MP9486A

100V Input, 3.5A Switching Current Limit Step-down Converter

The Future of Analog IC Technology®

PRELIMINARY SPECIFICATIONS SUBJECT TO CHANGE– INTERNAL USE ONLY

DESCRIPTION

The MP9486A is a high voltage input step-down switching regulator to deliver a constant current of up to 1A to load. It integrates a high-side high voltage power MOSFET with a current limit of typical 3.5A. The wide 4.5V to 100V input range accommodates a variety of step-down applications, making it ideal for automotive, industry and some lighting applications. Hysteresis voltage mode control is employed for very fast response, MPS's proprietary feedback control scheme minimizes the number of external components.

The switching frequency can be up to 1MHz, thus allowing for small component size. The thermal shut down and short circuit protection provide reliable, fault tolerant operations. A 170µA quiescent current allows its use in battery-powered applications.

The MP9486A is available in SOIC-8 with exposed pad packages.

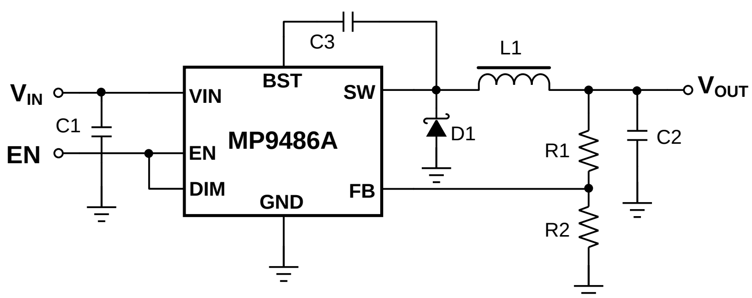
FEATURES

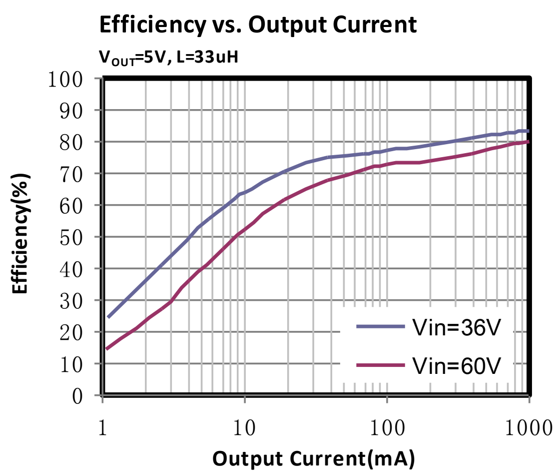
- Wide 4.5V to 100V Input Range
- 3.5A Typical Peak Switching Current Limit
- Hysteretic Control: Simple Compensation
- Up to 1MHz Switching Frequency
- PWM Dimming Control Input for LED Application
- Short Circuit Protection with Integrated High Side MOSFET
- Thermal Shut Down
- 170µA Quiescent Current
- Available in SOIC-8 with Exposed Pad Packages

APPLICATIONS

- Scooter, E-bike Control Power Supply
- Solar Energy System
- Automotive System Power
- Industrial Power Supply
- High Power LED Driver

TYPICAL APPLICATION





ORDERING INFORMATION

Part Number*	Package	Top Marking
MP9486AGN	SOIC-8 EP	*See Below*

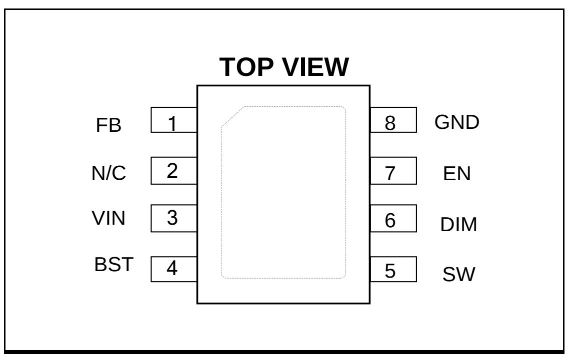
***** For Tape & Reel, add suffix –Z (e.g. MP9486AGN–Z);

TOP MARKING

MP9486A
LLLLLLLL
MPSYWW

MP9486A: part number;
LLLLLLLL: lot number;
MPS: MPS prefix:
Y: year code;
WW: week code:

PACKAGE REFERENCE



ABSOLUTE MAXIMUM RATINGS (1)

Supply Voltage (V_{IN}) .... -0.3V to +100V
Switch Voltage (V_{SW}) ....
.... -0.5V(-7V for 10ns) to V_{IN} + 0.5V
BST to SW .... -0.3V to +6V
All Other Pins .... -0.3V to +6V
Junction Temperature .... 150°C
Continuous Power Dissipation (T_A = +25°C) (2)
.... 2.5W
Lead Temperature .... 260°C
Storage Temperature .... -65°C to +150°C

Recommended Operating Conditions (3)

Supply Voltage V_{IN} .... 4.5V to 95V
EN and DIM Voltages .... 0V to 5V
Maximum Switching Frequency 1MHz
Operating Junction Temp. .... -40°C to +125°C

Thermal Resistance (4)	θ_{JA}	θ_{JC}	
SOIC8E (Exposed Pad)	50	10	°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 $P_D(MAX)=(T_J(MAX)-T_A)/\theta_{JA}$. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will 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 board.

ELECTRICAL CHARACTERISTICS

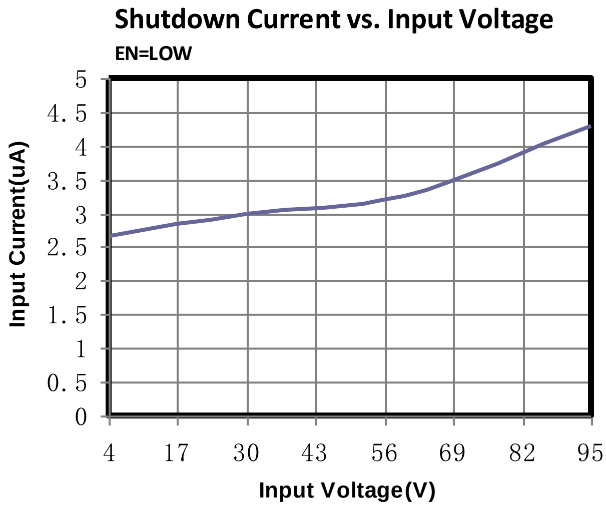
V_{IN} = 60V, T_A= +25°C, unless otherwise noted.

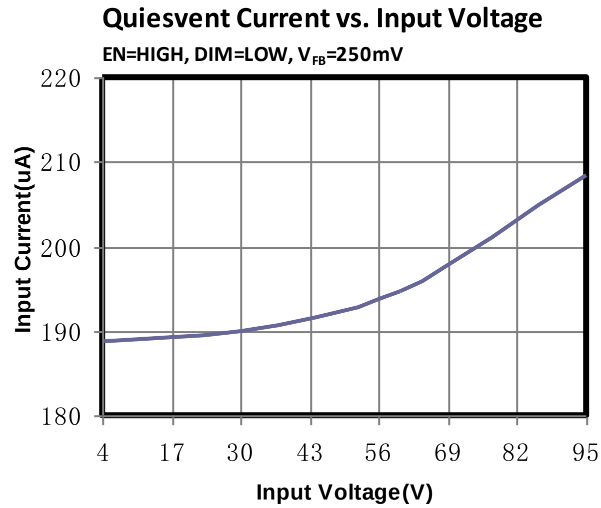
Parameter	Symbol	Condition	Min	Typ	Max	Units
VIN UVLO Threshold			3.6	4.0	4.35	V
VIN UVLO Hysteresis				0.4		V
Shutdown Supply Current		V_{EN} = 0V		2	5	µA
Quiescent Supply Current		No load, DIM=LOW, V_{FB} = 250mV		170	240	µA
Upper Switch On Resistance (5)	$R_{DS(ON)}$	$V_{BST} – V_{SW}$ = 5V		500		mΩ
Upper Switch Leakage Current	I_{SWLK}	V_{EN} = 0V, V_{SW} = 0V		0.01	1	µA
Current Limit	I_{PK}	V_{FB} = 0.15V	2.9	3.5	4.5	A
EN Up Threshold	V_{ENH}		1.4	1.55	1.7	V
EN Threshold Hysteresis	V_{ENHY}			320		mV
EN Input Current	I_{ENI}	V_{EN} =5V		0.01	1	µA
EN Pull-up Current	I_{ENS}	V_{EN} =2V		2	3	µA
DIM Up Threshold	V_{DIMH}		0.8	1.15	1.5	V
DIM Threshold Hysteresis	V_{DIMHY}			300		mV
DIM Input Current	I_{DIM}	V_{DIM} =5V or 0V	-1		1	µA
DIM On Propagation Delay	T_{DIMDH}	V_{FB}=0V, V_{DIM} Rising edge to V_{SW} Rising Edge		50		ns
DIM Off Propagation Delay	T_{DIMDL}	V_{FB}=0V, V_{DIM} Falling edge to V_{SW} Falling Edge		50		ns
Feedback Voltage Threshold High (5)	V_{FBH}	4.5V < V_{IN} < 95V, V_{FB} rising from 0V until V_{SW} < 30V	209	215	221	mV
Feedback Voltage Threshold Low (5)	V_{FBL}	4.5V < V_{IN} < 95V, V_{FB} falling from 0.25V until V_{SW} > 30V	179	185	191	mV
FB Pin Input Current	I_{FB}	V_{FB}=5V or 0V	-300		300	nA
FB Propagation Delay to Output High	T_{FBDH}	Falling edge of V_{FB} from 0.25V to 0V to V_{SW} rising edge		100		ns
FB Propagation Delay to Output High	T_{FBDL}	Rising edge of V_{FB} from 0V to 0.25V to V_{SW} falling edge		100		ns
Thermal Shutdown(5)		Hysteresis = 20°C		150		°C

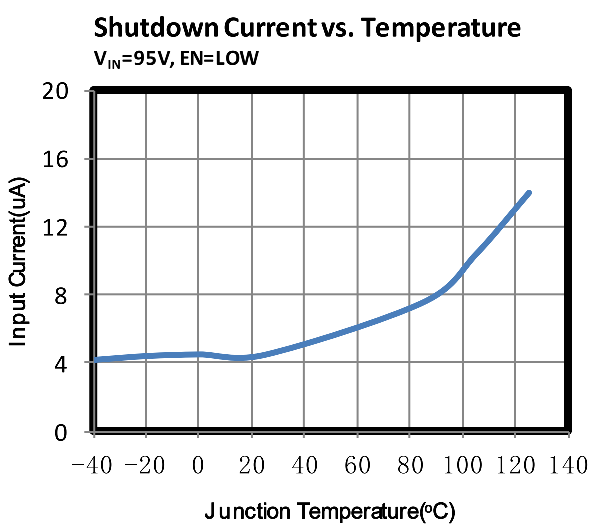
Note:
5) Guaranteed by design.

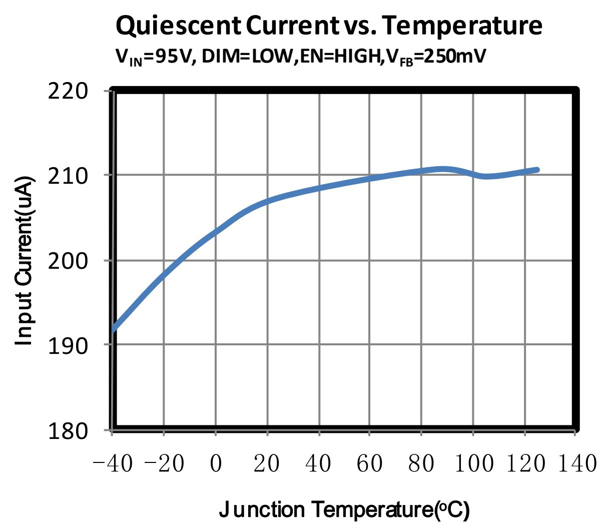
TYPICAL ELECTRICAL CHARACTERISTICS

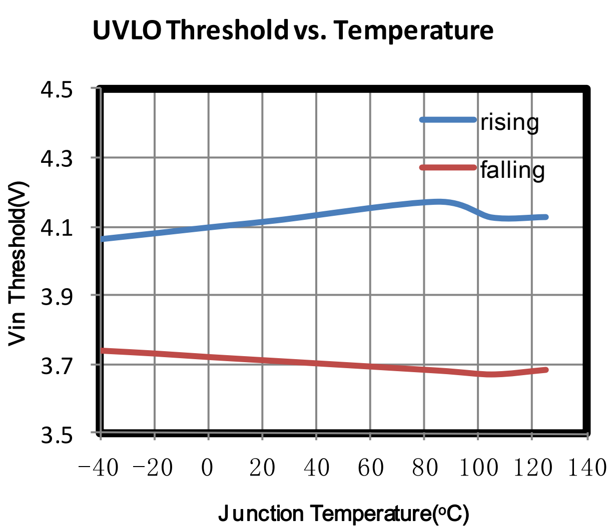
V_{IN} = 60V, T_A= +25°C, unless otherwise noted.

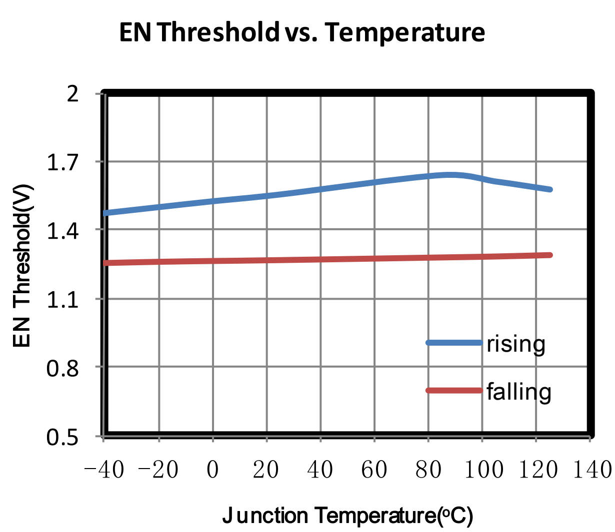






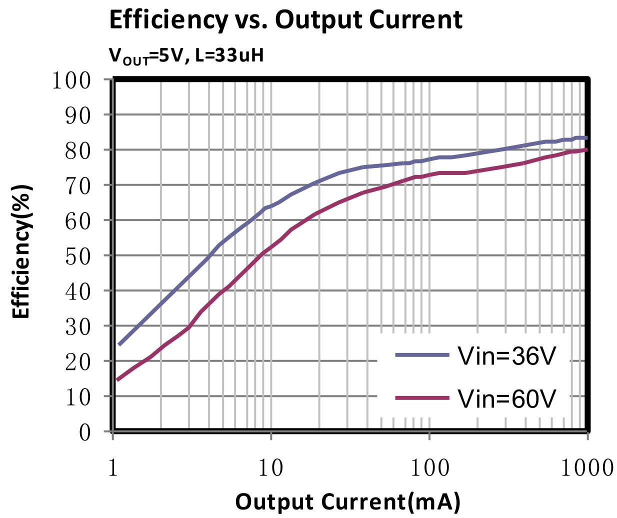


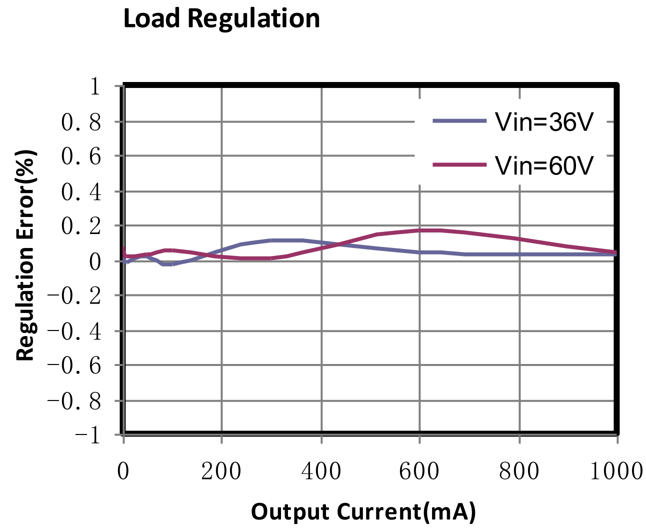


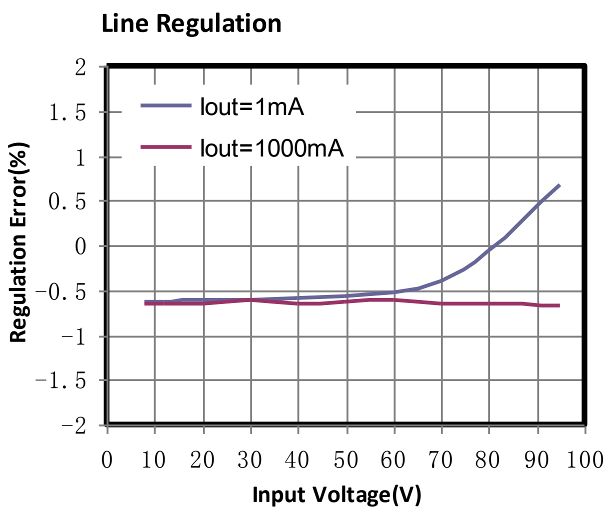


TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 60V, V_{OUT} = 5V, I_{OUT} = 1A, L=33µH, C_{OUT} = 100µF, T_A= +25°C, unless otherwise noted.





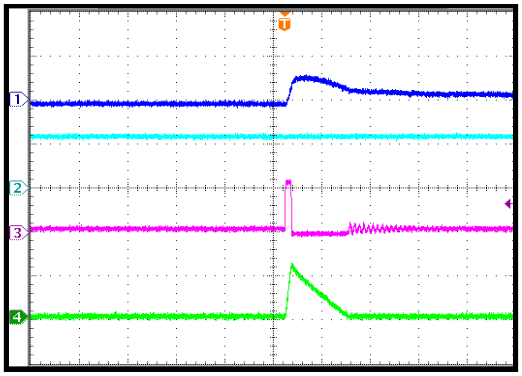


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 60V, V_{OUT} = 5V, I_{OUT} = 1A, L=33µH, C_{OUT} = 100µF, T_A= +25°C, unless otherwise noted.

Steady State

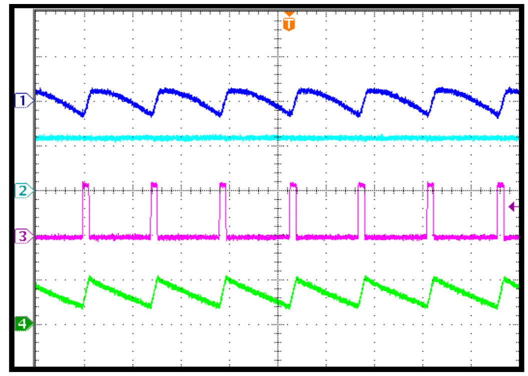
I_{OUT}=0A



4µs/div.

Steady State

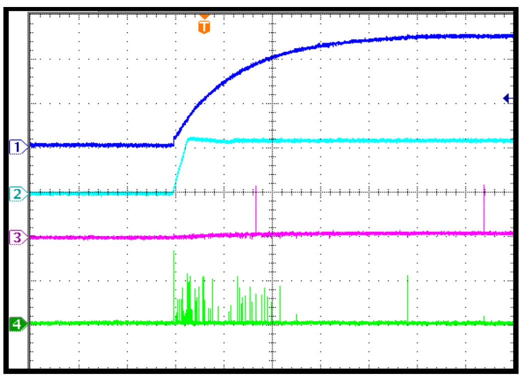
I_{OUT}=1A



4µs/div.

Power On

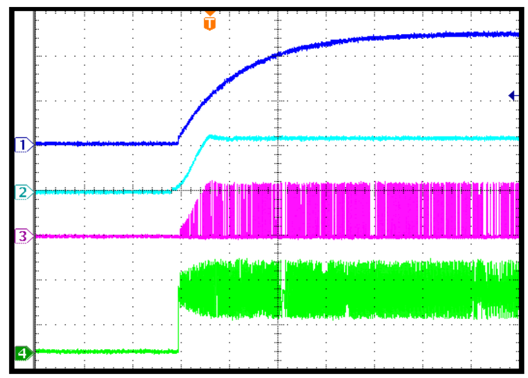
I_{OUT}=0A



20ms/div.

Power On

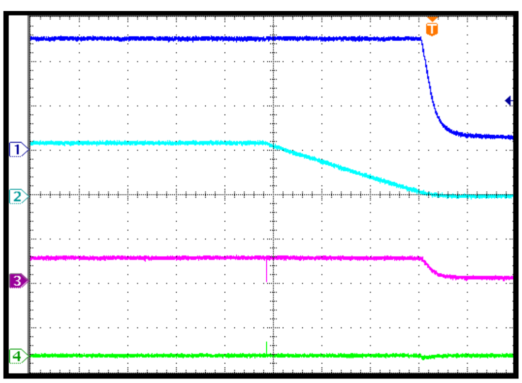
I_{OUT}=1A



20ms/div.

Power Off

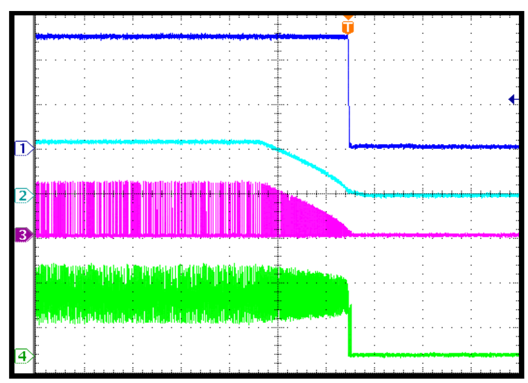
I_{OUT}=0A



100ms/div.

Power Off

I_{OUT}=1A



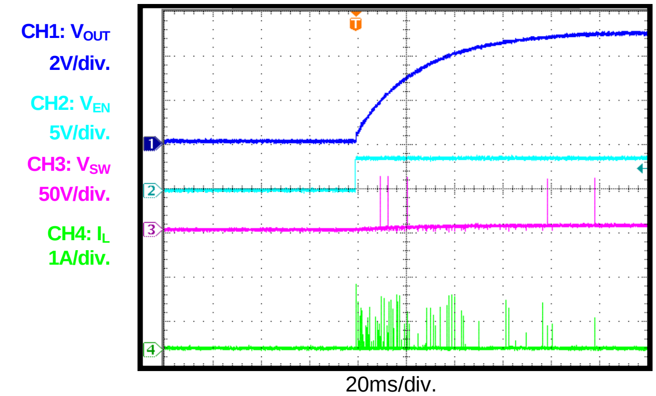
20ms/div.

TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 60V, V_{OUT} = 5V, I_{OUT} = 1A, L=33µH, C_{OUT} = 100µF, T_A= +25°C, unless otherwise noted.

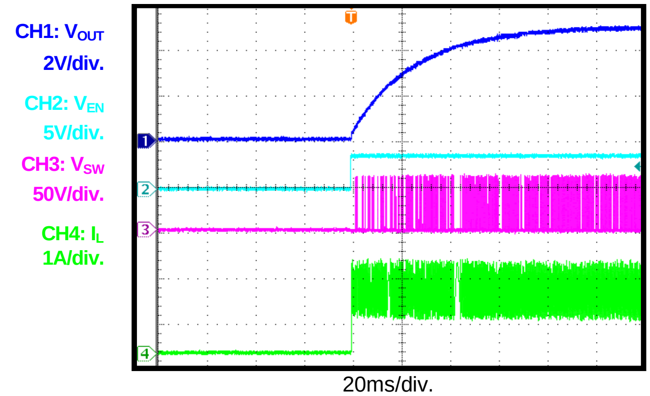
EN Start-Up

I_{OUT}=0A



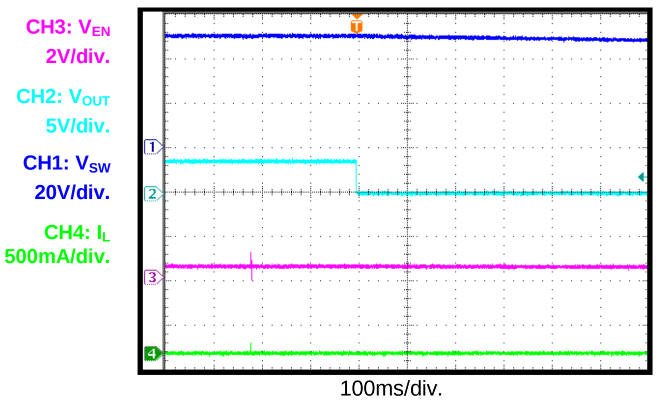
EN Start-Up

I_{OUT}=1A



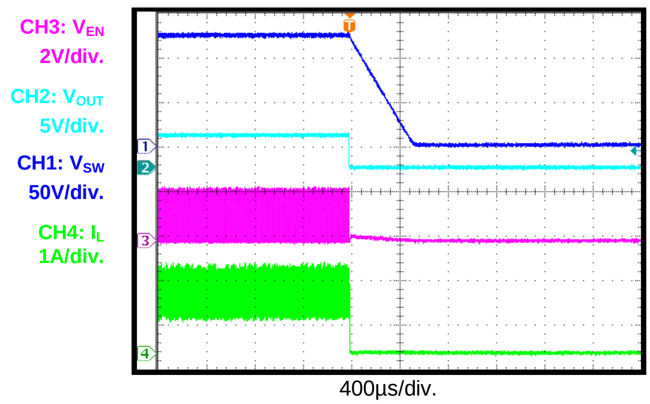
EN Shutdown

I_{OUT}=0A



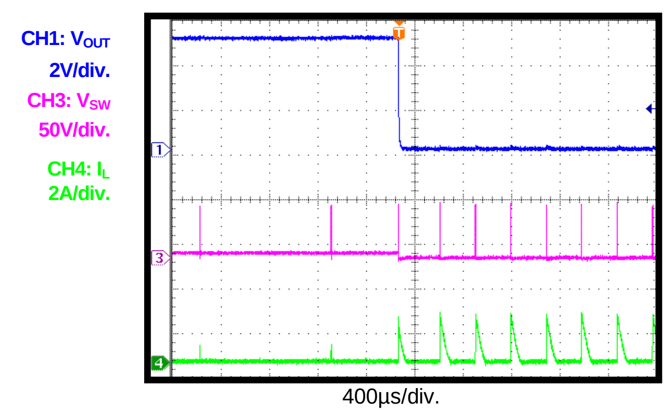
EN Shutdown

I_{OUT}=1A



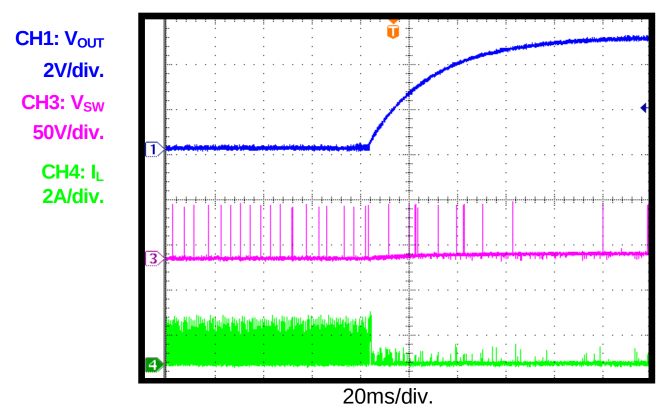
SCP Entry

I_{OUT}=0A



SCP Recovery

I_{OUT}=0A



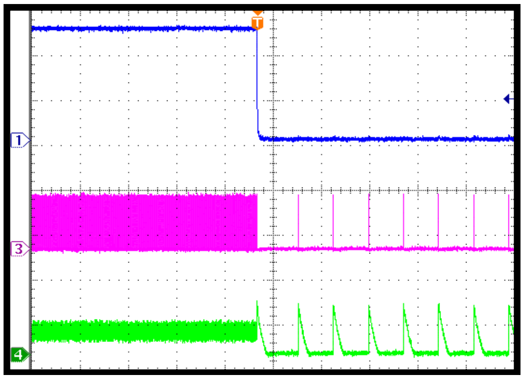
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 60V, V_{OUT} = 5V, I_{OUT} = 1A, L=33µH, C_{OUT} = 100µF, T_A= +25°C, unless otherwise noted.

SCP Entry

I_{OUT}=1A

CH1: V_{OUT} 2V/div.
CH3: V_{SW} 50V/div.
CH4: I_L 2A/div.

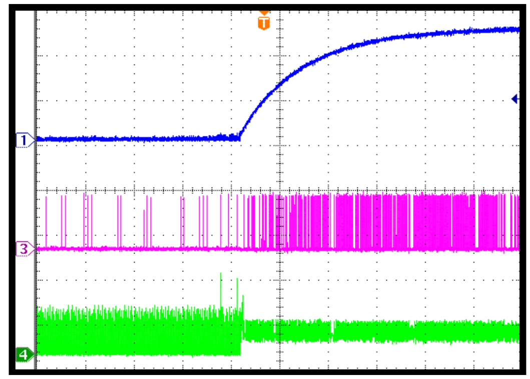


400µs/div.

SCP Recovery

I_{OUT}=1A, E-load turn-on Threshold=0.32V

CH1: V_{OUT} 2V/div.
CH3: V_{SW} 50V/div.
CH4: I_L 2A/div.

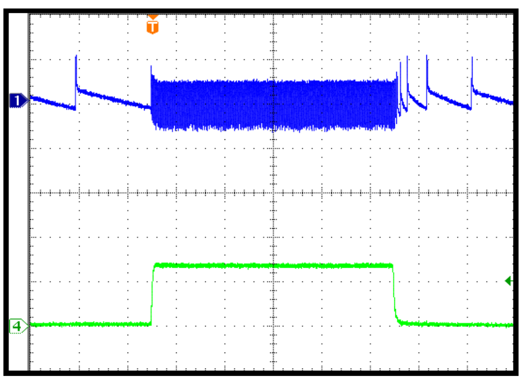


20ms/div.

Push-Button On

I_{OUT}=0A-->1A@70mA/µs

CH1: V_{OUT}/AC 50mV/div.
CH4: I_{LOAD} 1A/div.

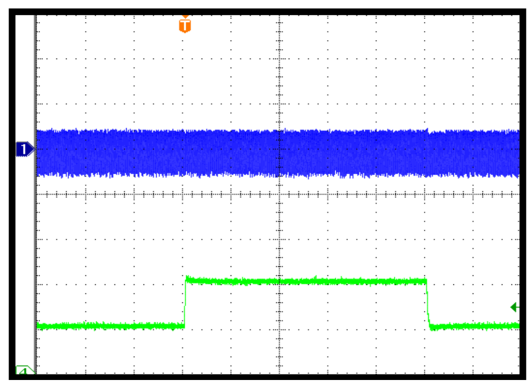


400µs/div.

Load Transient

I_{OUT}=1A-->2A@70mA/µs

CH1: V_{OUT}/AC 50mV/div.
CH4: I_{OUT} 1A/div.



400µs/div.

PIN FUNCTIONS

SOIC8E Pin #	Name	Description
1	FB	Feedback. This is the input to the voltage hysteretic comparators. The average FB voltage is maintained at 200mV by loop regulation.
2	N/C	Not connected
3	VIN	Input Supply. This supplies power to all the internal control circuitry, including BST regulators and the high-side switch. A decoupling capacitor to ground must be placed close to this pin to minimize switching spikes.
4	BST	Bootstrap. This is the positive power supply for the internal floating high-side MOSFET driver. Connect a bypass capacitor between this pin and SW pin.
5	SW	Switch Node. This is the output from the high-side switch. A Schottky rectifier to ground is required. The rectifier must be close to the SW pins to reduce switching spikes.
6	DIM	PWM Dimming Input. This pin is useful in LED driver application. Pulling this pin below the specified threshold for dimming off. Pulling it up above the specified threshold for dimming on. If there is no need for dimming function such as in constant voltage Buck application, connect DIM and EN pins together.
7	EN	Enable Input. Pulling this pin below the specified threshold shuts the chip down. Pulling it up above the specified threshold or leaving it floating enables the chip.
8	GND	Ground. It should be connected as close as possible to the output capacitor avoiding the high current switch paths. Connect exposed pad to GND plane for optimal thermal performance.

BLOCK DIAGRAM

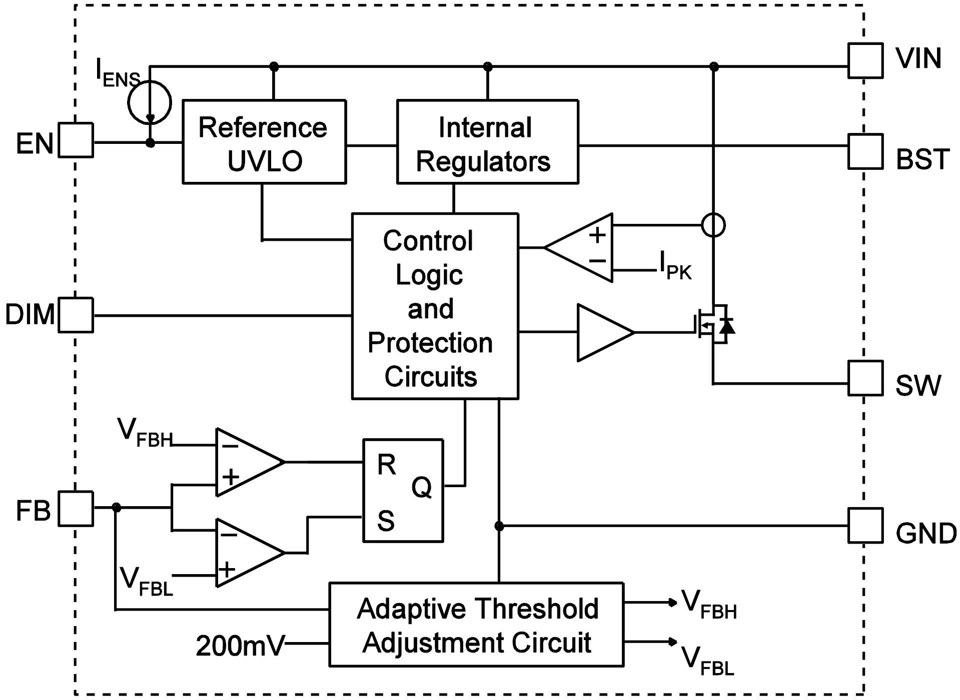


Figure 1—Function Block Diagram

OPERATION

Hysteresis Current Control with Adaptive Threshold Adjustment

MP9486A operates in a hysteresis voltage control mode to regulate the output voltage. FB pin is connected to the tap of a resistor divider which determines output voltage. The power MOSFET is turned on when V_{FB} drop to 185mV and remains on until V_{FB} rises to 215mV. The power MOSFET is turned off when V_{FB} rises to 215mV and remains off until V_{FB} falls to 185mV. The two thresholds of 215mV and 185mV are adaptive adjusted to compensate all the circuit delays so that the output voltage is regulated with 200mV average value at FB pin.

Enable Control

The MP9486A has a dedicated enable control pin (EN) with the positive logic. Its falling threshold is 1.23V, and its rising threshold is 1.55V (320mV higher).

When floating, EN is pulled up to about 3.0V by an internal 2µA(max. 3uA) current source so it is enabled. To pull it down, over 3µA current capability is needed.

Floating Driver and Bootstrap Charging

The floating power MOSFET driver is powered by an external bootstrap capacitor. This floating driver has its own UVLO protection. This UVLO's rising threshold is 2.2V with a threshold of 150mV.

The bootstrap capacitor is charged and regulated to about 5V by the dedicated internal bootstrap regulator.

In case the internal circuit does not have sufficient voltage and the bootstrap capacitor is not well charged, extra external circuitry can be used to ensure the bootstrap voltage is in the normal operational region. Refer to *External Bootstrap Diode* in Application section.

Under-Voltage Lockout (UVLO)

Under-voltage lockout (UVLO) is implemented to protect the chip from operating at insufficient supply voltage. The UVLO rising threshold is about 4.0V while its falling threshold is a consistent 3.6V.

Dimming Function for LED Application

Because the FB reference of MP9486A is very low, it is a good choice to use MP9486A for LED driver by connecting the LED current sense resistor between FB and GND. In such applications, MP9486A provides a DIM pin for dimming. To achieve the purpose, apply a pulse on this pin. The high level of the pulse should be >1.5V, and low level should<0.5V, the frequency can be as high as 20kHz.

Thermal Shutdown

Thermal shutdown is implemented to prevent the chip from operating at exceedingly high temperatures. When the silicon die temperature is higher than its upper threshold, it shuts down the whole chip. When the temperature is lower than its lower threshold, the chip is enabled again.

Output Short Protection

The output voltage is well regulated by making FB pin voltage at around 200mV. If the output is pulled low in OCP or is circuit-shorted to GND directly, the FB pin voltage is low even though the power MOSFET is turned on, the power MOSFET will be shut off if such failure time is longer than a blanking time. The blanking time is about 80µs. MP9486A will retry the operation after about 300us delay.

The power MOSFET current is also accurately sensed via a current sense MOSFET. If the current exceeds current limit, the IC is shut down. This offers extra protection under output short conditions. MP9486A will retry the operation after about 300us delay.

APPLICATION INFORMATION

COMPONENT SELECTION

Setting the Output Voltage

The Output Voltage V_{OUT} is set by a divider resistor consist of R1 and R2, refer to the circuit on Page 1. To get good noise immunity and low power loss, the R2 is recommended to be in the range of 5kΩ to 50kΩ. Assuming R2 is determined, then R1 can be computed as below:

$$R1 = \frac{V_{OUT} - V_{FB}}{V_{FB}} \times R2 \qquad (1)$$

Where V_{FB}=0.2V typically.

Output Capacitor and Frequency Setting

The output capacitor (COUT) is necessary to achieve a smooth output voltage. The ESR of the capacitor should be sufficiently large compared to the capacitance; otherwise, the system may behave in an unexpected way, and the current ripple may be very high. VFB changes from 185mV to 215mV when the power MOSFET switches on. To charge the capacitor and generate 215mV at FB, the system needs ESR and some inductor current. For example, for a 5V VOUT, if the forward capacitor is 0.1µF, the suggested ESR range of the output capacitor is 100mΩ to 250mΩ. Tantalum or aluminum electrolytic capacitors with a small ceramic capacitor are recommended.

A forward capacitor across R1 is recommended when the output capacitor is tantalum or aluminum electrolytic, which can set the wanted frequency if the output capacitor and ESR cannot be changed. The forward capacitor can reduce the output voltage ripple.

In some application, simply a forward capacitor may not get proper frequency, then we can add a forward resistor in series with the forward capacitor or even more add a ceramic on the output.

Inductor Selection

An inductor (L) is required to convert the switching voltage to a smooth current to the load. Although the output current is low, it is recommended that the inductor current be continuous in each switching period to prevent reaching the current limit. Calculate the inductor value with Equation (2):

$$L = \frac{(V_{IN} - V_{OUT}) * V_{OUT} * T}{F_{SW} \times I_{OUT} \times V_{IN} \times K} \qquad (2)$$

Where K is a coefficient of about 0.15 ~ 0.85.

Output Rectifier Diode

The output rectifier diode supplies the current to the inductor when the high-side switch is turned off. To reduce losses due to the diode forward voltage and recovery times, use a Schottky diode.

The average current through the diode is about:

$$I_D = I_{OUT} \times (1 - \frac{V_{OUT}}{V_{IN}}) \qquad (3)$$

Choose a diode whose maximum reverse voltage rating is greater than the maximum input voltage, and whose current rating is greater than the average diode current.

Input Capacitor C_{IN}

The input current to the step-down converter is discontinuous, therefore a capacitor is required to supply the AC current to the step-down converter while maintaining the DC input voltage. Use low ESR capacitors for the best performance especially under high switching frequency applications.

The RMS current through the input capacitor is about:

$$I_{IN\_AC} = I_{OUT} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times (1 - \frac{V_{OUT}}{V_{IN}})} \qquad (4)$$

With low ESR capacitors, the input voltage ripple can be estimated by:

$$\Delta V_{IN} = \frac{I_{OUT} \times V_{OUT}}{F_{SW} \times C_{IN} \times V_{IN}} \times (1 - \frac{V_{OUT}}{V_{IN}}) \qquad (5)$$

Choose the input capacitor with enough RMS current rating and enough capacitance for small input voltage ripple.

When electrolytic or tantalum capacitors are applied, a small, high quality ceramic capacitor, i.e. 0.1μF, should be placed as close to the IC as possible.

External Bootstrap Diode

An external bootstrap diode may enhance the efficiency of the LED driver. In below cases, an external BST diode is recommended from the 5V to BST pin:

- There is a 5V rail available in the system;
- VIN is no greater than 5V;
- VOUT is between 3.3V and 5V;

This diode is also recommended for high duty cycle operation (when V_{OUT}/V_{IN}>65%) and very high frequency (close to 1MHz) applications.

The bootstrap diode can be a low cost one such as IN4148 or BAT54.

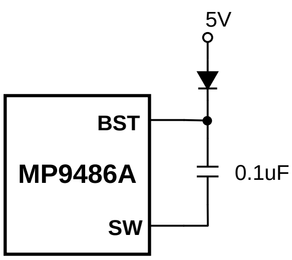


Figure 2—External Bootstrap Diode

Layout Consideration

Efficient PCB layout is critical for stable operation. Refer to Figure 3 and follow the guidelines below.

1, Place the input decoupling capacitor, catch diode, and MP9486A (VIN, SW, and PGND pin) as close to each other as possible.

2, Power traces should be short and wide to reduce voltage spikes on the SW node and lower EMI noise level.

3, Run the feedback trace as far from the inductor and noisy power traces as possible.

4, Thermal vias with 15mil barrel diameter and 40mil pitch (instance between the centers) are suggested under the exposed pad to improve thermal conduction.

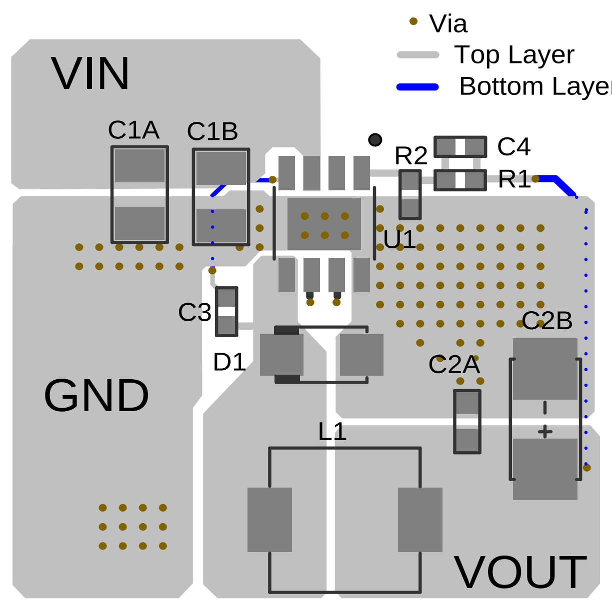


Figure 3: Layout Recommendation

Design Example

Below is a design example following the application guidelines for the following specifications:

Table 1: Design Example

Vin	8V to 95V
Vout	5V
Continuous Iout	0A to 1A
Pulse Iout	2A

The typical application circuit for V_{OUT} = 5V in Figure 5 shows the detailed application schematic, and it is the basis for the typical performance waveforms. For more detailed device applications, please refer to the related Evaluation Board Datasheets.

TYPICAL APPLICATION CIRCUITS

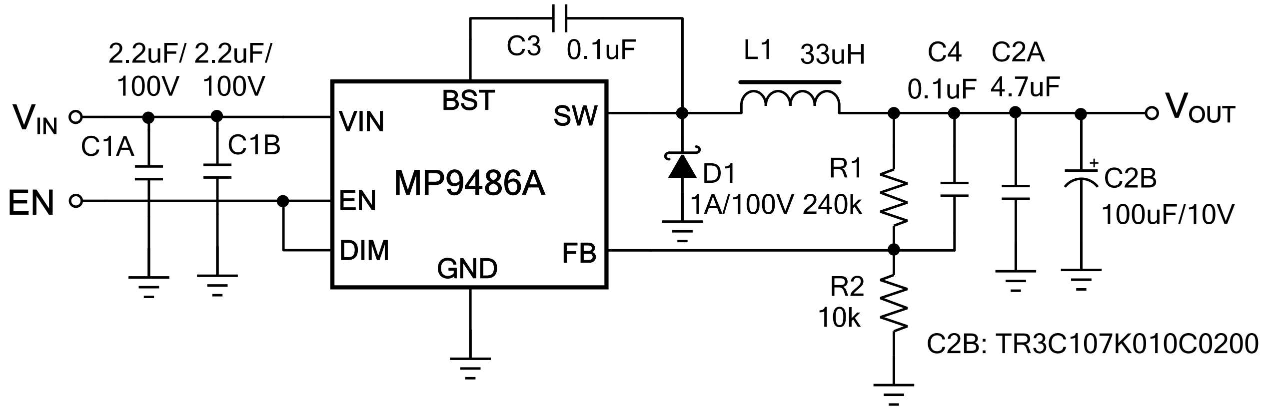


Figure 4: V_{IN}=8~95V, V_{OUT}=5V, I_{OUT}=1A

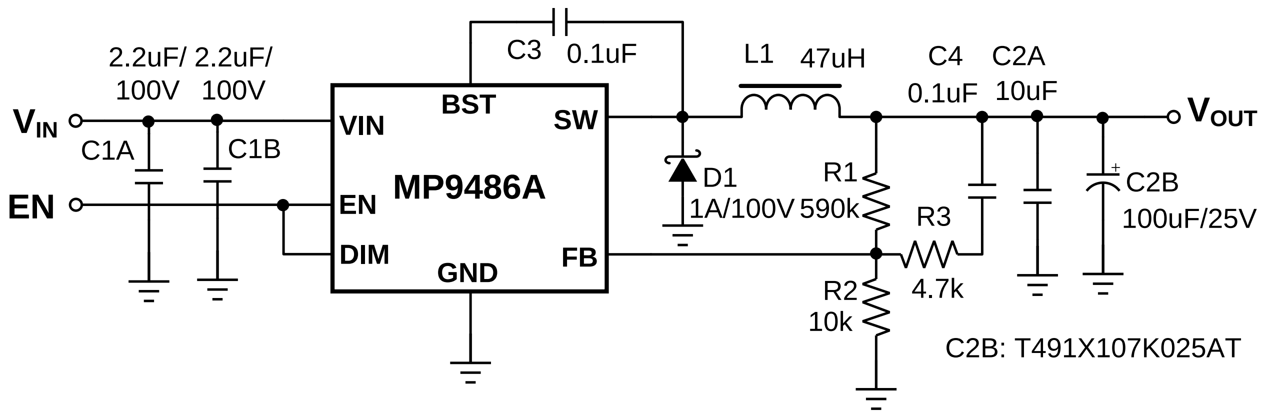
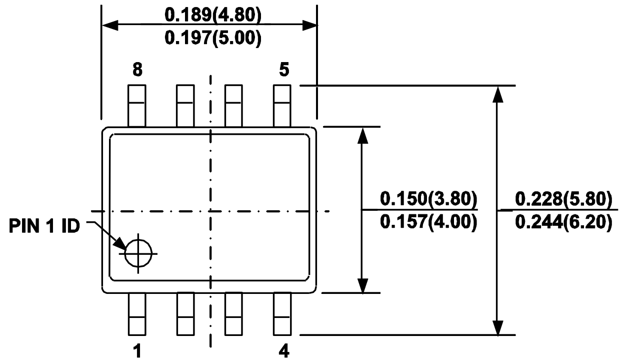


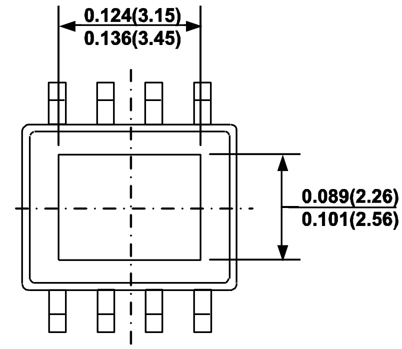
Figure 5: V_{IN}=15~95V, V_{OUT}=12V, I_{OUT}=1A

PACKAGE INFORMATION

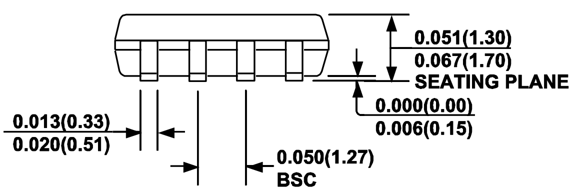
SOIC8E (EXPOSED PAD)



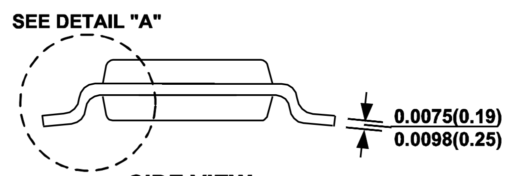
TOP VIEW



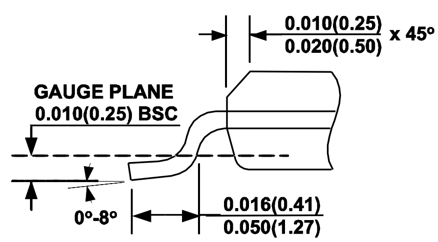
BOTTOM VIEW



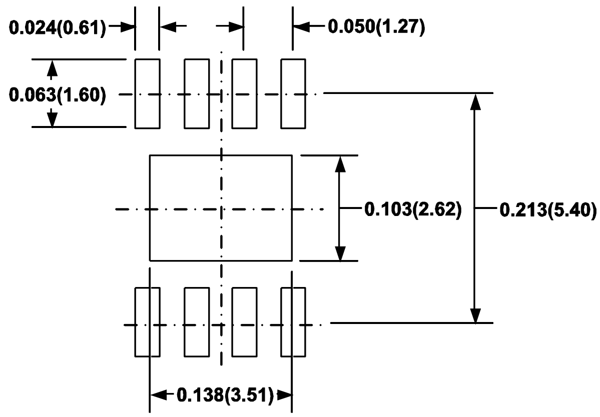
FRONT VIEW



SIDE VIEW



DETAIL "A"



RECOMMENDED LAND PATTERN

NOTE:

1) CONTROL DIMENSION IS IN INCHES. DIMENSION IN BRACKET IS IN MILLIMETERS.
2) PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.
3) PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.
4) LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.004" INCHES MAX.
5) DRAWING CONFORMS TO JEDEC MS-012, VARIATION BA.
6) DRAWING IS NOT TO SCALE.