

# MAX14871

## 4.5V to 36V Full-Bridge DC Motor Driver

### General Description

The MAX14871 DC motor driver provides a low-power and simple solution for driving and controlling brushed motors with voltages between 4.5V and 36V. Very low driver on resistance reduces power during dissipation.

The MAX14871 features a charge-pump-less design for reduced external components and low supply current. Integrated current regulation allows user-defined peak startup motor currents and requires minimal external components.

The MAX14871 includes 3 modes of current regulation: fast decay, slow decay, and 25% current ripple modes. Current regulation based on 25% ripple simplifies the design and enables regulation independent of motor characteristics. A separate voltage sense input (SNS) reduces current-sensing errors due to parasitic trace resistance.

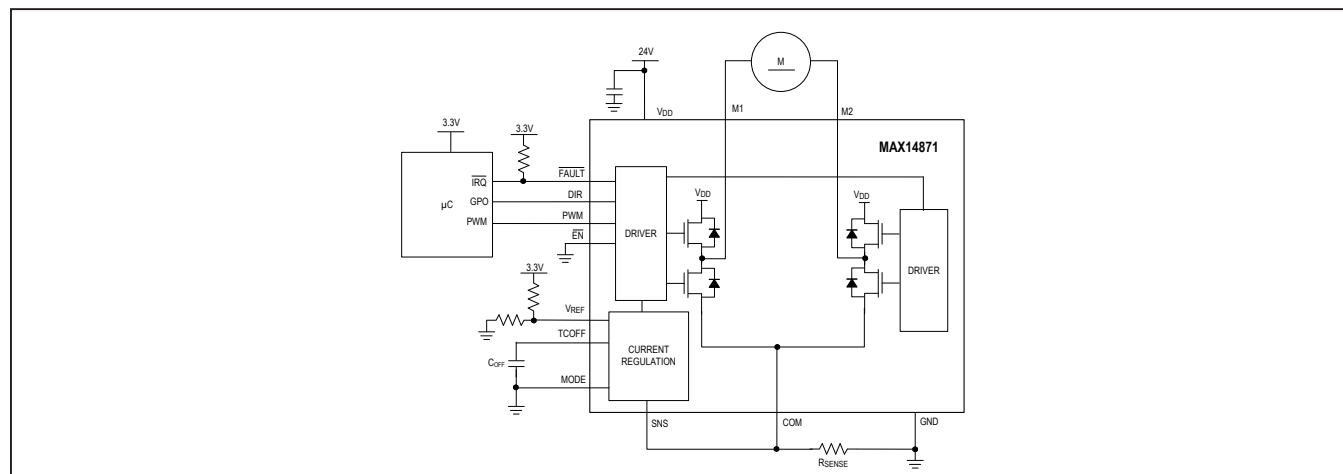
The MAX14871 features shoot-through protection and internal free-wheeling diodes that absorb inductive motor currents. Driver outputs are short-circuit-protected from shorts to ground, to the supply, and between M1 and M2. An active-low FAULT output signals thermal overload and overcurrents during fault conditions.

The MAX14871 is available in a 16-pin TSSOP-EP package and operates over the -40°C to +85°C temperature range.

### Applications

- Printers and Scanners
- Industrial Automation
- Vending and Gaming Machines

### Typical Application Circuit



### Benefits and Features

- Drive More Power and Reduce Footprint
  - Up to 2.8A Peak Motor-Current Package
  - Flexible 4.5V–36V Supply Enables Longer Runtime
- Low Power Consumption Runs Cooler and Longer
  - 334mΩ (typ) Total Bridge On-Resistance
  - 1mA (typ) Supply Current at 30kHz/24V
  - 10μA (max) Standby Current at 12V
- Simplified Designs Reduces Time to Market
  - Charge-Pump-Less Architecture
  - Current Regulation Only Requires a Sense Resistor
  - Current-Sense Input Simplifies PCB Layout
  - Internal/External VREF for Current Regulation
  - Fast/Slow/25% Ripple Current Regulation Modes
- Integrated Protection Provides Robust Driving Solutions
  - Short-Circuit-Protected Drivers
  - Thermal Shutdown Undervoltage Lockout
  - Diagnostic FAULT Output
  - -40°C to +85°C Temperature Range

*Ordering Information appears at end of data sheet.*

## Absolute Maximum Ratings

(All voltages referenced to GND)

$V_{DD}$	-0.3V to +40V
M1, M2	-0.3V to ( $V_{DD}+0.3V$ )
PWM, DIR, $\overline{FAULT}$ , $\overline{EN}$ , SNS, VREF, MODE, TCOFF	-0.3V to +6.0V
COM	-0.3V to +0.3V
Current Into M1, M2	$\pm 3A$
Continuous Power Dissipation ( $T_A = +70^\circ C$ )	

Single-Layer Board (derate at 21.3mW/ $^\circ C$ above $+70^\circ C$ )	1702mW
Multiple-Layer Board (derate at 26.1mW/ $^\circ C$ above $+70^\circ C$ )	2088mW
Operating Temperature Range	$-40^\circ C$ to $+85^\circ C$
Junction Temperature	$+150^\circ C$
Storage Temperature Range	$-65^\circ C$ to $+150^\circ C$
Lead Temperature (Soldering, 10s)	$+300^\circ C$
Solder Temperature (Reflow)	$+260^\circ C$

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## Package Thermal Characteristics (Note 1)

Junction-to-Case Thermal Resistance ( $\theta_{JC}$ )		Junction-to-Ambient Thermal Resistance ( $\theta_{JA}$ )	
TSSOP-EP (Single-Layer Board)	$3^\circ C/W$	TSSOP-EP (Single-Layer Board)	$47^\circ C/W$
TSSOP-EP (Multiple-Layer Board)	$3^\circ C/W$	TSSOP-EP (Multiple-Layer Board)	$38.3^\circ C/W$

**Note 2:** Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to [www.maximintegrated.com/thermal-tutorial](http://www.maximintegrated.com/thermal-tutorial).

## Electrical Characteristics

( $V_{DD} = 4.5V$  to  $36V$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $V_{DD} = 12V$ ,  $T_A = +25^\circ C$ )(Note 3)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
POWER SUPPLY							
Supply Voltage	V <sub>DD</sub>			4.5		36	V
Supply Current	I <sub>DD</sub>	$\overline{EN}$ = low, M1/M2 not connected	f <sub>PWM</sub> = 50kHz	1		mA	
			No switching	0.5	1.2		
Shutdown Supply Current	I <sub>SHDN</sub>	$\overline{EN}$ = high, Driver is in shutdown	V <sub>DD</sub> = 12V	3.7	10	μA	
			V <sub>DD</sub> = 36V	10	20		
Undervoltage Lockout Threshold	V <sub>UVLO</sub>	V <sub>DD</sub> rising		3.3	3.8	4.3	V
Undervoltage Lockout Threshold Hysteresis	V <sub>UVLO_HYST</sub>			400			mV
DRIVER (M1, M2)							
Driver Output Resistance (High-Side + Low-Side)	R <sub>ON</sub>	I <sub>M_</sub> = 2.8A	T <sub>J</sub> = 25°C	334	435	mΩ	
			T <sub>J</sub> = 125°C	465	620		
Driver Overload Current Limit	I <sub>M_OL</sub>			3			A
M1, M2 Leakage Current	I <sub>M_LKG</sub>	$\overline{EN}$ = High, V <sub>M1</sub> = V <sub>M2</sub> = 0V or V <sub>DD</sub>		-1	+1		μA
M1, M2 Body Diode Forward-Voltage	V <sub>BF</sub>	Low-side diode, $\overline{EN}$ = High, I <sub>F</sub> = 2.8A		1.5		V	
		High-side diode, $\overline{EN}$ = High, I <sub>F</sub> = 2.8A		1.5			

## Electrical Characteristics (continued)

(V<sub>DD</sub> = 4.5V to 36V, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at V<sub>DD</sub> = 12V, T<sub>A</sub> = +25°C)(Note 3)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>CURRENT REGULATION (VREF, SNS, COM, TCOFF, MODE)</b>						
MODE Select Threshold	V <sub>MODE_TH</sub>	Fixed Off-Time, Fast Decay Current Regulation			0.2	V
		25% Ripple Current Regulation	0.5		1	
		Fixed Off-Time, Slow Decay Current Regulation	1.5			
MODE Internal Pulldown Resistance	R <sub>MODE_PD</sub>	V <sub>MODE</sub> = 5V	0.6	1	2.2	MΩ
VREF Internal/External Select Threshold	V <sub>VREF_TH</sub>		0.2		0.4	V
VREF Voltage Range for External VREF Current Regulation	V <sub>VREF</sub>	V <sub>DD</sub> ≥ 5V	0.5		2	V
		V <sub>DD</sub> < 5V	0.5		1.3	
VREF Input Leakage	I <sub>VREF_LKG</sub>	VREF = 2V	-1		+1	μA
SNS Threshold for Internal V <sub>VREF</sub> Current Regulation	V <sub>SNS_IVR_THR</sub>	V <sub>SNS</sub> rising, V <sub>VREF</sub> < V <sub>VREF_TH</sub> . All current regulation modes	94	100	110	mV
	V <sub>SNS_IVR_THF</sub>	V <sub>SNS</sub> falling, 25% Ripple Mode, V <sub>VREF</sub> < V <sub>VREF_TH</sub>	-82	-75	-69	
SNS Threshold for External V <sub>VREF</sub> Current Regulation	V <sub>SNS_ER_THR</sub>	V <sub>SNS</sub> rising, V <sub>VREF</sub> > V <sub>VREF_TH</sub> . All current regulation modes		V <sub>VREF</sub> / A <sub>V</sub>		V
	V <sub>SNS_ER_THF</sub>	V <sub>SNS</sub> falling, 25% Ripple Mode, V <sub>VREF</sub> > V <sub>VREF_TH</sub>		0.75 x V <sub>VREF</sub> / A <sub>V</sub>		
Current-Sense Amplifier Gain	A <sub>V</sub>	V <sub>VREF</sub> = 1V (Note 4)	9.6	10	10.5	V/V
SNS Input Leakage Current	I <sub>SNS_LKG</sub>	V <sub>SNS</sub> = ±250mV	-1		+1	μA
COM Leakage Current	I <sub>COM_LKG</sub>	EN = High, V <sub>COM</sub> = ±250mV	-1		+1	μA
TCOFF Current	I <sub>TCOFF</sub>	TCOFF is connected to GND	6	10	15	μA
TCOFF Threshold	V <sub>TCOFF</sub>		0.92	1	1.08	V
<b>LOGIC SIGNALS (PWM, DIR, EN, FAULT)</b>						
Input Logic-High Voltage	V <sub>IH</sub>	PWM, DIR	2			V
Input Logic-Low Voltage	V <sub>IL</sub>	PWM, DIR			0.8	V
EN Input Logic-High Voltage	V <sub>EN_IH</sub>		1.6			V
EN Input Logic-Low Voltage	V <sub>EN_IL</sub>				0.4	V
Input Leakage Current	I <sub>IL</sub>	PWM, DIR, EN, V <sub>INPUT</sub> = 5.5V or 0V	-1		+1	μA
FAULT Output Low Voltage	V <sub>OL</sub>	FAULT asserted, I <sub>SINK</sub> = 5mA			0.5	V
FAULT Off Leakage Current	I <sub>F_LKG</sub>	FAULT deasserted, V <sub>FAULT</sub> = 5.5V	-1		+1	μA
<b>PROTECTION</b>						
Thermal-Shutdown Threshold	T <sub>SHDN</sub>	Temperature rising, FAULT asserted		+160		°C
Thermal-Shutdown Hysteresis	T <sub>SHDN_HYST</sub>			10		°C

## AC Electrical Characteristics

( $V_{DD}$  = 4.5V to 36V,  $T_A$  =  $T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $V_{DD}$  = 12V,  $T_A$  = +25°C)(Note 3)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
PWM Frequency	$f_{SW}$	$\overline{EN}$ = Low, Switching signal applied at PWM			50	kHz
Dead Time	$t_{DEAD}$			140		ns
M1, M2 Slew Rate	SR			200		V/ $\mu$ s
M1, M2 High-Side Propagation Delay	$t_{PR}$	$R_L$ = 1k $\Omega$ , $C_L$ = 50pF, PWM/DIR rising, Figure 1		620		ns
M1, M2 Low-Side Propagation Delay	$t_{PF}$	$R_L$ = 1k $\Omega$ , $C_L$ = 50pF, PWM/DIR falling, Figure 1		583		ns
Fixed Off-Time with Internal VREF Current Regulation	$t_{OFF\_D}$	PWM = High, $\overline{EN}$ = Low, $V_{SNS} > V_{SNS\_IVR\_THR}$ , $V_{VREF} < V_{VREF\_TH}$ , $T_{COFF}$ unconnected	7.8	15	22	$\mu$ s
Current Regulation Minimum On-Time	$t_{CR\_BL}$	PWM = High, $\overline{EN}$ = Low, $V_{SNS} > V_{SNS\_IR\_THR}$ or $V_{SNS\_ER\_THF}$		2.5		$\mu$ s
Overcurrent Blanking Time	$t_{OC\_BL}$	M1/M2 is shorted to $V_{DD}$ or GND, Figure 2		1		$\mu$ s
Overcurrent Autoretry Timeout	$t_{OC\_TO}$	PWM = High, $\overline{EN}$ = Low, $I_M$ or $I_{M2} > I_{M\_OL}$ , Figure 2		2		ms
Enable Turn-on Delay	$t_{EN\_ON}$	PWM = High, $R_L$ = 1k $\Omega$ , $C_L$ = 50pF, $\overline{EN}$ falling, M1/M2 rising to 10%, Figure 3		23		$\mu$ s
Enable Turn-off Delay	$t_{EN\_OFF}$	PWM = High, $R_L$ = 1k $\Omega$ , $C_L$ = 50pF, $\overline{EN}$ rising, M1/M2 falling to 90%, Figure 3		50		$\mu$ s

**Note 2:** All units are production tested at  $T_A$  = +25°C. Specifications over temperature are guaranteed by design.

**Note 3:**  $A_V$  is the fixed voltage gain of the internal current sense amplifier. It is the factor by which the  $V_{SNS}$  voltage is multiplied for comparison with the external VREF voltage when using external VREF current regulation. See the Applications Information section for more information.

## Test Circuits/Timing Diagrams

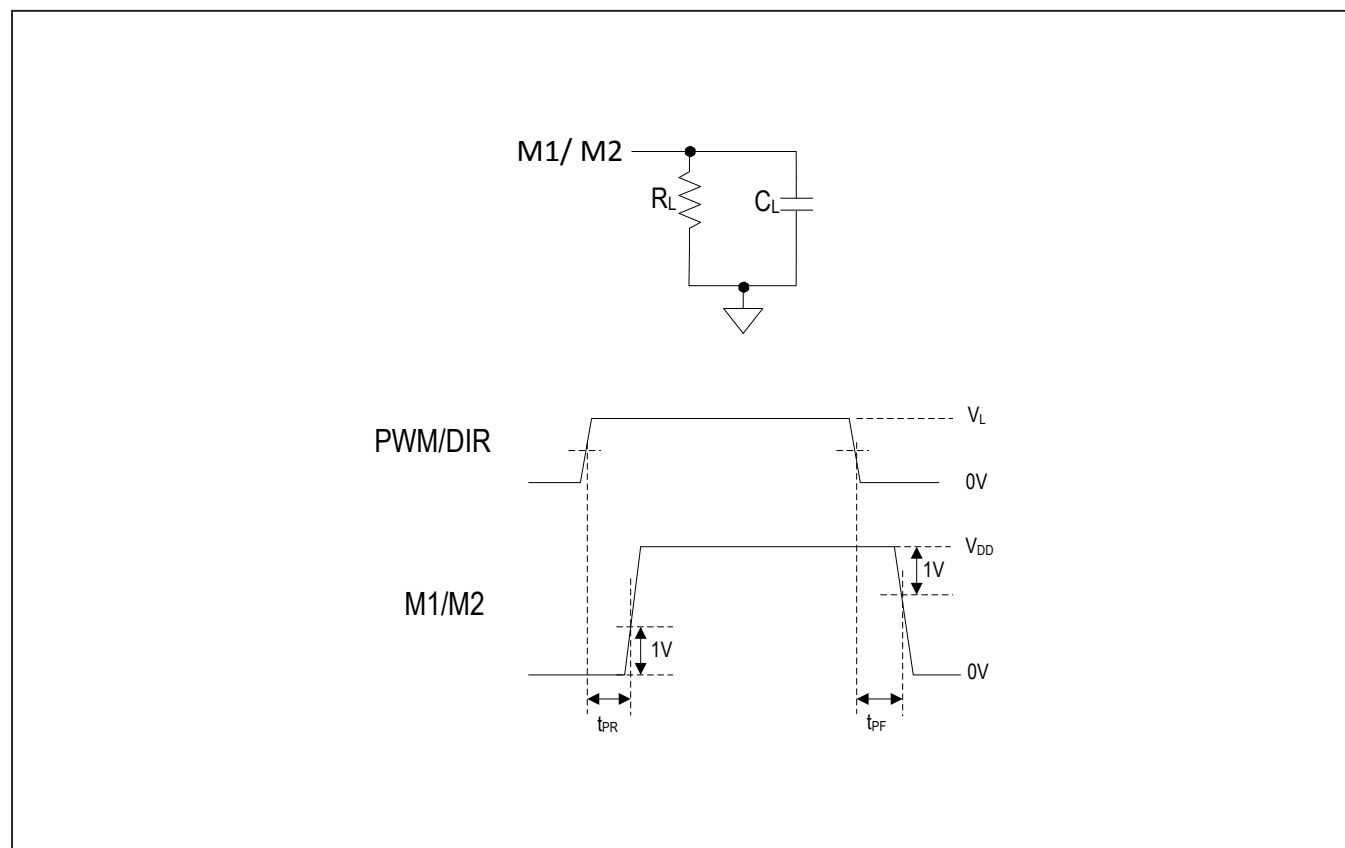


Figure 1. M1/M2 Propagation Delays

## Test Circuits/Timing Diagrams (continued)

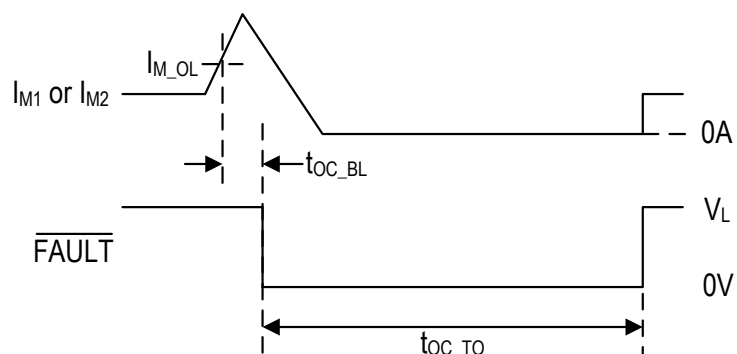


Figure 2. Overcurrent Autoretry Timeout

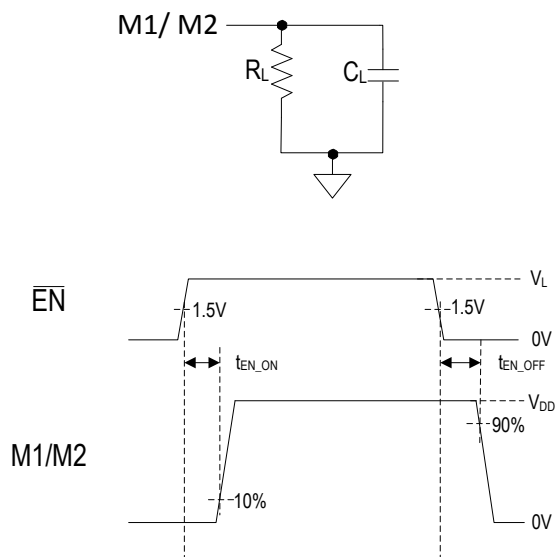
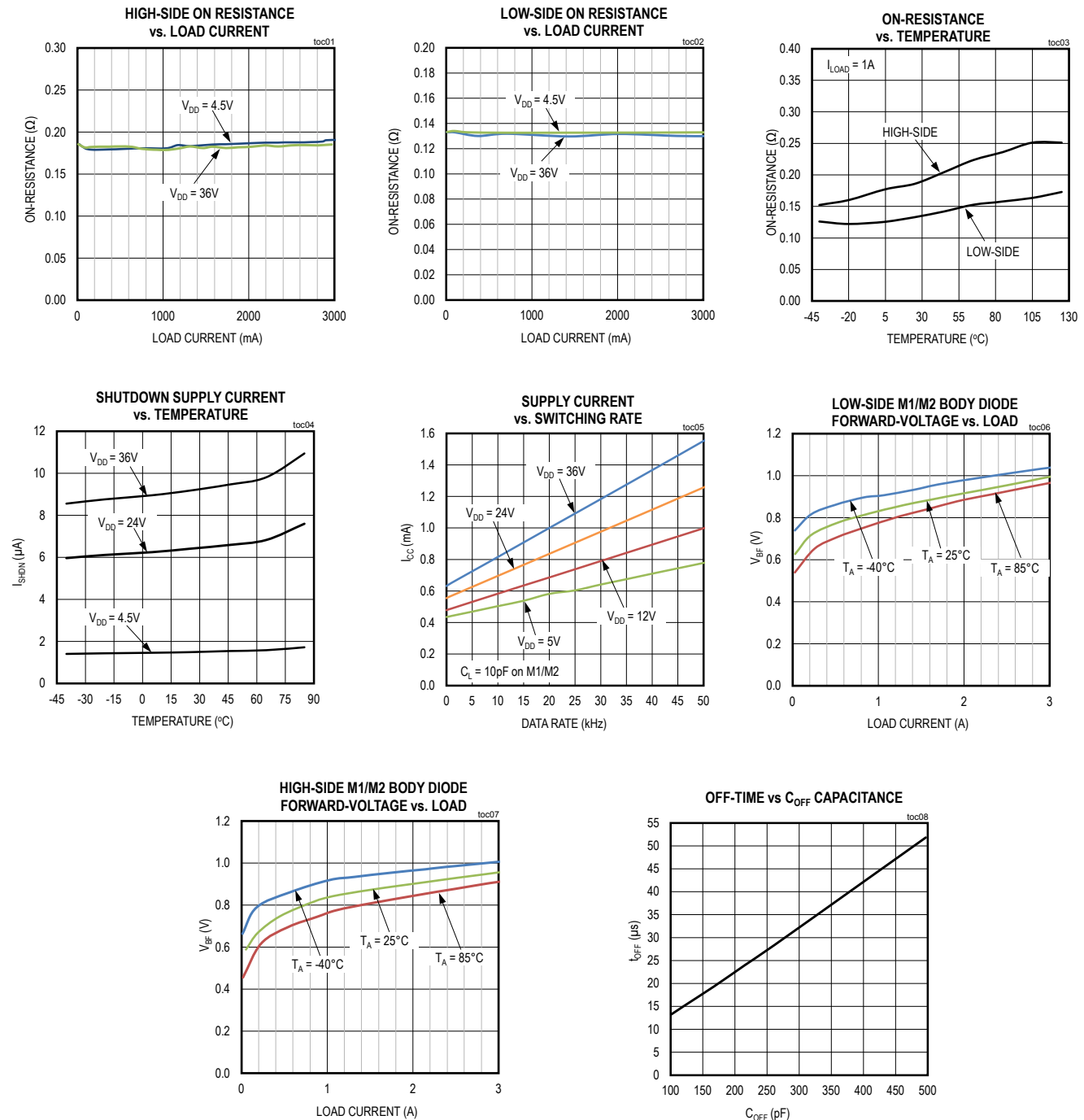


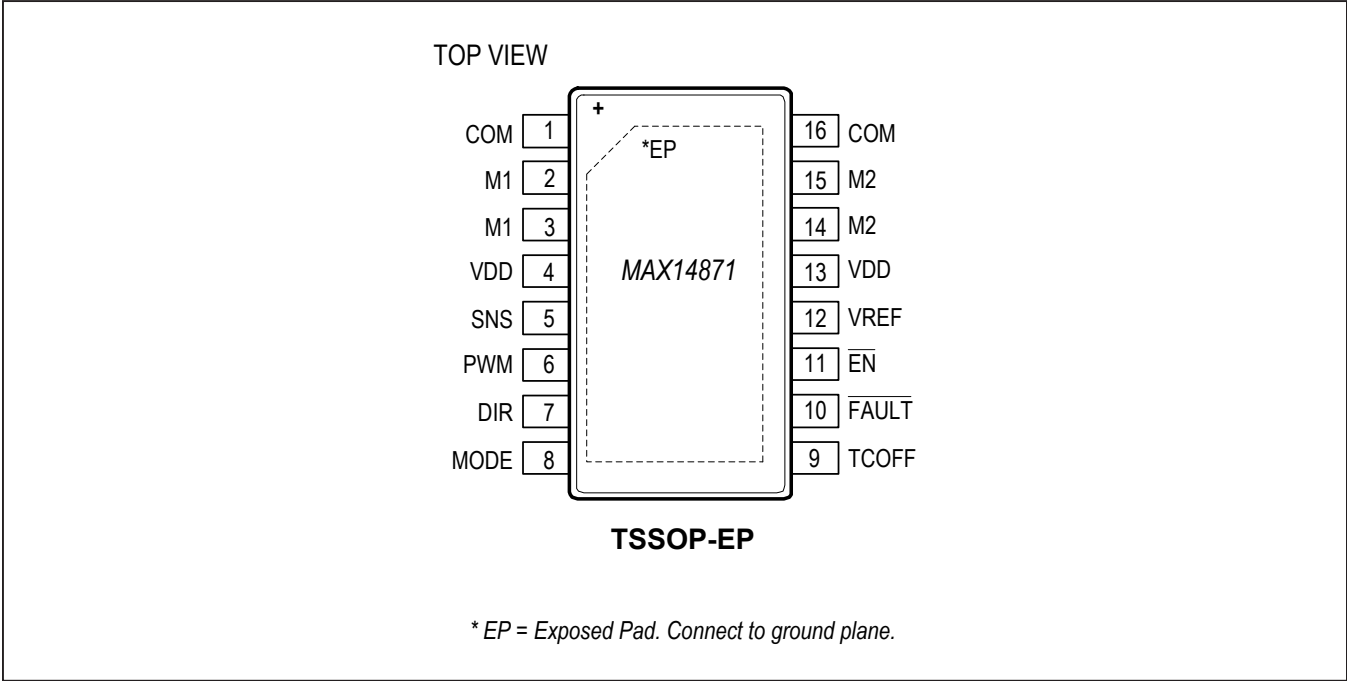
Figure 3. Enable/Disable Delays

## Typical Operating Characteristics

( $V_{DD} = 24V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



Pin Configuration



Pin Description

PIN	NAME	FUNCTION
1, 16	COM	COM Current Output. Connect a sense resistor, $R_{\text{SENSE}}$ , from COM to GND to use internal current regulation and/or external current control. Connect both COM pins together.
2, 3	M1	Motor Driver Output 1. See the <a href="#">Function Tables</a> for more information. Connect both M1 pins together.
4, 13	$V_{\text{DD}}$	Power Supply Input. Bypass $V_{\text{DD}}$ to GND with a 1 $\mu\text{F}$ ceramic capacitor as close to the device as possible. Connect both $V_{\text{DD}}$ pins together.
5	SNS	Current Sense Input. Connect SNS to COM to enable current regulation. To bypass current regulation, connect SNS to GND.
6	PWM	PWM Control Logic Input. PWM and DIR control M1 and M2. See the <a href="#">Function Tables</a> for more information.
7	DIR	Direction Control Logic Input. PWM and DIR control M1 and M2. See the <a href="#">Function Tables</a> for more information.
8	MODE	Current Regulation Mode Select Input. Connect MODE to GND for fast decay regulation. Connect $V_{\text{MODE}} > 1.5\text{V}$ for slow decay current regulation. Connect $0.5\text{V} \leq V_{\text{MODE}} \leq 1\text{V}$ for fast decay with 25% ripple. MODE has a 1M $\Omega$ internal pull-down resistor.
9	TCOFF	Current Regulation Timing Control. For external VREF-based current regulation, connect a capacitor to TCOFF to set the off-time ( $t_{\text{OFF}}$ ). For internal VREF-based current regulation leave TCOFF unconnected when using internal VREF-based current regulation. See the <a href="#">Current Regulation</a> section for more information.



## Pin Description (continued)

PIN	NAME	FUNCTION
10	$\overline{\text{FAULT}}$	Open-Drain Active-Low Fault Output. $\overline{\text{FAULT}}$ goes low during an overcurrent condition and thermal shutdown.
11	$\overline{\text{EN}}$	Active-Low Enable Input. Drive $\overline{\text{EN}}$ low to enable the driver outputs. Drive $\overline{\text{EN}}$ high to tri-state the driver outputs.
EP	GND	Ground
14, 15	M2	Motor Driver Output 2. See the <a href="#">Function Tables</a> for more information. Connect both M2 pins together.
12	V <sub>REF</sub>	Reference Voltage Input. The voltage applied to V <sub>REF</sub> sets the maximum motor current during external V <sub>REF</sub> -based current regulation. Set V <sub>REF</sub> < V <sub>REF_TH</sub> for internal V <sub>REF</sub> -based current regulation. See the <a href="#">Function Tables</a> and the <a href="#">Current Regulation</a> section for more information.
-	EP	Exposed Pad. Connect to ground.

## Function Table

## PWM/DIR Control Logic

INPUTS			OUTPUTS		OPERATING MODE
$\overline{\text{EN}}$	PWM	DIR	M1	M2	
1	X	X	High-Impedance	High-Impedance	Shutdown
0	0	X	GND	GND	Brake
0	1	0	GND	V <sub>DD</sub>	Counter-Clockwise/Reverse
0	1	1	V <sub>DD</sub>	GND	Clockwise/Forward

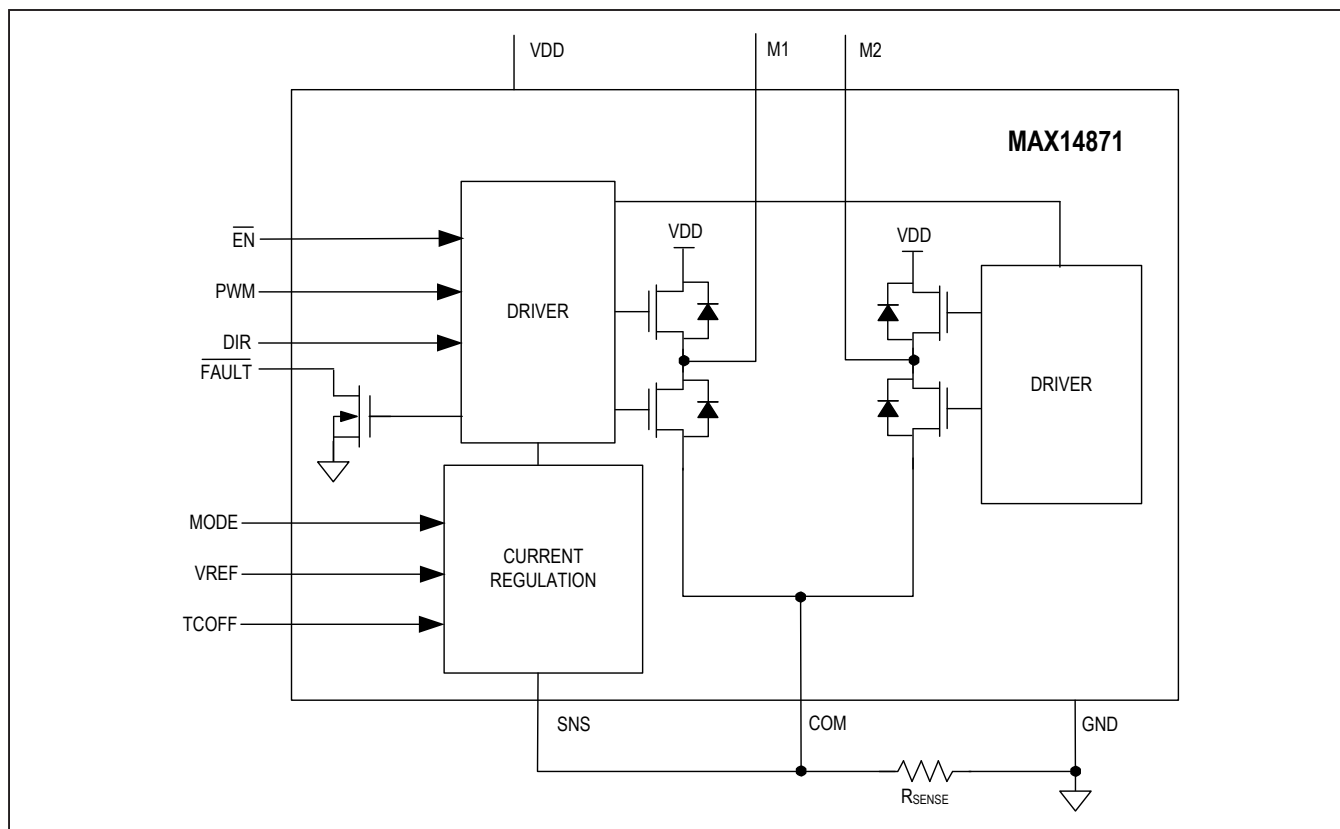
X = Don't care

## Current Regulation Logic

INPUTS				OPERATING MODE (SEE TABLE 1)
$\overline{\text{EN}}$	V <sub>REF</sub>	MODE	V <sub>SNS</sub>	
0	< 0.2V	X	< 0.1V	Normal PWM Operation. No current regulation.
0	< 0.2V	V <sub>MODE</sub> < 0.5V	> 0.1V	Current regulation based on 15μs (typ) fixed off-time control with fast decay using internal V <sub>REF</sub> .
0	< 0.2V	0.5V < V <sub>MODE</sub> < 1V	> 0.1V	Current regulation based on 25% current ripple fast decay using internal V <sub>REF</sub> .
0	< 0.2V	V <sub>MODE</sub> > 1.5V	> 0.1V	Current regulation based on 15μs (typ) fixed off-time control with slow decay using internal V <sub>REF</sub> .
0	> 0.4V	X	< V <sub>VREF</sub> /10	Normal PWM Operation. No current regulation.
0	> 0.4V	V <sub>MODE</sub> < 0.5V	> V <sub>VREF</sub> /10	Current regulation based on fixed TOFF-time control with fast decay using external V <sub>REF</sub> .
0	> 0.4V	0.5V < V <sub>MODE</sub> < 1V	> V <sub>VREF</sub> /10	Current regulation based on 25% current ripple fast decay using external V <sub>REF</sub> .
0	> 0.4V	V <sub>MODE</sub> > 1.5V	> V <sub>VREF</sub> /10	Current regulation based on fixed TOFF-time control with slow decay using external V <sub>REF</sub> .

X = Don't care

## Functional Diagram



## Detailed Description

The MAX14871 DC brushed motor driver provides a low-power and flexible solution for driving and controlling brushed motors with voltages between 4.5V and 36V. Peak motor currents of up to 2.8A ensure for large motor torque that is controllable by an external PWM signal and/or by autonomous internal current regulation.

Charge-pump-less design ensures for minimal external components and low supply current.

Integrated current regulation allows limiting peak startup motor currents. Shoot-through protection with a 140ns (typ) dead time ensures low operating current. Internal free-wheeling diodes absorb inductive motor currents. The  $\overline{\text{FAULT}}$  output signals thermal overload and overcurrents.

### Overcurrent Protection

The MAX14871 is protected against shorts on M1/M2 to any voltages between  $V_{DD}$  and GND, including shorts to GND,  $V_{DD}$  and between M1 and M2 via overcurrent limiting. When a current above 6A (typ) flows through

M1 or M2 for longer than 1 $\mu$ s, an overcurrent condition is detected and the H-bridge drivers are automatically disabled and the  $\overline{\text{FAULT}}$  output asserts.

If the overcurrent condition continues for longer than the overcurrent autoretry timeout (2ms (typ)) the MAX14871 enters autoretry mode. In autoretry mode, the M1 and M2 outputs are re-enabled for 1 $\mu$ s (typ) and  $\overline{\text{FAULT}}$  goes high impedance. The drivers are disabled again and  $\overline{\text{FAULT}}$  is re-asserted if the overcurrent condition persists.

### PWM Control

The PWM input is used for motor speed/torque control. Increasing or decreasing the duty cycle at PWM sets the effective (average) voltage across the motor terminals and allows first-order speed control.

When PWM is logic-high, the motor is driven in the direction defined by DIR. When PWM is logic low, the bridge is in brake mode. In brake mode, the motor current continues flowing and recirculates through the low-side transistors of the H-bridge driver, due to its inductive impedance and back EMF.

Slope Control

The MAX14871 drivers turn-on and turn-off with active slope control during the M1/M2 transition times. This integrated slew rate limiting reduces EMC, like conducted and radiated EMI, associated with high di/dt and dv/dt rates.

Thermal Shutdown

The MAX14871 includes integrated protection against thermal overload. When the junction temperature exceeds 160°C (typ), the H-bridge is tri-stated and  $\overline{\text{FAULT}}$  asserted. M1 and M2 are automatically re-enabled when the junction temperature falls to 150°C (typ).

Current Sensing

Connect a sense resistor ( $R_{\text{SENSE}}$ ) between COM and GND to monitor the motor current during operation. Select  $R_{\text{SENSE}}$  such that the voltage at COM created by motor current flowing through the sense resistor is limited to within 250mV relative to GND ( $-250\text{mV} \leq V_{\text{COM}} \leq +250\text{mV}$ ).

Minimize series trace resistance from  $R_{\text{SENSE}}$  to GND to minimize voltage sense errors due to parasitic trace interconnect resistance. Use a star ground connection between the MAX14871 GND pins and the GND-side of  $R_{\text{SENSE}}$ . Connect the SNS trace close to the  $R_{\text{SENSE}}$  resistor in order to minimize current-sensing error introduced by IR voltage created by the trace resistance of the high-current COM to  $R_{\text{SENSE}}$  trace. If external current monitoring/regulation is used, as shown in Figure 5, connect the voltage sense inputs close to the  $R_{\text{SENSE}}$  resistor. Optionally use differential voltage sensing for higher accuracy sensing. Connect the voltage sense close to the  $R_{\text{SENSE}}$  resistor and/or use differential voltage-sensing. See [Figure 4](#).

Current Regulation

The MAX14871 features internal current-regulation to limit the stall current. Current regulation is based on the maximum motor current (set with the  $R_{\text{SENSE}}$  resistor) and the voltage at VREF. When the motor current exceeds the value, the motor current is automatically reduced, either by driving both H-bridge outputs low (braking/slow decay),

Table 1. Current Regulation Modes

INPUTS		CURRENT REGULATION MODE			
MODE	VREF	Regulation Mode	Decay Type	VREF	TCOFF
0.75V	GND	25% Ripple	FAST	Internal (=1V)	-
0.75V	> 0.4V	25% Ripple	FAST	External	-
GND	GND	TCOFF	FAST	Internal (=1V)	15μs
> 1.5V	GND	TCOFF	SLOW	Internal (=1V)	15μs
GND	> 0.4V	TCOFF	FAST	External	Toff
> 1.5V	> 0.4V	TCOFF	SLOW	External	Toff

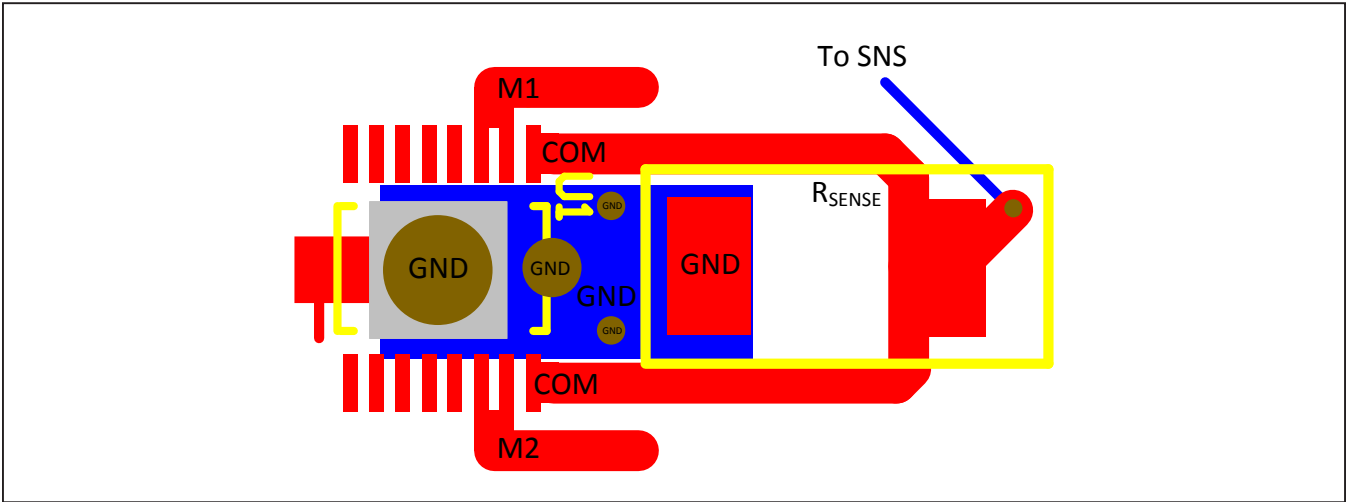


Figure 4. Star connection between COM, SNS, and GND

or by reversing the H-bridge direction (fast decay). The H-bridge is turned back to normal polarity after a defined delay time (TOFF mode) or after the motor current has reduced by 25% (25% ripple mode). See [Table 1](#). The MAX14871 [Function Tables](#) show how to set the regulation mode.

### Regulation Modes

The MAX14871 offers two internal current regulation modes: Constant off-time (TOFF) and 25% current ripple regulation. For both modes, regulation is set when the motor current ( $I_M$ ) exceeds the current limit defined by the VREF voltage and the sense resistor:

$$I_{M\_MAX} = V_{VREF} / (A_V \times R_{SENSE})$$

### VREF

Either the internal  $V_{VREF}$  voltage or an external voltage on VREF can be used for current regulation. Select internal VREF-based regulation by setting  $V_{VREF} < V_{REF\_TH}$ . The internal  $V_{VREF}$  is 1V (typ).

When an external voltage is used, the range of VREF is defined by  $V_{VREF}$ .

### Fixed Off-Time (TOFF-time) Regulation

Fixed off-time regulation turns the H-bridge driver off for a fixed time ( $t_{OFF}$  time), as defined by the value of the  $C_{OFF}$  capacitor connected between TCOFF and GND:

$$t_{OFF} (\mu s) = C_{OFF} (pF) / 10.$$

If  $V_{VREF} < V_{VREF\_TH}$  and TCOFF is left unconnected, then  $t_{OFF}$  is 15 $\mu s$  (typ).

During the fixed TOFF-time regulation, the H-bridge can operate in either slow or fast decay mode. See [Table 1](#).

### Slow Decay Mode

Slow decay, also called brake mode, is selected by setting  $V_{MODE} > 1.5V$ . In slow decay, both H-bridge low-side drivers are turned on so that the inductive motor current recirculates through the low-side transistors and the motor's terminals see a differential voltage near zero ( $V_{DIFF} = 2 \times I_M \times R_{ON\_LS}$ ). During the slow-decay TOFF period ( $t_{OFF}$ ) motor current does not flow through the external  $V_{DD}/GND$  supply and the voltage across  $R_{SENSE}$  is zero. The current decay during  $t_{OFF}$  is a first-order exponential decay with a time constant equal to the motor's electrical time constant (L/R). The rate of current decay during  $t_{OFF}$  is proportional to the motor's back EMF/rotational speed.

### Fast Decay Mode

Fast decay mode can be used as an alternative to slow decay during fixed off-time regulation. Fast decay is enabled by setting  $V_{MODE} < 0.2V$ . In fast decay, the H-bridge polarity is reversed during the  $t_{OFF}$  period, which results in faster motor current decay, since  $-V_{DD}$  is applied across the motor's terminals. The motor current decrease is first order with an L/R time constant and proportional to ( $V_{DD} + V_{EMF}$ ).

Note that if  $t_{OFF}$  is larger than the motor's L/R electrical time constant, the inductive current can reverse direction, causing the motor not to start-up. If fixed off-time regulation with fast decay is used, select TOFF carefully, based on the motor's electrical characteristics.

During fast decay, the motor's inductive current recirculates through the external  $V_{DD}$  supply, which charges up the  $V_{DD}$  bypass capacitor. Thus the voltage seen across  $R_{SENSE}$  is negative during the  $t_{OFF}$  delay.

### 25% Ripple Regulation

25% ripple regulation is based on the H-bridge switching to fast decay period until the motor current falls by 25%. When  $I_M$  reaches the regulation limit, the bridge enters fast decay until the  $I_M$  falls to 75% of the current limit. The H-bridge polarity is then turned back to normal drive. Thus the motor current ramps up and down between 75% and 100% of the set-point current.

25% ripple regulation eliminates  $t_{OFF}$  time tuning and the TCOFF capacitor, allowing motors to be exchanged without redesign.

Since 25% ripple regulation uses fast decay, the voltage seen across  $R_{SENSE}$  is negative during the time period that the H-bridge polarity is reversed.

Select 25% ripple regulation mode by setting  $0.5V < V_{MODE} < 1.0V$ . Leave TCOFF unconnected when 25% ripple is used.

## Applications Information

### Layout Considerations

Connect duplicate pins (COM pins and VDD pins) together with low-resistance traces. See the [Current Sensing](#) section for further layout recommendations.

### Power Considerations

The MAX14871 driver can generate more power than the package for the device can safely dissipate. Total power dissipation for the device is calculated using the following equation:

$$P_{TOTAL} = P_{DRIVER} + P_{SW} + P_D$$

The power dissipated inside of the driver is calculated as:

$$P_{\text{DRIVER}} = I_{\text{M\_LOAD}}^2 \times R_{\text{ON}}$$

where  $I_{\text{M\_LOAD}}$  is the motor current and  $R_{\text{ON}}$  is the on-resistance of the high and low-side FETs.

$P_{\text{SW}}$  is the power generated by the driver during the rise/fall times in switching, and includes both arms of the bridge. Calculate  $P_{\text{SW}}$  using the following equation:

$$\begin{aligned} P_{\text{SW}} &= I_{\text{M\_LOAD}} \times 2 \times V_{\text{DS}} \\ &= I_{\text{M\_LOAD}} \times 2 \times (1/2 \times V_{\text{DD}} \times f_{\text{SW}} \times t_{\text{R}}) \end{aligned}$$

where  $I_{\text{M\_LOAD}}$  is the motor current,  $t_{\text{R}}$  is the 200ns (typ) rise or fall time of the driver output, and  $f_{\text{SW}}$  is the switching frequency.

The internal diodes dissipate power during switching, as well. Calculate the power dissipated in the diodes as:

$$P_{\text{D}} = I_{\text{M\_LOAD}} \times 2 \times V_{\text{BF}} \times t_{\text{DEAD}} \times f_{\text{SW}}$$

### Operation Without Internal Current Regulation

To operate the MAX14871 without internal or external current regulation, connect SNS directly to GND. No sense resistor is required for this configuration. See [Figure 4](#).

### Operation with External Current Regulation

The motor current can be controlled by external PWM regulation using sense-resistor feedback in a control loop. To disable the internal current regulation circuitry of the MAX14871 and use external regulation, connect SNS directly to ground. See [Figure 5](#).

Note that, if fast decay control is used, the COM voltage pulses negatively when the H-bridge direction is inverted.

### Use of External Capacitors

Maxim does not recommend using external capacitors across the motor terminals. Added capacitance between H-bridge outputs increases the power dissipated in the H-bridge by:

$$P_{\text{D}} = V_{\text{DD}}^2 \times C \times f_{\text{SW}}$$

where  $C$  is the capacitance across M1/M2 and  $f_{\text{SW}}$  is the M1/M2 switching frequency. This power is dissipated without good reason.

Note that conducted EMI on the  $V_{\text{DD}}$  lines is also worsened due to the high-capacitive current spikes.

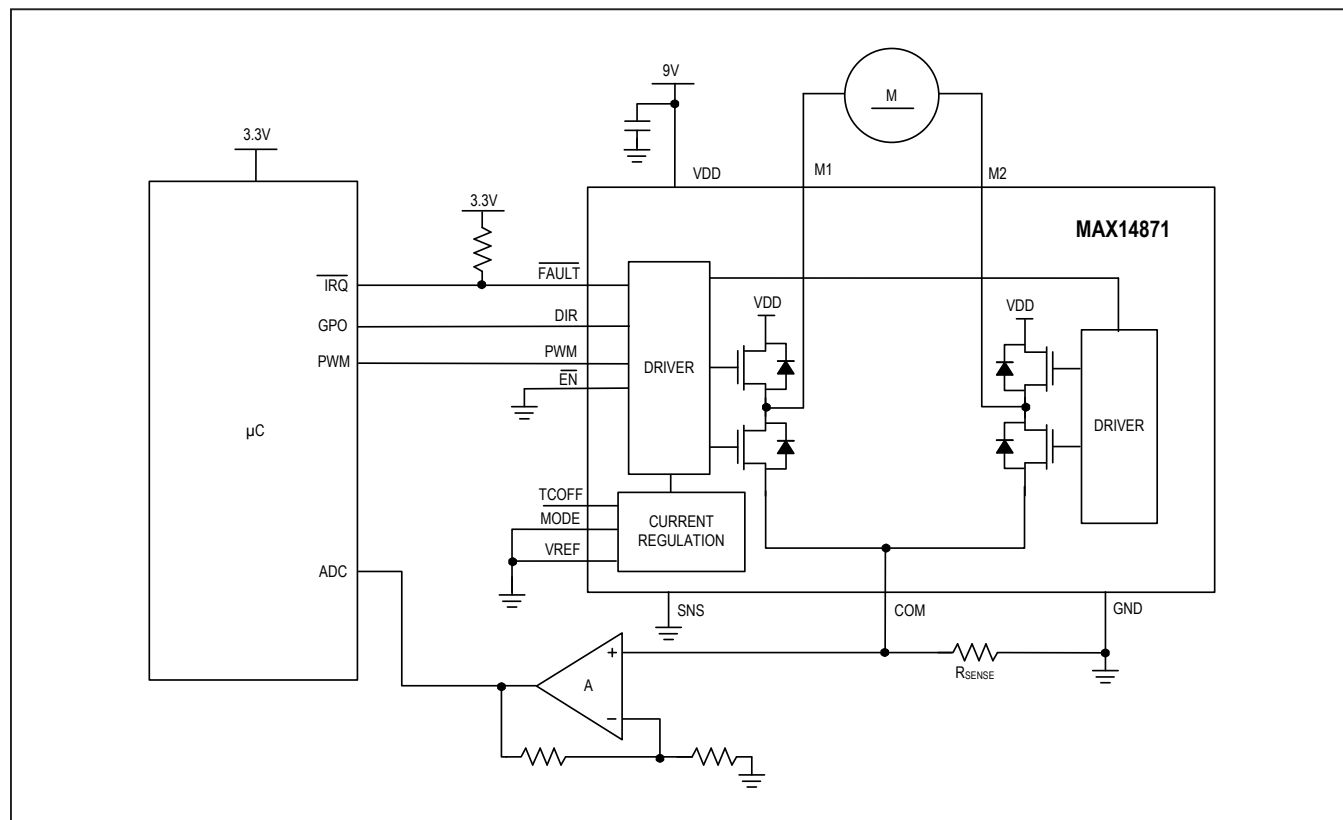


Figure 5. Operation with External Current Regulation

## Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX14871EUE+	-40°C to +85°C	16 TSSOP-EP

+Denotes a lead(Pb)-free/RoHS-compliant package.

\*EP = Exposed pad

## Chip Information

PROCESS: BiCMOS

## Package Information

For the latest package outline information and land patterns (footprints), go to [www.maximintegrated.com/packages](http://www.maximintegrated.com/packages). Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

PACKAGE TYPE	PACKAGE CODE	OUTLINE NO.	LAND PATTERN NO.
16 TSSOP-EP	U16E+3	<a href="#">21-0108</a>	<a href="#">90-0120</a>

## Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	9/14	Initial release	—

For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim Integrated's website at [www.maximintegrated.com](http://www.maximintegrated.com).

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