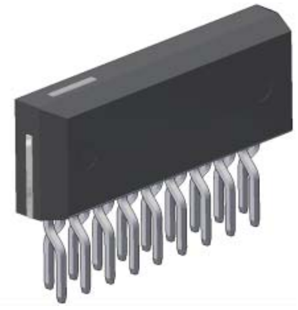
STA6940M

Brushed DC Motor Driver IC With PWM Control

Features and Benefits

- Power supply voltage, V_{BB} , 44 V maximum, 10 to 40 V normal operating range
- Logic supply voltage, V_{DD} , 3 to 5.5 V compatible
- Output current, I_O ,4 A average, 8 A maximum
- Output elements are all N-channel MOSFETs to reduce losses
- Internal charge pump
- Forward, reverse, free, and brake control modes available
- Constant-current control:
    - Off-time 35 µs, fixed (Slow Decay mode)
- Internal Overcurrent Protection (OCP) circuitry
    - Off-time 142 µs fixed (Fast Decay mode)
- Internal Thermal Shutdown (TSD) circuitry
- ZIP type 18-pin fully-molded package (STA package)

Package: 18-pin ZIP (STA)



Not to scale

Description

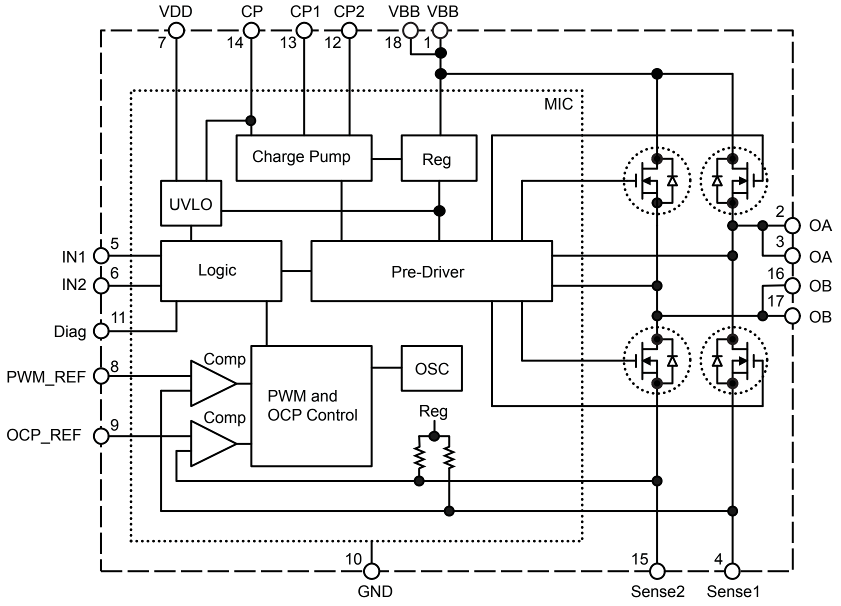
Combining low-power CMOS-compatible logic with high-current, high-voltage power MOSFET outputs, the STA6940M provides complete control and drive for brush DC motors. It provides internal fixed off time, pulse-width modulation (PWM) control of the output current, rated for 4 A normal operating level.

The CMOS logic section provides four modes of operation: forward and reverse normal drive rotation, outputs-off free spin (coast), and electronic braking.

The innovative multi-chip internal structure separates the main logic IC (MIC) from the four N-channel power MOSFETs. This results in lower thermal resistance and greater efficiency.

PWM control allows constant-current control of output while reducing heat generation and power losses by providing fixed off-time dual decay modes. The internal charge pump ensures full power availability for switching.

Functional Block Diagram



Selection Guide

Part Number	Package	Packing
STA6940M	18-pin ZIP through hole mount	18 pieces per tube

*Contact Allegro for additional packing options

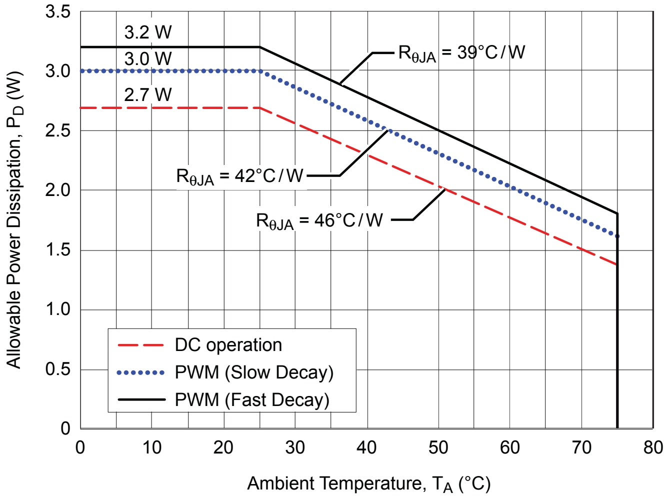
Absolute Maximum Ratings

Characteristic	Symbol	Notes	Rating	Units
Main Supply Voltage	V_{BB}		44	V
Logic Supply Voltage	V_{DD}		6	V
Output Current	I_O(max)	≤ 100 μs	8	A
Output Voltage	V_O		-1.5 to $V_{BB} + 1.5$	V
Logic Input Voltage	V_{IN}		-0.3 to $V_{DD} + 0.3$	V
PWM_REF Input Voltage	V_{PREF}		-0.3 to $V_{DD} + 0.3$	V
OCP_REF Input Voltage	V_{OREF}		-0.3 to $V_{DD} + 0.3$	V
Sensing Voltage	V_{RS}	Except $t_w < 1$ μs	–1 to 2	V
Power Dissipation	P_D	DC drive	2.7	W
		PWM drive (Slow Decay)	3.0	W
		PWM drive (Fast Decay)	3.2	W
Junction Temperature	T_J		150	ºC
Operating Ambient Temperature	T_A		–20 to 85	ºC
Storage Temperature	T_{stg}		–30 to 150	ºC

Recommended Operating Conditions

Characteristic	Symbol	Conditions	Min.	Typ.	Max.	Unit
Main Supply Voltage	V_{BB}		10	–	40	V
Output Current	I_O		–	–	4	A
Logic Supply Voltage	V_{DD}	Transient voltages at VDD pin must not exceed ±0.5 V	3.0	–	5.5	V
PWM Reference Input Voltage	V_{PREF}	Constant-current control	–	–	1	V
OCP Reference Input Voltage	V_{OREF}	OCP operating	–	–	2	V
Case Temperature	T_C	Package surface temperature without heatsink	–	–	85	°C

Power Derating Curve



All performance characteristics given are typical values for circuit or system baseline design only and are at the nominal operating voltage and an ambient temperature, T_A, of 25°C, unless otherwise stated.

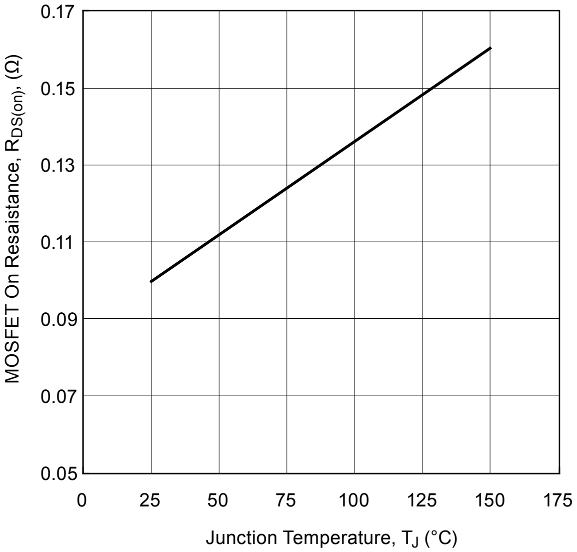
ELECTRICAL CHARACTERISTICS valid at T_A = 25°C, V_{BB} = 24 V, V_{DD} = 5 V; unless otherwise noted

Characteristics	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Main Supply Current	I_{BB}	Operating	–	–	20	mA
Logic Supply Current	I_{DD}		–	–	5	mA
Charge Pump Voltage	V_{cp}	V_{BB} = 10 to 40 V	–	V_{BB} + 5	–	V
Charge Pump Switching Frequency	f_{cp}		–	360	–	kHz
Main Supply Undervoltage Protection*	V_{UVBL}		–	7	–	V
	V_{UVBH}		–	7.8	–	V
Logic Supply Undervoltage Protection*	V_{UVDL}		–	2.3	–	V
	V_{UVDH}		–	2.5	–	V
Charge Pump Undervoltage Protection*	V_{UVCL}		–	3.8	–	V
	V_{UVCH}		–	4	–	V
MOSFET On Resistance	$R_{DS(on)}$	I_D = 4 A	–	0.1	0.13	Ω
MOSFET Body Diode Forward Voltage	V_F	I_F = 4 A	–	0.95	–	V
MOSFET Breakdown Voltage	V_{DSS}		53	–	–	V
Logic Input Voltage	V_{IL}		–	–	0.25 × V_{DD}	V
	V_{IH}		0.75 × V_{DD}	–	–	V
Logic Input Current	IIL		–	±1	–	µA
	IIH		–	±1	–	µA
Maximum Input Frequency	f_{clk}	Clock duty cycle = 50%	100	–	–	KHz
PWM_REF Pin Input Voltage	V_{PREF}	PWM_REF terminal	0.1	–	1.0	V
PWM_REF Pin Input Current	I_{PREF}		–	±10	–	µA
OCP_REF Pin Input Voltage	V_{OREF}	OCP_REF terminal	0.1	–	2.0	V
OCP_REF Pin Input Current	I_{OREF}		–	±10	–	µA
PWM Sensing Voltage	V_{PSEN}	Sense1, Sense2 terminals	V_{PREF} – 0.045	V_{PREF} – 0.015	V_{PREF} + 0.015	V
OCP Sensing Voltage	V_{OSEN}	Sense1, Sense2 terminals	V_{OREF} – 0.045	V_{OREF} – 0.015	V_{OREF} + 0.015	V
Sense1, Sense2 Pin Input Current	I_{SENSE}	Sense1, Sense2 terminals	–	±20	–	µA
Diag Pin Output Voltage	V_{DIAGL}	I_{DIAGL} = 1.25 mA	–	–	1.25	V
	V_{DIAGH}	I_{DIAGH} = –1.25 mA	V_{DD} – 1.25	–	–	V
Diag Pin Output Current	I_{DIAGL}	V_{DIAGL} = 0.5 V	–	–	1.25	mA
	I_{DIAGH}	V_{DIAGH} = V_{DD} – 0.5 V	–1.25	–	–	mA
Diag Pin Output Frequency	f_{DIAG}	During PWM off-time	–	90	–	kHz
PWM Minimum On-Time (Blanking Time)	$t_{on(min)}$		–	5	–	µs
PWM Off-Time	t_{POFF}	PWM operating	–	35	–	µs
OCP Minimum On-Time	t_{OON}	OCP operating	–	5	–	µs
OCP Off-Time	t_{OOFF}	OCP operating	–	142	–	µs
Crossover Current Delay Timing	t_{COCD}		150	–	750	ns
Switching Time	t_{con}	Measured from input to output on	–	3.0	–	µs
	t_{coff}	Measured from input to output off	–	2.7	–	µs
Thermal Shutdown Activation Temperature	T_{tsdon}	Package back side surface temperature after case permeated with heat from operation	–	140	–	ºC
Thermal Shutdown Release Temperature	T_{tsdoff}		–	115	–	ºC

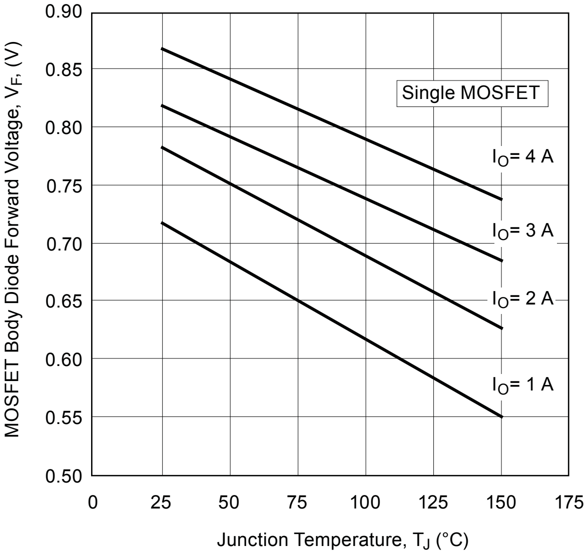
*The outputs will be disabled if any of the three undervoltage protection circuits are operating.

Characteristic Data

Output MOSFET On-Voltage, $V_{DS(on)}$



Output MOSFET Body Diodes Forward Voltage, V_F



Functional Description

Control IC (MIC) Functions

Regulator The regulator supplies the necessary operating power for the MOSFET gate drivers (see Pre-Driver section) and internal linear circuitry.

UVLO The main supply, logic supply, and charge pump all supply necessary operating power for proper operation. If any one of the supplies drop to the preset undervoltage lockout threshold, the outputs will be disabled.

Charge Pump The high-side gate pre-driver for the N-channel MOSFETs is powered from this charge pump, which operates at 100 kHz.

Pre-Driver This is the gate driver for the output N-channel MOSFETs. It is powered from the charge pump (high-side) or the internal regulator (low side).

Current Control and OCP The constant-current control and overcurrent protection circuitry reference the input voltages on the PWM_REF pin (for constant-current level) and OCP_REF (for overcurrent protection threshold). These functions use a fixed off-time control scheme.

OSC The oscillator is used for timing the current-control blanking time and PWM off-time.

Logic I/O Terminals

Motor Control Input Terminals (IN1, IN2) These are used to control the motor driver outputs to control the behavior of the motor, as shown in table 1. They have been designed with CMOS processes to ensure high input impedance. To help mitigate the effects of noise on these inputs, each terminal is internally fitted with a low-pass filter. These terminals are designed to be used with steady logic inputs (low or high).

Diagnostics Output Terminal (Diag) This logic output indicates normal operation, a fault condition, or PWM output off-time, as shown in table 2. To avoid damage, the Diag terminal must not be connected to the GND or supply terminals.

Table 1. Input Truth Table, PWM Control

Input		Output		Motor Function
IN1	IN2	OA	OB	
Low	Low	High Z	High Z	Free (coast)
High	Low	High	Low	Forward
Low	High	Low	High	Reverse
High	High	Low	Low	Brake

Table 2. Diag Terminal Output

Output	Indication
High	• No UVLO protection operating • Outputs ON
Pulse (approximately 90 kHz)	PWM off-time
Low	• Any UVLO protection operating • OCP operating • TSD operating

Basic Motor Control Functions

There are four states of motor output: free (coast), forward, reverse, and brake. This section describes the inputs and the MOSFET outputs that set these states.

Free (Coast) This state is set by low signals on both the IN1 and the IN2 logic inputs. All MOSFETs are turned off, and no current flows through the device to the motor. The motor is totally free to spin. The MOSFET states are shown in figure 1(A).

Forward This state is set by a high signal on the IN1 input and a low signal on the IN2 input. The high-side MOSFET on the OA side is turned on, and the low-side MOSFET on the OB side is turned on. Current flows through the device to drive motor rotation (the terms "forward" and "reverse" only serve to indicate opposite relative directions). The MOSFET states are shown in figure 1(B).

Reverse This state is set by a low signal on the IN1 input and a high signal on the IN2 input. The low-side MOSFET on the OA side is turned on, and the high-side MOSFET on the OB side is turned on. Current flows through the device to drive motor rotation (the terms "forward" and "reverse" only serve to indicate opposite relative directions). The MOSFET states are shown in figure 1(C).

Brake This state is set by high signals on both the IN1 and the IN2 logic inputs. Both high-side MOSFETs are turned off, and both low-side MOSFETs are turned on. The motor coils are shorted together providing resistance to rotation. The MOSFET states are shown in figure 1(D).

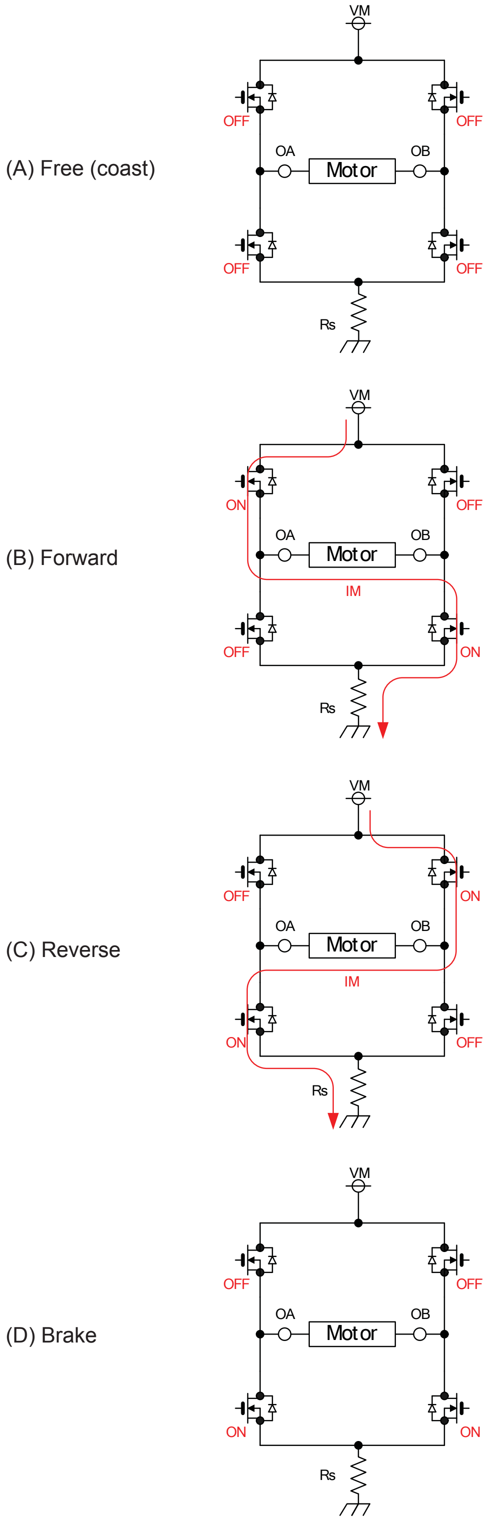


Figure 1. The panels demonstrate the MOSFET switching conditions and the resulting current flow for each of the four motor control states.

Constant-Current Control (PWM)

When the motor is starting up, the current, I_M, increases to the set current limit, as shown in figure 2. During operation, the motor current, I_M, is monitored using the voltage across resistor R_S, which is compared to the set point V_{PREF}.

When the current limit is reached, the device turns-off the high-side MOSFET and body-diode of the low-side MOSFET allows the back-EMF current to flow in the coil for 35 µs (Slow Decay mode), as shown in figure 3. After this time expires, the PWM control reverts to on. There is a blanking time of 5 µs during turn-on to prevent malfunction due to noise surges. During the blanking time, the current control does not operate, which means that the minimum on-time is also the blanking time.

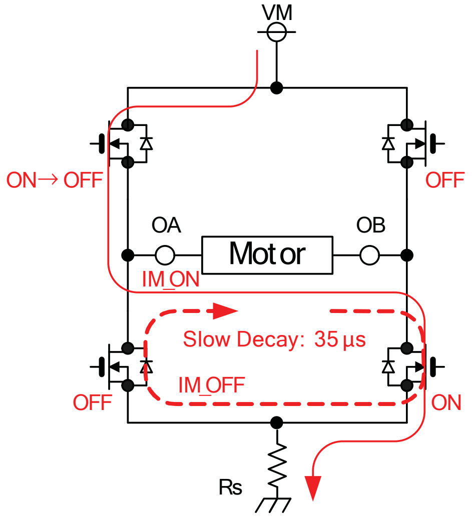


Figure 3. Currrent Control. The current path as current is rising is shown by the solid arrow (IM_ON), the off-time current is shown by the dashed arrow (IM_OFF).

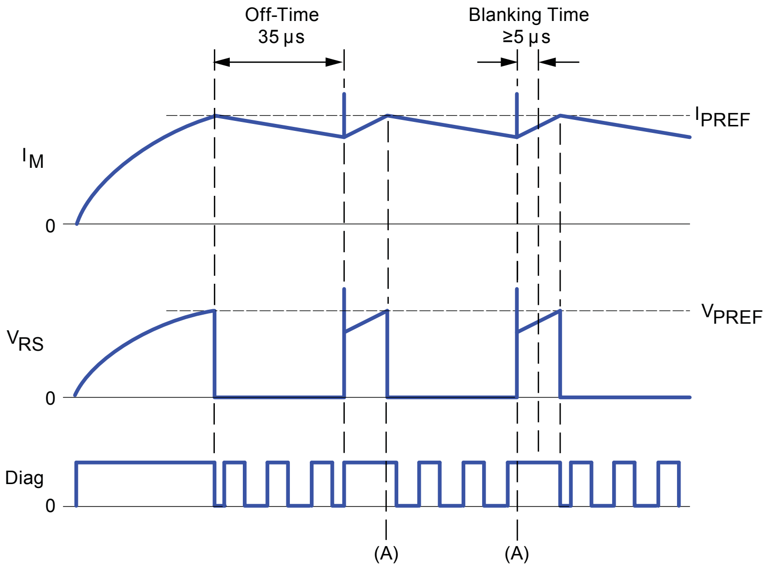


Figure 2. Currrent Control Waveforms. As can be seen at the points (A), PWM timing and Diag pin oscillation are NOT synchronous.

Phase PWM Control

The current-control method uses fixed off-time and blanking time, as detailed above. Even when the PWM_REF terminal is at a low voltage, however, the current will still flow, and increase, during the blanking time (minimum on-time). This minimal current, because of the fixed off-time, will only decay to a certain point. To enable current control below this minimal current level, the Phase PWM control method must be used. This is different from the PWM current control as detailed above, and external PWM signals with the correct on/off duty cycle must be used.

Phase PWM control has two modes, Fast Decay mode and Slow Decay Mode.

Fast Decay Mode This mode uses the Free motor state. In other words, during recirculation time, the IN1 and IN2 pins are both set low. During motor driving time, the current control point is determined by the duty cycle and frequency of the input signals:

- The input PWM signals must have an on-duty cycle greater than 50% for proper operation.
- The input PWM signals should have a recommended frequency of 30 to 50 kHz.

Motor rotation direction is determined by pulsing one or the other logic input, as shown in table 3. For the forward direction, current flows are shown in figure 4, and the input pulse and resulting current pulsing is shown in figure 5.

Another new method of control during recirculation, is to change the inputs shown in table 3, applying low signals instead of high (the pulsed signals remain as in the table). This method allows the driver to dissipate less heat by turning on the MOSFET for the back-EMF current decay instead of using the body diodes. This method is also known as Synchronous Rectifier control.

Table 3. Input Truth Table, Phase PWM Control

Input		Motor Function
IN1	**IN2**	
Fast Decay Mode		
PWM pulse	Low	Forward
Low	PWM pulse	Reverse
Slow Decay Mode		
PWM pulse	High	Forward
High	PWM pulse	Reverse

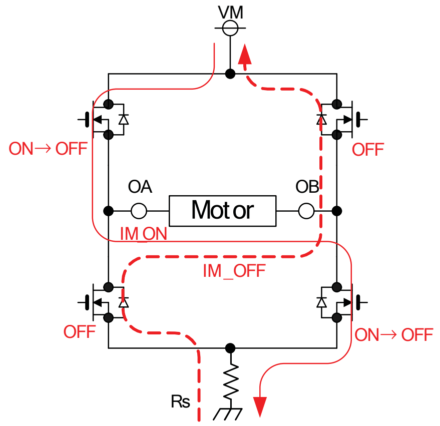


Figure 4. Phase PWM control (Fast Decay mode), current flows shown are for the forward direction

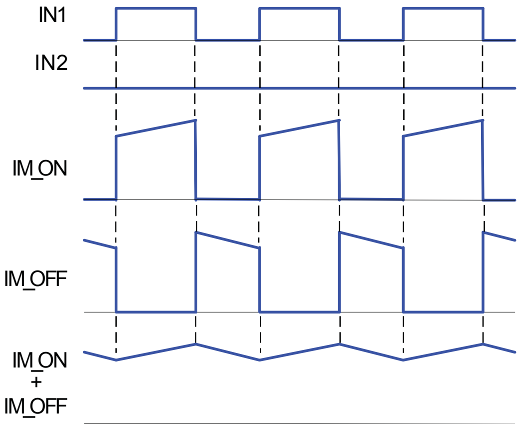


Figure 5. Phase PWM control (Fast Decay mode), logic input pulsing shown for the forward direction

Slow Decay Mode This mode uses the Brake motor state. In other words, during recirculation time, the IN1 and IN2 pins are both set high. During motor driving time, the current control point is determined by the duty cycle and frequency of the input signals:

- The input PWM signals must have an on-duty cycle less than 50% for proper operation.
- The input PWM signals should have a recommended frequency of 30 to 50 kHz.

Motor rotation direction is determined by pulsing one or the other logic input, as shown in table 3. For the forward direction, current flows are shown in figure 6, and the input pulse and resulting current pulsing is shown in figure 7.

Overcurrent Protection (OCP)

In the STA6940M, the overcurrent protection feature is designed to protect against rotor lock or coil short conditions. This protection is triggered when the motor current, I_M, as detected by the resistor R_S, reaches the set level of OCP_REF.

When the OCP threshold is reached, the driver turns-off all MOSFETs for 135 µs (figure 8). The decaying current must flow through the body diodes to the main supply (Fast Decay mode), as shown in figure 9.

Note: OCP operation does not disable the driver. OCP is flagged on the Diag pin, and the system logic of the application should control the response.

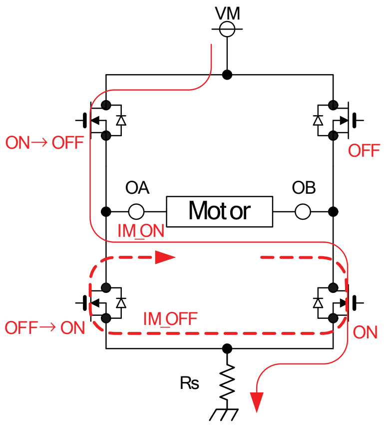


Figure 6. Phase PWM control (Slow Decay mode), current flows shown are for the forward direction

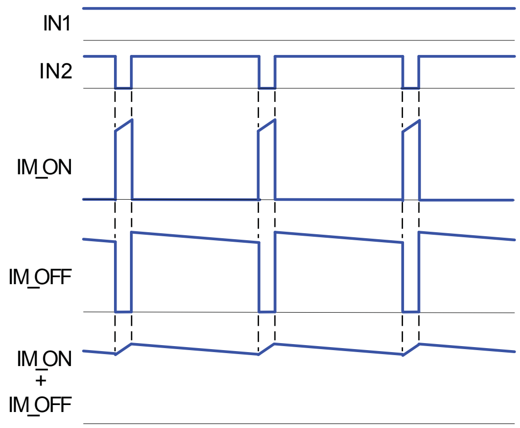


Figure 7. Phase PWM control (Slow Decay mode), logic input pulsing shown for the forward direction

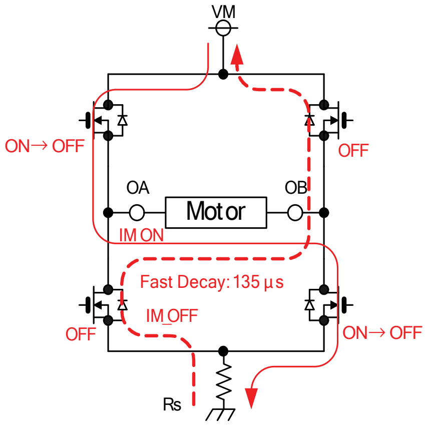


Figure 8. OCP operation (Fast Decay mode)

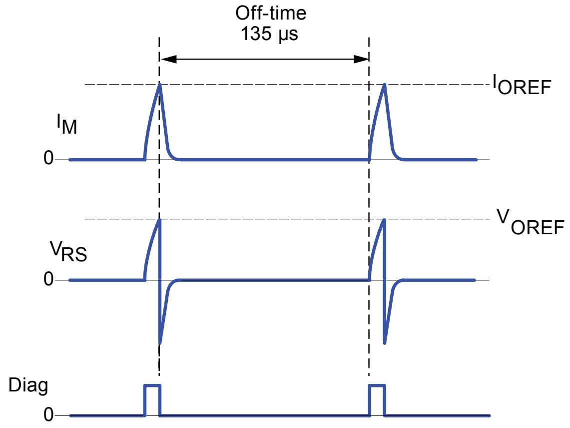


Figure 9. OCP operation waveforms (Fast Decay mode)

The constant-current set point, V_{PREF}, and the OCP threshold, V_{OREF}, may be set individually as needed.

- **$V_{PREF} < V_{OREF}$** With this relationship, constant-current control has priority. In order for OCP to operate, the OCP condition must be detected before the constant-current control is operating, that is, during the blanking time. During blanking time, the voltage V_{RS} could reach V_{OREF}, initiating OCP.
- **$V_{OREF} < V_{PREF}$** With this relationship, OCP has priority over constant-current control. At any time while the STA6940M is powered, if the voltage V_{RS} reaches V_{OREF}, OCP can operate.

Thermal Shutdown (TSD)

This device has internal thermal protection. The thermal shutdown function is of the auto-recovery type. The operating principle is that when the internal control IC (MIC) temperature reaches T_{tsdon} all outputs are disabled. When the temperature drops below T_{tsdoff} the device is reenabled.

When the device outputs are disabled, the function sets the Diag terminal low. Figure 10 shows the relationship of Diag output and case temperature, T_C.

Note: This device utilizes a multi-chip construction, the Control IC (MIC) and four separate MOSFETs. The temperature sensor is located on the control IC, however, the primary heat sources are the MOSFETs. Thus this internal thermal protection cannot react to sudden changes in MOSFET temperature.

Undervoltage Protection (UVLO)

If any of the voltages of the main supply, V_{BB}, logic supply, V_{DD}, or the charge pump, V_{CP} (V_{CP}-V_{BB}), fall below the preset threshold, the device will be disabled. (The charge pump voltage is derived from V_{BB} using the internal charge pump circuitry and connected capacitors.) The effects on output to the motor and to the Diag pin are shown in figure 11.

Note: The V_{BB} and V_{DD} voltage power-up sequence does not affect UVLO operation.

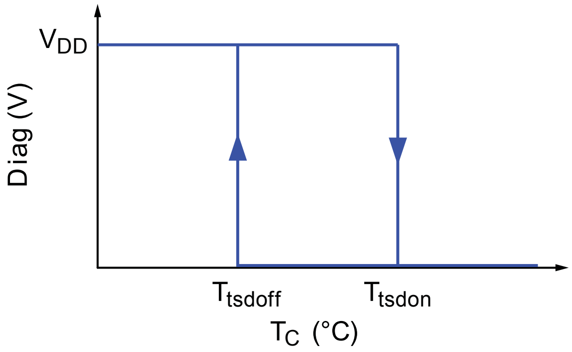


Figure 10. Thermal shutdown operation provides a hysteresis in supply voltage to the MOSFETs, which is monitored and sets the Diag pin output

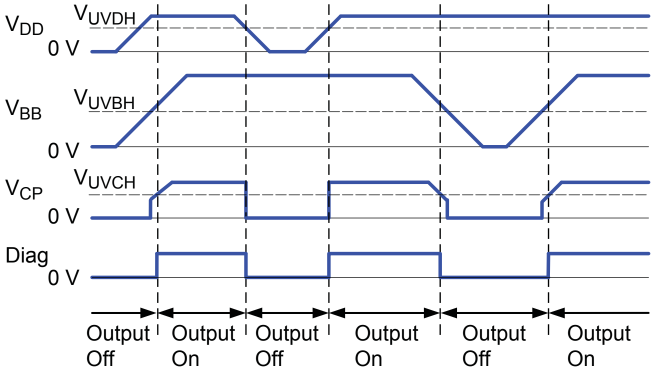


Figure 11. Operation of the UVLO circuits

Application Information

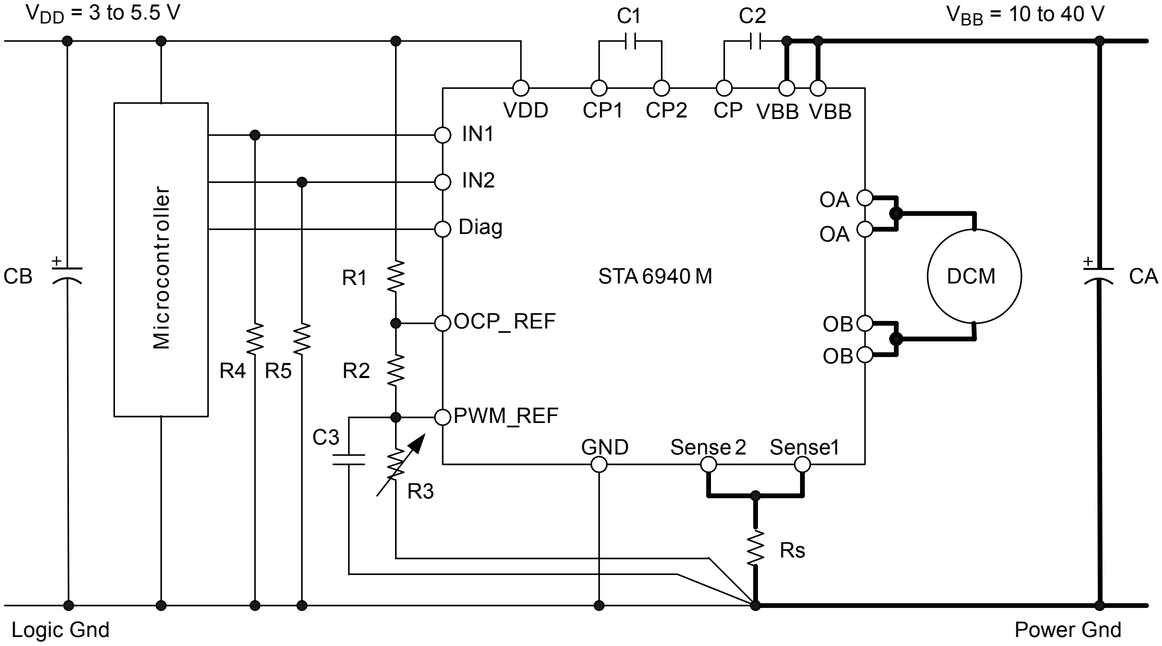


Figure 12. Typical application circuit

Reference Component Values

R1 = 3 kΩ R2 = 1 kΩ R3 = 1 kΩ R4 = 10 kΩ R5 = 10 kΩ *R_S = 0.22 Ω	CA = 100 μF / 50 V CB = 10 μF / 10 V C1 = 0.1 μF C2 = 0.1 μF C3 = 0.1 μF

*Please choose the proper power rating for R_S, taking into consideration the approximate power dissipation, as follows: $P_D \approx I_O^2 \times R_S \times$ On Duty Cycle.

- Surge voltage less than -1.0 V may occur on OA and OB outputs, therefore Schottky barrier diodes are recommended between those pins and GND
- Please take care to reduce noise on the VDD line.
- Noise voltages greater than 0.5 V on the VDD line may cause malfunction. Please take special care when laying out the return line and ground pattern.
- Separating IC GND (pin 10), VDD Gnd (signal ground) and VBB Gnd (power ground) helps reduce noise.
- Logic input terminals (IN1 and IN2) which are not externally controlled *must not* be left open; they should be pulled-up or pulled-down to the VDD or GND terminals, based on the required mode. Otherwise the device may malfunction.
- Unused logic output terminals (Diag) should be left open.
- The Sense1 and Sense2 terminals must be tied together, and then connected to R_S.
- Connecting only one of the Sensex terminals may result in damage to the device.

PWM Constant-Current Control Setting (R1, R2, R3, R_S)

The PWM fixed current control set point may be changed by using resistors R1, R2, R3 and R_S as shown in figure 12.

The formula for calculating Io is as follows:

$$I_O = V_{PREF} / R_S \quad , \tag{1}$$

where

$$V_{PREF} = \frac{R_3}{R_1 + R_2 + R_3} \times V_{DD} \quad . \tag{2}$$

If V_{PREF} is set below 0.1 V, external factors such as component tolerance and wiring impedances may affect the accuracy of the set current level.

The STA6940M uses a fixed off-time control scheme. During the off-time, the energy stored in the motor coils dissipates. If the set current point is too low, the motor current may become discontinuous and the motor torque will be greatly reduced as a result. Please take this into consideration when setting the minimal current level. Although setting such a low current level does not damage the device, the control of the set current level will become worse. This is illustrated in figure 13.

OCP Point Setting

The formula for setting the OCP point is the similar to that for constant-current, but using V_{OREF}:

$$I_{OCP} = V_{OREF} / R_S \quad , \tag{3}$$

where

$$V_{OREF} = \frac{R_2 + R_3}{R_1 + R_2 + R_3} \times V_{DD} \quad . \tag{4}$$

Power Supply (VBB, VDD) On/Off Sequence

This device will operate normally regardless of the power-up sequence of the power supplies.

Internal Logic Circuitry Connection

The following guidelines should be followed when connecting the internal circuitry:

- **Input Logic Terminals (IN1, IN2)** These terminals require a fixed logic level, and when they are unused, they should not be left open. They should be connected to VDD or GND as necessary.
- **Output Terminal (Diag)** The Diag terminal has an internal equivalent circuit as shown in figure 14. Because this is a CMOS circuit structure, if the terminal is not being used it should be left open.

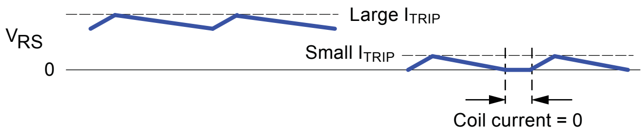


Figure 13. Minimum controllable current level

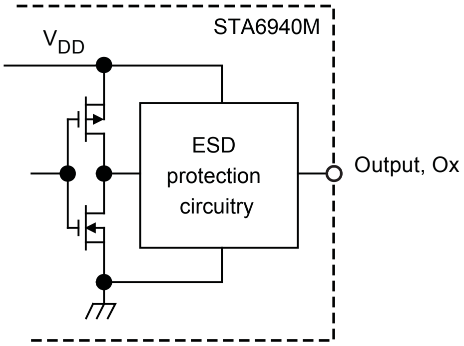


Figure 14. Diag terminal equivalent circuit

Thermal Considerations

To accurately calculate the losses incurred by the STA6940M, detailed knowledge of the motor characteristics, input waveforms, and dynamic properties of the circuit must all be considered. The formulas below are simplified approximations using worst-case conditions:

For constant voltage drive (DC current):

$$P_D = I_O^2 \times R_{DS(on)} \times 2 \;, \qquad (5)$$

and, for constant-current drive (PWM):

$$P_D = I_O^2 \times R_{DS(on)} \times 2 \times \frac{t_{ON}}{t_{ON}+t_{OFF}} + (\, I_O^2 \times \mathrm{R}_{DS(on)} + V_F \times I_O\,) \times \frac{t_{OFF}}{t_{ON}+t_{OFF}} \;, \qquad (6)$$

where:

$\mathrm{P_D}$ is the device power dissipation,

$\mathrm{I_O}$ is the motor current (≈ $\mathrm{I_O}$),

$\mathrm{R_{DS(on)}}$ is the internal MOSFET on-resistance,

$\mathrm{R_S}$ is the external sensing resistor,

$\mathrm{V_F}$ is the internal MOSFET body diode forward voltage,

$\mathrm{t_{ON}}$ is the PWM on-time, and

$\mathrm{t_{OFF}}$ is the PWM off-time.

Using the above calculated power dissipation, it is possible to estimate the junction temperature using the curves in figure 15. In the worst conditions (with high ambient temperatures), as long as the junction temperature does not exceed 150ºC the device will not be damaged. However, the actual temperature of the device should be measured along with the junction temperature calculation.

If a heatsink is being used, the $\Delta \mathrm{T_{JA}}$ (junction to ambient) as calculated previously will be different because the thermal resistance, $\mathrm{R_{\theta JA}}$, is different. The new value can be calculated using the heatsink heat resistance $\mathrm{R_{\theta FIN}}$:

$$R_{\theta JA} \approx R_{\theta JC} + R_{\theta FIN} = (R_{\theta JA} - R_{\theta CA}) + R_{\theta FIN} \;. \qquad (7)$$

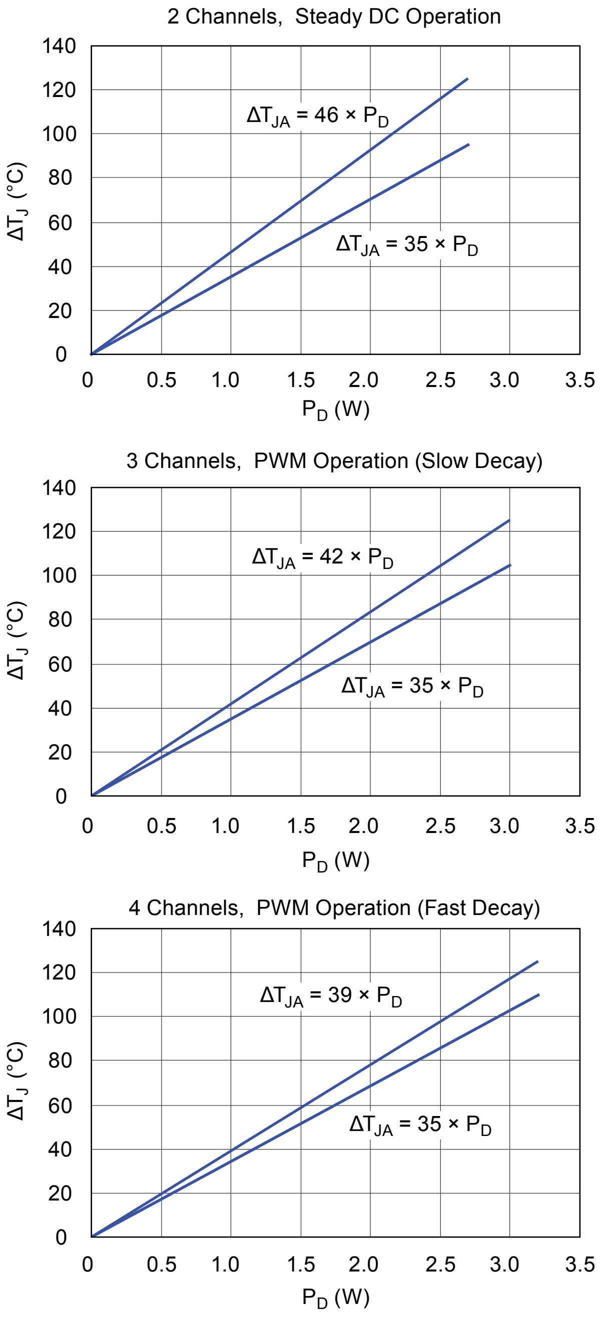


Figure 15. Change in junction temperature versus device power dissipation

To extrapolate the junction temperature, ΔT_J, using a measured device temperature, please use the following method:

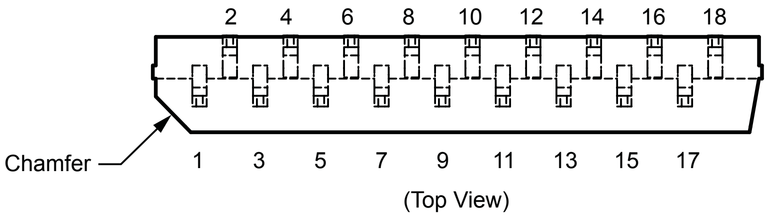
1. Measure the ambient temperature, T_A.
2. With the device mounted but not operating, measure the surface temperature of the device on the back side at the center.
3. Power-on the device, and after it reaches operating temperature, take the measurement again.
4. Subtract the value found in step 2 from the value found in step 3. This provides a value for ΔT_{CA}.
5. Refer to figure 15 and locate the value found in step 4 on the ΔT_{CA} trace.
6. Determine the corresponding power dissipation, P_D.
7. Substitute the values into the following equation:

$$\Delta T_J = \Delta T_{CA} + P_D \times R_{\theta JC} \quad (8)$$

Important notes:

- Please ensure that the maximum rated junction temperature (150ºC) will not be exceeded.
- The information provided above is to be used as reference for the design phase. The actual product must undergo empirical testing to ensure proper thermal design.
- The recommended maximum operating temperature for this device, without a heatsink is T_C = 80ºC maximum.

Pin-out Diagram

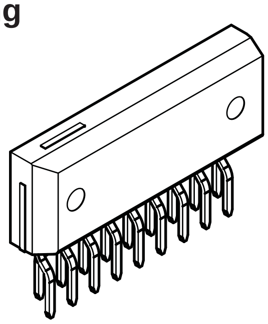


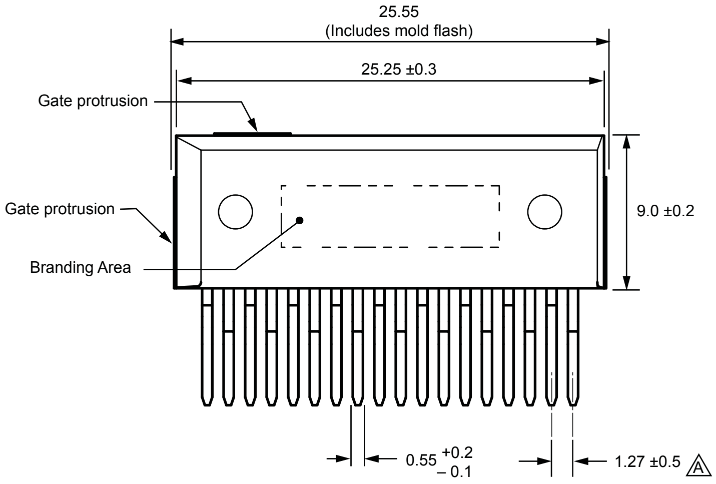
Terminal List Table

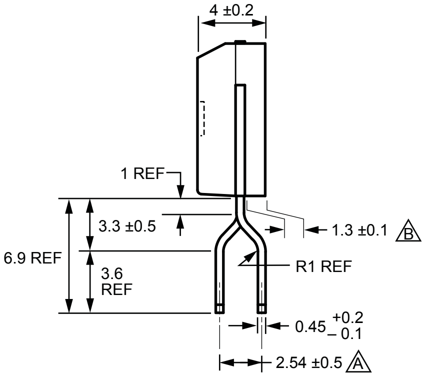
Number	Symbol	Function
1	VBB	Main supply input (motor supply)
2	OA	Motor terminal A
3		
4	Sense1	Motor current sensing
5	IN1	Control mode setting (please see truth table)
6	IN2	
7	VDD	Logic supply
8	PWM_REF	Constant-current setting
9	OCP_REF	Overcurrent setting
10	GND	Ground
11	Diag	PWM diagnostic and OCP output
12	CP2	Connection for charge pump
13	CP1	
14	CP	
15	Sense2	Motor overcurrent sensing
16	OB	Motor terminal B
17		
18	VBB	Main supply input (motor supply)

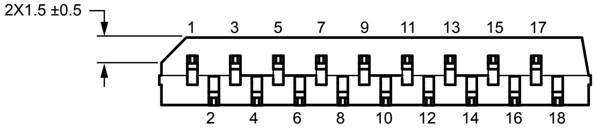
*The VBB terminals, 1 and 18, are internally connected.

Package Outline Drawing









△A Measured at pin tips
△B Measured at case base

Terminal core material: Cu
Terminal plating: Ni, with Pb-free solder coating

Dimensions in millimeters

Branding codes (exact appearance at manufacturer discretion):
1st line, type: STA6940M
2nd line, lot: *YMDD*
Where: Y is the last digit of the year of manufacture
M is the month (*1* to *9*, *O*, *N*, *D*)
DD is the date

Leadframe plating Pb-free. Device composition includes high-temperature solder (Pb >85%), which is exempted from the RoHS directive.

Because reliability can be affected adversely by improper storage environments and handling methods, please observe the following cautions.

Cautions for Storage

- Ensure that storage conditions comply with the standard temperature (5°C to 35°C) and the standard relative humidity (around 40 to 75%); avoid storage locations that experience extreme changes in temperature or humidity.
- Avoid locations where dust or harmful gases are present and avoid direct sunlight.
- Reinspect for rust on leads and solderability of products that have been stored for a long time.

Cautions for Testing and Handling

When tests are carried out during inspection testing and other standard test periods, protect the products from power surges from the testing device, shorts between adjacent products, and shorts to the heatsink.

Remarks About Using Silicone Grease with a Heatsink

- When silicone grease is used in mounting this product on a heatsink, it shall be applied evenly and thinly. If more silicone grease than required is applied, it may produce stress.
- Coat the back surface of the product and both surfaces of the insulating plate to improve heat transfer between the product and the heatsink.
- Volatile-type silicone greases may permeate the product and produce cracks after long periods of time, resulting in reduced heat radiation effect, and possibly shortening the lifetime of the product.
- Our recommended silicone greases for heat radiation purposes, which will not cause any adverse effect on the product life, are indicated below:

Type	Suppliers
G746	Shin-Etsu Chemical Co., Ltd.
YG6260	Momentive Performance Materials, Inc.
SC102	Dow Corning Toray Silicone Co., Ltd.

Soldering

- When soldering the products, please be sure to minimize the working time, within the following limits:

  260±5°C 10 s

  350±5°C 3 s
- Soldering iron should be at a distance of at least 1.5 mm from the body of the products

Electrostatic Discharge

- When handling the products, operator must be grounded. Grounded wrist straps worn should have at least 1 MΩ of resistance to ground to prevent shock hazard.
- Workbenches where the products are handled should be grounded and be provided with conductive table and floor mats.
- When using measuring equipment such as a curve tracer, the equipment should be grounded.
- When soldering the products, the head of soldering irons or the solder bath must be grounded in other to prevent leak voltages generated by them from being applied to the products.
- The products should always be stored and transported in our shipping containers or conductive containers, or be wrapped in aluminum foil.

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  In addition, it should be noted that since power devices or IC's including power devices have large self-heating value, the degree of derating of junction temperature affects the reliability significantly.
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