

TB67B001FTG, TB67B001AFTG

3-Phase PWM Driver for Sensorless Brushless Motors

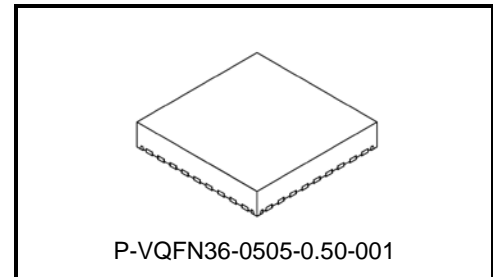
The TB67B001FTG, TB67B001AFTG is a three-phase PWM chopper driver for sensorless brushless motors. It controls motor rotation speed by changing the PWM duty cycle, based on the speed control input.

The difference of both products is as follows:

Lock detection signal (LD_OUT),

TB67B001FTG: Normal state: High, Abnormal state: Low

TB67B001AFTG: Normal state: Low, Abnormal state: High

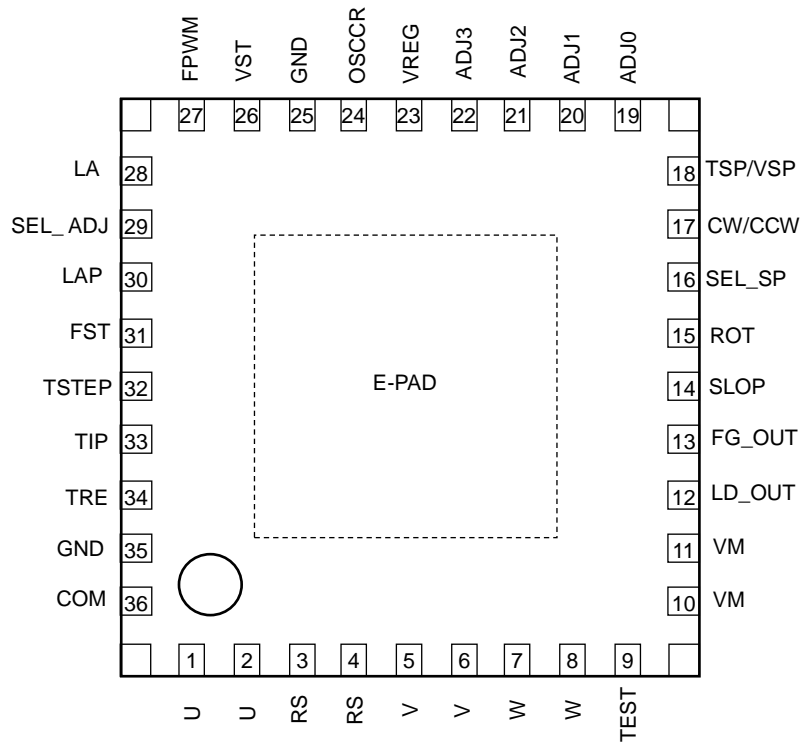


Weight: 0.05 g (typ.)

Features

- Sensorless drive in three-phase full-wave mode
- PWM chopper control
- Control based on the pulse duty input or analog voltage input is selectable
- Output current: Absolute maximum rating: 3A
- Power supply: Absolute maximum rating: 25 V
- Adjustable output PMW duty
- Lead angle control
- Overlapping commutation (120°, 135°, and 150°)
- Selectable soft switching
- Rotation speed detecting signal (FG_OUT)
- Lock detecting signal (LD_OUT)
TB67B001FTG: Normal state: High, Abnormal state: Low
TB67B001AFTG: Normal state: Low, Abnormal state: High
- Adjustable startup settings
- Forced commutation frequency control
- Selectable PWM frequency
- Restart
- Overcurrent protection (ISD)
- Thermal shutdown (TSD)
- Undervoltage lockout (UVLO)
- Current limiter

Pin Assignment



Note 1: Design the pattern in consideration of the heat design because the back side (E-PAD (3.4 mm × 3.4 mm)) and the four corners of the PAD have the role of heat radiation. (The back side (E-PAD) and the four corners of the PAD should be connected to GND because they are connected to the back of the chip electrically.)

Note 2: Because each U, V, W, RS, and VM has two pins, short out these two pins at the external pattern respectively.

Pin Description

| Pin No. | Symbol | I/O | Description |
|---------|---------|-----|--|
| 1 | U | O | U-phase output |
| 2 | U | O | U-phase output |
| 3 | RS | — | Connection pin for output current detecting resistance |
| 4 | RS | — | Connection pin for output current detecting resistance |
| 5 | V | O | V-phase output |
| 6 | V | O | V-phase output |
| 7 | W | O | W-phase output |
| 8 | W | O | W-phase output |
| 9 | TEST | — | Test pin (Connect to GND pin) |
| 10 | VM | — | Motor power supply pin |
| 11 | VM | — | Motor power supply pin |
| 12 | LD_OUT | O | Lock detecting signal output pin (open-drain) |
| 13 | FG_OUT | O | Rotation speed output pin (open-drain) |
| 14 | SLOP | I | Soft switching select input pin |
| 15 | ROT | I | Rotation speed of lead angle switching select pin |
| 16 | SEL_SP | I | Select pin: Pulse duty control of TSP/VSP input or analog voltage select pin |
| 17 | CW/CCW | I | Forward/Reverse rotation direction select input |
| 18 | TSP/VSP | I | Rotation speed command input (Pulse duty control and analog voltage control) |
| 19 | ADJ0 | I | Characteristics adjustment of input duty |
| 20 | ADJ1 | I | Characteristics adjustment input of PWM output duty 1 |
| 21 | ADJ2 | I | Characteristics adjustment input of PWM output duty 2 |
| 22 | ADJ3 | I | Characteristics adjustment input of PWM output duty 3 |
| 23 | VREG | — | Reference voltage output |
| 24 | OSCCR | — | Internal OSC setting pin |
| 25 | GND | — | Ground connection pin |
| 26 | VST | I | Duty cycle setting pin for DC excitation and forced commutation modes |
| 27 | FPWM | I | PWM frequency select input |
| 28 | LA | I | Lead angle setting input |
| 29 | SEL_ADJ | I | PWM duty function setting input |
| 30 | LAP | I | Overlapping commutation select pin |
| 31 | FST | I | Forced commutation frequency select input |
| 32 | TSTEP | — | PWM duty increasing time setting pin |
| 33 | TIP | — | Connection pin for a capacitor to set the DC excitation time |
| 34 | TRE | — | Connection pin for a capacitor to set the restart time |
| 35 | GND | — | Ground connection pin |
| 36 | COM | I | Connection pin for the center tap of the motor |

Functional Description

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

Timing charts may be simplified for explanatory purposes.

1. Sensorless Drive Mode

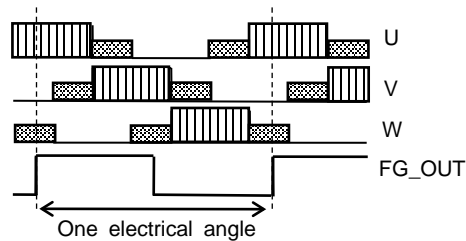
Based on the analog voltage input for a startup operation, the rotor is aligned to a known position in DC excitation mode. Then, the forced commutation signal is generated to start the motor rotation. As the motor rotates, the back-EMF occurs in each phase of the coil. When an input signal indicating the polarity of three phase voltage of the motor, including the back-EMF, is detected as a position signal, the motor driving signal is automatically switched from forced commutation signal to the normal commutation PWM signal that is based on the position signal input (back-EMF). Then, a BLDC motor starts running in sensorless commutation mode.

1) Forward /Reverse rotation direction switching: CW/CCW pin

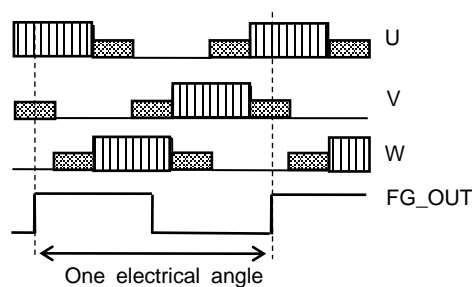
CW/CCW = Low: Forward direction, CW/CCW = High: Reverse direction

Do not switch the rotation direction during the motor operation to avoid stepping out. Switch the rotation direction after the motor operation stops.

• CW/CCW = Low (Forward)



• CW/CCW = High (Reverse)



2) Output of rotation speed signal: FG_OUT pin

Signal of 1 ppr (one pulse/one electrical angle) is outputted according to the motor induced voltage.

(*4-polar motor: 2 pulses are outputted per 1 motor rotation.)

Absolute Maximum Ratings (Note) (Ta = 25 °C)

| Characteristics | Symbol | Rating | Unit |
|-----------------------|---------------------------|-------------------------------|------|
| Power supply voltage | VM | 25 | V |
| Input voltage | V _{IN1} (Note1) | -0.3 to 6.0 | V |
| | V _{IN2} (Note2) | -0.3 to 25 | V |
| | V _{IN3} (Note3) | -0.3 to V _{REG} +0.3 | V |
| Output voltage | V _{OUT1} (Note4) | 25 | V |
| | V _{OUT2} (Note5) | 25 | V |
| Output current | I _{OUT1} (Note6) | 3 (Note9) | A |
| | I _{OUT2} (Note7) | 10 | mA |
| | I _{OUT3} (Note8) | 5 | mA |
| Power dissipation | P _D | 2.8 (Note10) | W |
| Operating temperature | T _{opr} | -40 to 105 | °C |
| Storage temperature | T _{stg} | -55 to 150 | °C |

Note: 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.

Please use the TB67B001FTG/AFTG within the specified operating ranges.

Note1: V_{IN1} is applicable to the voltage at the following pins: TSP/VSP and CW/CCW

Note2: V_{IN2} is applicable to the voltage at the COM pin.

Note3: V_{IN3} is applicable to the voltage at the following pins:

SLOP, ROT, SEL_SP, ADJ0, ADJ1, ADJ2, ADJ3, OSCCR, VST, FPWM, LA, SEL_ADJ, LAP, FST, TSTEP, TIP, and TRE

Note4: V_{OUT1} is applicable to the voltage at the following pins: U, V and W

Note5: V_{OUT2} is applicable to the voltage at the following pins: FG_OUT and LD_OUT

Note6: I_{OUT1} is applicable to the voltage at the following pins: U, V and W

Note7: I_{OUT2} is applicable to the voltage at the following pins: FG_OUT and LD_OUT

Note8: I_{OUT3} is applicable to the voltage at the VREG pin.

Note9: Output current may be limited by the ambient temperature or the device implementation.

The maximum junction temperature should not exceed T_{jmax} = 150°C

Note10: When mounted on the board (4 layers: FR4: 76.2 mm x 114.3 mm x 1.6 mm)

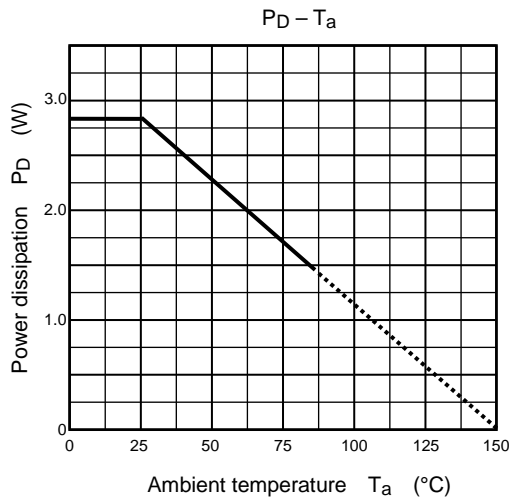
Operating Ranges

| Characteristics | Symbol | Min | Typ. | Max | Unit |
|---|---------|-----|------|-----|------|
| Power supply voltage 1 | VMopr1 | 5.5 | 12 | 22 | V |
| Power supply voltage 2 (Note11) | VMopr2 | 4 | 5 | 5.5 | V |
| Input frequency of TSP/VSP pin (Note12) | foprTSP | 0.4 | 25 | 100 | kHz |

Note11: When voltage of VM is 5.5 V or less, pay attention to use the IC because the characteristics of the output ON resistance and VREG output voltage change.

Note12: When the pulse duty of TSP/VSP pin is controlled (SEL_SP = Low)

Package Power Dissipation (Reference data)



Electrical Characteristics (Ta = 25°C, VM = 12 V, unless otherwise specified)

| Characteristics | Symbol | Test Conditions | Min | Typ. | Max | Unit |
|--|----------|---|--------------|-------|--------------|------|
| Static power supply current at VM | IM | TSP/VSP = GND | — | 5.5 | 8 | mA |
| Dynamic power supply current at VM | IM (opr) | TSP/VSP = VREG RS = TIP = COM = GND, | — | 6 | 8.5 | mA |
| Input current | IIN1 (H) | VIN = 5 V, FST, LAP, SEL_ADJ | — | 100 | 150 | μA |
| | IIN1 (L) | VIN = 0 V, FST, LAP, SEL_ADJ | -150 | -100 | — | |
| | IIN2A | TSP/VSP SEL_SP = VREG | -1 | — | 1 | |
| | IIN2D | TSP/VSP = 5V SEL_SP = GND | — | 100 | 150 | |
| | IIN2D | TSP/VSP = 0V SEL_SP = GND | -1 | — | 1 | |
| | IIN3 | ADJ0,ADJ1, ADJ2, ADJ3, VST,LA,FPWM | -1 | — | 1 | |
| | IN4 (H) | VIN = 5 V SEL_SP,CW/CCW, SLOP,ROT | — | 100 | 150 | |
| | IN4 (L) | VIN = 0V SEL_SP,CW/CCW, SLOP,ROT | -1 | 0 | — | |
| Input voltage | VIN1 (H) | TSP/VSP | 2.0 | — | — | V |
| | VIN1 (L) | SEL_SP = GND | GND | — | 0.8 | |
| | VIN2 (H) | FST, LAP, SEL_ADJ | VREG ×0.8 | — | VREG +0.3 | |
| | VIN2 (M) | | VREG ×0.4 | — | VREG ×0.6 | |
| | VIN2 (L) | | GND | — | VREG ×0.2 | |
| | VIN3 (H) | SEL_SP,CW/CCW, SLOP,ROT | 2.0 | — | — | |
| | VIN3 (L) | SEL_SP,CW/CCW, SLOP,ROT | GND | — | 0.8 | |
| Input voltage hysteresis | V1hys | TSP/VSP SEL_SP = GND (Reference data) | — | 0.12 | — | V |
| | V2hys | SEL_SP,CW/CCW, SLOP(Reference data) | — | 0.12 | — | |
| TSTEP pin setting time | Tsoft | TSTEP = 0.01μF (Reference data) | — | 0.099 | — | s |
| TIP pin setting time | Tip | TIP = 0.1 μF (Reference data) | — | 0.99 | — | s |
| TRE pin setting time | Tre | TRE = 1 μF (Reference data) | — | 9.9 | — | s |
| High-level TIP, TRE, and TSTEP voltage | VH | | 2.25 | 2.5 | 2.75 | V |
| Low-level TIP, TRE, and TSTEP voltage | VL | | 0.45 | 0.5 | 0.55 | V |
| COM pin input current | Icom | | -5 | -1.3 | 1 | μA |
| Position detection comparator offset voltage | Voffset | (Reference data) | -10 | 0 | 10 | mV |
| Low-level FG_OUT/LD_OUT output voltage | VFG_OUT | IOUT = 5mA | GND | — | 0.5 | V |
| FG_OUT/LD_OUT leakage current | ILFG_OUT | VOUT = 25 V | — | 0 | 2 | μA |
| Output ON-resistance at the U, V and W pins | RON1 (H) | IOUT = -0.1A | — | 0.3 | 0.6 | Ω |
| | RON1 (L) | IOUT = 0.1A | — | 0.3 | 0.6 | |
| | RON2 (H) | IOUT = -0.1A, VM = 4.0 V | — | 0.33 | 0.6 | |

| Characteristics | Symbol | Test Conditions | Min | Typ. | Max | Unit |
|---|---------------------|--|-------|-------|-------|------|
| | RON2 (L) | I _{OUT} = 0.1A, V _M = 4.0 V | — | 0.33 | 0.6 | |
| Output leakage current at the U, V and W pins | I _L (H) | V _{OUT} = 0 V | -10 | 0 | — | μA |
| | I _L (L) | V _{OUT} = 25 V | — | 0 | 10 | |
| Output diodes' forward voltage at the U, V and W pins | V _F (H) | I _{OUT} = 1.5A(Reference data) | — | 1.0 | 1.4 | V |
| | V _F (L) | I _{OUT} = -1.5A(Reference data) | — | 1.0 | 1.4 | |
| VST ON resistance in power on | RVST | | — | 600 | 1000 | Ω |
| TSP/VSP I/O characteristics in analog voltage control | V _{AD} (L) | TSP/VSP SEL_SP = VREG DUTY = 0% | 0.56 | 0.625 | 0.69 | V |
| | V _{AD} (H) | TSP/VSP SEL_SP = VREG DUTY = 100% | 2.81 | 3.125 | — | |
| Masking time of current limit detection | TRS | (Reference data) | — | 3 | — | μs |
| RS pin voltage for current detection | VRS | | 0.225 | 0.25 | 0.275 | V |
| PWM oscillation frequency | FPWM4 | (Reference data) | 171.5 | 190.6 | 209.7 | kHz |
| | FPWM3 | (Reference data) | 85.7 | 95.3 | 104.9 | |
| | FPWM2 | (Reference data) | 42.8 | 47.7 | 52.5 | |
| | FPWM1 | (Reference data) | 21.4 | 23.8 | 26.3 | |
| OSC frequency | OSC | OSCCR:20kΩ, 180pF(Reference data) | 10.98 | 12.2 | 13.42 | MHz |
| Masking time of over current detection | TISD | (Reference data) | — | 3 | — | μs |
| Current for over current detection | IISD | (Reference data) | — | 4.5 | — | A |
| Thermal shutdown | TSD | (Reference data) | — | 165 | — | °C |
| | TSDhys | Thermal shutdown hysteresis (Reference data) | — | 15 | — | |
| UVLO trip threshold voltage at the VM pin | VMUVLO | | 3.1 | 3.4 | 3.7 | V |
| UVLO recovery voltage at the VM pin | VMUVLOR | | 3.4 | 3.7 | 3.98 | V |
| UVLO trip threshold voltage at the VREG pin | VREGUVLO | | 2.7 | 3.0 | 3.3 | V |
| UVLO recovery voltage at the VREG pin | VREGUVLOR | | 2.9 | 3.2 | 3.45 | V |
| VREG output voltage | VREG1 | I _{VREG} = -5 mA | 4.5 | 5 | 5.5 | V |
| | VREG2 | I _{VREG} = -5 mA, V _M = 4.0V | 3.6 | 3.9 | 4.0 | V |

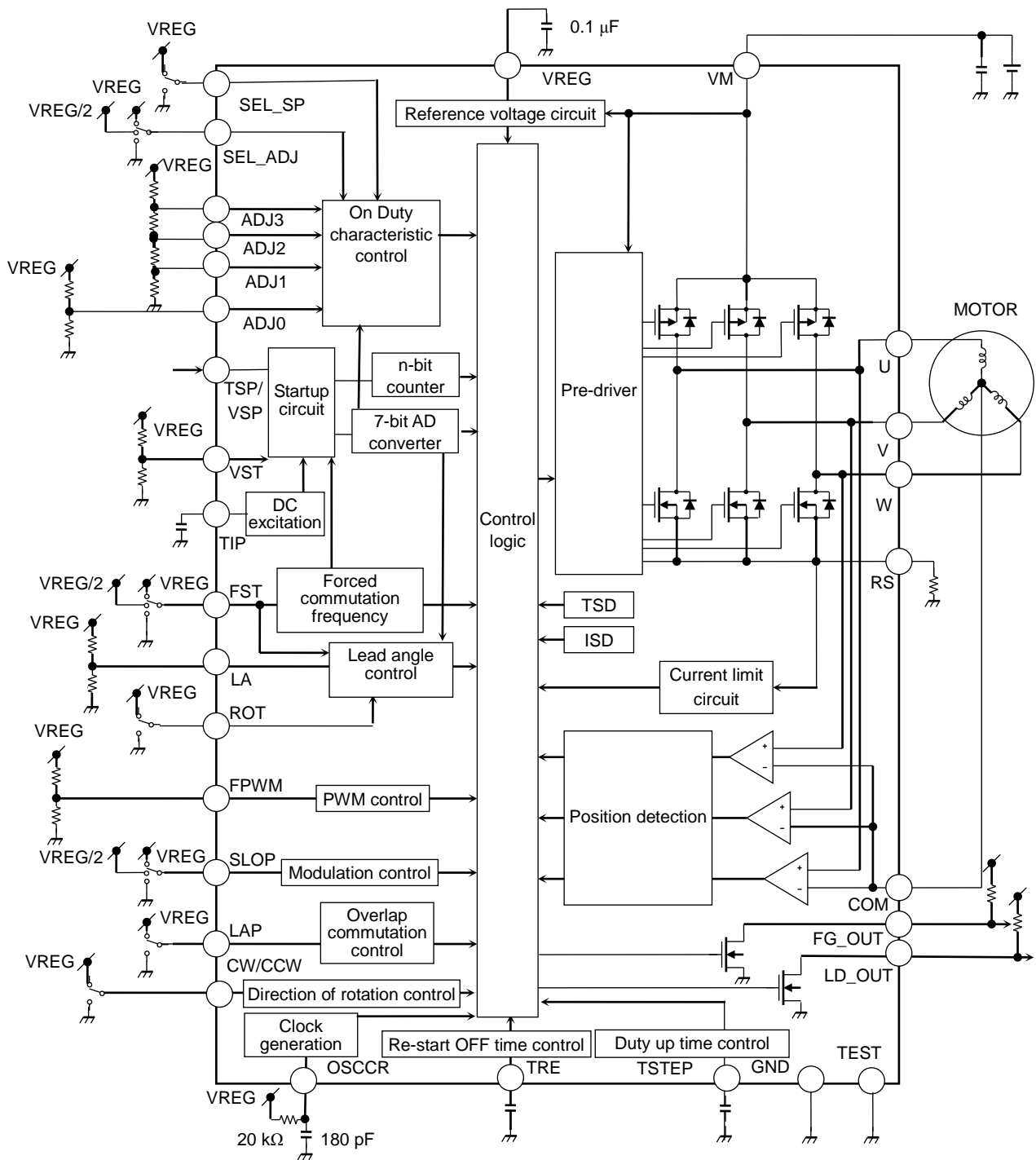
*Reference data: Toshiba does not implement testing before shipping.

Application Circuit Example

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

The application circuits shown in this document are provided for reference purposes only. Thorough evaluation is required, especially at the mass production design stage.

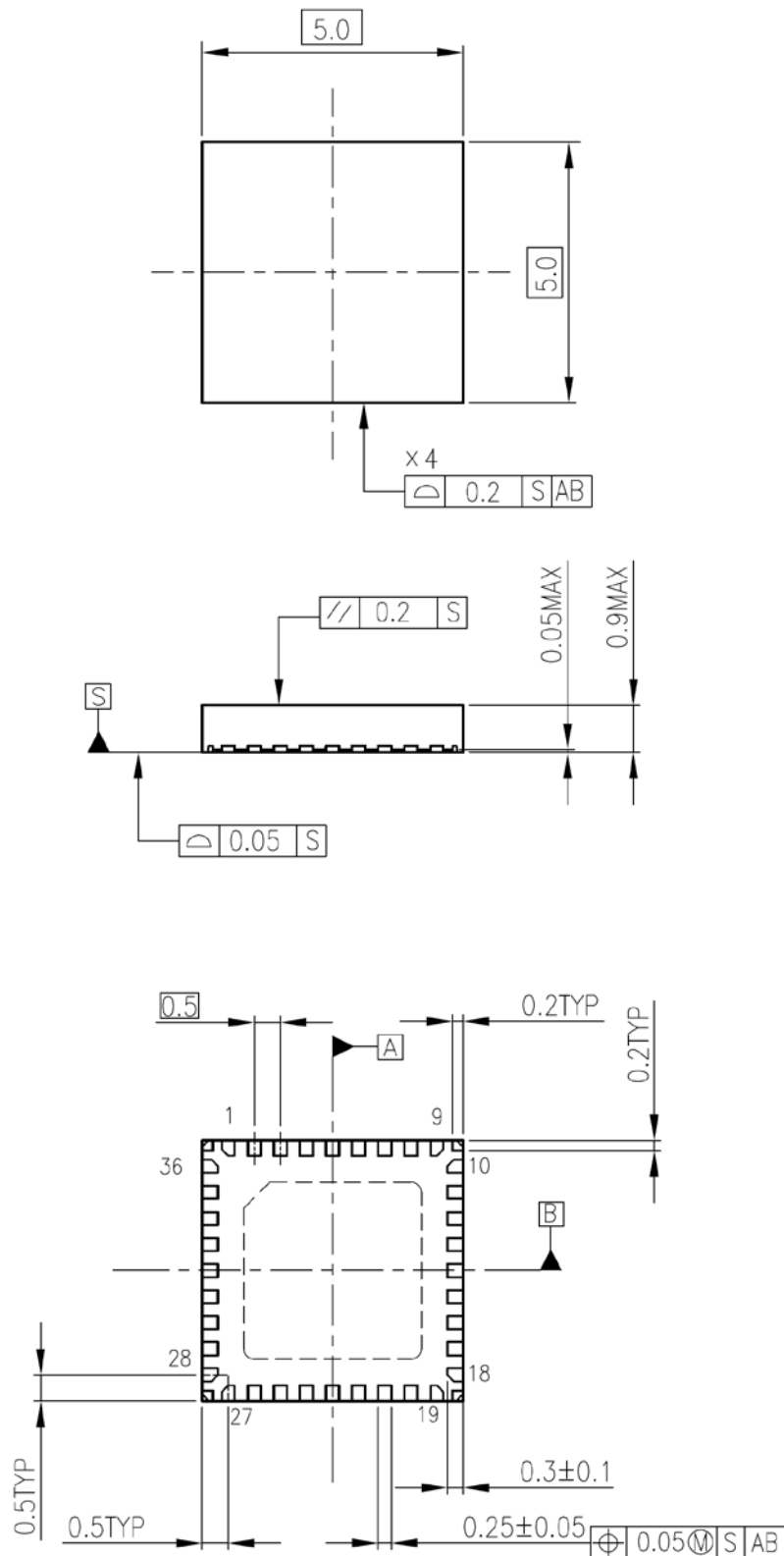
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Package Dimensions

P-VQFN36-0505-0.50-001

Unit: mm



Weight: 0.05g (typ.)

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.

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5. Test Circuits

Components in the test circuits are used only to obtain and confirm the device characteristics. These components and circuits are not guaranteed to prevent malfunction or failure from occurring in the application equipment.

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.

- (5) Carefully select external components (such as inputs and negative feedback capacitors) and load components (such as speakers), for example, power amp and regulator.
If there is a large amount of leakage current such as input or negative feedback condenser, the IC output DC voltage will increase. If this output voltage is connected to a speaker with low input withstand voltage, overcurrent or IC failure can cause smoke or ignition. (The over current can cause smoke or ignition from the IC itself.) In particular, please pay attention when using a Bridge Tied Load (BTL) connection type IC that inputs output DC voltage to a speaker directly.

Points to remember on handling of ICs

- (1) Over current Protection Circuit
Over current protection circuits (referred to as current limiter circuits) do not necessarily protect ICs under all circumstances. If the Over current protection circuits operate against the over current, clear the over current status immediately.
Depending on the method of use and usage conditions, such as exceeding absolute maximum ratings can cause the over current protection circuit to not operate properly or IC breakdown before operation. In addition, depending on the method of use and usage conditions, if over current continues to flow for a long time after operation, the IC may generate heat resulting in breakdown.
- (2) Thermal Shutdown Circuit
Thermal shutdown circuits do not necessarily protect ICs under all circumstances. If the thermal shutdown circuits operate against the over temperature, clear the heat generation status immediately. Depending on the method of use and usage conditions, such as exceeding absolute maximum ratings can cause the thermal shutdown circuit to not operate properly or IC breakdown before operation.
- (3) Heat Radiation Design
In using an IC with large current flow such as power amp, regulator or driver, please design the device so that heat is appropriately radiated, not to exceed the specified junction temperature (T_j) 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 consideration the effect of IC heat radiation with peripheral components.
- (4) Back-EMF
When a motor rotates in the reverse 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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