MP9518

Single-Phase, BLDC, Motor Driver with Integrated Hall Sensor

DESCRIPTION

The MP9518 is a single-phase, brushless, DC motor driver with integrated power MOSFETs and a hall-effect sensor. The MP9518 drives single-phase, brushless, DC fan motors with up to 1.2A of output current limit. The IC has a 3.3V to 18V input voltage range and input line reverse-voltage protection to save the external diode on the supply line.

The MP9518 controls the rotational speed through the PWM signal on the PWM pin. The MP9518 has a rotational speed detector feature and rotor lock fault indication on FG/RD with an open-drain collector output. The output speed versus the input duty curve can be programmed easily for flexible use. To reduce fan driver audible noise and power loss, the MP9518 features a soft on/off phase transition and automatic phase-lock function of the motor winding BEMF and current.

Full protection features include input over-voltage protection (OVP), under-voltage lockout (UVLO), rotor deadlocked protection, thermal shutdown, and input reverse protection.

The MP9518 requires a minimal number of external components to save solution cost. The MP9518 is available in a TSOT23-6 package.

FEATURES

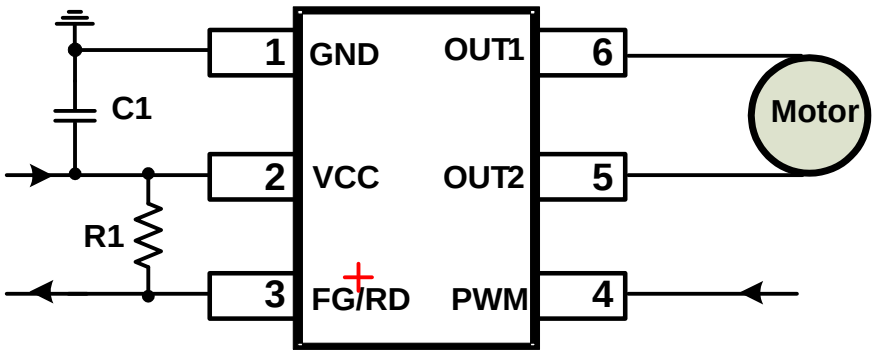
- Embedded Hall Sensor with High Sensitivity
- Wide 3.3V to 18V Operating Input Range
- Up to 1.2A Programmable Current Limit
- Integrated Power MOSFETs: Total 850mΩ (HS + LS)
- Automatic Phase Lock Detection of Winding BEMF and Current Zero-Crossing
- Soft On/Off Phase Transition
- Rotational Speed Indicator FG Signal
- 12kHz to 48kHz PWM Input Frequency Range
- Fixed 26kHz Output Switching Frequency
- Input Line Reverse-Voltage Protection (RVP)
- Rotor Deadlocked Protection and Automatic Recovery
- Thermal Protection and Automatic Recovery
- Built-In Input OVP, UVLO, and Automatic Recovery
- Available in a TSOT23-6 Package

APPLICATIONS

- CPU Fan for Personal Computers or Servers
- Brushless DC Motors

All MPS parts are lead-free, halogen-free, and adhere to the RoHS directive. For MPS green status, please visit the MPS website under Quality Assurance. “MPS” and “The Future of Analog IC Technology” are registered trademarks of Monolithic Power Systems, Inc.

TYPICAL APPLICATION



MPS Proprietary Information. Patent Protected. Unauthorized Photocopy and Duplication Prohibited.
© 2017 MPS. All Rights Reserved.

ORDERING INFORMATION

Part Number*	Package	Top Marking
MP9518GJ-xxxx**	TSOT23-6	*See Below*
MP9518GJS-xxxx**	TSOT23-6-SL	

* For Tape & Reel, add suffix –Z (e.g. MP MP9518GJS–Z).

** “xxxx” is the configuration code identifier for operating current limit, soft on/off, PLL disable, and RD/FG options. For the default case, the number is “0000”. Each “x” can have a hexadecimal value between 0 and F. Please work with an MPS FAE to create this unique “xxxx” code. The standard product versions are listed below:

1. MP9518GJS-0000: Default setting
2. MP9518GJS-0001: 1.2A current limit version
3. MP9518GJS-0002: 1.2A current limit and RD output version
4. MP9518GJS-0003: 1.2A current limit, soft on/off, and PLL disable version

TOP MARKING (MP9518GJ)

|AUGY

AUG: Product code of MP9518GJ
Y: Year code

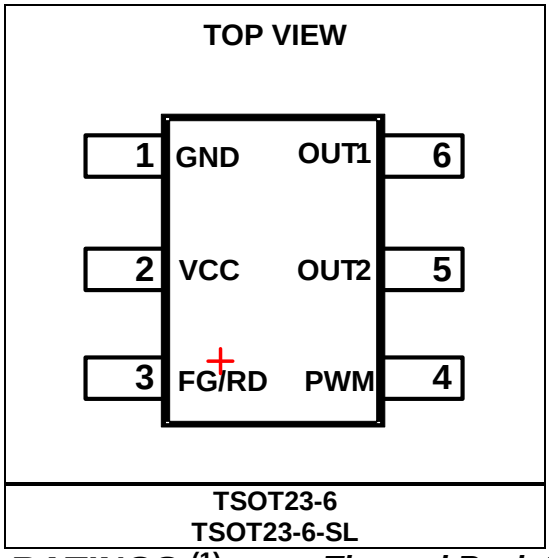
TOP MARKING (MP9518GJS)

AUGY
LLL

AUG: Product code of MP9518GJS
Y: Year code
LLL: lot number;

MPS Proprietary Information. Patent Protected. Unauthorized Photocopy and Duplication Prohibited.
© 2017 MPS. All Rights Reserved.

PACKAGE REFERENCE



TSOT23-6
TSOT23-6-SL

ABSOLUTE MAXIMUM RATINGS (1)

VCC ..... ±19V
FG/RD, $V_{OUT1/2}$ ..... -0.3V to VCC + 0.3V
All other pins ..... -0.3V to +6.5V
Continuous power dissipation (T_A = +25°C) (2) 1.25W
Junction temperature ..... 150°C
Lead temperature ..... 260°C
Storage temperature ..... -60°C to 150°C

Recommended Operating Conditions (3)

Supply voltage (VCC) ..... 3.3V to 18V
Operating junction temp. (T_J) ... -40°C to +125°C

Thermal Resistance (4)

	θ_{JA}	θ_{JC}
TSOT23-6	100	55 ... °C/W

NOTES:

1) Exceeding these ratings may damage the device.
2) The maximum allowable power dissipation is a function of the maximum junction temperature T_J (MAX), the junction-to-ambient thermal resistance θ_{JA}, and the ambient temperature T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P_D (MAX) = (T_J (MAX)-T_A)/θ_{JA}. Exceeding the maximum allowable power dissipation produces an excessive die temperature, causing the regulator to go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
3) The device is not guaranteed to function outside of its operating conditions.
4) Measured on JESD51-7, 4-layer PCB.

MPS Proprietary Information. Patent Protected. Unauthorized Photocopy and Duplication Prohibited.
© 2017 MPS. All Rights Reserved.

ELECTRICAL CHARACTERISTICS

VCC = 12V, T_J = -40°C to 125°C, unless otherwise noted.

Parameters	Symbol		Min	Typ	Max	Units
Input UVLO rising threshold	V_{UVLO}			3		V
Input UVLO hysteresis				0.15		V
Operating supply current	I_{CC}			6.5		mA
Reverse supply current	I_{CCREV}	VCC = -18V			1	mA
PWM input high voltage	V_{PWMH}		1.5			V
PWM input low voltage	V_{PWML}				0.4	V
PWM input frequency	F_{PWM}		12		48	kHz
Min PWM input low-level time (5)			200			ns
PWM input internal pull-up resistance				100		kΩ
HS switch-on resistance	R_{HSON}	I_O = 100mA, including reversed MOSFET		520		mΩ
LS switch-on resistance	R_{LSON}	I_O = 100mA		330		mΩ
Over-current limit protection threshold	I_{OCP}		-20%	1.8	+20%	A
Output current limit	I_{LMT}	Default	-15%	860	+15%	mA
Internal oscillator frequency	f_{CLK}		-15%	7	+15%	MHz
PWM output frequency	fs		-15%	26	+15%	kHz
FG output low-level voltage	V_{FG_L}	$I_{FG/RD}$ = 3mA, V_{PULL} = 5V			0.35	V
FG leakage current					1	μA
Soft turn-on angle	θ_{SON_100}	Default		23.9		°
Soft turn-off angle	θ_{SOFF_100}	Default		45		°
Adjustable delay angle	θe	Default		0		°
Rotor-lock detection time	T_{RD}			0.6		s
Minimum recommended magnetic field (5)				±1		mT
Thermal shutdown threshold (5)				150		°C
Thermal shutdown hysteresis (5)				25		°C

NOTE:

5) Guaranteed by design.

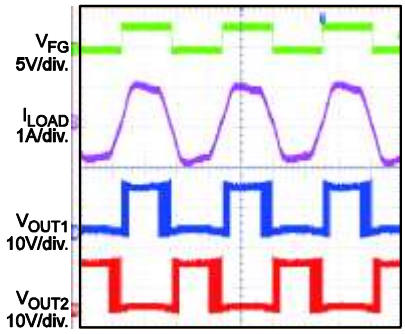
MPS Proprietary Information. Patent Protected. Unauthorized Photocopy and Duplication Prohibited.
© 2017 MPS. All Rights Reserved.

TYPICAL PERFORMANCE CHARACTERISTICS

VCC = 12V, T_A = 25°C, tested with fan unit unless otherwise noted.

Typical Waveform, 100% Duty Output

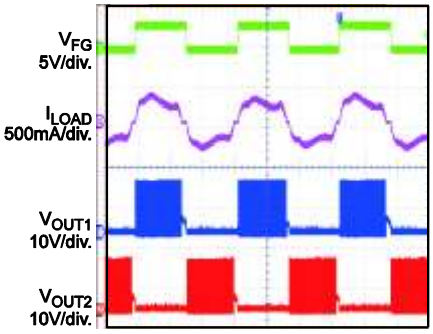
V_{CC}=12V DC, PWM=25kHz, 100% Duty



2ms/div.

Typical Waveform, 50% Duty Output

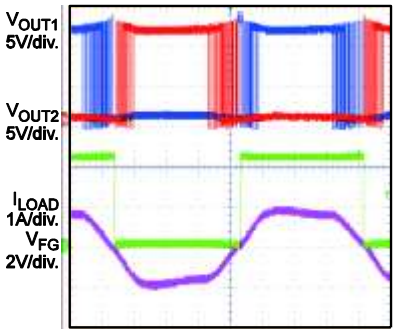
V_{CC}=12V DC, PWM=25kHz, 50% Duty



4ms/div.

Typical Waveform, Switching Soft On & Soft Off

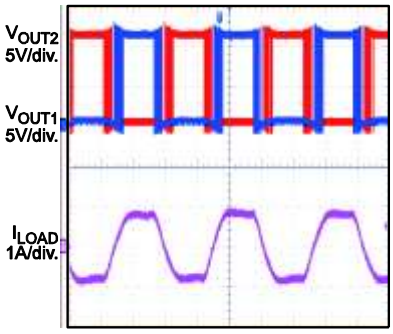
V_{CC}=12V DC, PWM= 5V DC, w/ soft on/off phase transition



800µs/div.

Typical Waveform, Enable Soft On & Soft Off

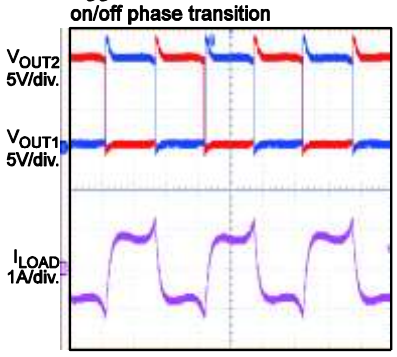
V_{CC}=12V DC, PWM= 5V DC, w/ soft on/off phase transition



2ms/div

Typical Waveform, Disable Soft On & Soft Off

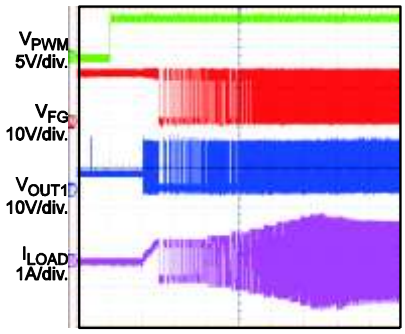
V_{CC}=12V DC, PWM= 5V DC, w/o soft on/off phase transition



2ms/div

Typical Waveform, Start Up with PWM

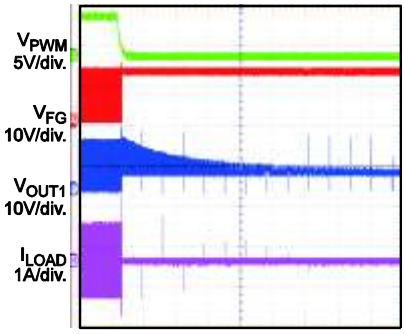
V_{CC}=12V DC, PWM= 0V to 5V DC



400ms/div

Typical Waveform, Shutdown with PWM

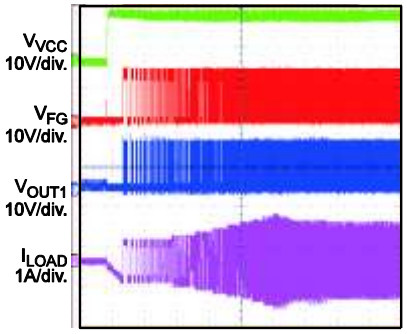
V_{CC}=12V DC, PWM=5V DC to 0V



1s/div

Typical Waveform, Start Up with VCC

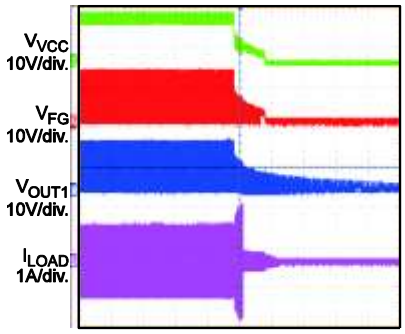
PWM=5V DC, V_{CC}= 0V to 12V DC



400ms/div

Typical Waveform, Shutdown with VCC

PWM=5V DC, V_{CC}=12V DC to 0V



1s/div

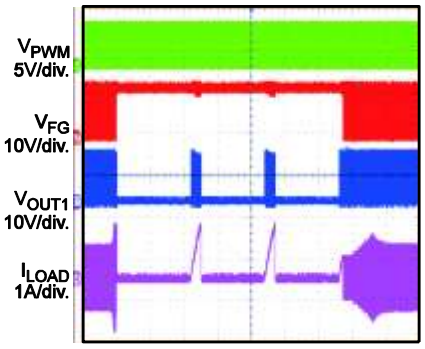
MPS Proprietary Information. Patent Protected. Unauthorized Photocopy and Duplication Prohibited.
© 2017 MPS. All Rights Reserved.

TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

VCC = 12V, T_A = 25°C, tested with fan unit unless otherwise noted.

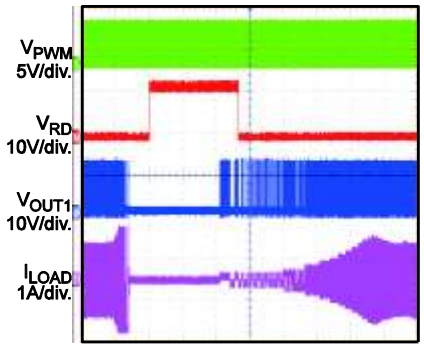
Typical Waveform, Rotor Lock & Release

V_{CC}= 12V DC, PWM=5V DC, Lock Rotor and Releaset



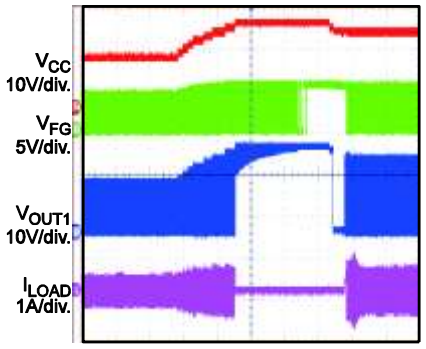
Typical Waveform, Rotor Lock & Release

V_{CC}= 12V DC, PWM=5V DC, Lock Rotor and Release



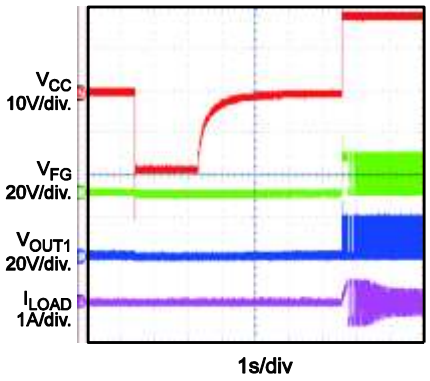
Typical Waveform, Over -Voltage Protection

PWM= 25kHz, 50% duty, V_{CC}=12V DC to 20V DC to 18V DC



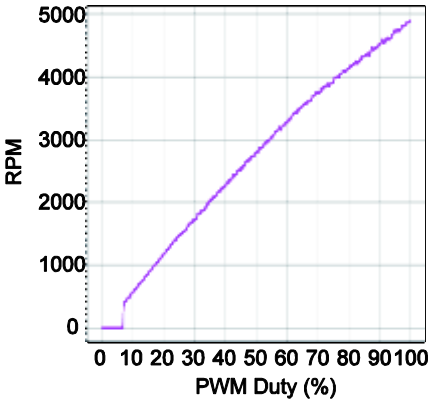
Typical Waveform, VCC Reverse Protection

VIN= 0V to -18V DC to 0V to +18V DC



Typical Curve, RPM Output vs. PWM Input Duty

V_{CC}=12V DC, PWM=25kHz, Test with Fan Unit, Default Register Setting



MPS Proprietary Information. Patent Protected. Unauthorized Photocopy and Duplication Prohibited.
© 2017 MPS. All Rights Reserved.

PIN FUNCTIONS

Pin #	Name	Description
1	GND	**Ground.**
2	VCC	**Input voltage supply.**
3	FG/RD	**Speed indication or rotor lock fault indication output.**
4	PWM	**Rotational speed control PWM input pin.** A PWM 12kHz to 48kHz is recommended in normal operation. PWM is an internal pull-up with 100kΩ of resistance to the internal LDO.
5	OUT2	**Motor driver output 2.** OUT2 is connected to the mid-point of the internal N-channel MOSFET half-bridge.
6	OUT1	**Motor driver output 1.** OUT2 is connected to the mid-point of the internal N-channel MOSFET half-bridge.

MPS Proprietary Information. Patent Protected. Unauthorized Photocopy and Duplication Prohibited.
© 2017 MPS. All Rights Reserved.

BLOCK DIAGRAM

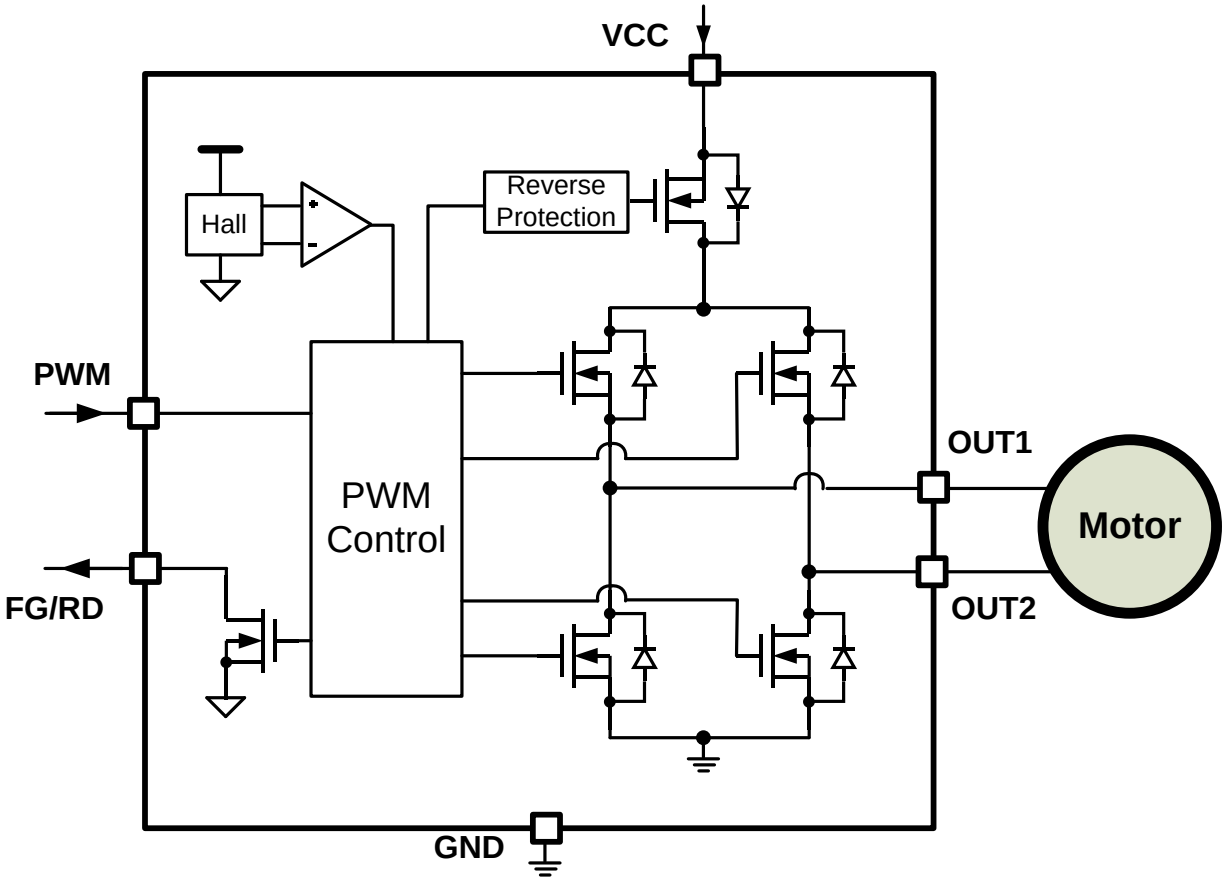


Figure 1: Functional Block Diagram

MPS Proprietary Information. Patent Protected. Unauthorized Photocopy and Duplication Prohibited.
© 2017 MPS. All Rights Reserved.

OPERATION

The MP9518 is a single-phase, brushless, DC motor driver with integrated power MOSFETs and a hall-effect sensor.

Speed Control

The MP9518 is controlled using a PWM input interface, which is compatible with industry-standard devices. The IC detects the PWM input signal duty cycle and linearly controls the H-bridge output duty cycle, so the fan speed increases as the input duty cycle increases.

The PWM input accepts a wide input frequency range (12kHz to 48kHz), while the output frequency is kept constant at 26kHz above the audible frequency range.

PWM Output Drive

The IC controls the H-bridge MOSFET switching to reduce speed variation and increase system efficiency (see Figure 2).

When the rotor magnet pole S comes around, the internal hall sensor outputs high. When the rotor magnet pole N comes around, the internal hall sensor outputs low. With this H_{A_IN} signal, the H_{A_OUT} signal is generated after the θe delay time, which is set from 0°. During the H_{A_OUT} high interval, the OUT2 and OUT1 switching status can be divided to different timing sections (see Figure 2).

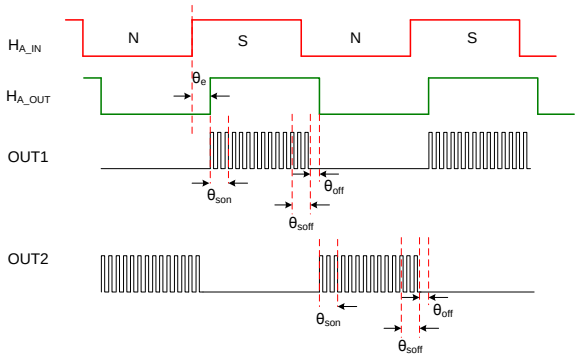


Figure 2: Timing Diagram

Soft Turn-On Section

During this time, OUT1 continues switching, and the duty cycle increases gradually from 0 to the target setting duty cycle in 16 steps max. OUT2 remains low. Determine the duration time from the linear interpolation between the SON_100 (23.9°) and SON_12P5 (45°) bits setting value.

Normal PWM Switching Section

During this time, OUT1 continues switching, and the duty cycle is fixed at the target setting duty. OUT2 remains low.

Soft Turn-Off Section

During this time, OUT1 continues switching, and the duty cycle gradually decreases from the target setting duty cycle to 0 in 16 steps max. OUT2 remains low. Determine the duration time from the linear interpolation between the SOFF_100 (45°) and SOFF_12P5 (23.9°) bits setting value.

Off Section

During this time, OUT1 remains at high impedance. OUT2 remains low. The time duration is adaptive from 0° to 45°. In steady state, this function block tries to maintain the phase lock of the hall output falling edge and winding current zero-crossing edge.

For a hall output low interval, the conducting phase changes, but the switching sequence remains the same.

Protection Circuits

The MP9518 is fully protected against over-voltage, under-voltage, over-current, over-temperature events, and input reverse protection.

Over-Current Protection (OCP)

The MP9518 protects against internal overload and short circuit by detecting current flowing through each MOSFET. If the current flowing through any MOSFET exceeds the over-current protection (OCP) threshold after around 1.5μs of blanking time, that MOSFET turns off immediately. After approximately 3.6s of delay, the bridge is re-enabled automatically.

Overload Current Limit

During normal switching, if the current flowing through the high-side MOSFET (HS-FET) of the H-bridge exceeds the threshold set by the register SUCL bits after around 1.5μs of blanking time, the HS-FET turns off immediately. The HS-FET resumes switching in the next switching cycle. The overload current limit is fixed at around 860mA.

MPS Proprietary Information. Patent Protected. Unauthorized Photocopy and Duplication Prohibited.
© 2017 MPS. All Rights Reserved.

To spin-up the fan driver softly during start-up, the current limit increases from 0 to 860mA in 16 steps (see Figure 3). Each step limit value lasts for 16 internal hall cycles. In rotor lock fault cases, the current limit increases with 16 steps with 600ms of detection time.

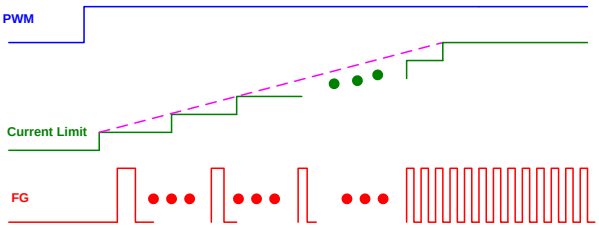


Figure 3: Start-Up Waveforms

Thermal Shutdown

Thermal monitoring is also integrated into the MP9518. If the die temperature rises above 150°C, the MOSFETs of the switching half-bridge turn off. Once the die temperature has fallen to a safe level, operation resumes automatically.

Under-Voltage Lockout (UVLO)

If at any time VCC falls below the under-voltage lockout threshold (UVLO) voltage, all circuitry in the device is disabled, and the internal logic is reset. Operation resumes when VCC rises above the UVLO threshold.

Rotor Deadlock Protection (RD)

The MP9518 detects the internal hall signal and outputs a deadlock indication signal to FG/RD if the FGRD bit is set to 11. If the IC cannot see the hall signal edge change during the 0.6s detection time, all MOSFETs of the H-bridge are turned off. FG/RD is an open-drain output. After 3.6s of recovery time, the IC attempts to start up again automatically. FG/RD is pulled low again only after three hall signal edges are detected after the rotor lock condition is released (see Figure 4).

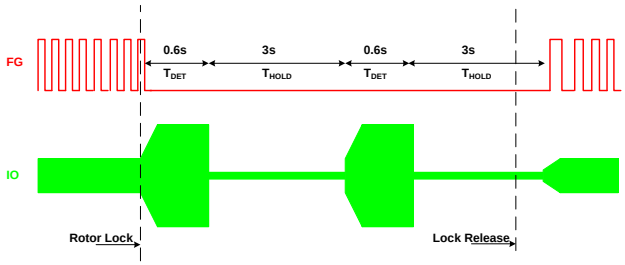


Figure 4: Rotor Deadlock Protection

Rotor Speed Indication (FG)

The MP9518 outputs a hall detection signal to FG/RD as speed indication. The output signal frequency can be the same as the internal hall sensor output frequency. FG/RD is an open-drain, so it needs a pull-up resistor in application.

Over-Voltage Protection (OVP)

If VCC exceeds the over-voltage threshold (19V), the IC turns off the H-bridge MOSFETs until VCC drops. Then the IC resumes normal operation.

Input Reverse Connection Protection

If the input line is reverse-connected to VCC and GND, the IC detects such fault conditions automatically and shuts down to avoid damage.

MPS Proprietary Information. Patent Protected. Unauthorized Photocopy and Duplication Prohibited.
© 2017 MPS. All Rights Reserved.

APPLICATION INFORMATION

Selecting the Input Capacitor

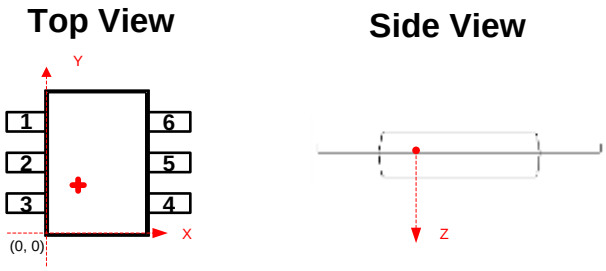
Place an input capacitor (C1) near VCC to keep the input voltage stable and reduce input switching voltage noise and ripple. The input capacitor impedance must be low at the switching frequency. Ceramic capacitors with X7R dielectrics are recommended for their low ESR characteristics. Ensure that the ceramic capacitance is dependent on the voltage rating. The DC bias voltage and value can lose as much as 50% of its capacitance at its rated voltage rating. Leave enough voltage rating margin when selecting the component. For most applications, a 1μF to 10μF ceramic capacitor is sufficient. In some applications, add an additional, large, electrolytic capacitor to absorb armature inductor energy if needed.

Selecting the PWM Input Resistor

When the input PWM signal rating is >6.5V, which exceeds the PWM voltage rating, a resistor (R2) is needed. The recommended value is 499Ω.

Hall Sensor Position

The hall sensor cell is located in the lower left corner of the package (see Figure 5).



(X, Y, Z) = (540μm, 508μm, 80μm)
Figure 5: Hall Sensor Position

Input Clamping Zener Diode

To avoid voltage spikes caused by the energy stored in the motor charges back to the input capacitor side, add a voltage-clamping Zener diode. For a 12V case, a 15V/SOD-323 package Zener diode is sufficient. If input connection reverse protection is needed, a diode in series with a Zener diode is recommended (see Section 1 in Figure 6).

Input Snubber

Due to the input capacitor energy charge/discharge during the phase transition soft switching, the input current has switching cycle ringing. If needed, add a 2Ω resistor in series with a 1μF capacitor as an R-C snubber in parallel with an input capacitor. This prevents switching cycle ringing efficiently (see Section 2 in Figure 6).

MPS Proprietary Information. Patent Protected. Unauthorized Photocopy and Duplication Prohibited.
© 2017 MPS. All Rights Reserved.

TYPICAL APPLICATION CIRCUITS

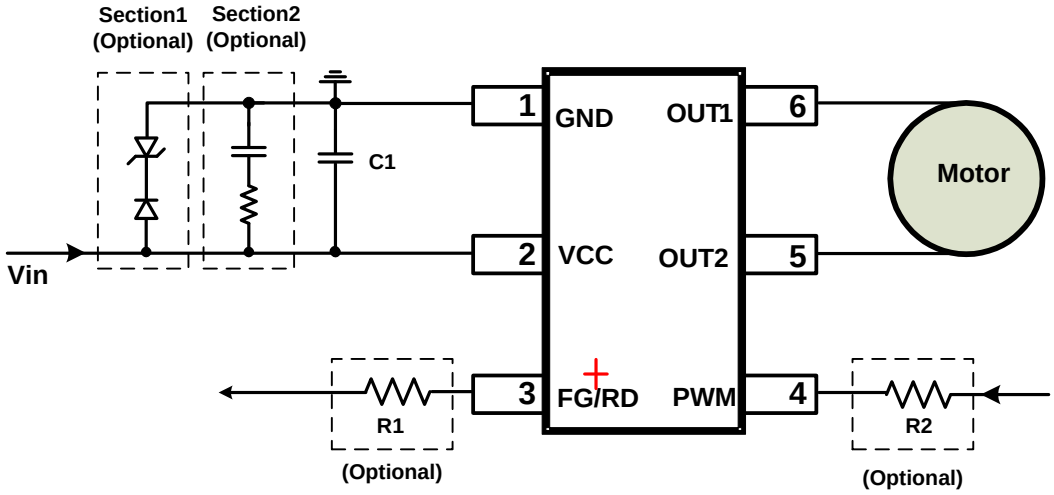
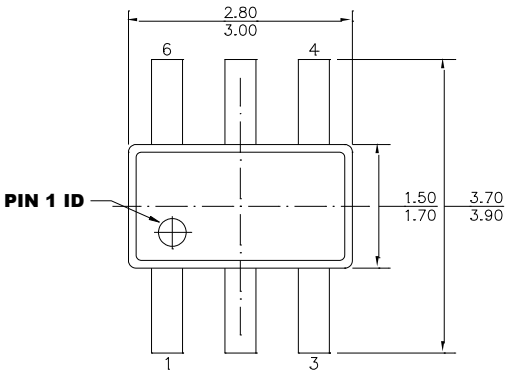


Figure 6: Typical Application Circuit for 12V VCC Input

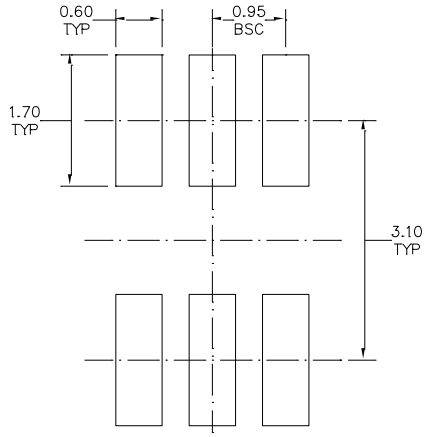
MPS Proprietary Information. Patent Protected. Unauthorized Photocopy and Duplication Prohibited.
© 2017 MPS. All Rights Reserved.

PACKAGE INFORMATION

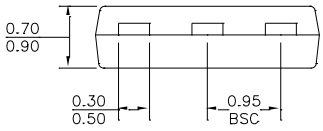
TSOT23-6-SL



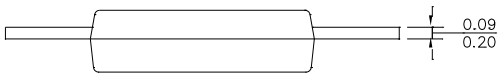
TOP VIEW



RECOMMENDED LAND PATTERN



FRONT VIEW



SIDE VIEW

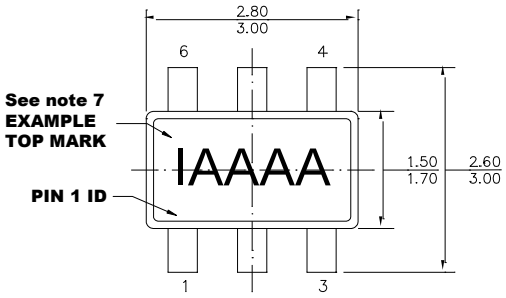
NOTE:

1) ALL DIMENSIONS ARE IN MILLIMETERS.
2) PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSION OR GATE BURR.
3) PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION.
4) LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.10 MILLIMETERS MAX.
5) DRAWING REFERENCE IS JEDEC MO-193.
6) DRAWING IS NOT TO SCALE.

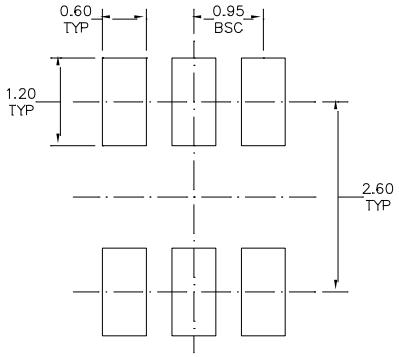
MPS Proprietary Information. Patent Protected. Unauthorized Photocopy and Duplication Prohibited.
© 2017 MPS. All Rights Reserved.

PACKAGE INFORMATION *(continued)*

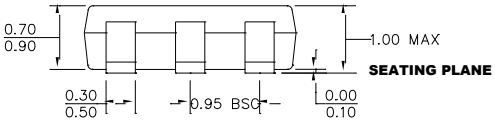
TSOT23-6L



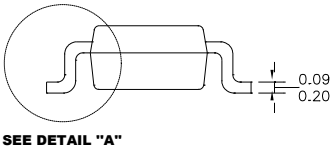
TOP VIEW



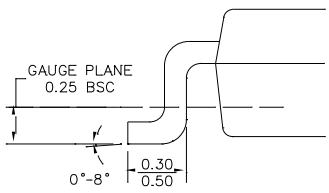
RECOMMENDED LAND PATTERN



FRONT VIEW



SIDE VIEW



DETAIL "A"

NOTE:

1) ALL DIMENSIONS ARE IN MILLIMETERS.
2) PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSION OR GATE BURR.
3) PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION.
4) LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.10 MILLIMETERS MAX.
5) DRAWING CONFORMS TO JEDEC MO-193, VARIATION AB.
6) DRAWING IS NOT TO SCALE.
7) PIN 1 IS LOWER LEFT PIN WHEN READING TOP MARK FROM LEFT TO RIGHT, (SEE EXAMPLE TOP MARK)

NOTICE: The information in this document is subject to change without notice. Please contact MPS for current specifications. Users should warrant and guarantee that third party Intellectual Property rights are not infringed upon when integrating MPS products into any application. MPS will not assume any legal responsibility for any said applications.

MPS Proprietary Information. Patent Protected. Unauthorized Photocopy and Duplication Prohibited.
© 2017 MPS. All Rights Reserved.