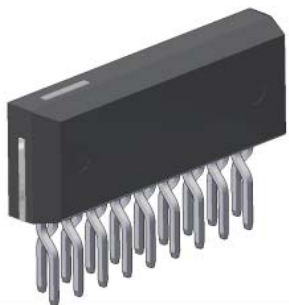


## Features and Benefits

- Package: 18-pin ZIP (STA)**



*Not to scale*

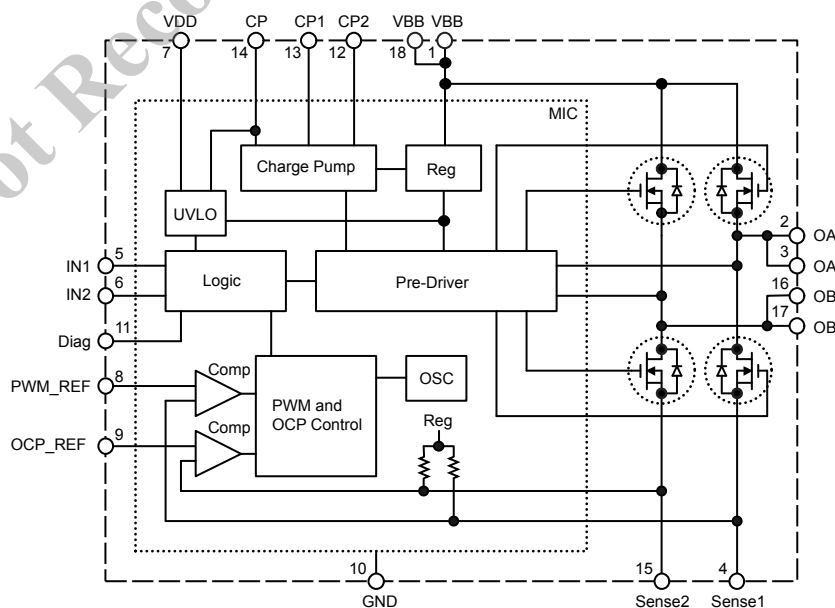
Combining low-power CMOS-compatible logic with high-current, high-voltage power MOSFET outputs, the STA6940M provides complete control and drive for brush DC motors. It provides internal fixed off time, pulse-width modulation (PWM) control of the output current, rated for 4 A normal operating level.

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

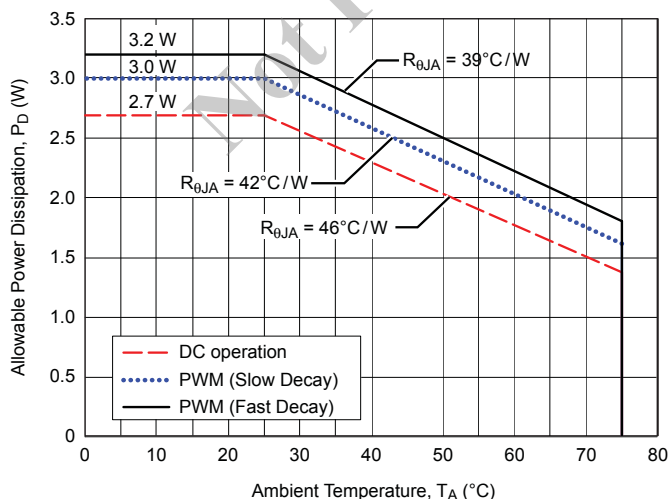
## Absolute Maximum Ratings

| Characteristic                | Symbol            | Notes                        | Rating                          | Units |
|-------------------------------|-------------------|------------------------------|---------------------------------|-------|
| Main Supply Voltage           | $V_{BB}$          |                              | 44                              | V     |
| Logic Supply Voltage          | $V_{DD}$          |                              | 6                               | V     |
| Output Current                | $I_O(\text{max})$ | $\leq 100 \mu\text{s}$       | 8                               | A     |
| Output Voltage                | $V_O$             |                              | $-1.5 \text{ to } V_{BB} + 1.5$ | V     |
| Logic Input Voltage           | $V_{IN}$          |                              | $-0.3 \text{ to } V_{DD} + 0.3$ | V     |
| PWM_REF Input Voltage         | $V_{PREF}$        |                              | $-0.3 \text{ to } V_{DD} + 0.3$ | V     |
| OCP_REF Input Voltage         | $V_{OREF}$        |                              | $-0.3 \text{ to } V_{DD} + 0.3$ | V     |
| Sensing Voltage               | $V_{RS}$          | Except $t_w < 1 \mu\text{s}$ | -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                             | °C    |
| Operating Ambient Temperature | $T_A$             |                              | -20 to 85                       | °C    |
| Storage Temperature           | $T_{stg}$         |                              | -30 to 150                      | °C    |

## 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 $\pm 0.5 \text{ V}$ | 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 Dissipation Curve



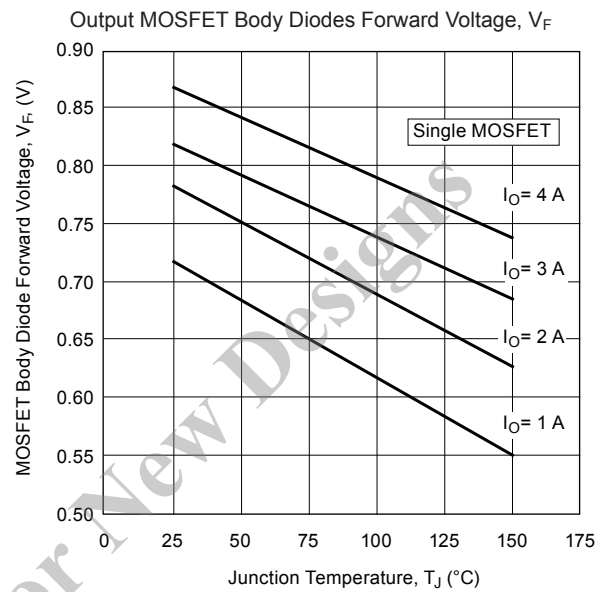
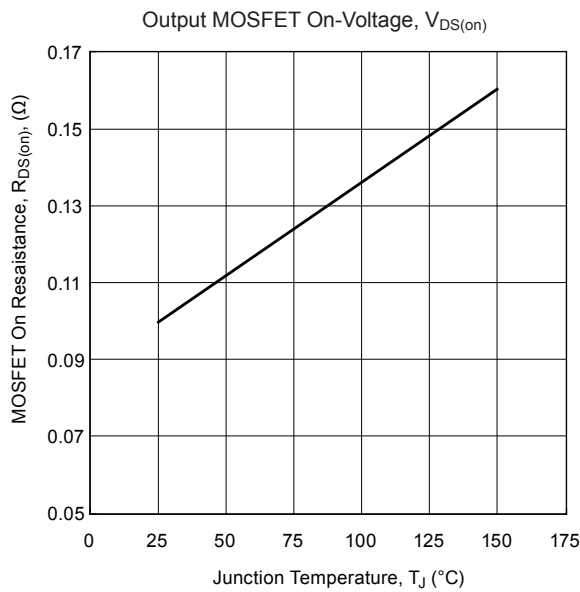
All performance characteristics given are typical values for circuit or system baseline design only and are at the nominal operating voltage and an ambient temperature,  $T_A$ , of 25°C, unless otherwise stated.

**ELECTRICAL CHARACTERISTICS** valid at  $T_A = 25^\circ\text{C}$ ,  $V_{BB} = 24\text{ V}$ ,  $V_{DD} = 5\text{ V}$ ; 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                     | $V_{CP}$      | $V_{BB} = 10\text{ to }40\text{ V}$   | –                    | $V_{BB} + 5$       | –                    | 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                    | $R_{DS(on)}$  | $I_D = 4\text{ A}$  | –                    | 0.1                | 0.13                 | $\Omega$         |
| MOSFET Body Diode Forward Voltage       | $V_F$         | $I_F = 4\text{ A}$  | –                    | 0.95               | –                    | V                |
| MOSFET Breakdown Voltage                | $V_{DSS}$     |   | 53                   | –                  | –                    | V                |
| Logic Input Voltage                     | $V_{IL}$      |   | –                    | –                  | $0.25 \times V_{DD}$ | V                |
|   | $V_{IH}$      |   | $0.75 \times V_{DD}$ | –                  | –                    | V                |
| Logic Input Current                     | $I_{IL}$      |   | –                    | $\pm 1$            | –                    | $\mu\text{A}$    |
|   | $I_{IH}$      |   | –                    | $\pm 1$            | –                    | $\mu\text{A}$    |
| 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               | $I_{PREF}$    |   | –                    | $\pm 10$           | –                    | $\mu\text{A}$    |
| OCP_REF Pin Input Voltage               | $V_{OREF}$    | OCP_REF terminal  | 0.1                  | –                  | 2.0                  | V                |
| OCP_REF Pin Input Current               | $I_{OREF}$    |   | –                    | $\pm 10$           | –                    | $\mu\text{A}$    |
| 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  | –                    | $\pm 20$           | –                    | $\mu\text{A}$    |
| Diag Pin Output Voltage                 | $V_{DIAGL}$   | $I_{DIAGL} = 1.25\text{ mA}$  | –                    | –                  | 1.25                 | V                |
|   | $V_{DIAGH}$   | $I_{DIAGH} = -1.25\text{ mA}$   | $V_{DD} - 1.25$      | –                  | –                    | V                |
| Diag Pin Output Current                 | $I_{DIAGL}$   | $V_{DIAGL} = 0.5\text{ V}$  | –                    | –                  | 1.25                 | mA               |
|   | $I_{DIAGH}$   | $V_{DIAGH} = V_{DD} - 0.5\text{ V}$   | -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                  | –                    | $\mu\text{s}$    |
| PWM Off-Time                            | $t_{POFF}$    | PWM operating   | –                    | 35                 | –                    | $\mu\text{s}$    |
| OCP Minimum On-Time                     | $t_{OON}$     | OCP operating   | –                    | 5                  | –                    | $\mu\text{s}$    |
| OCP Off-Time                            | $t_{OOFF}$    | OCP operating   | –                    | 142                | –                    | $\mu\text{s}$    |
| Crossover Current Delay Timing          | $t_{COCD}$    |   | 150                  | –                  | 750                  | ns               |
| Switching Time                          | $t_{con}$     | Measured from input to output on  | –                    | 3.0                | –                    | $\mu\text{s}$    |
|   | $t_{coff}$    | Measured from input to output off   | –                    | 2.7                | –                    | $\mu\text{s}$    |
| Thermal Shutdown Activation Temperature | $T_{tsdon}$   | Package back side surface temperature after case permeated with heat from operation | –                    | 140                | –                    | $^\circ\text{C}$ |
| Thermal Shutdown Release Temperature    | $T_{tsdoff}$  |   | –                    | 115                | –                    | $^\circ\text{C}$ |

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

Characteristic Data



## 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                         | <ul style="list-style-type: none"> <li>No UVLO protection operating</li> <li>Outputs ON</li> </ul>                            |
| Pulse (approximately 90 kHz) | PWM off-time  |
| Low                          | <ul style="list-style-type: none"> <li>Any UVLO protection operating</li> <li>OCP operating</li> <li>TSD operating</li> </ul> |

## 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).

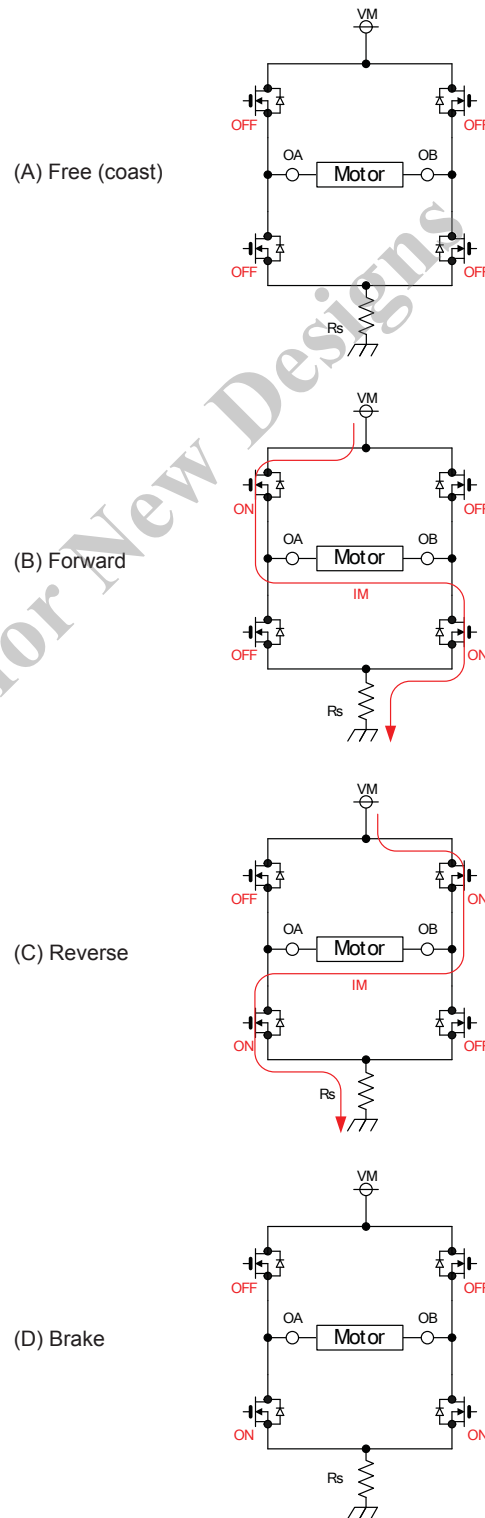


Figure 1. The panels demonstrate the MOSFET switching conditions and the resulting current flow for each of the four motor control states.

## 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  $35\ \mu\text{s}$  (Slow Decay mode), as shown in figure 3. After this time expires, the PWM control reverts to on. There is a blanking time of  $5\ \mu\text{s}$  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.

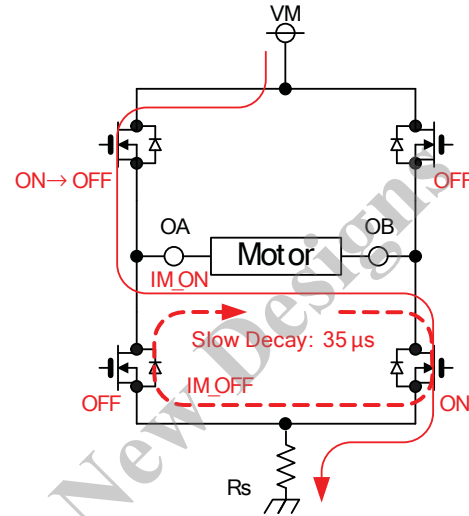


Figure 3. Current Control. The current path as current is rising is shown by the solid arrow ( $I_{M\_ON}$ ), the off-time current is shown by the dashed arrow ( $I_{M\_OFF}$ ).

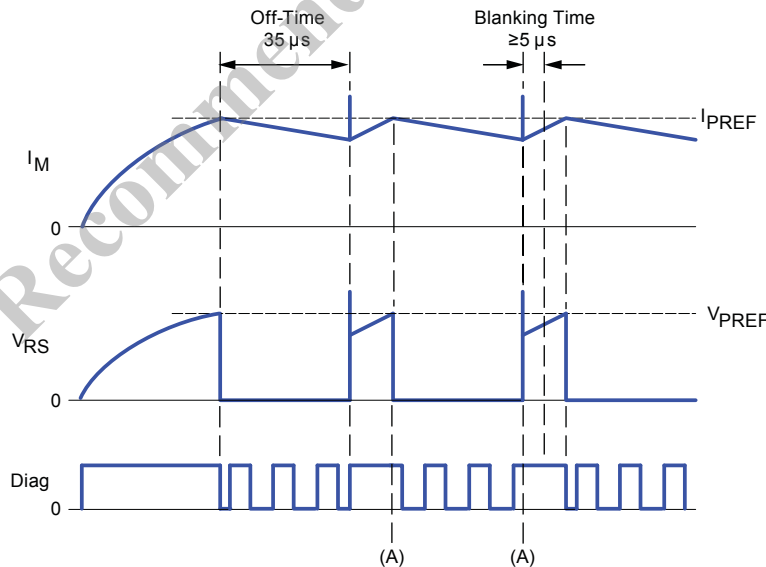


Figure 2. Current Control Waveforms. As can be seen at the points (A), PWM timing and Diag pin oscillation are NOT synchronous.

## 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.

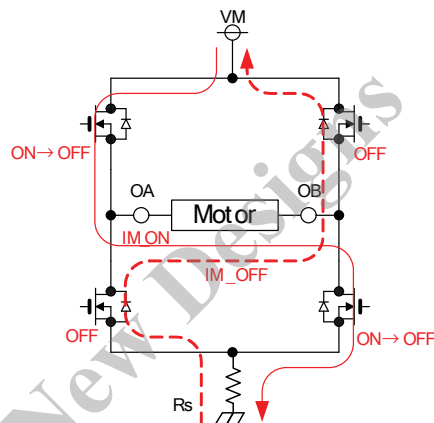


Figure 4. Phase PWM control (Fast Decay mode), current flows shown are for the forward direction

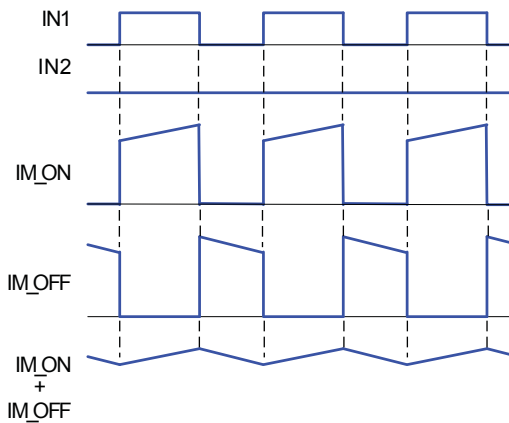


Figure 5. Phase PWM control (Fast Decay mode), logic input pulsing shown for the forward direction

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        |



**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.

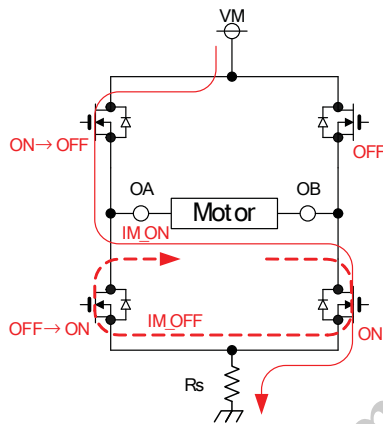


Figure 6. Phase PWM control (Slow Decay mode), current flows shown are for the forward direction

## 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  $\mu$ s (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.

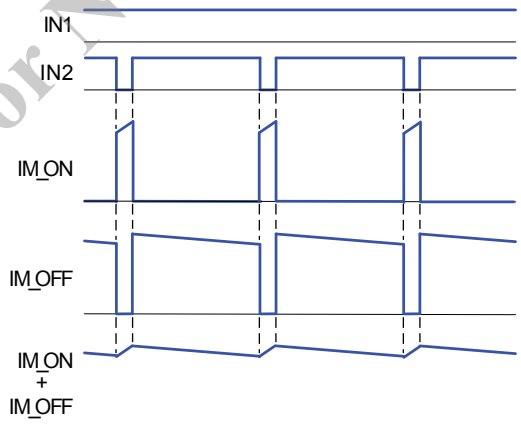


Figure 7. Phase PWM control (Slow Decay mode), logic input pulsing shown for the forward direction

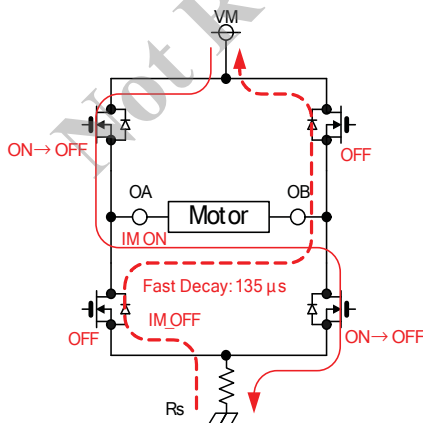


Figure 8. OCP operation (Fast Decay mode)

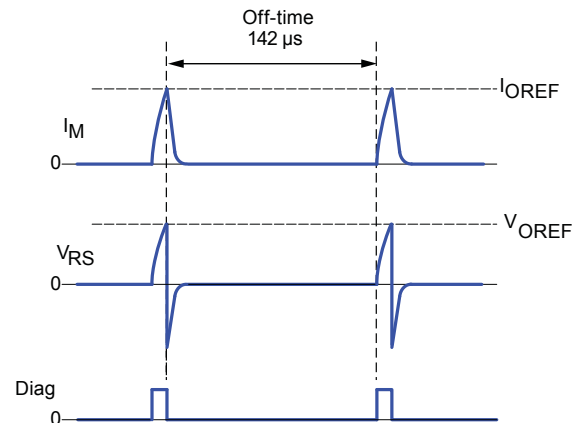


Figure 9. OCP operation waveforms (Fast Decay mode)

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.

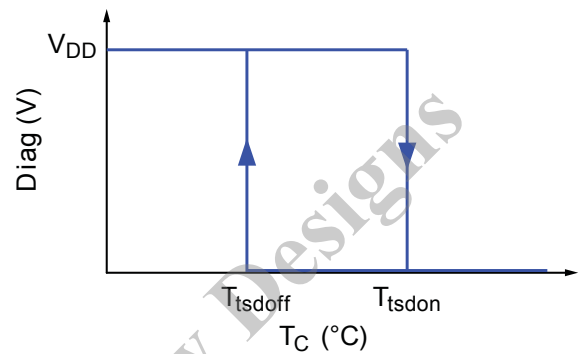


Figure 10. Thermal shutdown operation provides a hysteresis in supply voltage to the MOSFETs, which is monitored and sets the Diag pin output

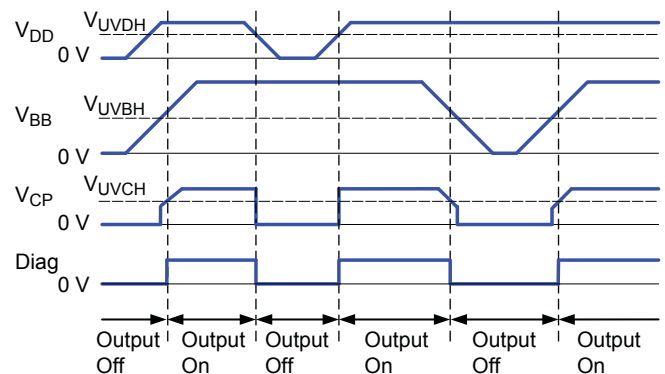


Figure 11. Operation of the UVLO circuits

## Application Information

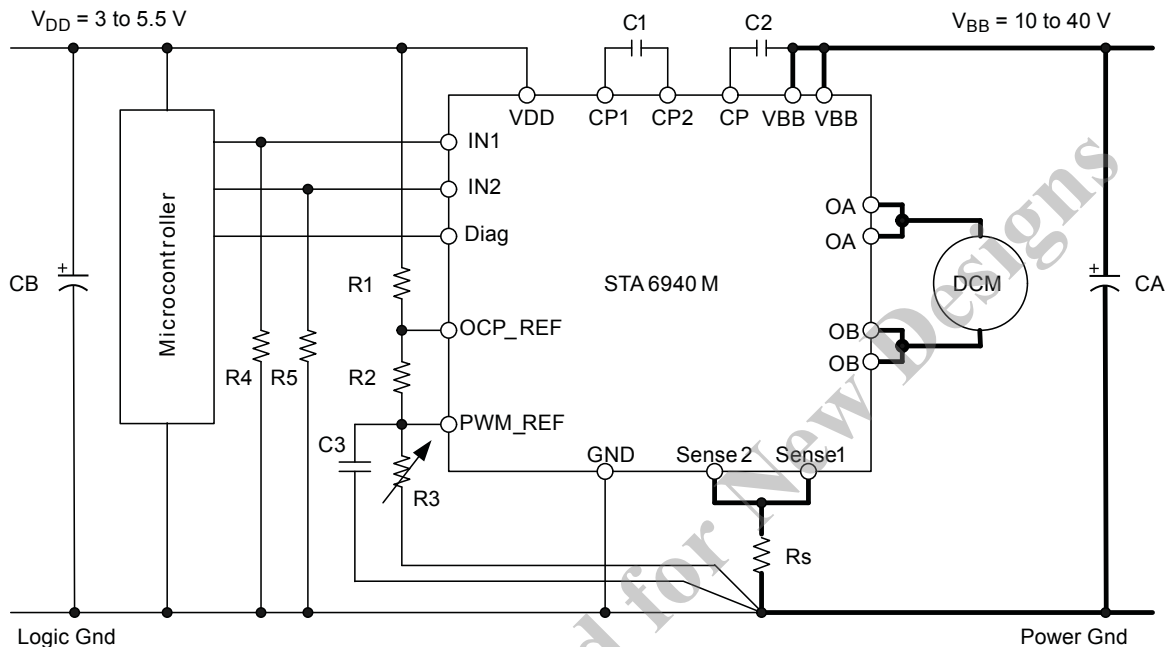


Figure 12. Typical application circuit

### Reference Component Values

|                                 |                         |
|---------------------------------|-------------------------|
| R1 = 3 k $\Omega$               | CA = 100 $\mu$ F / 50 V |
| R2 = 1 k $\Omega$               | CB = 10 $\mu$ F / 10 V  |
| R3 = 1 k $\Omega$               | C1 = 0.1 $\mu$ F        |
| R4 = 10 k $\Omega$              | C2 = 0.1 $\mu$ F        |
| R5 = 10 k $\Omega$              | C3 = 0.1 $\mu$ F        |
| *R <sub>S</sub> = 0.22 $\Omega$ |                         |

\*Please choose the proper power rating for R<sub>S</sub>, taking into consideration the approximate power dissipation, as follows:  $P_D \approx I_O^2 \times R_S \times \text{On Duty Cycle}$ .

- 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 ground (signal ground) and VBB ground (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<sub>S</sub>.
- Connecting only one of the Sensex terminals may result in damage to the device.

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

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

The formula for calculating IO is as follows:

$$I_O = V_{PREF} / R_S \quad (1)$$

where

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

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  $V_{OREF}$ :

$$I_{OCP} = V_{OREF} / R_S \quad (3)$$

where

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

## Power Supply (VBB, VDD) On/Off Sequence

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

However, note that the VDD pin must not be set to 3 V or less when the IC operation remains stopped while a voltage is applied to the VBB pin.

## 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.

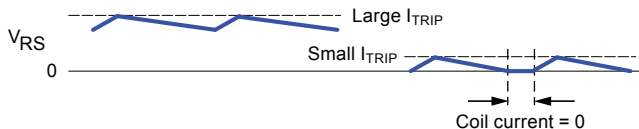


Figure 13. Minimum controllable current level

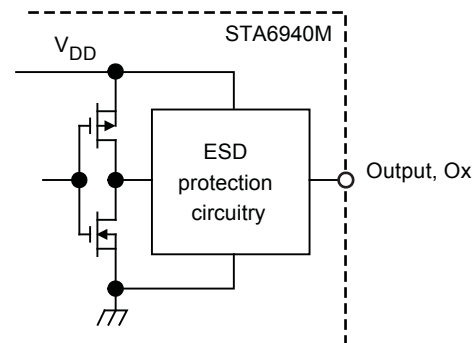


Figure 14. Diag terminal equivalent circuit

## 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):

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

and, for constant-current drive (PWM):

$$P_D = I_O^2 \times R_{DS(on)} \times 2 \times \frac{t_{ON}}{t_{ON} + t_{OFF}} + (I_O^2 \times R_{DS(on)} + V_F \times I_O) \times \frac{t_{OFF}}{t_{ON} + t_{OFF}} \quad (6)$$

where:

$P_D$  is the device power dissipation,

$I_O$  is the motor current ( $\approx I_{O1}$ ),

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

$R_S$  is the external sensing resistor,

$V_F$  is the internal MOSFET body diode forward voltage,

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

$t_{OFF}$  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 150°C 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  $\Delta T_{JA}$  (junction to ambient) as calculated previously will be different because the thermal resistance,  $R_{\theta JA}$ , is different. The new value can be calculated using the heatsink heat resistance  $R_{\theta FIN}$ :

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

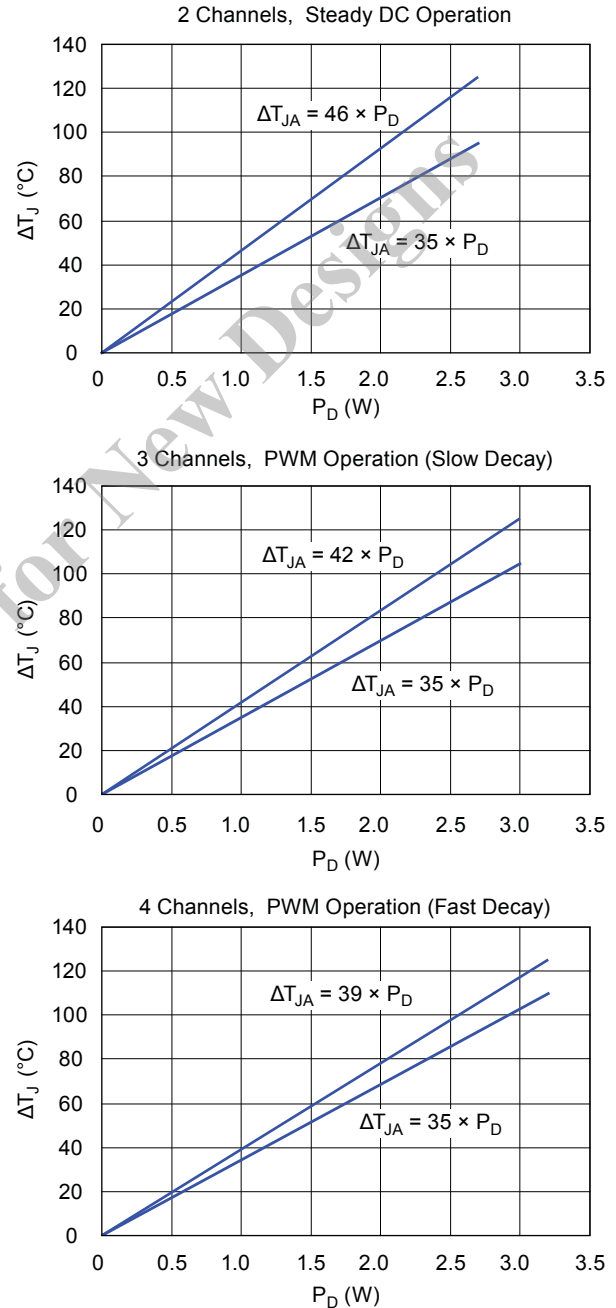


Figure 15. Change in junction temperature versus device power dissipation

To extrapolate the junction temperature,  $\Delta T_J$ , using a measured device temperature, please use the following method:

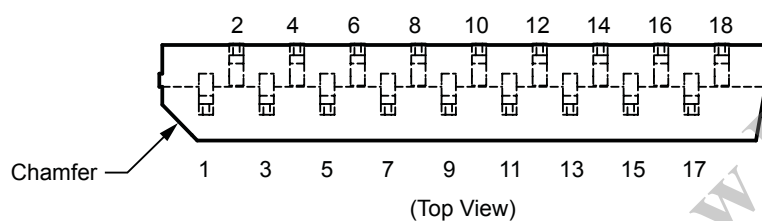
1. Measure the ambient temperature,  $T_A$ .
2. With the device mounted but not operating, measure the surface temperature of the device on the back side at the center.
3. Power-on the device, and after it reaches operating temperature, take the measurement again.
4. Subtract the value found in step 2 from the value found in step 3. This provides a value for  $\Delta T_{CA}$ .
5. Refer to figure 15 and locate the value found in step 4 on the  $\Delta T_{CA}$  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:

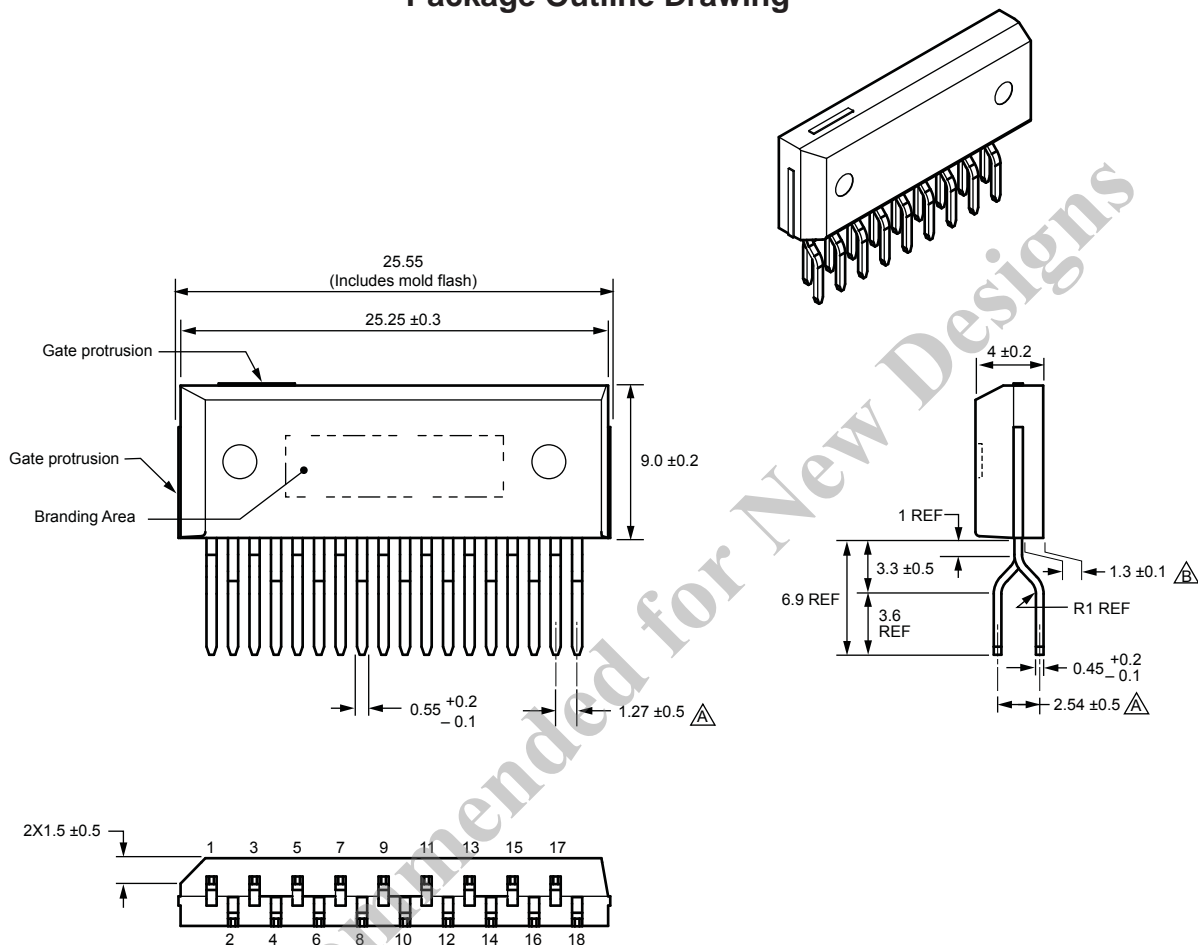
- Please ensure that the maximum rated junction temperature (150°C) will not be exceeded.
- The information provided above is to be used as reference for the design phase. The actual product must undergo empirical testing to ensure proper thermal design.
- The recommended maximum operating temperature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



- △ Measured at pin tips
- △ 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 order 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.

- 
- The contents in this document are subject to changes, for improvement and other purposes, without notice. Make sure that this is the latest revision of the document before use.
  - Application and operation examples described in this document are quoted for the sole purpose of reference for the use of the products herein and Sanken can assume no responsibility for any infringement of industrial property rights, intellectual property rights or any other rights of Sanken or any third party which may result from its use.
  - Although Sanken undertakes to enhance the quality and reliability of its products, the occurrence of failure and defect of semiconductor products at a certain rate is inevitable. Users of Sanken products are requested to take, at their own risk, preventative measures including safety design of the equipment or systems against any possible injury, death, fires or damages to the society due to device failure or malfunction.
  - Sanken products listed in this document are designed and intended for the use as components in general purpose electronic equipment or apparatus (home appliances, office equipment, telecommunication equipment, measuring equipment, etc.).

When considering the use of Sanken products in the applications where higher reliability is required (transportation equipment and its control systems, traffic signal control systems or equipment, fire/crime alarm systems, various safety devices, etc.), and whenever long life expectancy is required even in general purpose electronic equipment or apparatus, please contact your nearest Sanken sales representative to discuss, prior to the use of the products herein.

The use of Sanken products without the written consent of Sanken in the applications where extremely high reliability is required (aerospace equipment, nuclear power control systems, life support systems, etc.) is strictly prohibited.

- In the case that you use Sanken products or design your products by using Sanken products, the reliability largely depends on the degree of derating to be made to the rated values. Derating may be interpreted as a case that an operation range is set by derating the load from each rated value or surge voltage or noise is considered for derating in order to assure or improve the reliability. In general, derating factors include electric stresses such as electric voltage, electric current, electric power etc., environmental stresses such as ambient temperature, humidity etc. and thermal stress caused due to self-heating of semiconductor products. For these stresses, instantaneous values, maximum values and minimum values must be taken into consideration.

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.

- When using the products specified herein by either (i) combining other products or materials therewith or (ii) physically, chemically or otherwise processing or treating the products, please duly consider all possible risks that may result from all such uses in advance and proceed therewith at your own responsibility.
- Anti radioactive ray design is not considered for the products listed herein.
- Sanken assumes no responsibility for any troubles, such as dropping products caused during transportation out of Sanken's distribution network.
- The contents in this document must not be transcribed or copied without Sanken's written consent.