Motor Driver Usage Considerations

Applicable Products: TB62208/210/211/213/214/215/216/218

This document includes application circuit examples and IC usage considerations for motor driver evaluation purposes only. Please note that some expressions in this document is not officially guaranteed. Please see the datasheet for more specification.

1. Power Supply

1.1 Operating ranges (VM power supply)

The absolute maximum voltage is rated at 40V, but please remind to use the IC between 10 to 38V (operating range).

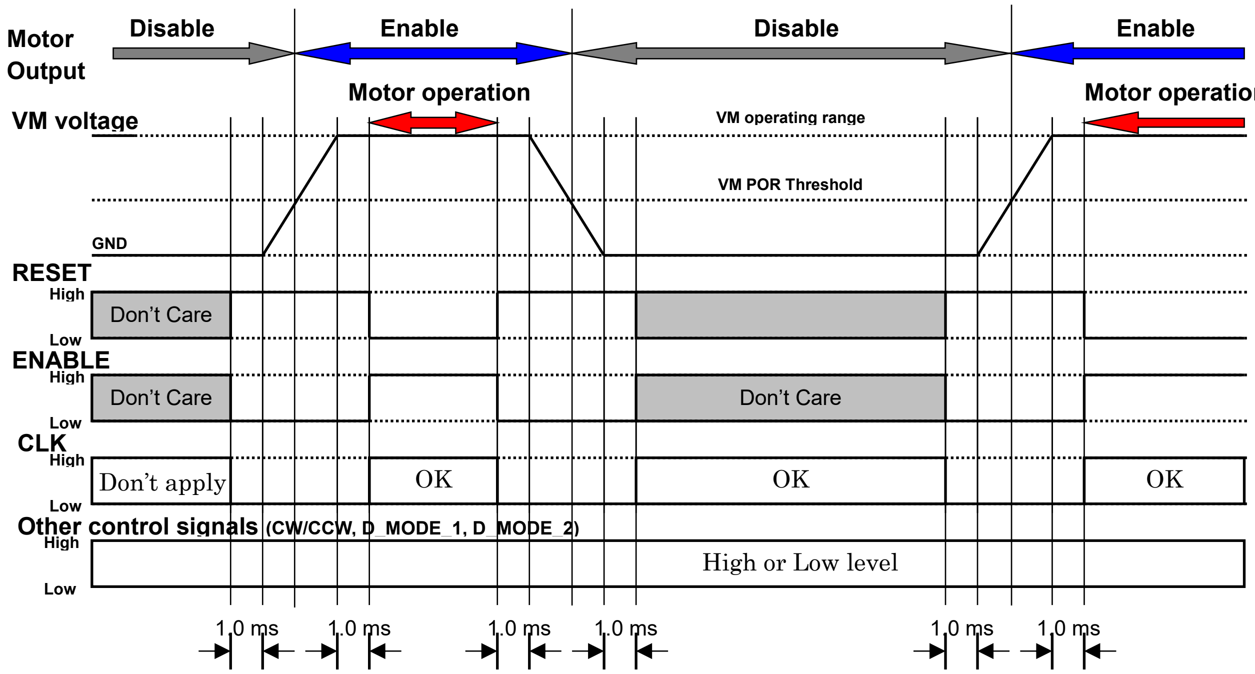
1.2 Power on and off sequence (For CLK-IN interface drivers)

Before applying the VM power supply, set the RESET pin to High, and ENABLE pin to Low. Also, set both pins as mentioned above when turning off the power supply. Each motor driver has an internal voltage monitor circuit to avoid false operation, but it is preferred to set the pins accordingly during power on and off sequence.

When control signals are applied while VM power is OFF:

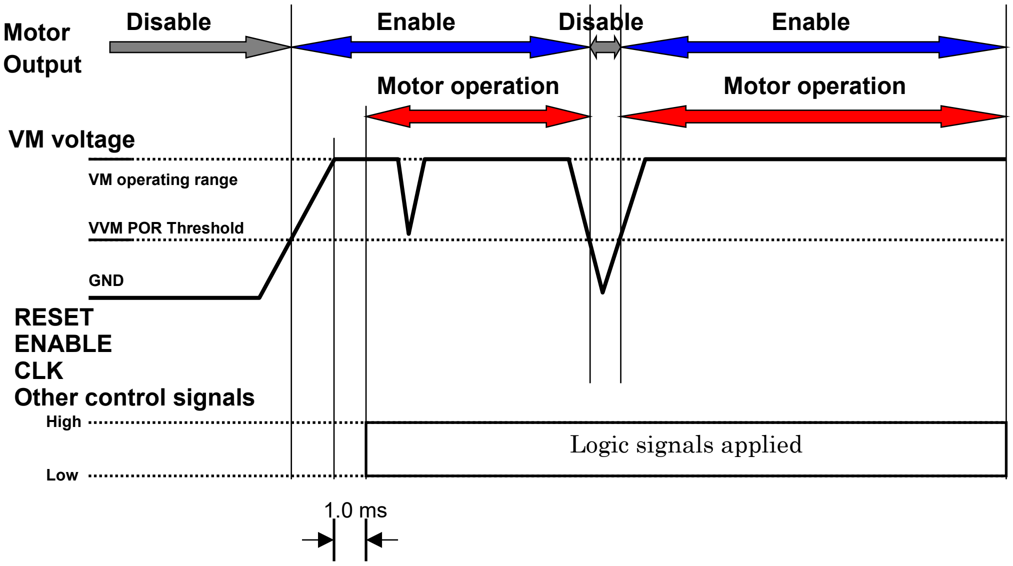
The motor drivers are designed to avoid false operation even if the control signals are applied, and VM power is not. Since this feature is not tested, therefore is not guaranteed. Also, each motor driver has an internal VM voltage monitor circuit (Power-on-reset also known as Under Voltage Lockout circuit) which will monitor the supplied voltage and avoid the driver to be operational if the voltage is below the VM POR threshold. But note that if the control signals are applied before and/or during the VM power on sequence; the device may start the motor operation before the VM reaches the proper operating range, which may lead to malfunction. Similar malfunction may occur if the signals are applied during power off sequence.

Therefore, please apply the control signals after the VM power reaches the actual operating voltage and is stable, before applying any control signals. Please refer to the timing chart shown below for an example of the power-on and power-off sequence.



When the VM voltage level decreases while operation:

If the VM voltage level drops below the VM POR threshold, the output stage will be turned off. Please set the VM voltage to the proper operating level to restart the motor function. Also, even if the VM level decreases, but does not reach below the VM POR threshold; it may still cause false operation due to the voltage drop. Therefore, please keep the VM voltage stable at all times.



Characteristics	Symbol	Test condition	Min	Typ	Max	Unit
VM POR Threshold	V_{MR}	Ta = 25 °C, V_M = 24 V	7.0	8.0	9.0	V

If a momentary power failure occurs after the VM power is applied, and then the "V_{CC} voltage drops below 4.75V and the VM returns to 7V or higher", the driver's built-in protection circuit may activate which will stop the motor operation. If such power fluctuations occur, set the VM voltage to GND level or apply the controls signals to standby to restart the device.

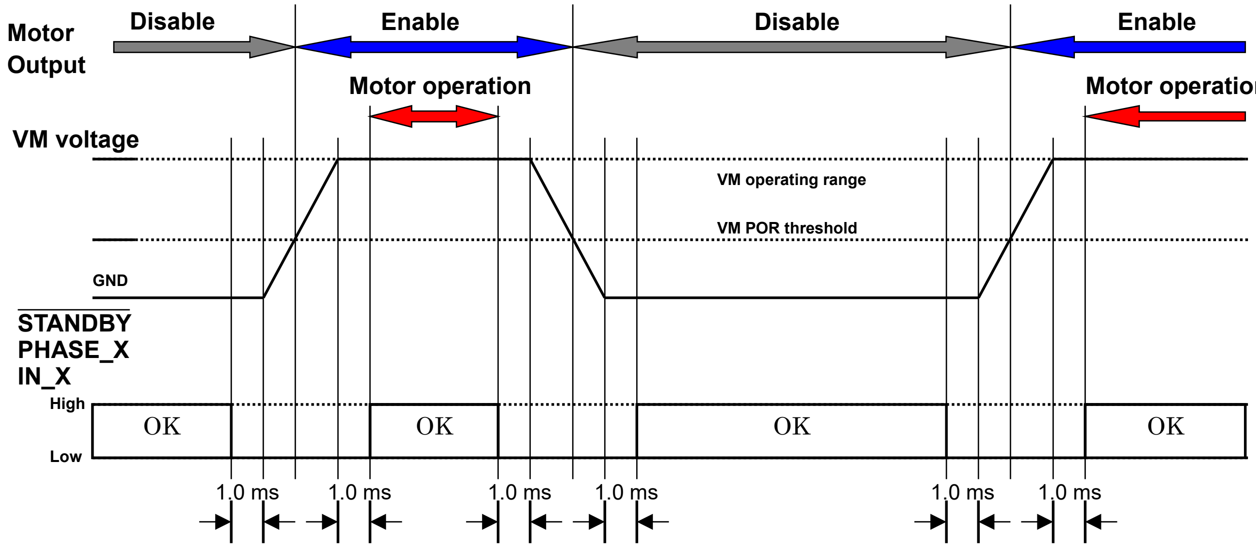
1.3 Power on and off sequence (For PHASE-IN interface drivers)

Set the $\overline{\text{STANDBY}}$, PHASE_A, PHASE_B, IN_A1, IN_A2, IN_B1, IN_B2, ENABLE_A, ENABLE_B signals to Low before applying the VM power supply. Also, set each signal as mentioned above during power off sequence. Each motor driver has an internal voltage monitor circuit to avoid false operation, but it is preferred to set the pins accordingly during power on and off sequence.

When control signals are applied while VM power is OFF:

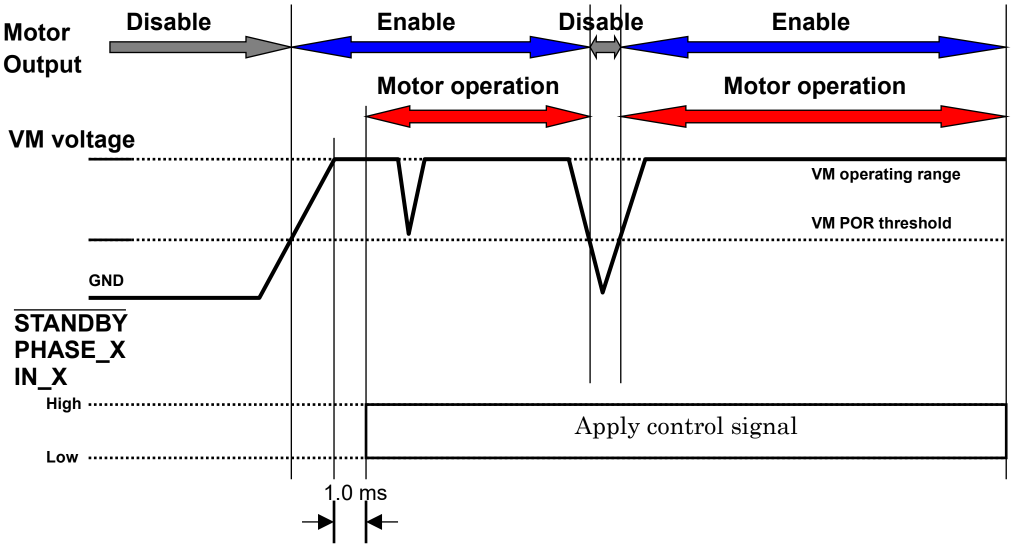
The motor drivers are designed to avoid false operation even if the control signals are applied, and VM power is not. Since this feature is not tested, therefore is not guaranteed. Also, each motor driver has an internal VM voltage monitor circuit (Power-on-reset also known as Under Voltage Lockout circuit) which will monitor the supplied voltage and avoid the driver to be operational if the voltage is below the VM POR threshold. But note that if the control signals are applied before and/or during the VM power on sequence; the device may start the motor operation before the VM reaches the proper operating range, which may lead to malfunction. Similar malfunction may occur if the signals are applied during power off sequence.

Therefore, please apply the control signals after the VM power reaches the actual operating voltage and is stable, before applying any control signals. Please refer to the timing chart shown below for an example of the power-on and power-off sequence.



When the VM voltage level decreases while operation:

If the VM voltage level drops below the VM POR threshold, the output stage will be turned off. Please set the VM voltage to the proper operating level to restart the motor function. Also, even if the VM level decreases, but does not reach below the VM POR threshold; it may still cause false operation due to the voltage drop. Therefore, please keep the VM voltage stable at all times.



Behavior of the driver when VM voltage suddenly drops during motor operation

If the VM voltage suddenly drops during motor operation, the VM voltage monitor circuit (VM POR) will turn off the output stage and all the settings will be reset. When the VM voltage recovers and goes above the VM POR threshold, the motor operation will start. But if the VM voltage suddenly drops, but does not below the VM POR threshold, the voltage drop may cause the motor to malfunction.

Characteristics	Symbol	Test condition	Min	Typ.	Max	Unit
VM POR Threshold	V_{MR}	Ta = 25 °C, V_M = 24 V	7.0	8.0	9.0	V

If a momentary power failure occurs after the VM power is applied, and then the “VCC voltage drops below 4.75V and the VM returns to 7V or higher”, the driver’s built-in protection circuit may activate which will stop the motor operation. If such power fluctuations occur, set the VM voltage to GND level or apply the controls signals to standby to restart the device.

2. Control signals

Generally, stepping motor drivers are controlled by Phase input or Clock input. For H-Bridge drivers, it is controlled by either IN input or PWM input. Control interface is based on each driver, therefore please refer to each product's datasheet. As for IN pins and Phase pins, if external noise causes the input level to surpass the input level threshold, it may cause some false operation. Keep the pins which are set to Low within VIN(L) range, and High within VIN(H) range at all times. Consider adding CR filters or capacitors to countermeasure external noises.

3. Motor output current

3.1 Calculation of the current threshold for constant current PWM

Each motor driver can set the constant current PWM threshold by VREF voltage and sense resistor value.

$I_{OUT} = 0.2 \times V_{ref}\,[V] \times (1 / RS[\Omega])$

"0.2" is the typical V_{ref}(gain)
(For specifications, please refer to each device's datasheet.)

i.e. Setting the current threshold of Iout=0.8A, with V_{ref}=0.88V, select 0.22Ω sense resistor (with 0.5W and above capability)

Please see the below for pros and cons of the sense resistor value.

* When using a smaller sense resistor value; current sensing is done with the voltage differential between the VM and RS pin. Therefore, using smaller value will generate smaller voltage differential between the two pins, which as a result may lead to a decrease of the current sensing.
* When using a larger sense resistor value; the power ratio required for the sense resistor itself will increase due to the higher power ($P=I^2 \times R$) when running the motor.

3.2 OSCM oscillation frequency

OSCM oscillation frequency can be approximately calculated using the formula below.

$f_{OSCM} = 1 / [0.56 \times C_{OSC} \times (R_{OSC} + 500)]$

C_{OSC} : Capacitor value
R_{OSC} : Resistor value

Note that the above formula is intended to be used for an approximate calculation. Please see each product datasheet for additional information.

i.e. $C_{OSC} = 270 \times 10^{-12}$ [F]、$R_{OSC} = 3600$ [Ω]

$f_{OSCM} = 1.61 \times 10^{6} \Rightarrow 1.6$ MHz

Regularly, sequence of Charge→Slow→Fast will occur within 1 PWM cycle, but if the motor current level does not reach the current threshold within 1 PWM cycle, the device will be kept at charge state until it reaches the current setting. Therefore, by just monitoring the motor current it may seem that the PWM cycle has doubled. Therefore, please evaluate/test under each usage condition and set tune the chopping frequency if needed.

4. IC Power Consumption

The power consumed by the motor drivers are approximately the sum of the following. 1) The power consumed by the output stage, and 2) the power consumed by the logic and other analog circuits.

Power consumption of the output stage

- Whether in Charge mode, Fast mode or Slow mode, the power will be consumed by 2 MOSFETs per H-Bridge.

The power consumption of 1 H-Bridge can be calculated with the formula below.

$$P\ (out) = I_{OUT}\ (A) \times V_{DS}\ (V) = I_{OUT}^2 \times R_{ON}$$

The current consumed by the logic and other circuits should be considered for both operational and in standby mode.

I (IM3) ：Operational
I (IM1) ：Standby

The current consumed by the logic circuit is indicated as Imax. The logic circuits operate off a voltage regulator that is internally connected to the VM power supply. It consists of the digital logic connected to VM and the network affected by the switching of the output transistors. The total power consumed by Imax can be estimated as:

$$P\ (IM3) = VM\ (V) \times IM3\ (A)$$
$$P\ (IM1) = VM\ (V) \times IM1(A)$$

Therefore, the approximate calculation of the total power consumption is

$$P = P\ (out) + P\ (IM3)$$

P(out) will be dependent to the operation status of the motor driver, therefore the total power consumption will change. The power consumption during standby mode is as follows.

$$P = P\ (IM1)$$

4.1 Thermal calculation

Please evaluate the device sufficiently and take utmost care when designing the board for better thermal performance.

If the ambient temperature is high, the power dissipation will be lower. Please see the Pd-Ta graph for reference, and design the board accordingly with additional margin. The correlation between the ambient temperature and the junction temperature is as follows. Please keep the junction temperature within the absolute maximum rating at all times.

$$Tj = P \times R_{th\ (j\text{-}a)} + Ta$$

※ : $R_{th\ (j\text{-}a)}$: Thermal resistance of junction to ambient temperature
※ : Ta: Ambient temperature

Note that the $R_{th\ (j\text{-}a)}$ will be dependent to the board layout/design, soldering conditions, usage conditions etc.

5. Package and layout considerations

For each packages, especially packages with exposed thermal pad (and four corner pins) on the bottom like QFN, to be soldered to a large GND area. The larger GND areas will be better for both noise and thermal issues.
Also, place multiple thermal vias directly to the board's thermal pad to disperse temperature effectively.
Note that most of the heat generated by the device will be concentrated at 1cm square from the device, therefore please avoid placing external components around this area and have as much GND area as possible.

Also, the motor drivers monitor the motor current with the voltage difference between the VM and RS pin. To get accurate current measurement, please consider the below when designing the board.

1) Place the decoupling capacitor at the branch point of RSA and RSB.

2) Consider keeping the board impedance between Ach and Bch the same. When placing vias to go around a certain pattern, place the same number of vias on both sides.

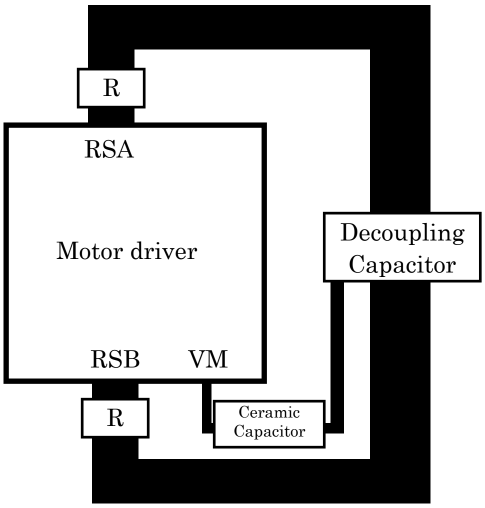


Figure: Board pattern image (VM-RS)

Please contact through our website for additional information.

6. Fuse

Use an appropriate power supply fuse for the power supply line to ensure that a large current does not continuously flow in the 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 to smoke or ignition. To minimize the effects of the flow of a large current in the case of breakdown, appropriate settings, such as fuse capacity, fusing time and insertion circuit location, are required.

This IC incorporates over current detection circuit (ISD) that turns off the output of the IC when over current is detected in the IC. However, it does not necessarily protect ICs under all circumstances. If the over current detection 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.

To avoid above IC destruction and malfunctions caused by noise, the over current detection circuit has a dead band time. So, it is concerned that the over current detection circuit may not operate depending on the output load conditions because of the dead band time. Therefore, in order to avoid continuing this over current state, use the fuse for the power supply line.

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) 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.

(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 (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.

(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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