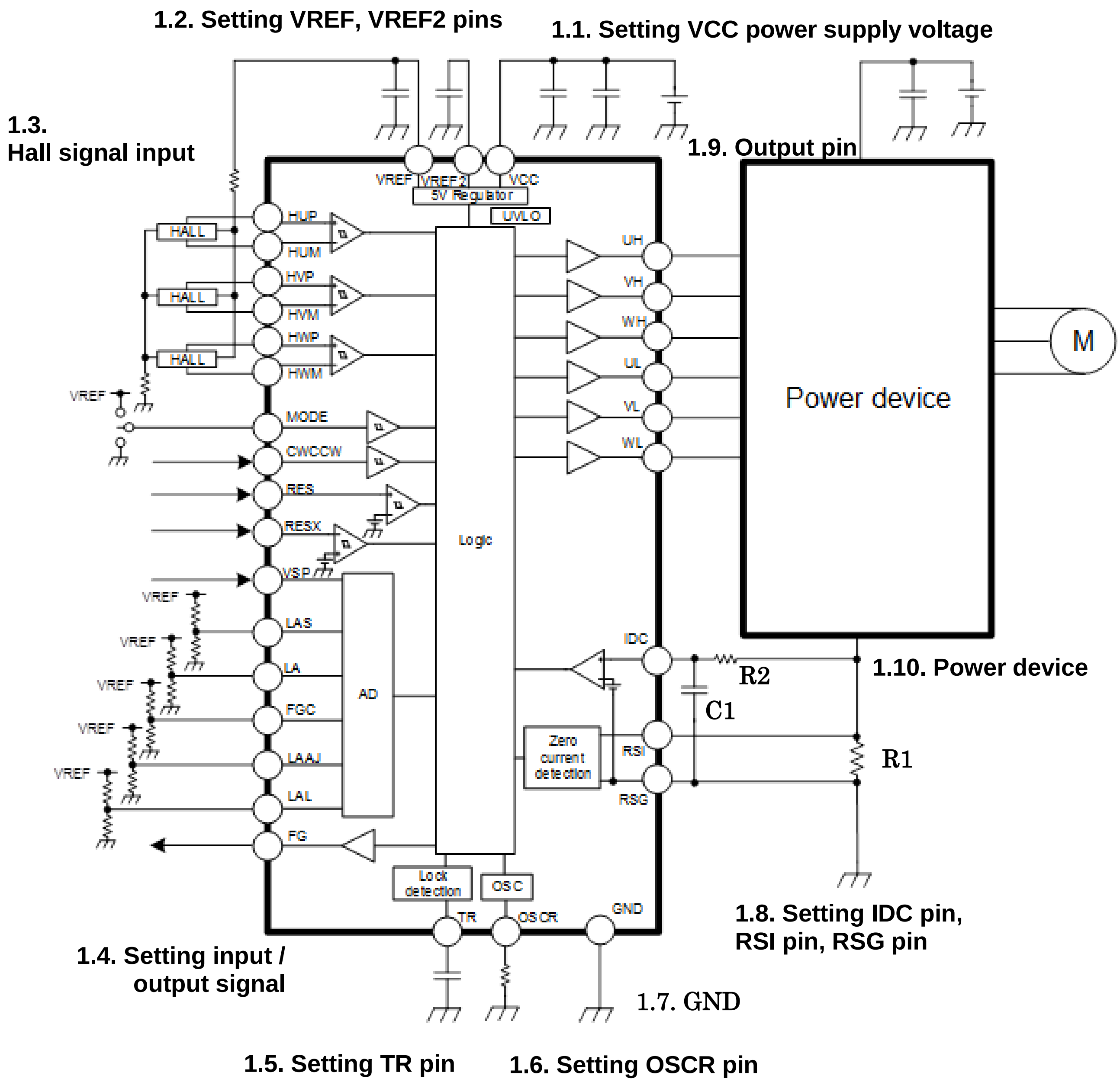
Precautions for Use

Overview

This product was developed for applications of three-phase brushless fan motors.
TC78B041FNG adopts SSOP30 type package.
The TC78B042FTG adopts a VQFN32 type package with the addition of RESX and VREF2 pins.

Contents

1. Application circuit example



Note: The RESX and VREF2 pins are only on the TC78B042FTG.

Fig. 1.1 Application circuit example

1.1. Setting VCC power supply voltage

If necessary, connect ceramic capacitors or electrolytic capacitors between VCC and GND as close to the IC as possible to reduce noise and voltage fluctuations at the VCC pin. Ceramic capacitors are particularly effective in suppressing high-frequency power supply fluctuations and noise when they are connected near the IC.

Table 1.1 VCC pin power supply voltage operating range

Item	Operating Range	Unit
VCC Pin Power Supply Voltage	6 - 16.5	V

Table 1.2 VCC pin capacitors

Item	Recommended Usage Range	Unit
Electrolytic capacitor	1 - 47	µF
Ceramic capacitor	0.001 - 1	µF

- Note: The absolute maximum rating of the VCC pin is 18V. The absolute maximum rating is a standard that must not be exceeded even momentarily.

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

Please use within the described operating range.

1.2. Setting VREF, VREF2 pins

The TC78B041FNG has a VREF pin with a 5V reference voltage output.

The TC78B042FTG has a VREF pin with a 5V reference voltage output and a VREF2 pin with a 5V reference voltage output 2.

The absolute maximum rated output current of the VREF pin is 35mA. It is 35mA including the absolute maximum rated output current of 3mA for the VREF2 pin, so use them within the range. In addition, the VREF2 pin is branched from the VREF pin and output, and is an auxiliary pin to reduce the routing of the VREF pin wiring when mounted on the board. Use the VREF pin to supply the voltage of hall elements.

Also, if necessary, connect a ceramic capacitor between VREF and GND as close to the IC as possible to reduce noise and voltage fluctuations at the VREF and VREF2 pins. Also, when using the VREF2 pin, connect a ceramic capacitor between VREF2 and GND as close to the IC as possible.

Table 1.3 VREF pin capacitors and VREF2 pin capacitors

Item	Recommended Usage Range	Unit
Ceramic capacitor	0.1 - 1	µF

1.3. Hall signal input

In order for the motor to rotate, it is necessary to input a signal to switch the commutation with the hall signal to this IC. When rotating the motor in the forward direction with a sine-wave, arrange the hall element so that the hall signal is input at the timing shown in Fig. 1.2 to the counter electromotive voltage (Back-EMF) of the motor. If the hall signal is input at the timing shown in Fig. 1.3, the motor will rotate in the reverse direction or in a square-wave, so review the connection of the hall signal input.

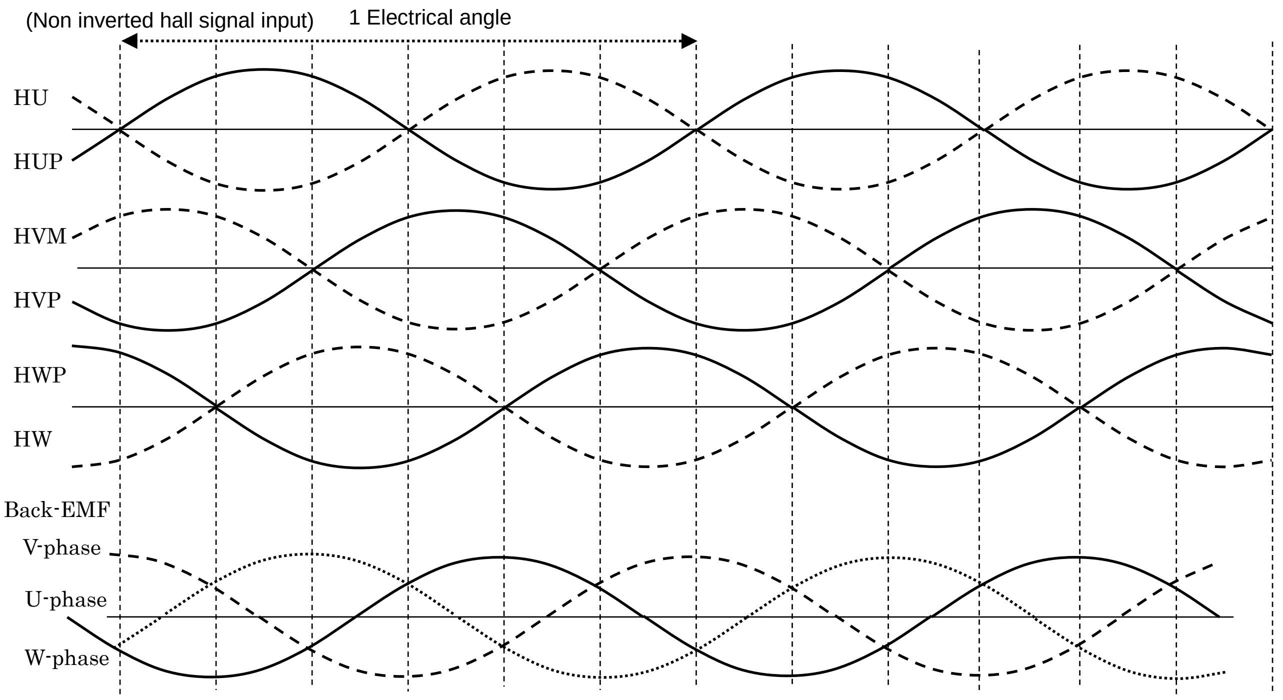


Fig. 1.2 Non inverted hall signal input

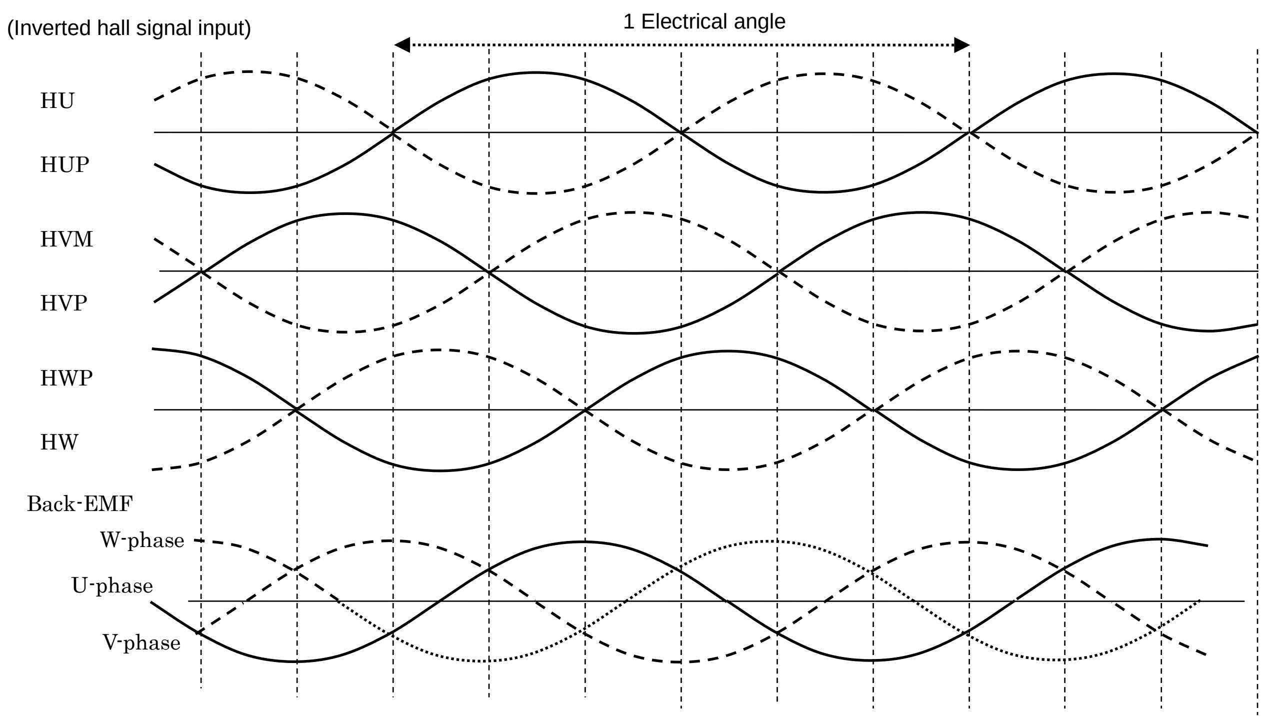


Fig. 1.3 Inverted hall signal input

1.3.1. Sine-wave drive and square-wave drive

Depending on the timing of the hall signal input as shown below, the motor is driven by a sine wave or by a square wave.
If the hall signal frequency is less than 1Hz, the motor is driven by a square wave. If the hall signal frequency is 1Hz or higher, depending on the input order of hall signals and the setting of the rotation direction, the motor is driven by a sine wave or a square wave.

(1) Conditions for Sine-Wave Drives
When CWCCW = Low (during forward rotation), sine-wave drive is performed when a hall signal is input at the following timing.

Output timing of the hall comparator built into this IC which input the hall signal

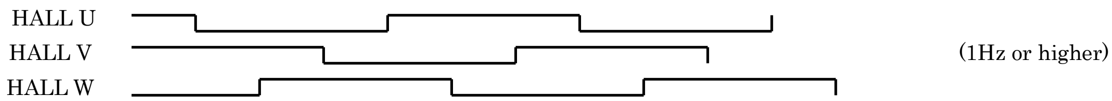


Fig. 1.4 Conditions for sine-wave drives (CWCCW = Low)

When CWCCW = High (during reverse rotation), sine-wave drive is performed when a hall signal is input at the following timing.

Output timing of the hall comparator built into this IC which input the hall signal

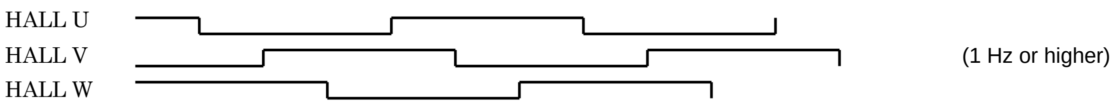


Fig. 1.5 Conditions for sine-wave drives (CWCCW = High)

(2) Conditions for Square-Wave Drives
When CWCCW = Low (during forward rotation), square-wave drive is performed when a hall signal is input at the following timing.

Output timing of the hall comparator built into this IC which input the hall signal

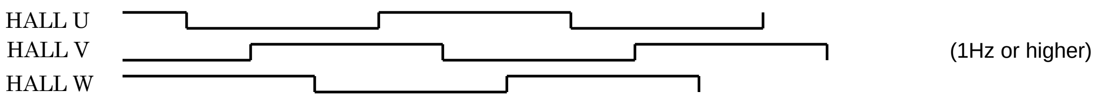


Fig. 1.6 Conditions for square-wave drives (CWCCW = Low)

When CWCCW = High (during reverse rotation), square wave drive is performed when a hall signal is input at the following timing.

Output timing of the hall comparator built into this IC which input the hall signal

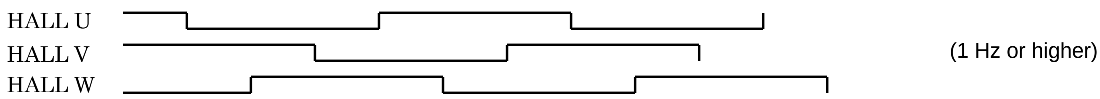


Fig. 1.7 Conditions for square-wave drives (CWCCW = High)

Note: If you are trying to drive the motor with a sine wave and the motor is driven by a square wave, it is possible that the direction of rotation of the motor and the input order of the hall signal do not match.
For example, when connecting the hall signal switching the plus and minus of the hall signal input pin, the input order of the hall signal should be changed from the square-wave drive order to the sine-wave drive order, so the motor is driven by a sine wave.

1.3.2. Hall element input

When a hall signal is input by a hall element, the range of common mode voltage of this IC is VW = 0.2 to 3.5 V. The value of input hysteresis is VHhys = 7.5 mV (Typ.). The value of input sensitivity is Vs = 40 mV or higher. Adjust the resistance values of R1a and R2a so each of them is within those ranges. Also, as the hall signal input pins have high impedance and are easily affected by noise, connect the noise removal capacitors C1a, C2a, and C3a with about 100pF to 1μF to prevent malfunction due to noise.

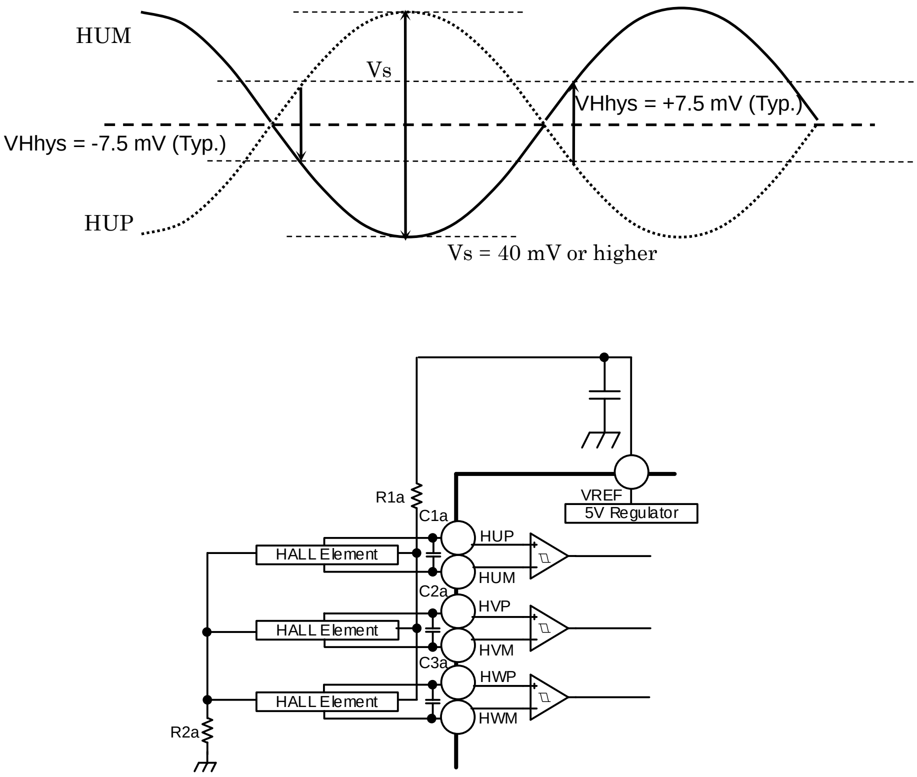


Fig. 1.8 Hall element input example

1.3.3. Hall IC input

When inputting a hall signal with a hall IC, fix one side of the hall input pin to a voltage that is about half the amplitude of the hall IC signal, and connect the hall IC so that the hall IC signal is input to the hall input pin on the other side.

As shown in Fig. 1.9 set the hall input pins on one side to half of VREF voltage with R4b and R5b, and input the hall IC signal amplitude 0V to 5V (VREF pin voltage) to the hall input pins on the other side. Also, since the hall signal input pins have high impedance and are easily affected by noise, connect a low-pass filter for noise removal to prevent malfunction due to noise. Adjust the low-pass filter within the range of R1b, R2b, R3b: 1kΩ to 100kΩ, C1b, C2b, C3b: 100pF to 1μF so that noise can be removed.

If the output structure of the hall IC is push-pull, hall IC input will be as shown in Fig. 1.9. However, if the output structure of the hall IC is an open drain / open collector, pull-up connection to the VREF pin as shown by R6c, R7c, and R8c in Fig. 1.10.

If the timing phase of the hall input signal is inverted, reconnecting the contact pins for half of the VREF voltage and the hall signal input (replace HUP, HVP, and HWP with HUM, HVM, and HWM) enables you to return the phase inversion to the normal phase.

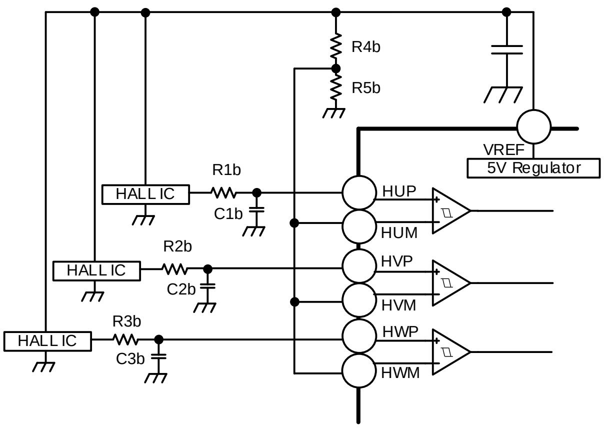


Fig. 1.9 Hall IC input example (For hall IC output push-pull)

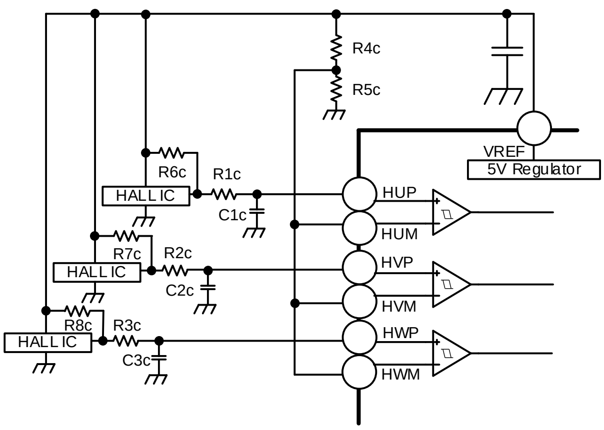


Fig. 1.10 Hall IC input example (For hall IC output open drain / open collector)

1.4. Setting input / output signal

1.4.1. VSP pin, MODE pin

By changing the input voltage of the VSP pin, the Duty of the commutation signal output changes, and the rotation speed of the motor can be controlled.

Input mode of VSP pin can be selected between A and B by using MODE pin.

Table 1.4 Setting MODE pin

MODE Pin	VSP Pin Input Type
High	B mode
Low/Open	A mode

1.4.2. CWCCW pin

If you switch when the motor is rotating, a large current will flow due to the counter electromotive voltage, which may destroy the motor. Ensure you switch while the motor is stopped.

1.4.3. RES, RESX pins

The RES pin sets the commutation signal output to Low when low level is input to the RES pin.
The RESX pin sets the commutation signal output to Low when high level is input to the RESX pin.
The TC78B042FTG has both a RES pin and a RESX pin, but the TC78B041FNG has a RES pin but no RESX pin.

Table 1.5 Setting RES pin, RESX pin

RES Pin	RESX Pin (TC78B042FTG only)	Commutation Signal Output (UH, VH, WH, UL, VL, WL)
High/Open	High	Low
High/Open	Low/Open	Normal operation
Low	High	Low
Low	Low/Open	Low

Since the impedance of the RES pin and RESX pin is high, be careful prevent malfunction due to noise when creating the board layout pattern. If necessary, connect a capacitor close to the pins.

1.4.4. LA pin, LAAJ pin, LAL pin

Even if you do not need to use the LA pin, LAAJ pin, and LAL pin functions, connect each pin to a fixed voltage (example: GND) instead of opening it, and set each function.

1.4.5. FGC pin, FG pin

The rotation pulse signal output to the FG pin changes depending on the setting of the FGC pin.
For the FG pin signal set in STEP 8, the lead angle value at which the motor is rotating can be read from the Duty of the signal. Approximately the lead angle value (°) = (0.6 × Duty (%)) -0.94.
Since STEP 7 and STEP 8 are in test mode, a pulse signal may be output regardless of whether or not the motor is rotating, so please use it for evaluation only.

Table 1.6 Relationship between FGC pin settings and FG pin output signals

STEP	FGC [V]	FG
0	0.00	3 pulses / Electric angle
1	0.31	2.4 pulses / Electric angle
2	0.63	
3	0.94	2 pulses / Electric angle
4	1.25	
5	1.56	0.8 pulses / Electric angle
6	1.88	
7	2.19	Test mode 1
8	2.50	Test mode 2: Lead angle value timing
9	2.81	1 pulse / Electric angle

1.5. Setting TR pin

Connect a capacitor to the TR pin to set the motor lock detection function.
If the motor does not rotate within the motor lock detection drive period, the lock detection function will operate, so set the optimum capacitor value. If you do not use the lock detection function, connect the TR pin to GND.

1.6. Setting OSCR pin

The reference clock fosc is determined by the resistance value of the OSCR pin and sets the PWM frequency (carrier frequency). When the resistance of the OSCR pin is 22 kΩ, the oscillation frequency is 9.22 MHz (typ.) and the carrier frequency is 18 kHz (typ.).
Carrier frequency: FC = fosc / 512 (Hz)

Table 1.7 Setting OSCR pin

OSCR Pin Resistance Value [kΩ]	Standard Clock fosc [MHz](Typ.)	PWM Frequency (Carrier Frequency) FC[kHz](Typ.)
27	7.62	14.9
24	8.5	16.6
22	9.22	18
20	10.06	19.6
18	11.08	21.6
16	12.33	24.1
15	13.07	25.5

This IC consists of not only the PWM frequency but also the time (frequency) such as dead time from the reference clock, so the times change according to the setting of the reference clock frequency.

1.7. GND

Create a board layout pattern so that it is not affected by the power system GND of the motor.

1.8. Setting IDC pin, RSI pin, RSG pin

The output current limit function operates when the IDC pin voltage exceeds 0.5V (Typ.). As the output current is detected by the detection resistor R1, the output current value for the output limiting function to operate is as follows.

Output current value = IDC pin voltage (0.5V) / Detection resistor R1
Example:
When R1 = 1Ω, the output limiting function operates when the output current value = 0.5V and 1Ω = 0.5A.

The IDC pin has a built-in 200 kΩ for input, a 5 pF filter and a digital filter, but if the output current limiting function malfunctions due to PWM switching noise, adjust the low-pass filter values of R2 and C1 and connect the IDC pin.

The ground reference for the IDC pin and RSI pin is the RSG pin, so connect the ground side of the detection resistor R1 to the RSG pin.

When not using the auto lead angle control function (Intelligent Phase Control: InPAC), connect the RSI pin to GND.
When not using the output current limit function, connect the IDC pin to GND.

1.9. Output pin

As the output is PWM-switched, pay attention to switching noise when creating the board layout pattern.

1.10. Power device

A gate driver is used in combination with a power FET or IGBT for a power device. It can also be used in combination with an intelligent power devices (IPD).

2. Maximum rotation speed

Since in output PWM the motor is started with sine wave shape, if the motor speed is high, the number of output PWM switchings per rotation may decrease, and the output current may not become a sine-wave shape.
Therefore, it is recommended to use the relevant product so that (output PWM frequency / maximum rotation frequency of electric angle) is 100 or more.

Example: When the output PWM frequency = 20kHz and the maximum rotation frequency of 1 electric angle = 200Hz,
Resolution = 20kHz / 200Hz = 100

The auto lead angle control function has a rotation speed (i.e. one electrical angular frequency of hall signal) that enables normal auto lead angle control has a limit (Finpac).and Finpac depends on the PWM frequency (carrier frequency) and the phase correction value (LAAJ pin function). It can be calculated by the formula of "Finpac=PWM frequency x {(30+phase)/540}". If the rotation speed exceeds this value, the automatic advance function may not work.

Example: When PWM frequency = 16.2 kHz, phase (LAAJ pin function) = 0° setting,
Finpac = 900 Hz

3. Auto lead angle control function (Intelligent Phase Control: InPAC)

- The auto lead angle control function determines once per electric angle the lead angle or delay angle from the plus or minus of the U-phase output current at the position of 150° timing (in the case of forward rotation) from the rising edge of the HUP of the hall signal. When the results of four consecutive judgments match, the phase of the commutation signal output (within the range of 0° to 58°) is changed every 1 STEP (0.94°), and the position at the timing of 150° is controlled to match the zero-cross position of the output current (So that the position is such that plus and minus are judged alternately). If the judgment results do not match, the phase of the commutation signal output does not change.

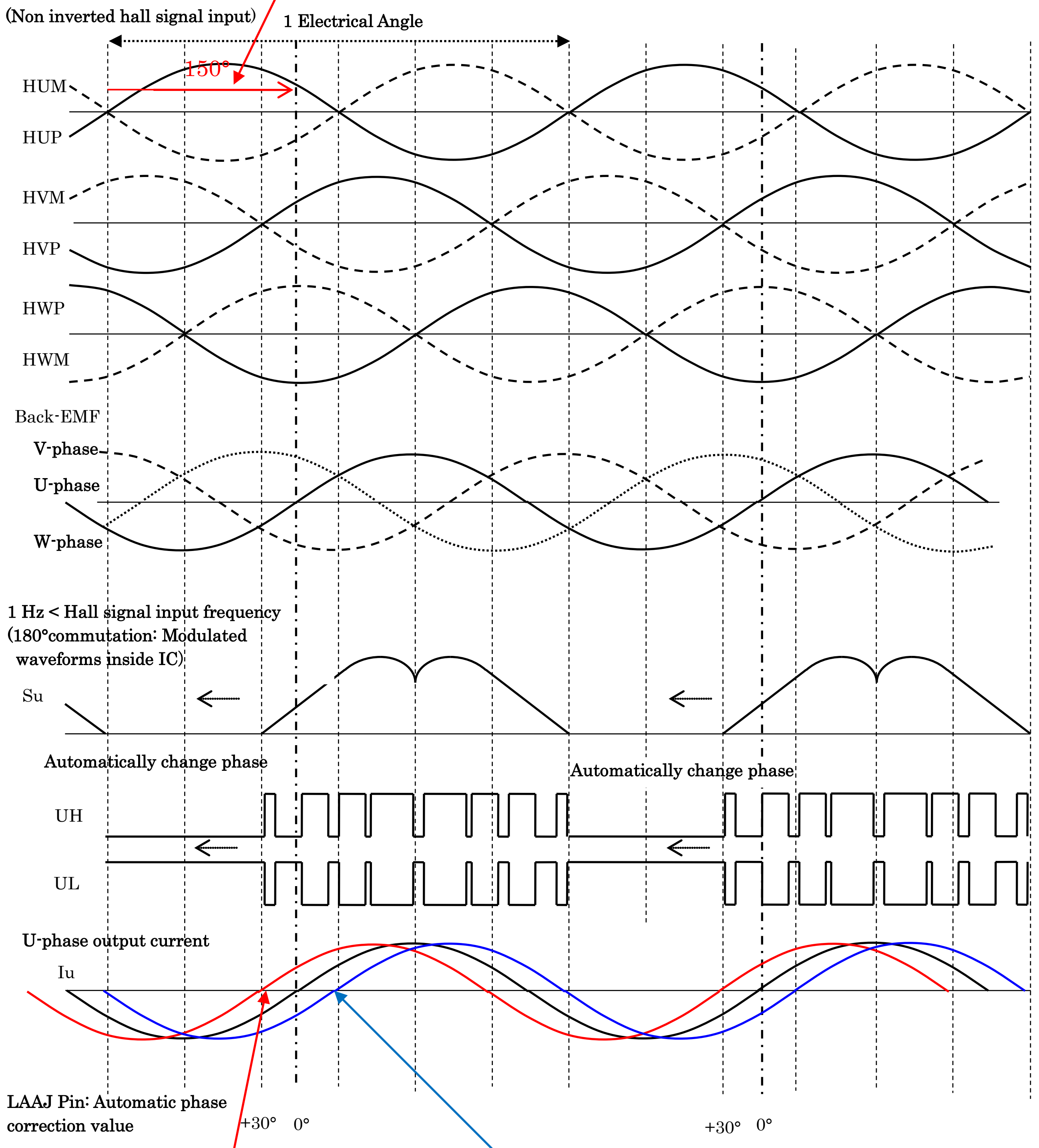
- At the U-phase output current judgment position, the PWM Duty for one output PWM may be modulated in order to detect the plus or minus of the output current. Therefore, the output current may be distorted at that timing.

- The auto lead angle function adjusts the zero cross of the U-phase output current to the position where the timing of 150° from the rise of the HUP of the hall signal (in the case of forward rotation) and the zero cross of the U-phase Back-EMF match. Control is performed so the optimum motor efficiency is obtained when the U-phase Back-EMF and the zero-cross phase of the U-phase output current match.

- The auto lead angle control function detects the zero cross of the output current and automatically adjusts the lead angle. Therefore, if the VSP pin input voltage is low and sufficient current does not flow to the output, the zero cross of the output current may not be detected accurately and the auto lead angle control function may not operate correctly. In such cases, use the function of the LAL pin.

- In the automatic lead angle setting, when the current limit (IDC pin function) operates at the zero cross detection point of the output current, and the phase of the automatic advance cannot be determined because the output current cannot be detected accurately. Control advances the lead angle gradually, but not to advance too much the lead angle, the upper limit of the advance is controlled by the current limit lead angle control function (IDC advance) using the LA pin.

The lead angle control is judged by whether the current is positive or negative based on the timing of 150° from the rise of the hall signal HUP (0° timing).



If the current is positive at the reference (0° timing), the lead angle judgment is controlled by the delay angle.

If the current is negative at the reference (0° timing), the lead angle judgment is controlled by the lead angle.

Fig. 3.1 Auto lead angle control function (Intelligent Phase Control: InPAC) timing

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.

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