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5.0 A H-Bridge with Load Current Feedback

The 33887 is a monolithic H-Bridge Power IC with a load current feedback feature making it ideal for closed-loop DC motor control. The IC incorporates internal control logic, charge pump, gate drive, and low $R_{DS(ON)}$ MOSFET output circuitry. The 33887 is able to control inductive loads with continuous DC load currents up to 5.0 A, and with peak current active limiting between 5.2 A and 7.8 A. Output loads can be pulse width modulated (PWM-ed) at frequencies up to 10 kHz. The load current feedback feature provides a proportional (1/375th of the load current) constant-current output suitable for monitoring by a microcontroller's A/D input. This feature facilitates the design of closed-loop torque/speed control as well as open load detection.

A Fault Status output pin reports undervoltage, short circuit, and overtemperature conditions. Two independent inputs provide polarity control of two half-bridge totem-pole outputs. Two disable inputs force the H-Bridge outputs to tri-state (exhibit high-impedance).

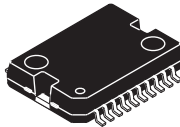
The 33887 is parametrically specified over a temperature range of $-40^{\circ}\text{C} \leq T_A \leq 125^{\circ}\text{C}$ and a voltage range of $5.0\text{ V} \leq V^+ \leq 28\text{ V}$. Operation with voltages up to 40 V with derating of the specifications.

Features

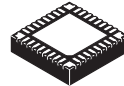
- Fully specified operation 5.0 V to 28 V
- Limited operation with reduced performance up to 40 V
- $120\text{ m}\Omega$ $R_{DS(ON)}$ Typical H-Bridge MOSFETs
- TTL/CMOS Compatible Inputs
- PWM Frequencies up to 10 kHz
- Active Current Limiting (Regulation)
- Fault Status Reporting
- Sleep Mode with Current Draw $\leq 50\ \mu\text{A}$ (Inputs Floating or Set to Match Default Logic States)

33887

H-BRIDGE

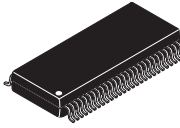


VW SUFFIX (Pb-FREE)
98ASH70702A
20-PIN HSOP



FK SUFFIX
98ASA10583D
36-PIN PQFN

Bottom View



EK SUFFIX (Pb-FREE)
98ASA10506D
54-PIN SOICW-EP

ORDERING INFORMATION		
Device	Temperature Range (T_A)	Package
MC33887APVW/R2	-40°C to 125°C	20 HSOP
MC33887PFK/R2		36 PQFN
MC33887PEK/R2		54 SOICW-EP

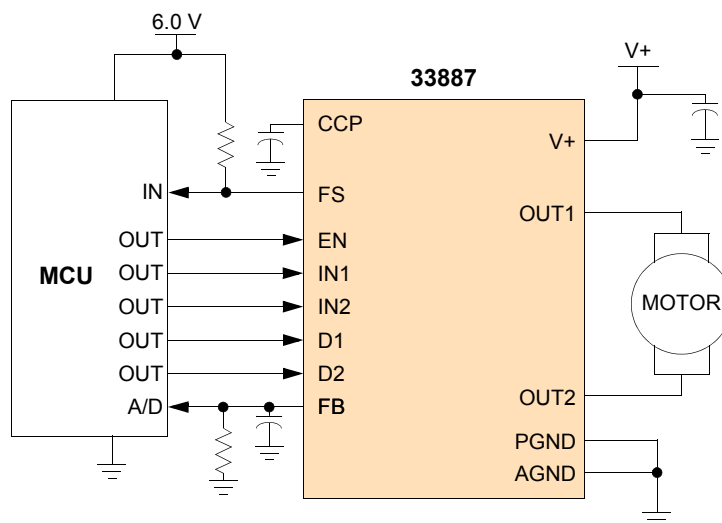


Figure 1. 33887 Simplified Application Diagram

* This document contains certain information on a new product. Specifications and information herein are subject to change without notice.

INTERNAL BLOCK DIAGRAM

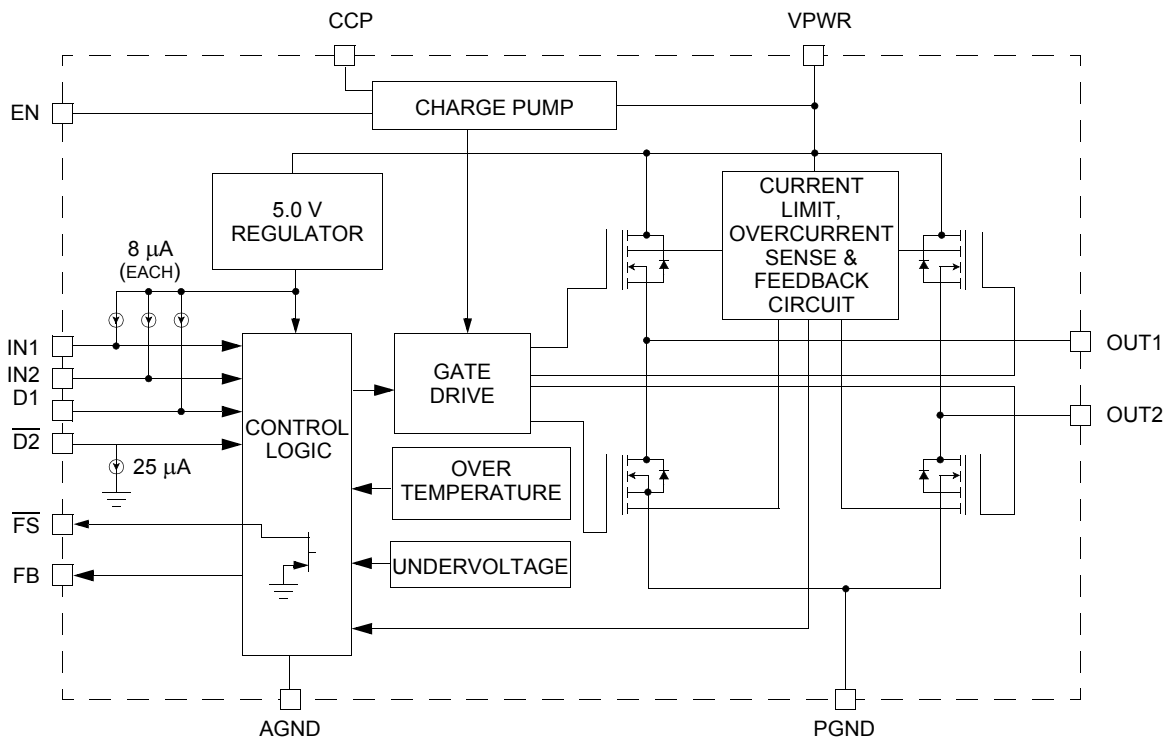
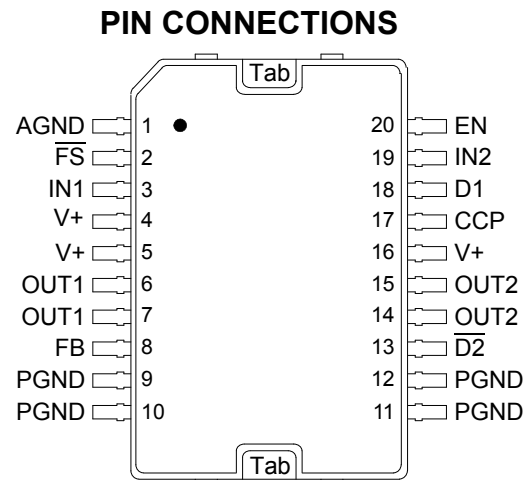


Figure 2. 33887 Simplified Internal Block Diagram


Figure 3. 33887 Pin Connections
Table 1. 33887 HSOP PIN DEFINITIONS

A functional description of each pin can be found in the [Functional Pin DescriptionS](#) section, [page 21](#).

Pin	Pin Name	Formal Name	Definition
1	AGND	Analog Ground	Low-current analog signal ground.
2	\overline{FS}	Fault Status for H-Bridge	Open drain active LOW Fault Status output requiring a pull-up resistor to 5.0 V.
3	IN1	Logic Input Control 1	Logic input control of OUT1 (i.e., IN1 logic HIGH = OUT1 HIGH).
4, 5, 16	V+	Positive Power Supply	Positive supply connections
6, 7	OUT1	H-Bridge Output 1	Output 1 of H-Bridge.
8	FB	Feedback for H-Bridge	Current sensing feedback output providing ground referenced 1/375th (0.00266) of H-Bridge high-side current.
9–12	PGND	Power Ground	High-current power ground.
13	$\overline{D2}$	Disable 2	Active LOW input used to simultaneously tri-state disable both H-Bridge outputs. When $\overline{D2}$ is Logic LOW, both outputs are tri-stated.
14, 15	OUT2	H-Bridge Output 2	Output 2 of H-Bridge.
17	CCP	Charge Pump Capacitor	External reservoir capacitor connection for internal charge pump capacitor.
18	D1	Disable 1	Active HIGH input used to simultaneously tri-state disable both H-Bridge outputs. When D1 is Logic HIGH, both outputs are tri-stated.
19	IN2	Logic Input Control 2	Logic input control of OUT2 (i.e., IN2 logic HIGH = OUT2 HIGH).
20	EN	Enable	Logic input Enable control of device (i.e., EN logic HIGH = full operation, EN logic LOW = Sleep Mode).
Tab/Pad	Thermal Interface	Exposed Pad Thermal Interface	Exposed pad thermal interface for sinking heat from the device. Note Must be DC-coupled to analog ground and power ground via very low impedance path to prevent injection of spurious signals into IC substrate.

Transparent Top View of Package

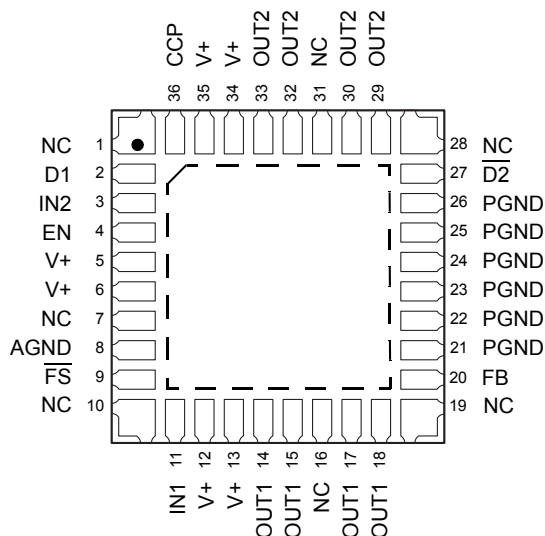


Figure 4. 33887 Pin Connections

Table 2. PQFN PIN DEFINITIONS

 A functional description of each pin can be found in the [Functional Pin DescriptionS](#) section, [page 21](#).

Pin	Pin Name	Formal Name	Definition
1, 7, 10, 16, 19, 28, 31	NC	No Connect	No internal connection to this pin.
2	D1	Disable 1	Active HIGH input used to simultaneously tri-state disable both H-Bridge outputs. When D1 is Logic HIGH, both outputs are tri-stated.
3	IN2	Logic Input Control 2	Logic input control of OUT2 (i.e., IN2 logic HIGH = OUT2 HIGH).
4	EN	Enable	Logic input Enable control of device (i.e., EN logic HIGH = full operation, EN logic LOW = Sleep Mode).
5, 6, 12, 13, 34, 35	V+	Positive Power Supply	Positive supply connections.
8	AGND	Analog Ground	Low-current analog signal ground.
9	\overline{FS}	Fault Status for H-Bridge	Open drain active LOW Fault Status output requiring a pull-up resistor to 5.0 V.
11	IN1	Logic Input Control 1	Logic input control of OUT1 (i.e., IN1 logic HIGH = OUT1 HIGH).
14, 15, 17, 18	OUT1	H-Bridge Output 1	Output 1 of H-Bridge.
20	FB	Feedback for H-Bridge	Current feedback output providing ground referenced 1/375th ratio of H-Bridge high-side current.
21–26	PGND	Power Ground	High-current power ground.
27	$\overline{D2}$	Disable 2	Active LOW input used to simultaneously tri-state disable both H-Bridge outputs. When D2 is Logic LOW, both outputs are tri-stated.
29, 30, 32, 33	OUT2	H-Bridge Output 2	Output 2 of H-Bridge.
36	CCP	Charge Pump Capacitor	External reservoir capacitor connection for internal charge pump capacitor.
Pad	Thermal Interface	Exposed Pad Thermal Interface	Exposed pad thermal interface for sinking heat from the device. Note: Must be DC-coupled to analog ground and power ground via very low impedance path to prevent injection of spurious signals into IC substrate.

Transparent Top View of Package

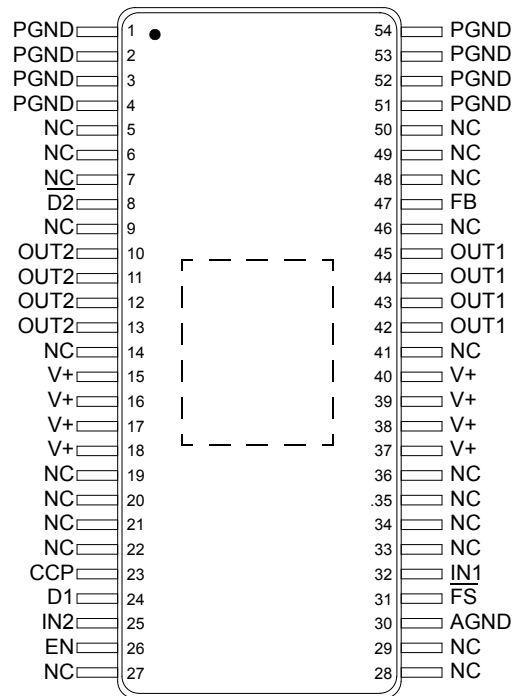


Figure 5. 33887 Pin Connections

Table 3. SOICW-EP PIN DEFINITIONS

 A functional description of each pin can be found in the [Functional Pin DescriptionS](#) section, [page 21](#).

Pin	Pin Name	Formal Name	Definition
1–4, 51–54	PGND	Power Ground	High-current power ground.
5–7, 9, 14, 19–22, 27–29, 33–36, 41, 46, 48–50	NC	No Connect	No internal connection to this pin.
8	$\overline{D2}$	Disable 2	Active LOW input used to simultaneously tri-state disable both H-Bridge outputs. When $\overline{D2}$ is Logic LOW, both outputs are tri-stated.
10–13	OUT2	H-Bridge Output 2	Output 2 of H-Bridge.
15–18, 37–40	V+	Positive Power Supply	Positive supply connections.
23	CCP	Charge Pump Capacitor	External reservoir capacitor connection for internal charge pump capacitor.
24	D1	Disable 1	Active HIGH input used to simultaneously tri-state disable both H-Bridge outputs. When D1 is Logic HIGH, both outputs are tri-stated.
25	IN2	Logic Input Control 2	Logic input control of OUT2 (i.e., IN2 logic HIGH = OUT2 HIGH).
26	EN	Enable	Logic input Enable control of device (i.e., EN logic HIGH = full operation, EN logic LOW = Sleep Mode).
30	AGND	Analog Ground	Low-current analog signal ground.
31	\overline{FS}	Fault Status for H-Bridge	Open drain active LOW Fault Status output requiring a pull-up resistor to 5.0 V.
32	IN1	Logic Input Control 1	Logic input control of OUT1 (i.e., IN1 logic HIGH = OUT1 HIGH).

Table 3. SOICW-EP PIN DEFINITIONS

A functional description of each pin can be found in the [Functional Pin DescriptionS](#) section, [page 21](#).

Pin	Pin Name	Formal Name	Definition
42–45	OUT1	H-Bridge Output 1	Output 1 of H-Bridge.
47	FB	Feedback for H-Bridge	Current feedback output providing ground referenced 1/375th ratio of H-Bridge high-side current.
Pad	Thermal Interface	Exposed Pad Thermal Interface	Exposed pad thermal interface for sinking heat from the device. Note Must be DC-coupled to analog ground and power ground via very low impedance path to prevent injection of spurious signals into IC substrate.

ELECTRICAL CHARACTERISTICS

MAXIMUM RATINGS

MAXIMUM RATINGS

All voltages are with respect to ground unless otherwise noted.

Rating	Symbol	Value	Unit
ELECTRICAL RATINGS			
Supply Voltage ⁽¹⁾	V+	-0.3 to 40	V
Input Voltage ⁽²⁾	V _{IN}	-0.3 to 7.0	V
FS Status Output ⁽³⁾	V _{FS}	-0.3 to 7.0	V
Continuous Current ⁽⁴⁾	I _{OUT}	5.0	A
ESD Voltage ⁽⁵⁾			V
Human Body Model	V _{ESD1}	±2000	
Machine Model	V _{ESD2}	±200	
THERMAL RATINGS			
Storage Temperature	T _{STG}	-65 to 150	°C
Operating Temperature ⁽⁶⁾			°C
Ambient	T _A	-40 to 125	
Junction	T _J	-40 to 150	
Peak Package Reflow Temperature During Reflow ^{(7), (8)}	T _{PPRT}	Note 8.	°C

Notes

- Performance at voltages greater than 28V is degraded. See [Electrical Performance Curves on page 18](#) and 19 for typical performance. Extended operation at higher voltages has not been fully characterized and may reduce the operational lifetime.
- Exceeding the input voltage on IN1, IN2, EN, D1, or $\overline{D2}$ may cause a malfunction or permanent damage to the device.
- Exceeding the pull-up resistor voltage on the open Drain \overline{FS} pin may cause permanent damage to the device.
- Continuous current capability so long as junction temperature is $\leq 150^\circ\text{C}$.
- ESD1 testing is performed in accordance with the Human Body Model ($C_{ZAP} = 100 \text{ pF}$, $R_{ZAP} = 1500 \Omega$), ESD2 testing is performed in accordance with the Machine Model ($C_{ZAP} = 200 \text{ pF}$, $R_{ZAP} = 0 \Omega$).
- The limiting factor is junction temperature, taking into account the power dissipation, thermal resistance, and heat sinking provided. Brief nonrepetitive excursions of junction temperature above 150°C can be tolerated as long as duration does not exceed 30 seconds maximum. (nonrepetitive events are defined as not occurring more than once in 24 hours.)
- Pin soldering temperature limit is for 10 seconds maximum duration. Not designed for immersion soldering. Exceeding these limits may cause malfunction or permanent damage to the device.
- Freescale's Package Reflow capability meets Pb-free requirements for JEDEC standard J-STD-020C. For Peak Package Reflow Temperature and Moisture Sensitivity Levels (MSL), Go to www.freescale.com, search by part number [e.g. remove prefixes/suffixes and enter the core ID to view all orderable parts. (i.e. MC33xxx enter 33xxx), and review parametrics.

MAXIMUM RATINGS (continued)

All voltages are with respect to ground unless otherwise noted.

Rating	Symbol	Value	Unit
THERMAL RESISTANCE (AND PACKAGE DISSIPATION) RATINGS ^{(9), (10), (11), (12)}			
Junction-to-Board (Bottom Exposed Pad Soldered to Board) HSOP (6.0 W) PQFN (4.0 W) SOICW-EP (2.0 W)	$R_{\theta JB}$	~7.0 ~8.0 ~9.0	°C/W
Junction-to-Ambient, Natural Convection, Single-Layer Board (1s) ⁽¹³⁾ HSOP (6.0 W) PQFN (4.0 W) SOICW-EP (2.0 W)	$R_{\theta JA}$	~41 ~50 ~62	°C/W
Junction-to-Ambient, Natural Convection, Four-Layer Board (2s2p) ⁽¹⁴⁾ HSOP (6.0 W) PQFN (4.0 W) SOICW-EP (2.0 W)	$R_{\theta JMA}$	~18 ~21 ~23	°C/W
Junction-to-Case (Exposed Pad) ⁽¹⁵⁾ HSOP (6.0 W) PQFN (4.0 W) SOICW-EP (2.0 W)	$R_{\theta JC}$	~0.8 ~1.2 ~2.0	°C/W

Notes

- 9 The limiting factor is junction temperature, taking into account the power dissipation, thermal resistance, and heat sinking.
- 10 Exposed heatsink pad plus the power and ground pins comprise the main heat conduction paths. The actual $R_{\theta JB}$ (junction-to-PC board) values will vary depending on solder thickness and composition and copper trace thickness. Maximum current at maximum die temperature represents ~16 W of conduction loss heating in the diagonal pair of output MOSFETs. Therefore, the $R_{\theta JC}$ -total must be less than 5.0 °C/W for maximum load at 70°C ambient. Module thermal design must be planned accordingly.
- 11 Thermal resistance between the die and the printed circuit board per JEDEC JESD51-8. Board temperature is measured on the top surface of the board near the package.
- 12 Junction temperature is a function of on-chip power dissipation, package thermal resistance, mounting site (board) temperature, ambient temperature, air flow, power dissipation of other components on the board, and board thermal resistance.
- 13 Per SEMI G38-87 and JEDEC JESD51-2 with the single-layer board (JESD51-3) horizontal.
- 14 Per JEDEC JESD51-6 with the board horizontal.
- 15 Indicates the maximum thermal resistance between the die and the exposed pad surface as measured by the cold plate method (MIL SPEC-883 Method 1012.1) with the cold plate temperature used for the case temperature.

STATIC ELECTRICAL CHARACTERISTICS

Table 4. STATIC ELECTRICAL CHARACTERISTICS

Characteristics noted under conditions $5.0\text{ V} \leq V_+ \leq 28\text{ V}$ and $-40^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$ unless otherwise noted. Typical values noted reflect the approximate parameter mean at $T_A = 25^\circ\text{C}$ under nominal conditions unless otherwise noted.

Characteristic	Symbol	Min	Typ	Max	Unit
POWER SUPPLY					
Operating Voltage Range ⁽¹⁶⁾	V_+	5.0	–	28	V
Sleep State Supply Current ⁽¹⁷⁾ $I_{\text{OUT}} = 0\text{ A}, V_{\text{EN}} = 0\text{ V}$	$I_{\text{Q(SLEEP)}}$	–	25	50	μA
Standby Supply Current $I_{\text{OUT}} = 0\text{ A}, V_{\text{EN}} = 5.0\text{ V}$	$I_{\text{Q(STANDBY)}}$	–	–	20	mA
Threshold Supply Voltage					
Switch-OFF	$V_{+(\text{THRES-OFF})}$	4.15	4.4	4.65	V
Switch-ON	$V_{+(\text{THRES-ON})}$	4.5	4.75	5.0	V
Hysteresis	$V_{+(\text{HYS})}$	150	–	–	mV
CHARGE PUMP					
Charge Pump Voltage $V_+ = 5.0\text{ V}$ $8.0\text{ V} \leq V_+ \leq 28\text{ V}$	$V_{\text{CP}} - V_+$	3.35 –	– –	– 20	V
CONTROL INPUTS					
Input Voltage (IN1, IN2, D1, $\overline{\text{D2}}$)					V
Threshold HIGH	V_{IH}	3.5	–	–	
Threshold LOW	V_{IL}	–	–	1.4	
Hysteresis	V_{HYS}	0.7	1.0	–	
Input Current (IN1, IN2, D1) $V_{\text{IN}} = 0.0\text{ V}$	I_{INP}	-200	-80	–	μA
Input Current ($\overline{\text{D2}}$, EN) $V_{\overline{\text{D2}}} = 5.0\text{ V}$	I_{INP}	–	25	100	μA

Notes

- 16 Specifications are characterized over the range of $5.0\text{ V} \leq V_+ \leq 28\text{ V}$. See [See Electrical Performance Curves on page 18](#) and 19 and the [See Functional Description on page 21](#) for information about operation outside of this range.
- 17 $I_{\text{Q(sleep)}}$ is with sleep mode function enabled.

Table 4. STATIC ELECTRICAL CHARACTERISTICS

Characteristics noted under conditions $5.0\text{ V} \leq V_{+} \leq 28\text{ V}$ and $-40^{\circ}\text{C} \leq T_{A} \leq 125^{\circ}\text{C}$ unless otherwise noted. Typical values noted reflect the approximate parameter mean at $T_{A} = 25^{\circ}\text{C}$ under nominal conditions unless otherwise noted.

Characteristic	Symbol	Min	Typ	Max	Unit
POWER SUPPLY					
POWER OUTPUTS (OUT1, OUT2)					
Output ON-Resistance ⁽¹⁸⁾ $5.0\text{ V} \leq V_{+} \leq 28\text{ V}$, $T_{J} = 25^{\circ}\text{C}$ $8.0\text{ V} \leq V_{+} \leq 28\text{ V}$, $T_{J} = 150^{\circ}\text{C}$ $5.0\text{ V} \leq V_{+} \leq 8.0\text{ V}$, $T_{J} = 150^{\circ}\text{C}$	$R_{DS(ON)}$	–	120	–	mΩ
Active Current Limiting Threshold (via Internal Constant OFF-Time PWM) on Low-Side MOSFETs ⁽¹⁹⁾	I_{LIM}	5.2	6.5	7.8	A
High-Side Short Circuit Detection Threshold	I_{SCH}	11	–	–	A
Low-Side Short Circuit Detection Threshold	I_{SCL}	8.0	–	–	A
Leakage Current ⁽²⁰⁾ $V_{OUT} = V_{+}$ $V_{OUT} = \text{Ground}$	$I_{OUT(LEAK)}$	–	100	200	μA
Output MOSFET Body Diode Forward Voltage Drop $I_{OUT} = 3.0\text{ A}$	V_{F}	–	–	2.0	V
Overtemperature Shutdown Thermal Limit Hysteresis	T_{LIM} T_{HYS}	175 10	– –	225 30	°C

HIGH-SIDE CURRENT SENSE FEEDBACK

Feedback Current $I_{OUT} = 0\text{ mA}$ $I_{OUT} = 500\text{ mA}$ $I_{OUT} = 1.5\text{ A}$ $I_{OUT} = 3.0\text{ A}$ $I_{OUT} = 6.0\text{ A}$	I_{FB}	– 1.07 3.6 7.2 14.4	– 1.33 4.0 8.0 16	600 1.68 4.62 9.24 18.48	μA mA mA mA mA
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FAULT STATUS ⁽²¹⁾

Fault Status Leakage Current ⁽²²⁾ $V_{FS} = 5.0\text{ V}$	$I_{FS(LEAK)}$	–	–	10	μA
Fault Status SET Voltage ⁽²³⁾ $I_{FS} = 300\text{ μA}$	$V_{FS(LOW)}$	–	–	1.0	V

Notes

- 18 Output-ON resistance as measured from output to V_{+} and ground.
- 19 Active current limitation applies only for the low-side MOSFETs.
- 20 Outputs switched OFF with D1 or D2.
- 21 Fault Status output is an open Drain output requiring a pull-up resistor to 5.0 V.
- 22 Fault Status Leakage Current is measured with Fault Status HIGH and *not* SET.
- 23 Fault Status Set Voltage is measured with Fault Status LOW and SET with $I_{FS} = 300\text{ μA}$.

DYNAMIC ELECTRICAL CHARACTERISTICS

Table 5. DYNAMIC ELECTRICAL CHARACTERISTICS

Characteristics noted under conditions $5.0\text{ V} \leq V_+ \leq 28\text{ V}$ and $-40^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$ unless otherwise noted. Typical values noted reflect the approximate parameter mean at $T_A = 25^\circ\text{C}$ under nominal conditions unless otherwise noted.

Characteristic	Symbol	Min	Typ	Max	Unit
TIMING CHARACTERISTICS					
PWM Frequency ⁽²⁴⁾	f_{PWM}	–	10	–	kHz
Maximum Switching Frequency During Active Current Limiting ⁽²⁵⁾	f_{MAX}	–	–	20	kHz
Output ON Delay ⁽²⁶⁾ V+ = 14 V	$t_{\text{D(ON)}}$	–	–	18	μs
Output OFF Delay ⁽²⁶⁾ V+ = 14 V	$t_{\text{D(OFF)}}$	–	–	18	μs
I_{LIM} Output Constant-OFF Time for Low-Side MOSFETs ^{(27), (28)}	t_{A}	15	20.5	26	μs
I_{LIM} Blanking Time for Low-Side MOSFETs ^{(29), (28)}	t_{B}	12	16.5	21	μs
Output Rise and Fall Time ⁽³⁰⁾ V+ = 14 V, $I_{\text{OUT}} = 3.0\text{ A}$	$t_{\text{F}}, t_{\text{R}}$	2.0	5.0	8.0	μs
Disable Delay Time ⁽³¹⁾	$t_{\text{D(DISABLE)}}$	–	–	8.0	μs
Power-ON Delay Time ⁽³²⁾	t_{POD}	–	1.0	5.0	ms
Wake-Up Delay Time ⁽³²⁾	t_{WUD}	–	1.0	5.0	ms
Output MOSFET Body Diode Reverse Recovery Time ⁽³³⁾	t_{RR}	100	–	–	ns

Notes

- 24 The outputs can be PWM-controlled from an external source. This is typically done by holding one input high while applying a PWM pulse train to the other input. The maximum PWM frequency obtainable is a compromise between switching losses and switching frequency. See Typical Switching Waveforms, [Figures 12 through 19](#), pp. 14–17.
- 25 The Maximum Switching Frequency during active current limiting is internally implemented. The internal current limit circuitry produces a constant-OFF-time pulse-width modulation of the output current. The output load's inductance, capacitance, and resistance characteristics affect the total switching period (OFF-time + ON-time) and thus the PWM frequency during current limit.
- 26 Output Delay is the time duration from the midpoint of the IN1 or IN2 input signal to the 10% or 90% point (dependent on the transition direction) of the OUT1 or OUT2 signal. If the output is transitioning HIGH-to-LOW, the delay is from the midpoint of the input signal to the 90% point of the output response signal. If the output is transitioning LOW-to-HIGH, the delay is from the midpoint of the input signal to the 10% point of the output response signal. See [Figure 6](#), page 12.
- 27 I_{LIM} Output Constant-OFF Time is the time during which the internal constant-OFF time PWM current regulation circuit has tri-stated the output bridge.
- 28 Load currents ramping up to the current regulation threshold become limited at the I_{LIM} value. The short circuit currents possess a di/dt that ramps up to the I_{SCH} or I_{SCL} threshold during the I_{LIM} blanking time, registering as a short circuit event detection and causing the shutdown circuitry to force the output into an immediate tri-state latch-OFF. See [Figures 10 and 11](#), page 13. Operation in Current Limit mode may cause junction temperatures to rise. Junction temperatures above $\sim 160^\circ\text{C}$ will cause the output current limit threshold to progressively “fold back”, or decrease with temperature, until $\sim 175^\circ\text{C}$ is reached, after which the T_{LIM} thermal latch-OFF will occur. Permissible operation within this fold-back region is limited to nonrepetitive transient events of duration not to exceed 30 seconds. See [Figure 9](#), page 12.
- 29 I_{LIM} Blanking Time is the time during which the current regulation threshold is ignored so that the short-circuit detection threshold comparators may have time to act.
- 30 Rise Time is from the 10% to the 90% level and Fall Time is from the 90% to the 10% level of the output signal. See [Figure 8](#), page 12.
- 31 Disable Delay Time is the time duration from the midpoint of the D (disable) input signal to 10% of the output tri-state response. See [Figure 7](#), page 12.
- 32 Parameter has been characterized but not production tested.
- 33 Parameter is guaranteed by design but not production tested.

TIMING DIAGRAMS

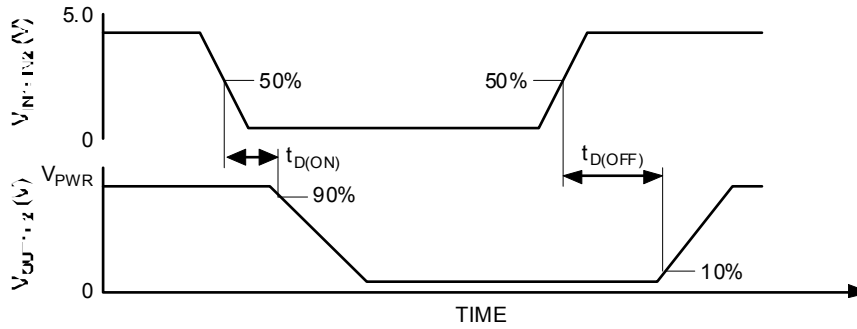


Figure 6. Output Delay Time

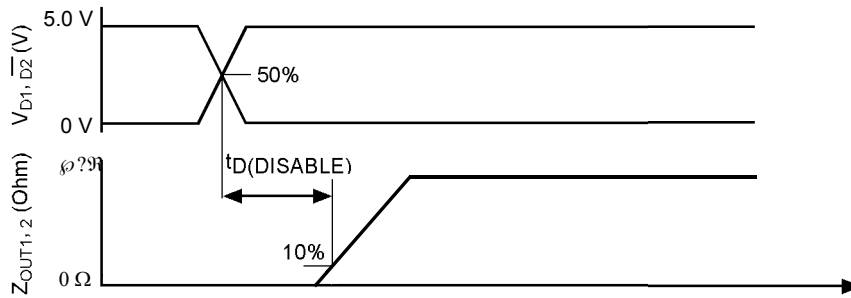


Figure 7. Disable Delay Time

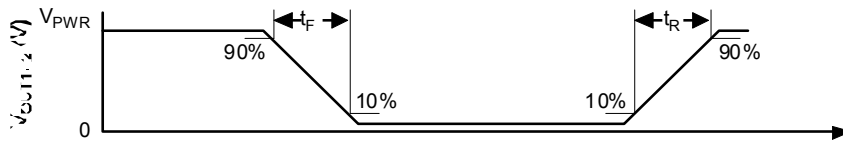


Figure 8. Output Switching Time

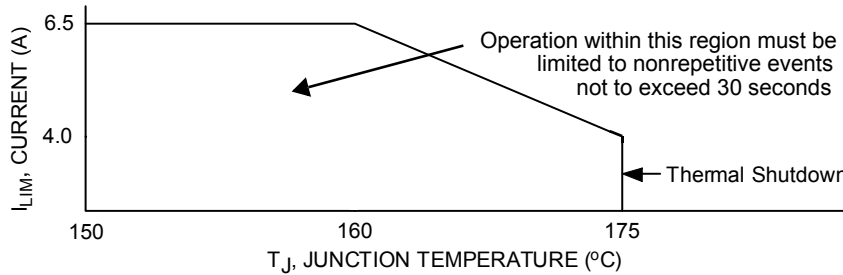


Figure 9. Active Current Limiting Versus Temperature (Typical)

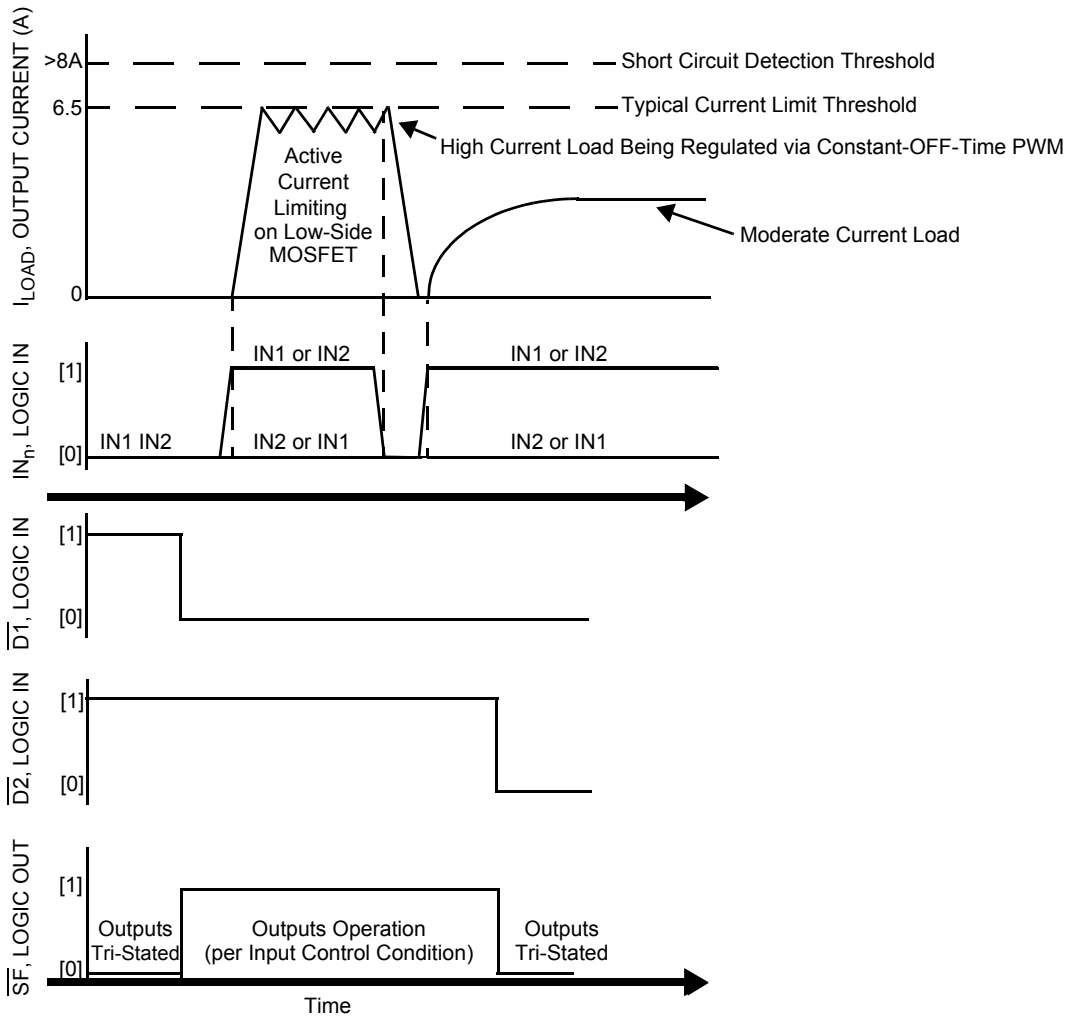


Figure 10. Operating States

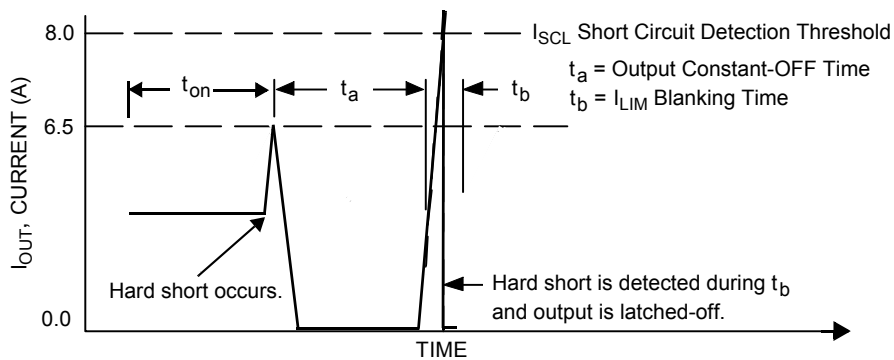


Figure 11. Example Short Circuit Detection Detail on Low-Side MOSFET

TYPICAL SWITCHING WAVEFORMS

Important For all plots, the following applies:
 • Ch2=2.0 A per division

- $L_{LOAD}=533 \mu\text{H}$ @ 1.0 kHz
- $L_{LOAD}=530 \mu\text{H}$ @ 10.0 kHz
- $R_{LOAD}=4.0 \Omega$

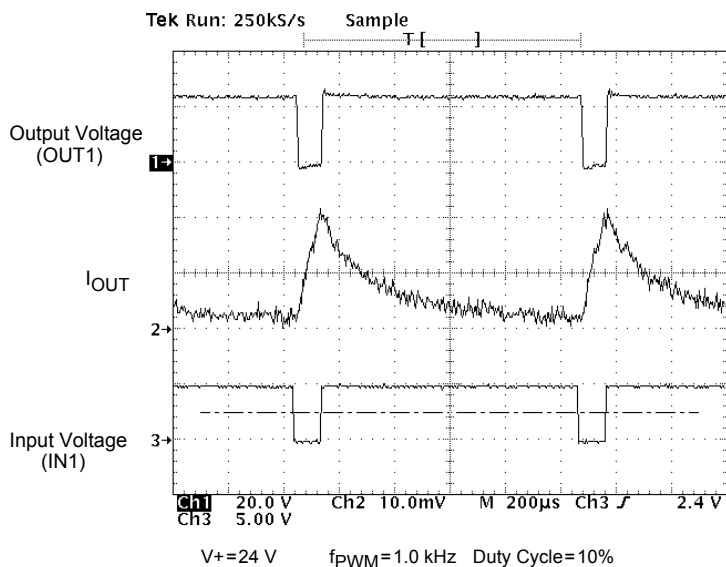


Figure 12. Output Voltage and Current vs. Input Voltage at $V+ = 24 \text{ V}$, PMW Frequency of 1.0 kHz, and Duty Cycle of 10%

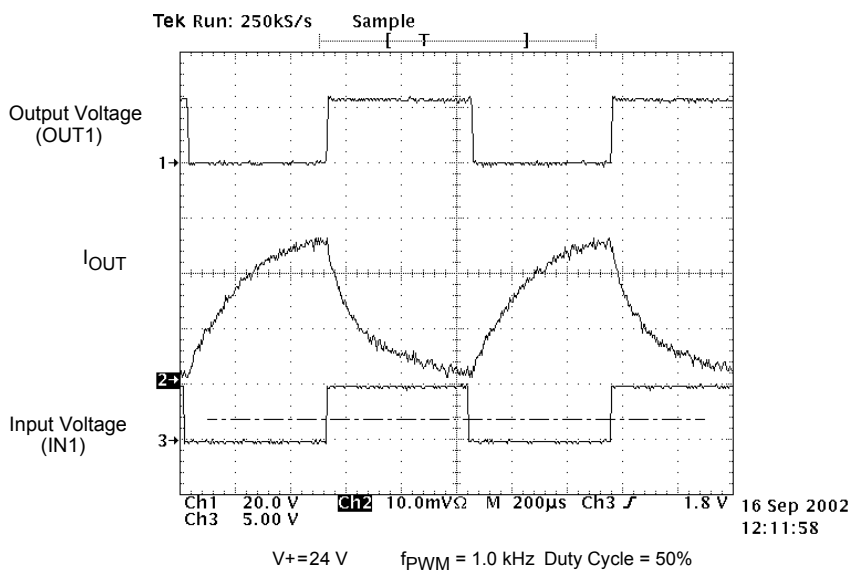


Figure 13. Output Voltage and Current vs. Input Voltage at $V+ = 24 \text{ V}$, PMW Frequency of 1.0 kHz, and Duty Cycle of 50%

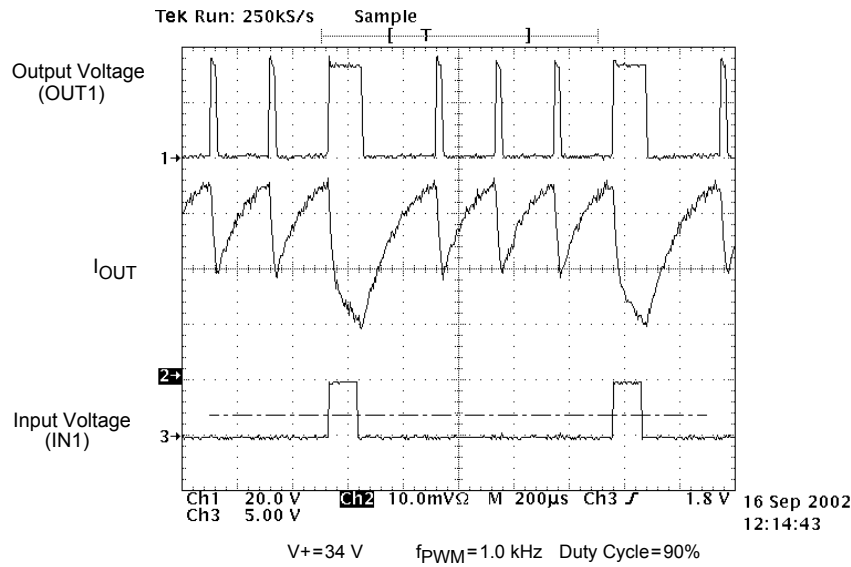


Figure 14. Output Voltage and Current vs. Input Voltage at $V^+ = 34\text{ V}$, PMW Frequency of 1.0 kHz, and Duty Cycle of 90%, Showing Device in Current Limiting Mode

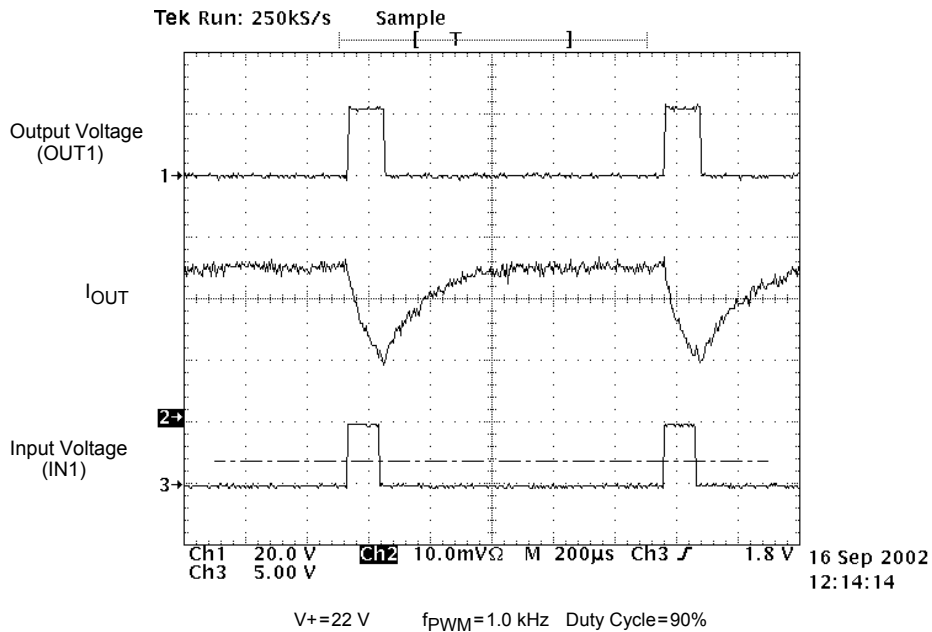


Figure 15. Output Voltage and Current vs. Input Voltage at $V^+ = 22\text{ V}$, PMW Frequency of 1.0 kHz, and Duty Cycle of 90%

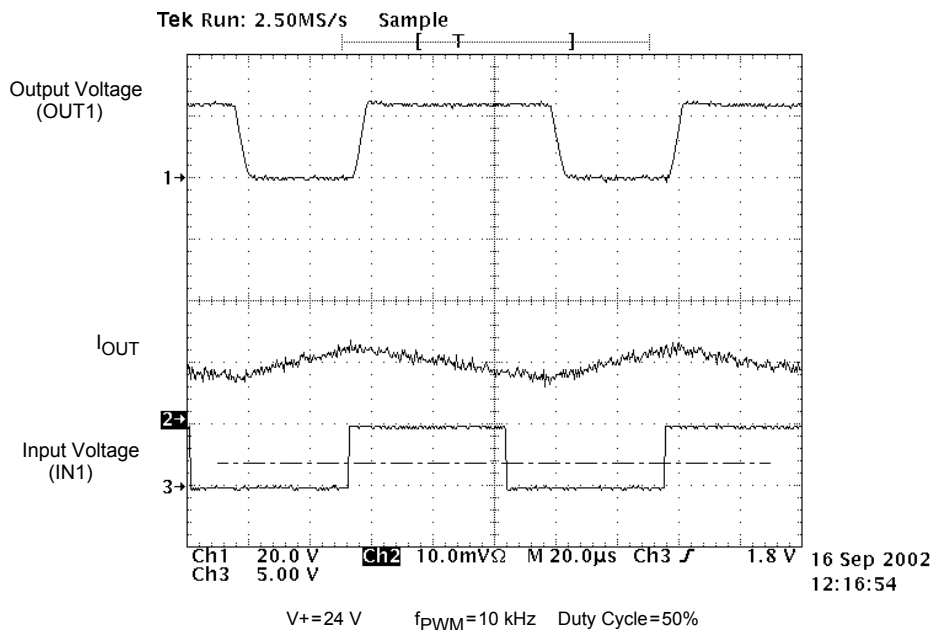


Figure 16. Output Voltage and Current vs. Input Voltage at $V^+ = 24\text{ V}$, PMW Frequency of 10 kHz, and Duty Cycle of 50%

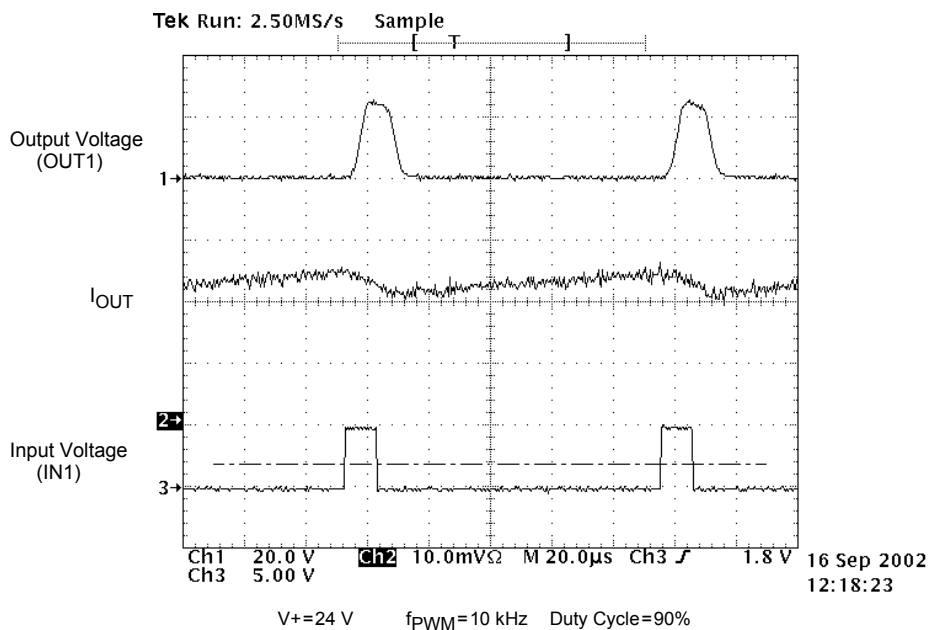


Figure 17. Output Voltage and Current vs. Input Voltage at $V^+ = 24\text{ V}$, PMW Frequency of 10 kHz, and Duty Cycle of 90%

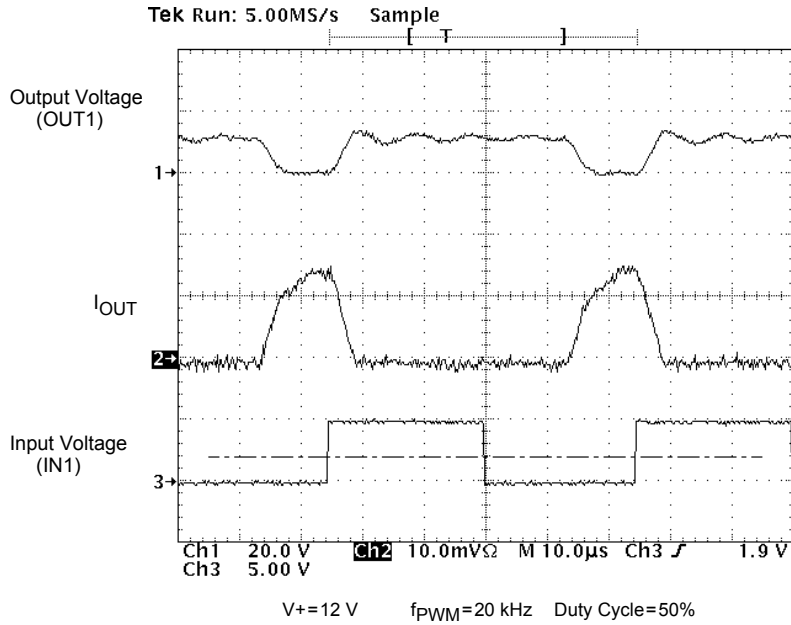


Figure 18. Output Voltage and Current vs. Input Voltage at V+ = 12 V, PMW Frequency of 20 kHz, and Duty Cycle of 50% for a Purely Resistive Load

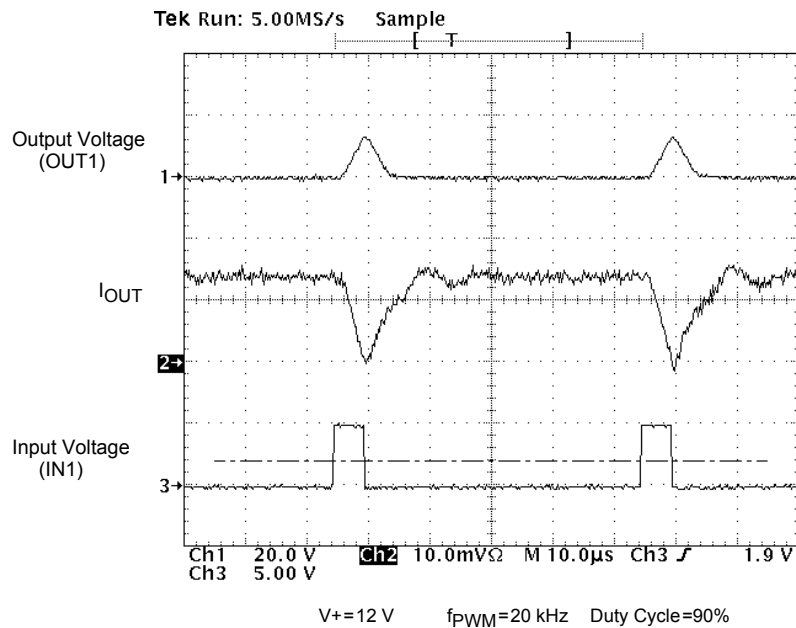


Figure 19. Output Voltage and Current vs. Input Voltage at V+ = 12 V, PMW Frequency of 20 kHz, and Duty Cycle of 90% for a Purely Resistive Load

ELECTRICAL PERFORMANCE CURVES

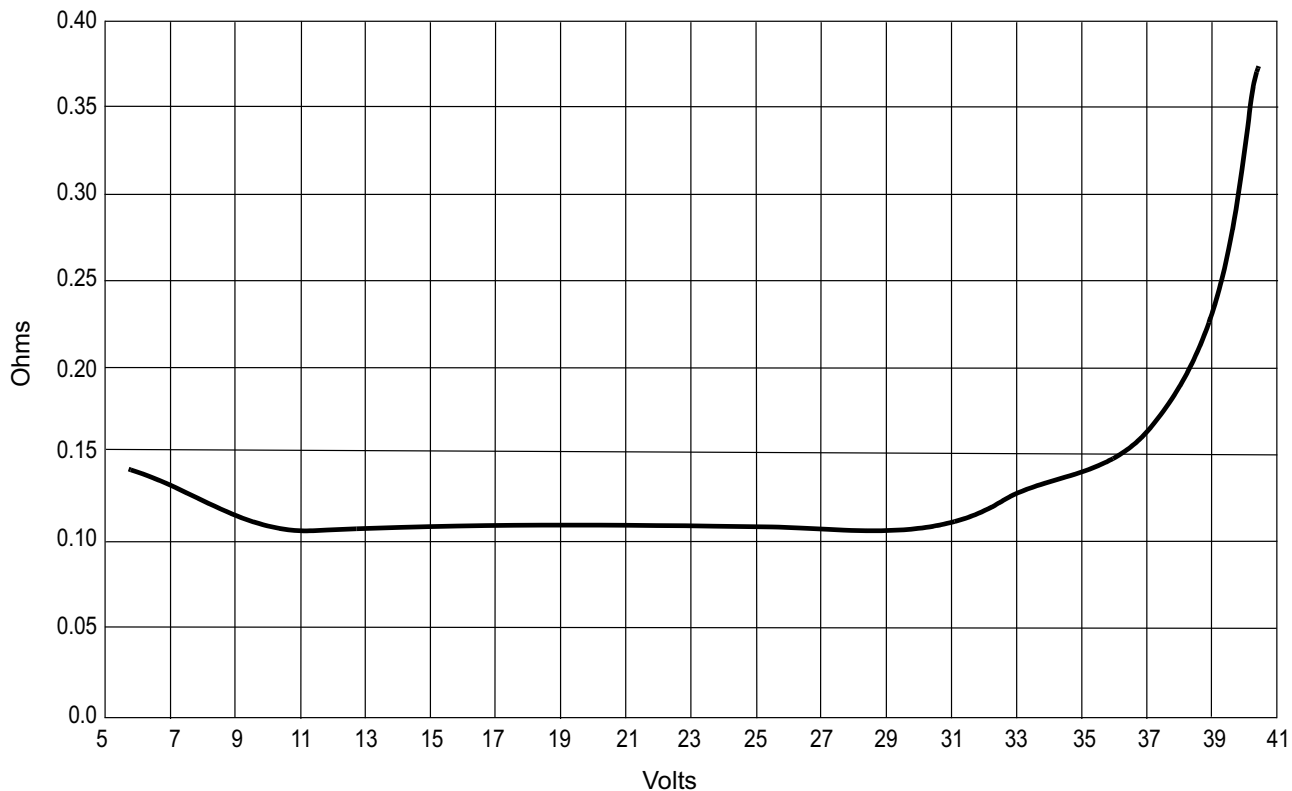


Figure 20. Typical High-Side $R_{DS(ON)}$ Versus $V+$

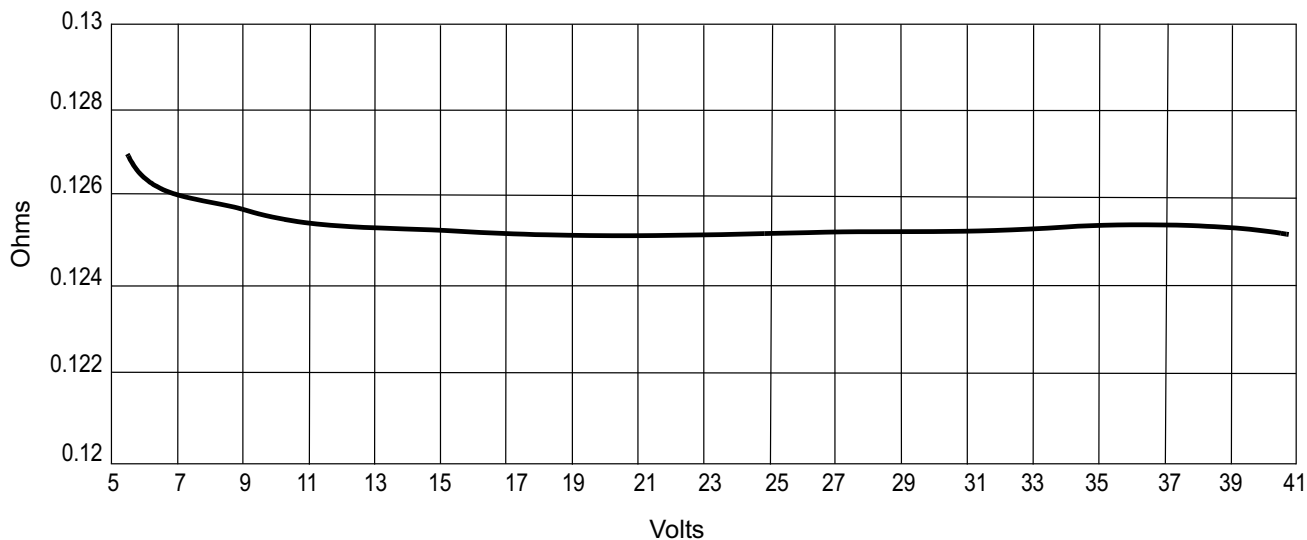


Figure 21. Typical Low-Side $R_{DS(ON)}$ Versus $V+$

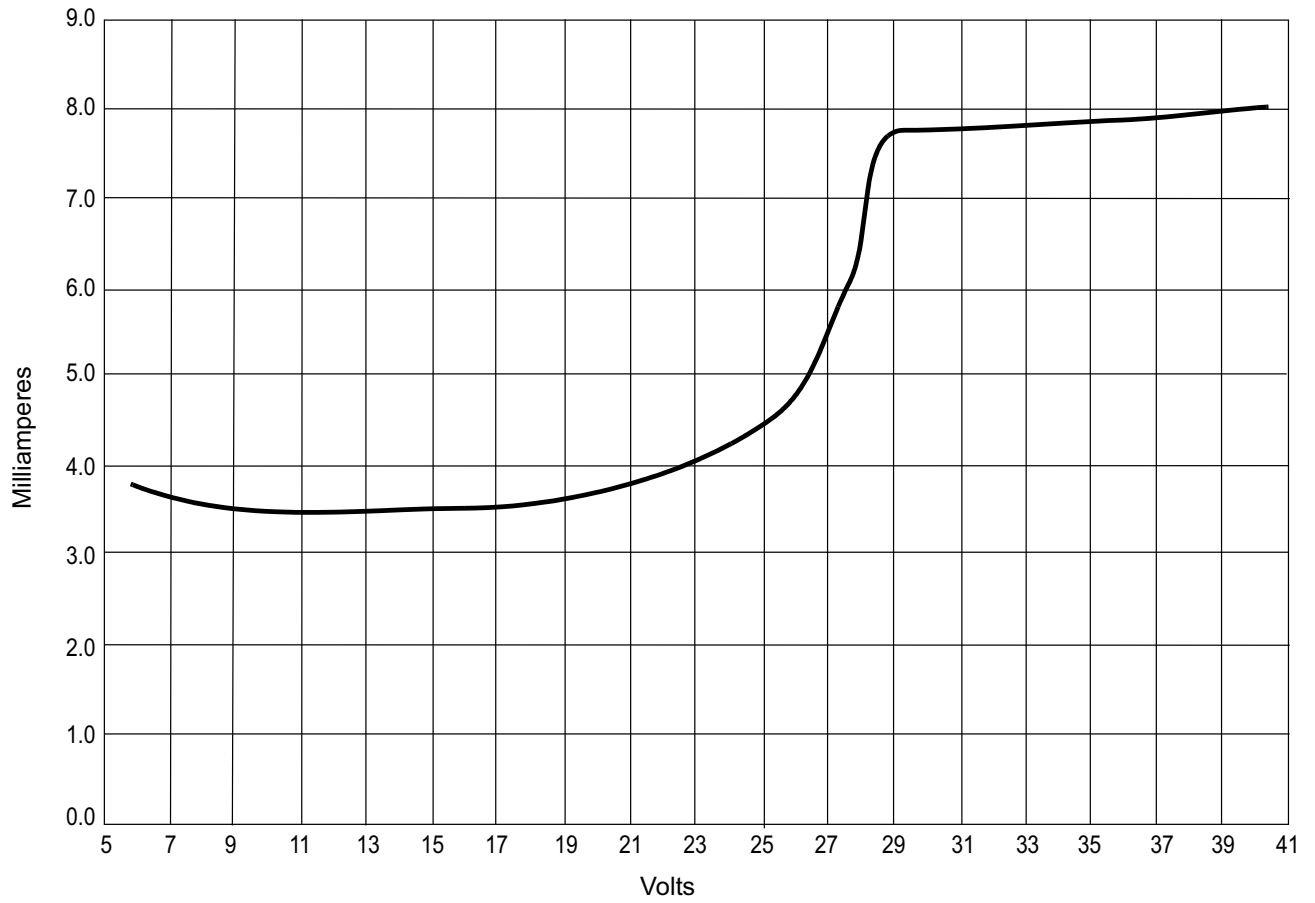


Figure 22. Typical Quiescent Supply Current Versus V+

Table 6. Truth Table

The tri-state conditions and the fault status are reset using D1 or $\overline{D2}$. The truth table uses the following notations: L = LOW, H = HIGH, X = HIGH or LOW, and Z = High impedance (all output power transistors are switched off).

Device State	Input Conditions					Fault Status Flag	Output States	
	EN	D1	$\overline{D2}$	IN1	IN2		\overline{FS}	OUT1
Forward	H	L	H	H	L	H	H	L
Reverse	H	L	H	L	H	H	L	H
Freewheeling Low	H	L	H	L	L	H	L	L
Freewheeling High	H	L	H	H	H	H	H	H
Disable 1 (D1)	H	H	X	X	X	L	Z	Z
Disable 2 ($\overline{D2}$)	H	X	L	X	X	L	Z	Z
IN1 Disconnected	H	L	H	Z	X	H	H	X
IN2 Disconnected	H	L	H	X	Z	H	X	H
D1 Disconnected	H	Z	X	X	X	L	Z	Z
$\overline{D2}$ Disconnected	H	X	Z	X	X	L	Z	Z
Undervoltage ⁽³⁴⁾	H	X	X	X	X	L	Z	Z
Overtemperature ⁽³⁵⁾	H	X	X	X	X	L	Z	Z
Short Circuit ⁽³⁵⁾	H	X	X	X	X	L	Z	Z
Sleep Mode EN	L	X	X	X	X	H	Z	Z
EN Disconnected	Z	X	X	X	X	H	Z	Z

Notes

- 34 In the case of an undervoltage condition, the outputs tri-state and the fault status is SET logic LOW. Upon undervoltage recovery, fault status is reset automatically or automatically cleared and the outputs are restored to their original operating condition.
- 35 When a short circuit or overtemperature condition is detected, the power outputs are tri-state latched-OFF independent of the input signals and the fault status flag is SET logic LOW.

FUNCTIONAL DESCRIPTION

INTRODUCTION

Numerous protection and operational features (speed, torque, direction, dynamic braking, PWM control, and closed-loop control), in addition to the 5.0 A current capability, make the 33887 a very attractive, cost-effective solution for controlling a broad range of small DC motors. In addition, a

pair of 33887 devices can be used to control bipolar stepper motors. The 33887 can also be used to excite transformer primary windings with a switched square wave to produce secondary winding AC currents.

FUNCTIONAL PIN DESCRIPTIONS

POWER GROUND AND ANALOG GROUND (PGND AND AGND)

Power and analog ground pins should be connected together with a very low impedance connection.

POSITIVE POWER SUPPLY (V+)

V+ pins are the power supply inputs to the device. All V+ pins must be connected together on the printed circuit board with as short as possible traces offering as low impedance as possible between pins.

V+ pins have an undervoltage threshold. If the supply voltage drops below a V+ undervoltage threshold, the output power stage switches to a tri-state condition and the fault status flag is SET and the Fault Status pin voltage switched to a logic LOW. When the supply voltage returns to a level that is above the threshold, the power stage automatically resumes normal operation according to the established condition of the input pins and the fault status flag is automatically reset logic HIGH.

As V+ increases in value above 28 V, the charge pump performance begins to degrade. At +40 V, the charge pump is effectively non-functional. Operation at this high voltage level will result in the output FETs not being enhanced when turned on. This means that the voltage on the output will be $V_{OUT} = (V+) - V_{GS}$. This increased voltage drop under load will produce a higher power dissipation.

FAULT STATUS (\overline{FS})

The \overline{FS} pin is the device fault status output. This output is an active LOW open drain structure requiring a pull-up resistor to 5.0 V. Refer to [Table 6, Truth Table](#), page 20.

LOGIC INPUT CONTROL AND DISABLE (IN1, IN2, D1, AND $\overline{D2}$)

These pins are input control pins used to control the outputs. These pins are 5.0 V CMOS-compatible inputs with hysteresis. The IN1 and IN2 independently control OUT1 and OUT2, respectively. D1 and $\overline{D2}$ are complementary inputs used to tri-state disable the H-Bridge outputs.

When either D1 or $\overline{D2}$ is SET (D1 = logic HIGH or $\overline{D2}$ = logic LOW) in the disable state, outputs OUT1 and OUT2 are both tri-state disabled; however, the rest of the circuitry is fully operational and the supply $I_{Q(standby)}$ current is reduced to a

few milliamperes. Refer to [Table 6, Truth Table](#), and [STATIC ELECTRICAL CHARACTERISTICS](#) table, page 9.

H-BRIDGE OUTPUT (OUT1 AND OUT2)

These pins are the outputs of the H-Bridge with integrated output MOSFET body diodes. The bridge output is controlled using the IN1, IN2, D1, and $\overline{D2}$ inputs. The low-side MOSFETs have active current limiting above the I_{LIM} threshold. The outputs also have thermal shutdown (tri-state latch-OFF) with hysteresis as well as short circuit latch-OFF protection.

A disable timer (time t_b) USED to detect currents that are higher than current limit is activated at each output activation to facilitate hard short detection (see [Figure 11](#), page 13).

Charge Pump Capacitor (CCP)

A filter capacitor (up to 33 nF) can be connected from the charge pump output pin and PGND. The device can operate without the external capacitor, although the C_{CP} capacitor helps to reduce noise and allows the device to perform at maximum speed, timing, and PWM frequency.

ENABLE (EN)

The EN pin is used to place the device in a sleep mode so as to consume very low currents. When the EN pin voltage is a logic LOW state, the device is in the sleep mode. The device is enabled and fully operational when the EN pin voltage is logic HIGH. An internal pull-down resistor maintains the device in sleep mode in the event EN is driven through a high impedance I/O or an unpowered microcontroller, or the EN input becomes disconnected.

FEEDBACK FOR H-BRIDGE (FB)

The 33887 has a feedback output (FB) for "real time" monitoring of H-Bridge high-side current to facilitate closed-loop operation for motor speed and torque control.

The FB pin provides current sensing feedback of the H-Bridge high-side drivers. When running in forward or reverse direction, a ground referenced 1/375th (0.00266) of load current is output to this pin. Through an external resistor to ground, the proportional feedback current can be converted to a proportional voltage equivalent and the controlling microcontroller can "read" the current proportional

voltage with its analog-to-digital converter (ADC). This is intended to provide the user with motor current feedback for motor torque control. The resistance range for the linear operation of the FB pin is $100 < R_{FB} < 200 \Omega$.

If PWM-ing is implemented using the disable pin inputs (either D1 or $\overline{D2}$), a small filter capacitor (1.0 μF or less) may be required in parallel with the external resistor to ground for fast spike suppression.

FUNCTIONAL DEVICE OPERATION

OPERATIONAL MODES

The 33887 Simplified Internal Block Diagram shown in [Figure 2](#), page [2](#), is a fully protected monolithic H-Bridge with Enable, Fault Status reporting, and High-Side current sense feedback to accommodate closed-loop PWM control. For a DC motor to run, the input conditions need be as follows: Enable input logic HIGH, D1 input logic LOW, $\overline{D2}$ input logic HIGH, \overline{FS} flag cleared (logic HIGH), one IN logic LOW and the other IN logic HIGH (to define output polarity). The 33887 can execute dynamic braking by simultaneously turning on either both high-side MOSFETs or both low-side MOSFETs in the output H-Bridge; e.g., IN1 and IN2 logic HIGH or IN1 and IN2 logic LOW.

The 33887 outputs are capable of providing a continuous DC load current of 5.0 A from a 28 V V+ source. An internal charge pump supports PWM frequencies to 10 kHz. An external pull-up resistor is required at the \overline{FS} pin for fault status reporting. The 33887 has an analog feedback (current mirror) output pin (the FB pin) that provides a constant-current source ratioed to the active high-side MOSFET. This can be used to provide “real time” monitoring of load current to facilitate closed-loop operation for motor speed/torque control.

Two independent inputs (IN1 and IN2) provide control of the two totem-pole half-bridge outputs. Two disable inputs

(D1 and $\overline{D2}$) provide the means to force the H-Bridge outputs to a high-impedance state (all H-Bridge switches OFF). An EN pin controls an enable function that allows the 33887 to be placed in a power-conserving sleep mode.

The 33887 has undervoltage shutdown with automatic recovery, active current limiting, output short-circuit latch-OFF, and overtemperature latch-OFF. An undervoltage shutdown, output short-circuit latch-OFF, or overtemperature latch-OFF fault condition will cause the outputs to turn OFF (i.e., become high impedance or tri-stated) and the fault output flag to be set LOW. Either of the Disable inputs or V+ must be “toggled” to clear the fault flag.

Active current limiting is accomplished by a constant OFF-time PWM method employing active current limiting threshold triggering. The active current limiting scheme is unique in that it incorporates a junction temperature-dependent current limit threshold. This means the active current limiting threshold is “ramped down” as the junction temperature increases above 160°C, until at 175°C the current will have been decreased to about 4.0 A. Above 175°C, the overtemperature shutdown (latch-OFF) occurs. This combination of features allows the device to remain in operation for 30 seconds at junction temperatures above 150°C for nonrepetitive unexpected loads.

PROTECTION AND DIAGNOSTIC FEATURES

SHORT CIRCUIT PROTECTION

If an output short circuit condition is detected, the power outputs tri-state (latch-OFF) independent of the input (IN1 and IN2) states, and the fault status output flag is SET logic LOW. If the D1 input changes from logic HIGH to logic LOW, or if the $\overline{D2}$ input changes from logic LOW to logic HIGH, the output bridge will become operational again and the fault status flag will be reset (cleared) to a logic HIGH state.

The output stage will always switch into the mode defined by the input pins (IN1, IN2, D1, and $\overline{D2}$), provided the device junction temperature is within the specified operating temperature range.

ACTIVE CURRENT LIMITING

The maximum current flow under normal operating conditions is internally limited to I_{LIM} (5.2 A to 7.8 A). When the maximum current value is reached, the output stages are tri-stated for a fixed time (t_a) of 20 μ s typical. Depending on the time constant associated with the load characteristics, the current decreases during the tri-state duration until the next output ON cycle occurs (see [Figures 11](#) and [14](#), page [13](#) and page [15](#), respectively).

The current limiting threshold value is dependent upon the device junction temperature. When $-40^\circ\text{C} \leq T_J \leq 160^\circ\text{C}$, I_{LIM} is between 5.2 A to 7.8 A. When T_J exceeds 160°C , the I_{LIM} current decreases linearly down to 4.0 A typical at 175°C . Above 175°C the device overtemperature circuit detects T_{LIM}

and overtemperature shutdown occurs (see [Figure 9](#), page [12](#)). This feature allows the device to remain operational for a longer time but at a regressing output performance level at junction temperatures above 160°C .

Output Avalanche Protection

An inductive fly-back event, namely when the outputs are suddenly disabled and V+ is lost, could result in electrical overstress of the drivers. To prevent this the V+ input to the 33887 should not exceed the maximum rating during a fly-back condition. This may be done with either a zener clamp and/or an appropriately valued input capacitor with sufficiently low ESR.

OVERTEMPERATURE SHUTDOWN AND HYSTERESIS

If an overtemperature condition occurs, the power outputs are tri-stated (latched-OFF) and the fault status flag is SET to logic LOW.

To reset from this condition, D1 must change from logic HIGH to logic LOW, or $\overline{D2}$ must change from logic LOW to logic HIGH. When reset, the output stage switches ON again, provided that the junction temperature is now below the overtemperature threshold limit minus the hysteresis.

Note Resetting from the fault condition will clear the fault status flag.

TYPICAL APPLICATIONS

Figure 23 shows a typical application schematic. For precision high-current applications in harsh, noisy environments, the V+ by-pass capacitor may need to be substantially larger.

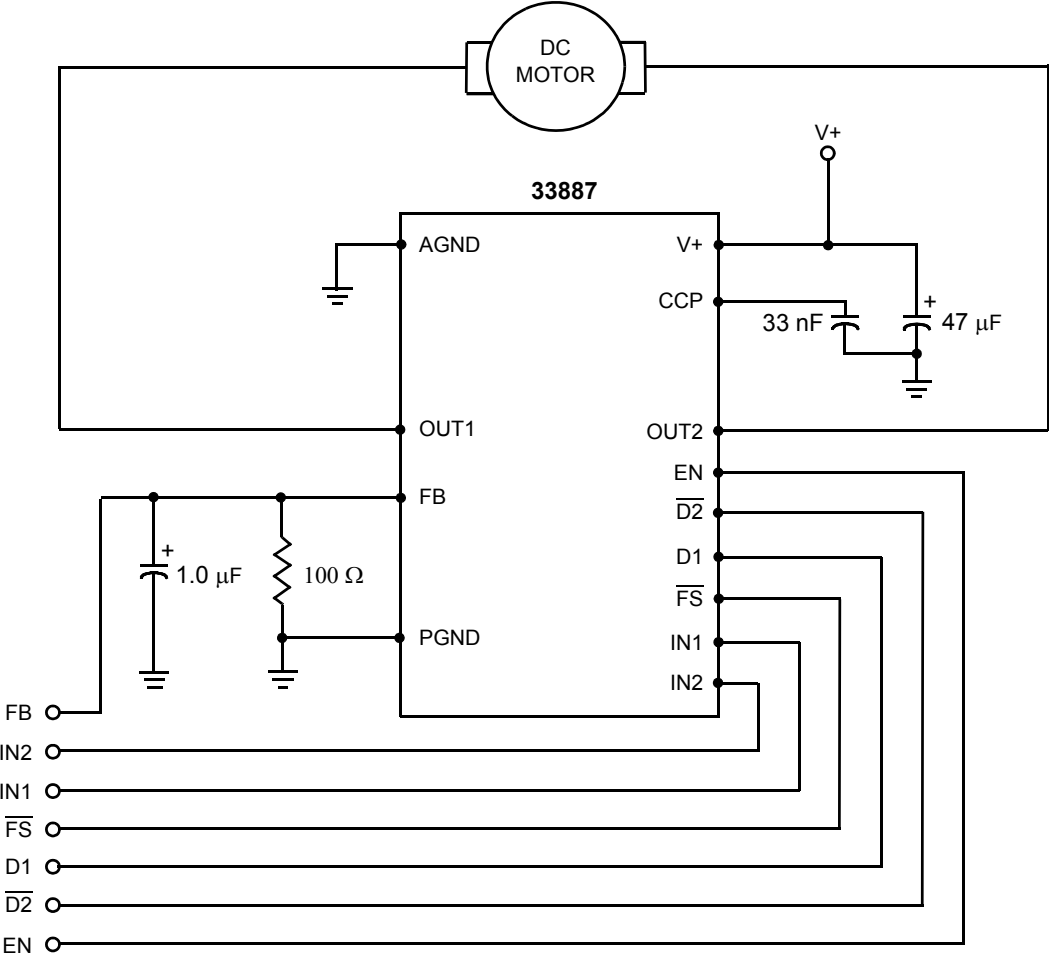


Figure 23. 33887 Typical Application Schematic