# SA8875

## 6.5-40.0V 6.5A Brushed DC Motor Driver (PWM Control)

## Description

The SA8875 device is a brushed-DC motor driver for robotics, appliances, industrial equipment, and other small machines. Two logic inputs control the H-bridge driver, which consists of four N-channel MOSFETs that can control motors bidirectionally with up to 6.5A peak current. The inputs can be pulse width modulated (PWM) to control motor speed, using a choice of current-decay modes. Setting both inputs low enter a low-power sleep mode.

The SA8875 device features integrated current regulation, based on the analog input VREF and the voltage on the ISEN pin, which is proportional to motor current through an external sense resistor. The ability to limit current to a known level can significantly reduce the system power requirements and bulk capacitance needed to maintain stable voltage, especially for motor startup and stall conditions.

The device is fully protected from faults and short circuits, including undervoltage (UVLO), overcurrent (OCP), and overtemperature (TSD). When the fault condition is removed, the device automatically resumes normal operation.

## Features

- 6.5 to 40.0 V Operating Voltage
- 200-mΩ Typical $R_{DSON}$ (HS + LS)
- 6.5A Peak Current Drive
- PWM Control Interface
- Integrated Current Regulation
- Low-Power Sleep Mode
- H-Bridge Motor Driver
  – Drives One DC Motor, One Winding of a Stepper Motor, or Other Loads
- **Integrated Protection Features**
  – VM Undervoltage Lockout (UVLO)
  – Overcurrent Protection (OCP)
  – Thermal Shutdown (TSD)
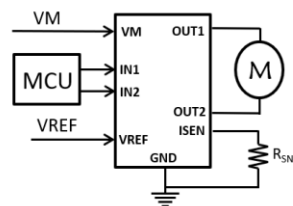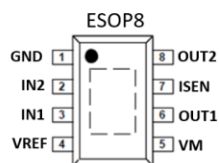  – Automatic Fault Recovery
- ESOP8 Package Available

## Applications

- Robotics (Sweeping robot, R/C servo)
- 2-4 Li Battery Motor Applications
- Appliances
- Industrial Equipment
- Any Relevant DC Motor Applications.
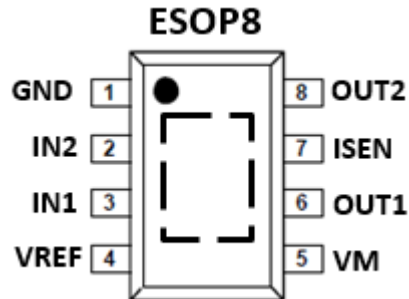
## Device Information

| Part No. | Package | Quantity |
|---|---|---|
| SA8875 | ESOP8 | 4000/Reel |

## SA8875 Package & Simplified Schematic

# 6.5-40.0V 6.5A Brushed DC Motor Driver (PWM Control)

## Pin Configuration and Functions

ESOP8

```
GND  1  ●        8  OUT2
IN2  2           7  ISEN
IN1  3           6  OUT1
VREF 4           5  VM
```

| NO. | NAME | TYPE | DESCRIPTION |
|-----|------|------|-------------|
| 1 | GND | P | Logic ground. Connect to board ground |
| 2 | IN2 | I | Logic inputs. Controls the H-bridge output. Has internal pulldowns. |
| 3 | IN1 | I | Logic inputs. Controls the H-bridge output. Has internal pulldowns. |
| 4 | VREF | I | Analog input. Apply a voltage between 0.3 to 5 V. |
| 5 | VM | P | 6.5 to 40.0V power supply. Connect a 22-µF bypass capacitor to ground, as well as sufficient bulk capacitance, rated for the VM voltage. |
| 6 | OUT1 | O | H-bridge output. Connect directly to the motor or other inductive load. |
| 7 | ISEN | P | High-current ground path. If using current regulation, connect ISEN to a resistor (low-value, high-power-rating) to ground. If not using current regulation, connect ISEN directly to ground. |
| 8 | OUT2 | O | H-bridge output. Connect directly to the motor or other inductive load. |
| | | | Thermal pad. Connect to board ground. For good thermal dissipation, use large ground planes on multiple layers, and multiple nearby vias connecting those planes. |

# 6.5-40.0V 6.5A Brushed DC Motor Driver (PWM Control)

## Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)

|  |  | MIN | MAX | UNIT |
|---|---|---|---|---|
| Power supply voltage | VM | -0.3 | 40.0 | V |
| Logic input voltage | IN1, IN2 | -0.3 | 7.0 | V |
| Reference input pin voltage | VREF | -0.3 | 6.0 | V |
| Continuous phase node pin voltage | OUT1, OUT2 | -0.3 | VM+0.7 | V |
| Current sense input pin voltage | ISEN | -0.3 | 0.5 | V |
| ESD (HBM) | VM, IN1, IN2, OUT1, OUT2, VREF, ISEN | 2 |  | kV |
| Output current (100% duty cycle) | IOUT | 0 | 5.5 | A |
| Operating junction temperature, | $T_J$ | -40 | 150 | °C |
| Storage temperature, | $T_{stg}$ | -65 | 150 | °C |
| Thermal Impedance | $\theta_{JA}$ |  | 45 | °C/W |

## Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

|  |  | MIN | MAX | UNIT |
|---|---|---|---|---|
| Power supply voltage | VM | 6.5 | 36.0 | V |
| Logic input voltage | IN1, IN2 | 0 | 5.5 | V |
| Reference input pin voltage | VREF | 0.3 | 5.0 | V |
| Logic input PWM frequency | $f_{PWM}$ | 0 | 200 | kHz |
| Peak output current | IPEAK | 0 | 6.5 | A |

# 6.5-40.0V 6.5A Brushed DC Motor Driver (PWM Control)

## Electrical Characteristics

$T_A$ = 25°C, over recommended operating conditions (unless otherwise noted)

| PARAMETER UNIT | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **POWER SUPPLY (VM)** | | | | | | |
| VM | VM operating voltage | | 6.5 | | 40 | V |
| $I_{VM\_ON}$ | VM operating supply current | VM=24V | | 1.0 | 2.0 | mA |
| $I_{VM\_OFF}$ | VM sleep current | VM=24V | | 2.0 | 10 | uA |
| Ton | Turn-on time | VM>$V_{UVLO}$, with IN1 or IN2 high | | 30 | 50 | us |
| **MOTOR DRIVER OUTPUTS (OUT1, OUT2)** | | | | | | |
| $R_{DSON}$ | High-side & Low-side FET on resistance | VM=12V, LS+HS, $I_{OUT}$=1A | | 200 | 300 | mΩ |
| | | VM=24V, LS+HS, $I_{OUT}$=1A | | 200 | 300 | mΩ |
| $T_{DEAD}$ | Output dead time | | | 200 | | ns |
| $V_D$ | Body diode forward voltage | $I_{OUT}$=1A | | 0.8 | 1 | V |
| **LOGIC-LEVEL INPUTS (IN1, IN2)** | | | | | | |
| $V_{INH}$ | Input logic high voltage | | 1.5 | | | V |
| $V_{INL}$ | Input logic low voltage | | 0 | | 0.5 | V |
| $V_{IN\_HYS}$ | Input logic hysteresis | | | 0.1 | | V |
| $I_{INH}$ | Input logic high current | IN=3.3V | | 33 | 50 | uA |
| $I_{INL}$ | Input logic low current | IN=0V | | 0 | 1 | |
| $R_{PD}$ | Pulldown resistance | to GND | | 100 | 200 | KΩ |
| $T_{PD}$ | Propagation delay | INx to OUTx change | | 500 | | ns |
| $T_{SLP}$ | Time to sleep | Inputs low to sleep | | 1.0 | | ms |
| **CURRENT REGULATION** | | | | | | |
| $A_V$ | ISEN gain | VREF=2.5V | | 10.0 | | V/V |
| $T_{OFF}$ | PWM off-time | | | 28.0 | | us |
| $T_{BLANK}$ | PWM blanking time | | | 2.0 | | |
| **PROTECTION CIRCUITS** | | | | | | |
| $V_{UVLO\_R}$ | VM rises until operation recovers | | | 6.10 | 6.45 | V |
| $V_{UVLO\_F}$ | VM falls until UVLO triggers | | | 5.90 | 6.25 | |
| $V_{UVLO\_H}$ | VM undervoltage hysteresis | | | 0.20 | | |
| $I_{OCP}$ | Overcurrent protection trip level | | | 7.0 | | A |
| $T_{OCP}$ | Overcurrent deglitch time | | | 1.5 | | us |
| $T_{RETRY}$ | Overcurrent retry time | | | 3.0 | | ms |
| $T_{SD}$ | Thermal shutdown temperature | | | 170 | | °C |
| $T_{HYS}$ | Thermal shutdown hysteresis | | | 40 | | |

# SA8875

## 6.5-40.0V 6.5A Brushed DC Motor Driver (PWM Control)

## Detailed Description

### Overview

The SA8875 device is an optimized 8-pin device for driving brushed DC motors with 6.5 to 40.0 V and up to 6.5-A peak current. The integrated current regulation restricts motor current to a predefined maximum. Two logic inputs control the H-bridge driver, which consists of four N-channel MOSFETs that have a typical $R_{DS}$(on) of 200mΩ (including one high-side and one low-side FET). A single-power input, VM, serves as both device power and the motor winding bias voltage. The integrated charge pump of the device boosts VM internally and fully enhances the high-side FETs. Motor speed can be controlled with pulse-width modulation, at frequencies between 0 to 200 kHz. The device has an integrated sleep mode that is entered by bringing both inputs low. An assortment of protection features prevents the device from being damaged if a system fault occurs.

### Functional Block Diagram
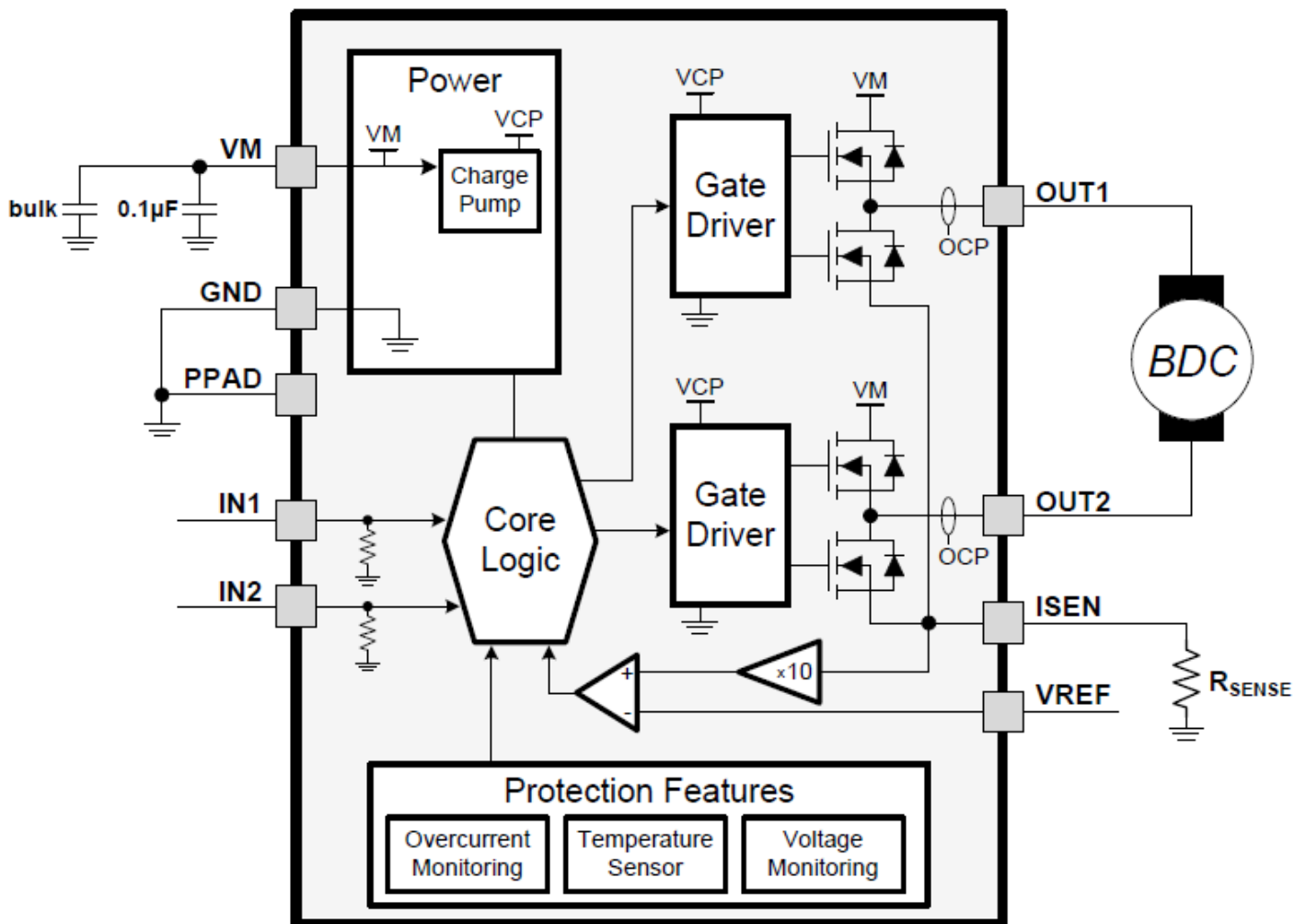
# 6.5-40.0V 6.5A Brushed DC Motor Driver (PWM Control)

## Feature Description

### Bridge Control

The SA8875 output consists of four N-channel MOSFETs that are designed to drive high current. These outputs are controlled by the two logic inputs IN1 and IN2as listed in Table 1.

**Table 1. H-Bridge Control**

| IN1 | IN2 | OUT1 | OUT2 | DESCRIPTION |
|-----|-----|--------|--------|-------------|
| 0 | 0 | High-Z | High-Z | Coast; H-bridge disabled to High-Z (sleep entered after 1 ms) |
| 0 | 1 | L | H | Reverse (Current OUT2 → OUT1) |
| 1 | 0 | H | L | Forward (Current OUT1 → OUT2) |
| 1 | 1 | L | L | Brake; low-side slow decay |

The inputs can be set to static voltages for 100% duty cycle drive, or they can be pulse-width modulated (PWM) for variable motor speed. When using PWM, switching between driving and braking typically works best. For example, to drive a motor forward with 50% of the maximum RPM, IN1 = 1 and IN2 = 0 during the driving period, and IN1 = 1 and IN2 = 1 during the other period. Alternatively, the coast mode (IN1 = 0, IN2 = 0) for *fast current decay* is also available. The input pins can be powered before VM is applied.
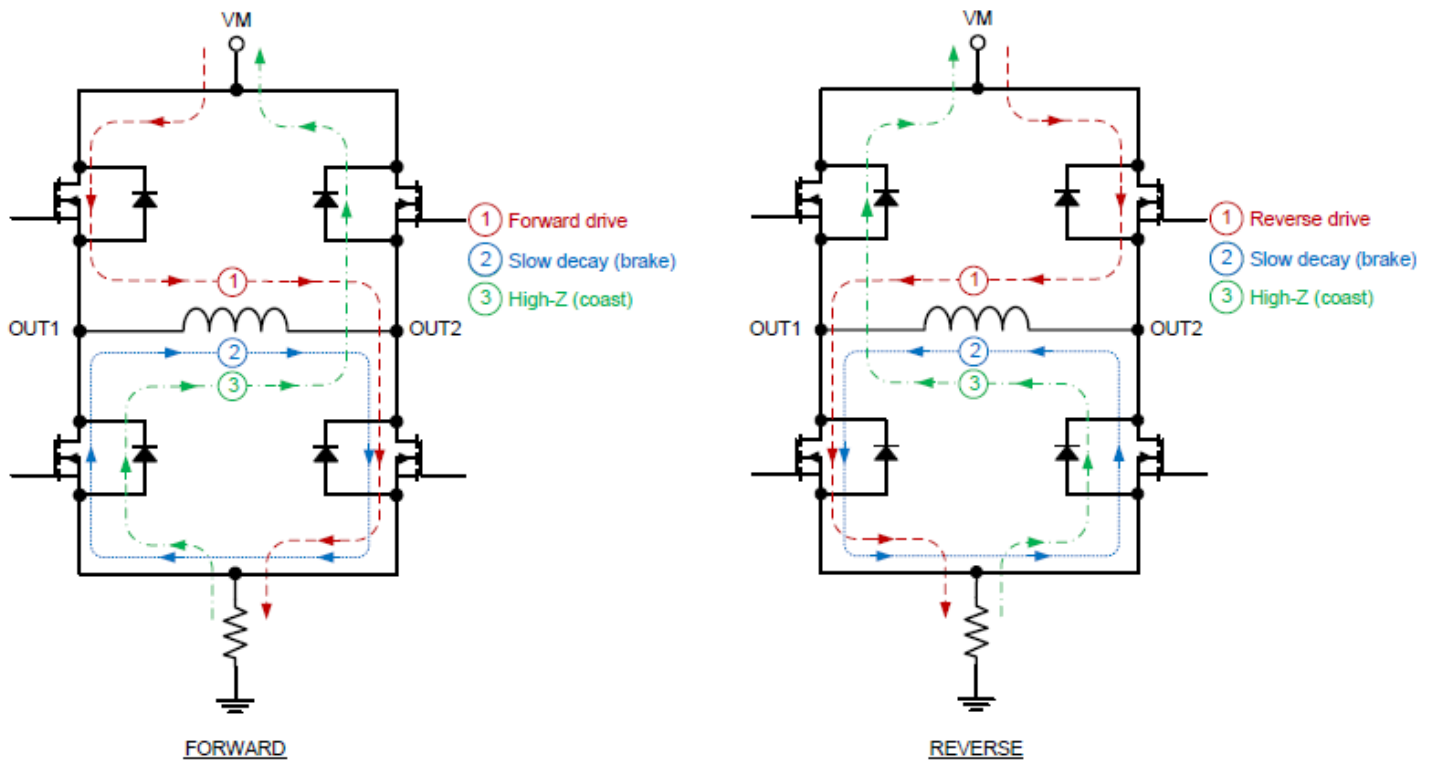


**Figure 4. H-Bridge Current Paths**

## 6.5-40.0V 6.5A Brushed DC Motor Driver (PWM Control)

**Sleep Mode**
When the IN1 and IN2 pins are both low for time $t_{SLEEP}$ (typically 1 ms), the SA8875 device enters a low-power sleep mode, where the outputs remain High-Z and the device uses $I_{VMOFF}$ (μA) of current. If the device is powered up while both inputs are low, it immediately enters sleep mode. After the IN1 or IN2 pins are high for at least 5μs, the device is operational 30μs ($t_{ON}$) later.

**Current Regulation**
The SA8875 device limits the output current based on the analog input, VREF, and the resistance of an external sense resistor on the ISEN pin according to Equation 1:

$$I_{TRIP}(A) = \frac{VREF(V)}{A_V \times R_{ISEN}(\Omega)} = \frac{VREF(V)}{10 \times R_{ISEN}(\Omega)}$$

For example, if VREF = 3.3 V and a $R_{ISEN}$ = 0.15 Ω, the SA8875 device limits motor current to 2.2 A no matter how much load torque is applied. For guidelines on selecting a sense resistor, see the Sense Resistor section. When $I_{TRIP}$ is reached, the device enforces slow current decay by enabling both low-side FETs, and it does this for a time of $t_{OFF}$ (typically 28 μs).
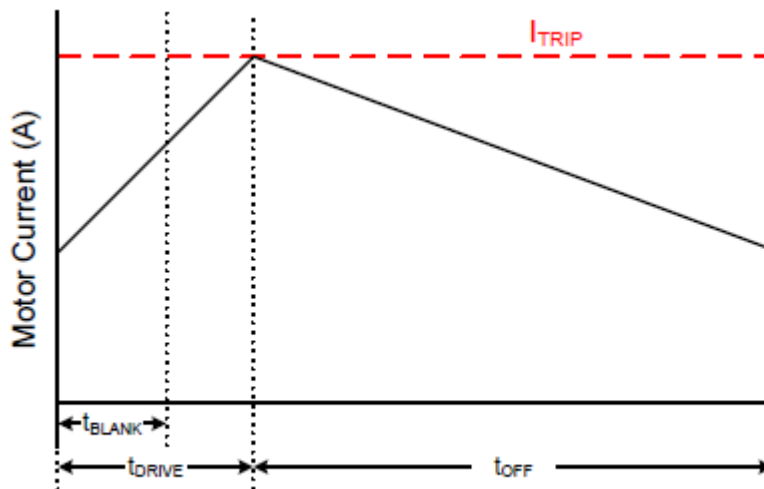


**Figure 5. Current-Regulation Time Periods**

After $t_{OFF}$ elapses, the output is re-enabled according to the two inputs, INx. The drive time ($t_{DRIVE}$) until reaching another $I_{TRIP}$ event heavily depends on the VM voltage, the back-EMF of the motor, and the inductance of the motor.

**Dead Time**
When an output changes from driving high to driving low, or driving low to driving high, dead time is automatically inserted to prevent shoot-through. The $t_{DEAD}$ time is the time in the middle when the output is High-Z. If the output pin is measured during $t_{DEAD}$, the voltage depends on the direction of current. If the current is leaving the pin, the voltage is a diode drop below ground. If the current is entering the pin, the voltage is a diode drop above VM. This diode is the body diode of the high-side or low-side FET.

# 6.5-40.0V 6.5A Brushed DC Motor Driver (PWM Control)
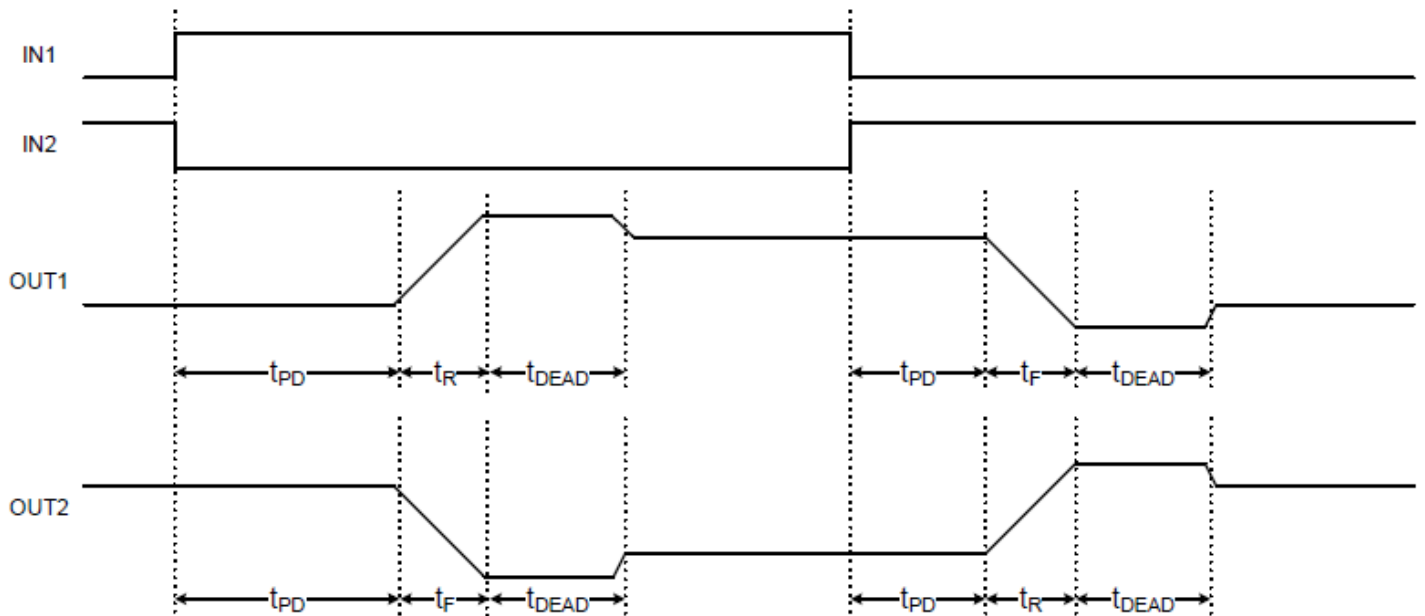


**Figure 6. Propagation Delay Time**

## Protection Circuits

The SA8875 device is fully protected against VM undervoltage, overcurrent, and overtemperature events.

### VM Undervoltage Lockout (UVLO)

If at any time the voltage on the VM pin falls below the undervoltage-lockout threshold voltage, all FETs in the H-bridge will be disabled. Operation resumes when VM rises above the UVLO threshold.

### Overcurrent Protection (OCP)

If the output current exceeds the OCP threshold, IOCP, for longer than $t_{OCP}$, all FETs in the H-bridge are disabled for a duration of $t_{RETRY}$. After that, the H-bridge is re-enabled according to the state of the INx pins. If the overcurrent fault is still present, the cycle repeats; otherwise normal device operation resumes.

### Thermal Shutdown (TSD)

If the die temperature exceeds safe limits, all FETs in the H-bridge are disabled. After the die temperature has fallen to a safe level, operation automatically resumes.

**Table 2. Protection Functionality**

| FAULT | CONDITION | H-BRIDGE BECOMES | RECOVERY |
|---|---|---|---|
| VM undervoltage lockout (UVLO) | $VM < V_{UVLO}$ | Disabled | $VM > V_{UVLO}$ |
| Overcurrent (OCP) | $I_{OUT} > I_{OCP}$ | Disabled | $t_{RETRY}$ |
| Thermal Shutdown (TSD) | $T_J > 150°C$ | Disabled | $T_J < T_{SD} - T_{HYS}$ |

## 6.5-40.0V 6.5A Brushed DC Motor Driver (PWM Control)

## Device Functional Modes
The SA8875 device can be used in multiple ways to drive a brushed DC motor.

### PWM With Current Regulation
This scheme uses all of the capabilities of the device. The ITRIP current is set above the normal operating current, and high enough to achieve an adequate spin-up time, but low enough to constrain current to a desired level. Motor speed is controlled by the duty cycle of one of the inputs, while the other input is static. Brake or slow decay is typically used during the off-time.

### PWM Without Current Regulation
If current regulation is not required, the ISEN pin should be directly connected to the PCB ground plane. The VREF voltage must still be 0.3 to 5 V, and larger voltages provide greater noise margin. This mode provides the highest-possible peak current which is up to 7.5 A for a few hundred milliseconds (depending on PCB characteristics and the ambient temperature). If current exceeds 7.5 A, the device might reach overcurrent protection (OCP) or overtemperature shutdown (TSD). If that happens, the device disables and protects itself for about 3ms ($t_{RETRY}$) and then resumes normal operation.

### Static Inputs with Current Regulation
The IN1 and IN2 pins can be set high and low for 100% duty cycle drive, and ITRIP can be used to control the current of the motor, speed, and torque capability.
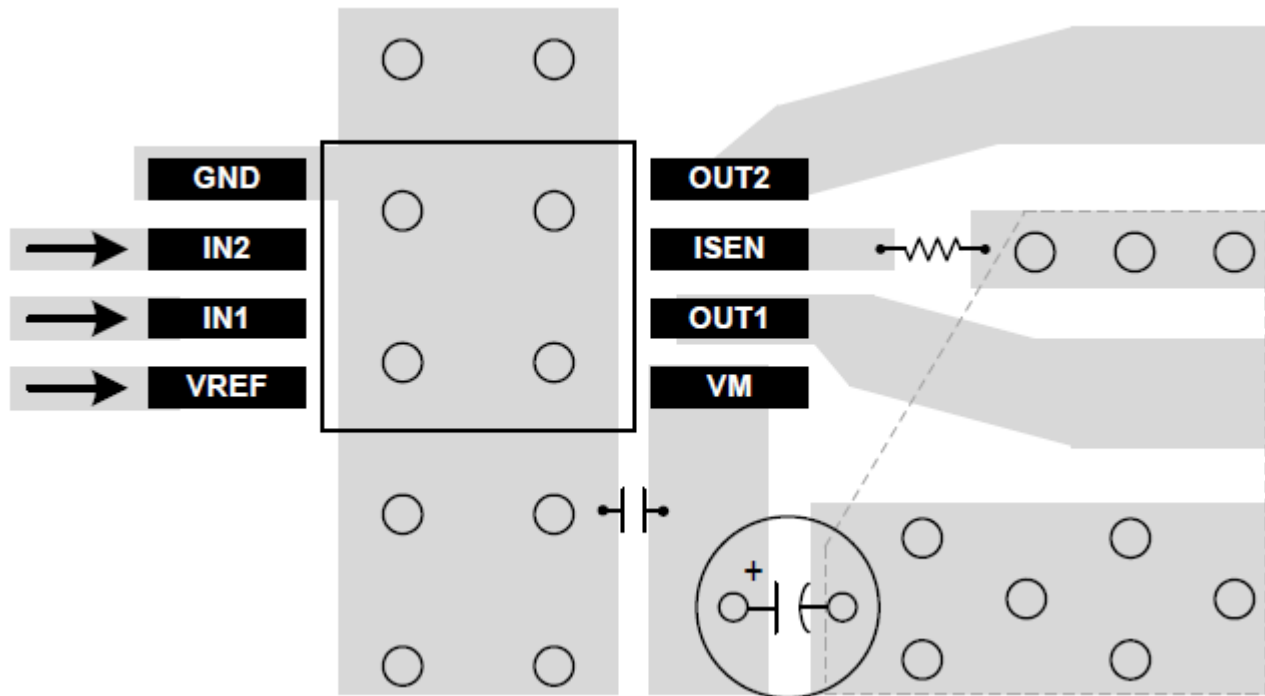
### VM Control
In some systems, varying VM as a means of changing motor speed is desirable. See the *Motor Voltage* section for more information.

### Layout Example
The following shows the recommended layout and component placement.

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## Thermal Considerations

The SA8875 device has thermal shutdown (TSD) as described in the *Thermal Shutdown (TSD)* section. If the die temperature exceeds approximately 170°C, the device is disabled until the temperature drops below the temperature hysteresis level. Any tendency of the device to enter TSD is an indication of either excessive power dissipation, insufficient heatsinking, or too high of an ambient temperature.

## Power Dissipation

Power dissipation in the SA8875 device is dominated by the power dissipated in the output FET resistance, RDS(on). Use the equation in the *Drive Current* section to calculate the estimated average power dissipation when driving a load.

Note that at startup, the current is much higher than normal running current; this peak current and its duration must be also be considered.

The maximum amount of power that can be dissipated in the device is dependent on ambient temperature and heatsinking.

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**NOTE**

$R_{DS(on)}$ increases with temperature, so as the device heats, the power dissipation increases. This fact must be taken into consideration when sizing the heatsink.

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The power dissipation of the SA8875 device is a function of RMS motor current and the FET

## 6.5-40.0V 6.5A Brushed DC Motor Driver (PWM Control)

resistance (RDS(ON)) of each output.

$$Power \approx I_{RMS}^2 \times (High - side\ RDSON + Low - side\ RDSON)$$

For this example, the ambient temperature is 58°C, and the junction temperature reaches 66°C. At 58°C, the sum of RDS(ON) is about 0.26Ω. With an example motor current of 0.8 A, the dissipated power in the form of heat is 0.8 A$^2$ × 0.26 Ω = 0.17 W.

The temperature that the SA8875 reaches will depend on the thermal resistance to the air and PCB. It is important to solder the device PowerPAD to the PCB ground plane, with vias to the top and bottom board layers, in order dissipate heat into the PCB and reduce the device temperature. In the example used here, the SA8875 device had an effective thermal resistance R$_{θJA}$ of 48°C/W, and:

$$T_J = T_A + (P_D \times R_{\theta JA}) = 58°C + (0.17W \times 48°C/W) = 66°C \quad (4)$$

**Heatsinking**
The PowerPAD package uses an exposed pad to remove heat from the device. For proper operation, this pad must be thermally connected to copper on the PCB to dissipate heat. On a multi-layer PCB with a ground plane, this connection can be accomplished by adding a number of vias to connect the thermal pad to the ground plane.

On PCBs without internal planes, a copper area can be added on either side of the PCB to dissipate heat. If the copper area is on the opposite side of the PCB from the device, thermal vias are used to transfer the heat between top and bottom layers.

## 6.5-40.0V 6.5A Brushed DC Motor Driver (PWM Control)

**Package Information**

**ESOP8**