MP2367

3A, 28V, 340KHz Step-Down Converter

PRELIMINARY SPECIFICATIONS SUBJECT TO CHANGE – INTERNAL USE ONLY

DESCRIPTION

The MP2367 is a monolithic step down regulator. The device integrates 130mΩ MOSFET that provides 3A continuous load current over a wide operating input voltage of 4.75V to 28V. Current mode control provides fast transient response and cycle-by-cycle current limit.

An adjustable soft-start prevents inrush current at turn-on. In shutdown mode, the supply current drops to 1µA.

This device, available in an 8-pin SOIC package, provides a very compact system solution with minimal reliance on external components.

EVALUATION BOARD REFERENCE

Board Number	Dimensions
EV2367DN-00A	2.0"X x 1.5"Y x 0.5"Z

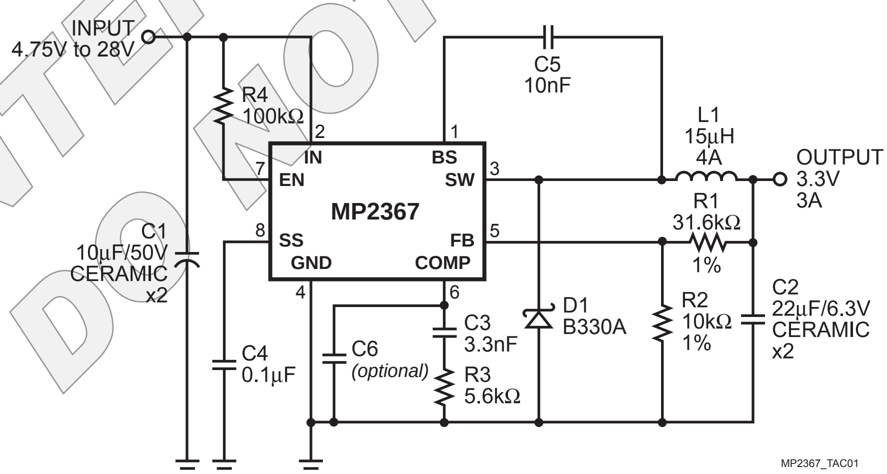
FEATURES

- 3A Output Current
- Wide 4.75V to 28V Operating Input Range
- Integrated Power MOSFET Switches
- Output Adjustable from 0.8V to 25V
- Up to 95% Efficiency
- Programmable Soft-Start
- Stable with Low ESR Ceramic Output Capacitors
- Fixed 340KHz Frequency
- Cycle-by-Cycle Over Current Protection
- Input Under Voltage Lockout
- Thermally Enhanced 8-Pin SOIC Package

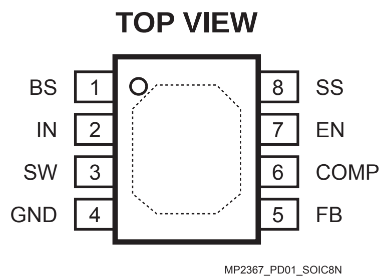
APPLICATIONS

- Distributed Power Systems
- Pre-Regulator for Linear Regulators
- Notebook Computers

TYPICAL APPLICATION



PACKAGE REFERENCE



Part Number*	Package	Temperature
MP2367DN	SOIC8N (Exposed Pad)	–40°C to +85°C

* For Tape & Reel, add suffix –Z (eg. MP2367DN–Z)
For Lead Free, add suffix –LF (eg. MP2367DN–LF–Z)

ABSOLUTE MAXIMUM RATINGS (1)

Supply Voltage V_{IN} .... –0.3V to +30V
Switch Voltage V_{SW} .... –1V to V_{IN} + 0.3V
Boost Voltage V_{BS} .... V_{SW} – 0.3V to V_{SW} + 6V
All Other Pins .... –0.3V to +6V
Junction Temperature .... 150°C
Lead Temperature .... 260°C
Storage Temperature .... –65°C to +150°C

Recommended Operating Conditions (2)

Input Voltage V_{IN} .... 4.75V to 28V
Output Voltage V_{OUT} .... 0.8V to 25V
Ambient Operating Temperature ... –40°C to +85°C

Thermal Resistance (3) θ_{JA} θ_{JC}

SOIC8N .... 50 ...... 10... °C/W

Notes:
1) Exceeding these ratings may damage the device.
2) The device is not guaranteed to function outside of its operating conditions.
3) Measured on approximately 1" square of 1 oz copper.

ELECTRICAL CHARACTERISTICS

V_{IN} = 12V, T_A = +25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ (4)	Max	Units
Shutdown Supply Current		V_{EN} = 0V		0.3	3.0	μA
Supply Current		V_{EN} = 2.7V, V_{FB} = 0.9V		1.3	1.5	mA
Feedback Voltage	V_{FB}	4.75V ≤ V_{IN} ≤ 28V, V_{COMP} < 2V	0.78	0.80	0.82	V
Feedback Overvoltage Threshold			0.95	1.0	1.05	V
Error Amplifier Voltage Gain	A_{EA}			400		V/V
Error Amplifier Transconductance	G_{EA}	ΔI_C = ±10μA	550	820	1100	μA/V
High-Side Switch On Resistance	$R_{DS(ON)1}$			130		mΩ
Low-Side Switch On Resistance	$R_{DS(ON)2}$			1.2		Ω
High-Side Switch Leakage Current		V_{EN} = 0V, V_{SW} = 0V		0	10	μA
Upper Switch Current Limit			5.0	6.0		A
COMP to Current Sense Transconductance	G_{CS}		5	6		A/V
Oscillation Frequency	F_{osc1}		300	340	380	KHz
Short Circuit Oscillation Frequency	F_{osc2}	V_{FB} = 0V		110		KHz
Maximum Duty Cycle	D_{MAX}	V_{FB} = 0.7V		90		%
Minimum On Time				220		ns
EN Shutdown Threshold Voltage		V_{EN} Rising	1.1	1.3	1.5	V
EN Shutdown Threshold Voltage Hysteresis				220		mV
EN Lockout Threshold Voltage			2.2	2.5	2.7	V
EN Lockout Hysteresis				210		mV

ELECTRICAL CHARACTERISTICS *(continued)*

V_{IN} = 12V, T_A = +25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ [4]	Max	Units
EN Lockout Threshold Voltage			2.2	2.5	2.7	V
EN Lockout Hysteresis				210		mV
Input Under Voltage Lockout Threshold		V_{IN} Rising	3.80	4.05	4.30	V
Input Under Voltage Lockout Threshold Hysteresis				210		mV
Soft-Start Current		V_{SS} = 0V		6		µA
Soft-Start Period		C_{SS} = 0.1µF		15		ms
Thermal Shutdown				160		°C

Note:
4) Guaranteed by design, not tested.

PIN FUNCTIONS

Pin #	Name	Description
1	BS	High-Side Gate Drive Boost Input. BS supplies the drive for the high-side N-Channel MOSFET switch. Connect a 0.01µF or greater capacitor from SW to BS to power the high side switch.
2	IN	Power Input. IN supplies the power to the IC, as well as the step-down converter switches. Drive IN with a 4.75V to 28V power source. Bypass IN to GND with a suitably large capacitor to eliminate noise on the input to the IC. See *Input Capacitor*.
3	SW	Power Switching Output. SW is the switching node that supplies power to the output. Connect the output LC filter from SW to the output load. Note that a capacitor is required from SW to BS to power the high-side switch.
4	GND	Ground (Connect Exposed Pad to Pin 4)
5	FB	Feedback Input. FB senses the output voltage to regulate that voltage. Drive FB with a resistive voltage divider from the output voltage. The feedback reference voltage is 0.8V. See *Setting the Output Voltage*.
6	COMP	Compensation Node. COMP is used to compensate the regulation control loop. Connect a series RC network from COMP to GND to compensate the regulation control loop. In some cases, an additional capacitor from COMP to GND is required. See *Compensation Components.*
7	EN	Enable Input. EN is a digital input that turns the regulator on or off. Drive EN high to turn on the regulator, drive it low to turn it off. Pull up with 100kΩ resistor for automatic startup.
8	SS	Soft-start Control Input. SS controls the soft-start period. Connect a capacitor from SS to GND to set the soft-start period. A 0.1µF capacitor sets the soft-start period to 15ms. To disable the soft-start feature, leave SS unconnected.

BLOCK DIAGRAM

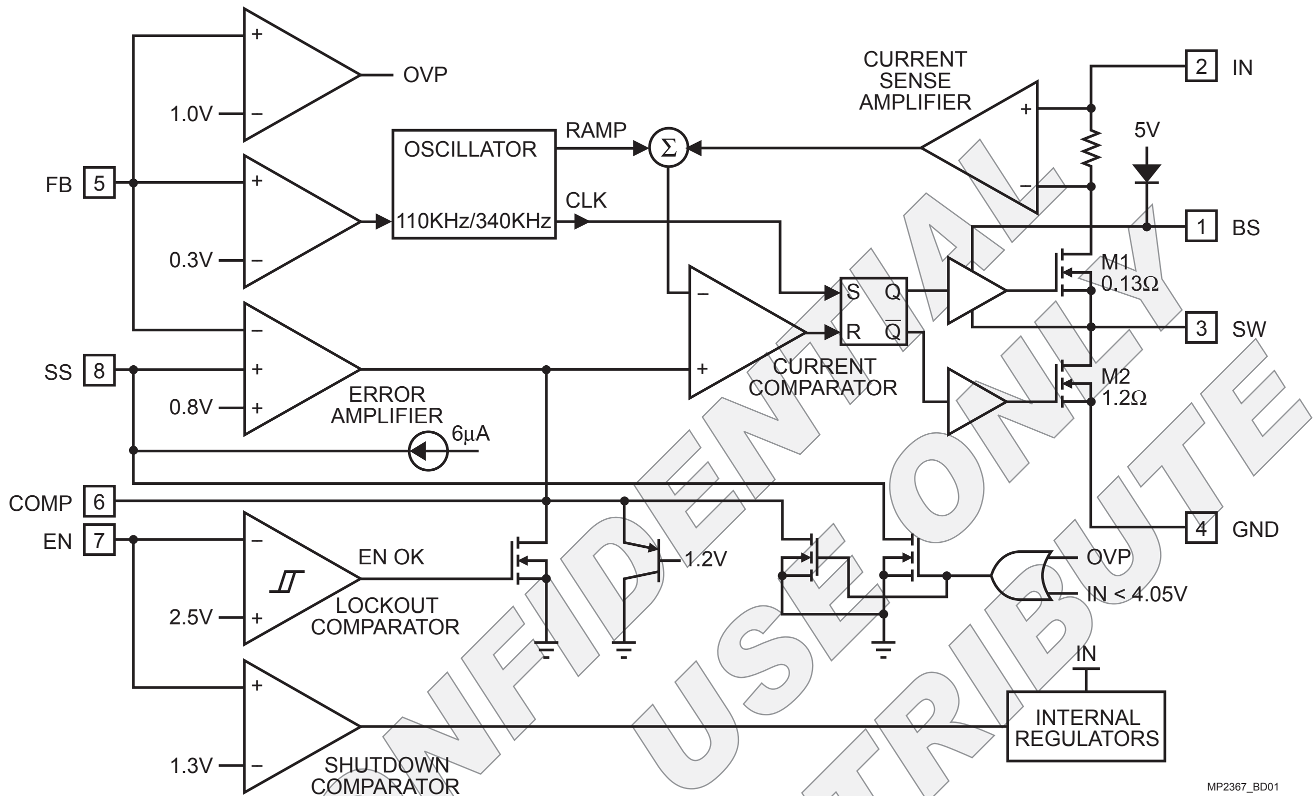


Figure 1—Functional Block Diagram

OPERATION

FUNCTIONAL DESCRIPTION

The MP2367 is a current-mode step-down regulator. It regulates input voltages from 4.75V to 28V down to an output voltage as low as 0.8V, and supplies up to 3A of load current.

The MP2367 uses current-mode control to regulate the output voltage. The output voltage is measured at FB through a resistive voltage divider and amplified through the internal transconductance error amplifier. The voltage at COMP pin is compared to the switch current measured internally to control the output voltage.

The converter uses an internal N-Channel MOSFET switch to step-down the input voltage to the regulated output voltage. Since the high side MOSFET requires a gate voltage greater than the input voltage, a boost capacitor connected between SW and BS is needed to drive the high side gate. The boost capacitor is charged from the internal 5V rail when SW is low. An internal 1.2Ω switch from SW to GND is used to insure that SW is pulled to GND when switch is off to fully charge the BS capacitor.

When the MP2367 FB pin exceeds 20% of the nominal regulation voltage of 0.8V, the over voltage comparator is tripped; the COMP pin and the SS pin are discharged to GND, forcing the high-side switch off.

APPLICATIONS INFORMATION

COMPONENT SELECTION

Setting the Output Voltage

The output voltage is set using a resistive voltage divider from the output voltage to FB pin. The voltage divider divides the output voltage down to the feedback voltage by the ratio:

$$V_{FB} = V_{OUT}\frac{R2}{R1+R2}$$

Thus the output voltage is:

$$V_{OUT} = 0.8 \times \frac{R1+R2}{R2}$$

Where V_{FB} is the feedback voltage and V_{OUT} is the output voltage.

A typical value for R2 can be as high as 100kΩ, but a typical value is 10kΩ. Using that value, R1 is determined by:

$$R1 = 12.5 \times (V_{OUT} - 0.8)(k\Omega)$$

For example, for a 3.3V output voltage, R2 is 10kΩ, and R1 is 31.3kΩ.

Inductor

The inductor is required to supply constant current to the output load while being driven by the switched input voltage. A larger value inductor will result in less ripple current that will result in lower output ripple voltage. However, the larger value inductor will have a larger physical size, higher series resistance, and/or lower saturation current. A good rule for determining the inductance to use is to allow the peak-to-peak ripple current in the inductor to be approximately 30% of the maximum switch current limit. Also, make sure that the peak inductor current is below the maximum switch current limit. The inductance value can be calculated by:

$$L = \frac{V_{OUT}}{f_S \times \Delta I} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Where V_{IN} is the input voltage, f_S is the 340KHz switching frequency, and ΔI_L is the peak-to-peak inductor ripple current.

Choose an inductor that will not saturate under the maximum inductor peak current. The peak inductor current can be calculated by:

$$I_{LP} = I_{LOAD} + \frac{V_{OUT}}{2 \times f_S \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Where I_{LOAD} is the load current.

Optional Schottky Diode

During the transition between high-side switch and low-side switch, the body diode of the low-side power MOSFET conducts the inductor current. The forward voltage of this body diode is high. An optional Schottky diode may be paralleled between the SW pin and GND pin to improve overall efficiency.

Input Capacitor

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. Ceramic capacitors are preferred, but tantalum or low-ESR electrolytic capacitors may also suffice. Choose X5R or X7R dielectrics when using ceramic capacitors.

Since the input capacitor (C1) absorbs the input switching current it requires an adequate ripple current rating. The RMS current in the input capacitor can be estimated by:

$$I_{C1} = I_{LOAD} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)}$$

The worst-case condition occurs at $V_{IN} = 2V_{OUT}$, where $I_{C1} = I_{LOAD}/2$. For simplification, choose the input capacitor whose RMS current rating greater than half of the maximum load current.

The input capacitor can be electrolytic, tantalum or ceramic. When using electrolytic or tantalum capacitors, a small, high quality ceramic capacitor, i.e. 0.1μF, should be placed as close to the IC as possible. When using ceramic capacitors, make sure that they have enough capacitance to provide sufficient charge to prevent excessive voltage ripple at input. The input voltage ripple caused by capacitance can be estimated by:

$$\Delta V_{IN} = \frac{I_{LOAD}}{f_S \times C1} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Where C1 is the input capacitance value.

Output Capacitor

The output capacitor is required to maintain the DC output voltage. Ceramic, tantalum, or low ESR electrolytic capacitors are recommended. Low ESR capacitors are preferred to keep the output voltage ripple low. The output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times f_S \times C2}\right)$$

Where C2 is the output capacitance value and R_{ESR} is the equivalent series resistance (ESR) value of the output capacitor.

In the case of ceramic capacitors, the impedance at the switching frequency is dominated by the capacitance. The output voltage ripple is mainly caused by the capacitance. For simplification, the output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_S^{\,2} \times L \times C2} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

In the case of tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be approximated to:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times R_{ESR}$$

The characteristics of the output capacitor also affect the stability of the regulation system. The MP2367 can be optimized for a wide range of capacitance and ESR values.

Compensation Components

MP2367 employs current mode control for easy compensation and fast transient response. The system stability and transient response are controlled through the COMP pin. COMP pin is the output of the internal transconductance error amplifier. A series capacitor-resistor combination sets a pole-zero combination to control the characteristics of the control system.

The DC gain of the voltage feedback loop is given by:

$$A_{VDC} = R_{LOAD} \times G_{CS} \times A_{VEA} \times \frac{V_{FB}}{V_{OUT}}$$

Where A_{VEA} is the error amplifier voltage gain, 400V/V; G_{CS} is the current sense transconductance, 6.0A/V; R_{LOAD} is the load resistor value.

The system has 2 poles of importance. One is due to the compensation capacitor (C3) and the output resistor of error amplifier, and the other is due to the output capacitor and the load resistor. These poles are located at:

$$f_{P1} = \frac{G_{EA}}{2\pi \times C3 \times A_{VEA}}$$

$$f_{P2} = \frac{1}{2\pi \times C2 \times R_{LOAD}}$$

Where, G_{EA} is the error amplifier transconductance, 820μA/V, and R_{LOAD} is the load resistor value.

The system has one zero of importance, due to the compensation capacitor (C3) and the compensation resistor (R3). This zero is located at:

$$f_{Z1} = \frac{1}{2\pi \times C3 \times R3}$$

The system may have another zero of importance, if the output capacitor has a large capacitance and/or a high ESR value. The zero, due to the ESR and capacitance of the output capacitor, is located at:

$$f_{ESR} = \frac{1}{2\pi \times C2 \times R_{ESR}}$$

In this case, a third pole set by the compensation capacitor (C6) and the compensation resistor (R3) is used to compensate the effect of the ESR zero on the loop gain. This pole is located at:

$$f_{P3} = \frac{1}{2\pi \times C6 \times R3}$$

The goal of compensation design is to shape the converter transfer function to get a desired loop gain. The system crossover frequency where the feedback loop has the unity gain is important.

Lower crossover frequencies result in slower line and load transient responses, while higher crossover frequencies could cause system unstable. A good rule of thumb is to set the crossover frequency to approximately one-tenth of the switching frequency. Switching frequency for the MP2367 is 340KHz, so the desired crossover frequency is 34KHz.

Table 1 lists the typical values of compensation components for some standard output voltages with various output capacitors and inductors. The values of the compensation components have been optimized for fast transient responses and good stability at given conditions.

Table 1—Compensation Values for Typical Output Voltage/Capacitor Combinations

V_{OUT}	L	C2	R3	C3	C6
1.8V	4.7µH	100µF Ceramic	5.6kΩ	3.3nF	None
2.5V	4.7µH - 6.8µH	47µF Ceramic	4.7kΩ	4.7nF	None
3.3V	6.8µH - 10µH	22µFx2 Ceramic	5.6kΩ	3.3nF	None
5V	10µH - 15µH	22µFx2 Ceramic	7.5kΩ	3.3nF	None
12V	15µH - 22µH	22µFx2 Ceramic	10kΩ	1.2nF	None
1.8	4.7µH	100µF SP-CAP	10kΩ	2.2nF	100pF
2.5V	4.7µH - 6.8µH	47µF SP-CAP	5.6kΩ	3.3nF	None
3.3V	6.8µH - 10µH	47µF SP-CAP	6.8kΩ	2.2nF	None
5V	10µH - 15µH	47µF SP CAP	10kΩ	2.2nF	None
2.5V	4.7µH - 6.8µH	560µF Al. 30mΩ ESR	10kΩ	7.5nF	1.5nF
3.3V	6.8µH - 10µH	560µF Al 30mΩ ESR	10kΩ	10nF	1.5nF
5V	10µH - 15µH	470µF Al. 30mΩ ESR	15kΩ	7.5nF	1nF
12V	15µH - 22µH	220µF Al. 30mΩ ESR	15kΩ	10nF	390pF

To optimize the compensation components for conditions not listed in Table 1, the following procedure can be used.

1. Choose the compensation resistor (R3) to set the desired crossover frequency. Determine the R3 value by the following equation:

$$R3 = \frac{2\pi \times C2 \times f_C}{G_{EA} \times G_{CS}} \times \frac{V_{OUT}}{V_{FB}}$$

Where f_C is the desired crossover frequency, 34KHz.

2. Choose the compensation capacitor (C3) to achieve the desired phase margin. For applications with typical inductor values, setting the compensation zero, f_{Z1}, below one forth of the crossover frequency provides sufficient phase margin. Determine the C3 value by the following equation:

$$C3 > \frac{4}{2\pi \times R3 \times f_C}$$

3. Determine if the second compensation capacitor (C6) is required. It is required if the ESR zero of the output capacitor is located at less than half of the 340KHz switching frequency, or the following relationship is valid:

$$\frac{1}{2\pi \times C2 \times R_{ESR}} < \frac{f_S}{2}$$

If this is the case, then add the second compensation capacitor (C6) to set the pole f_{P3} at the location of the ESR zero. Determine the C6 value by the equation:

$$C6 = \frac{C2 \times R_{ESR}}{R3}$$

External Bootstrap Diode

It is recommended that an external bootstrap diode be added when the system has a 5V fixed input or the power supply generates a 5V output. This helps improve the efficiency of the regulator. The bootstrap diode can be a low cost one such as IN4148 or BAT54.

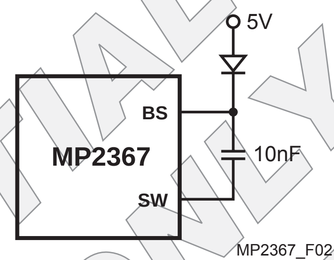


Figure 2—External Bootstrap Diode

This diode is also recommended for high duty cycle operation (when $\frac{V_{OUT}}{V_{IN}}$>65%) and high output voltage (V_{OUT}>12V) applications.

TYPICAL APPLICATION CIRCUITS

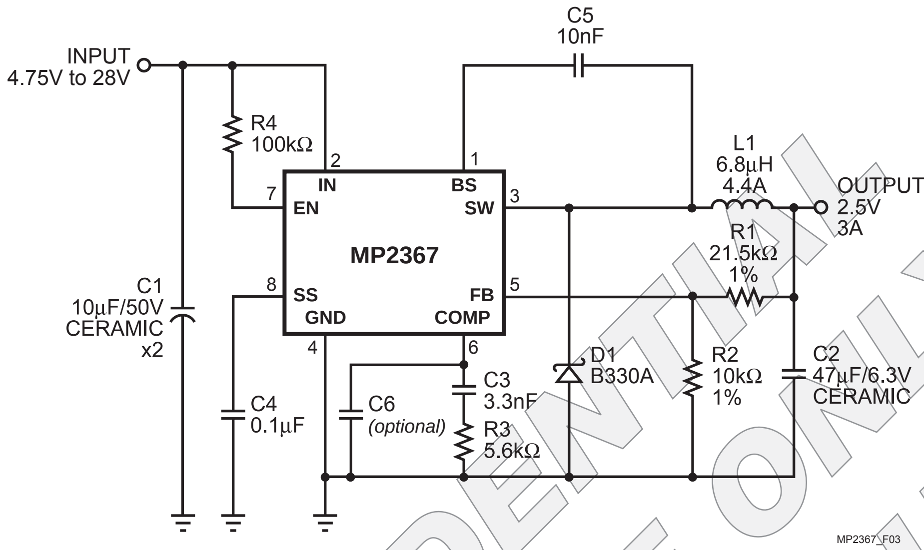


Figure 3—MP2367 with AVX 47µF, 6.3V Ceramic Output Capacitor

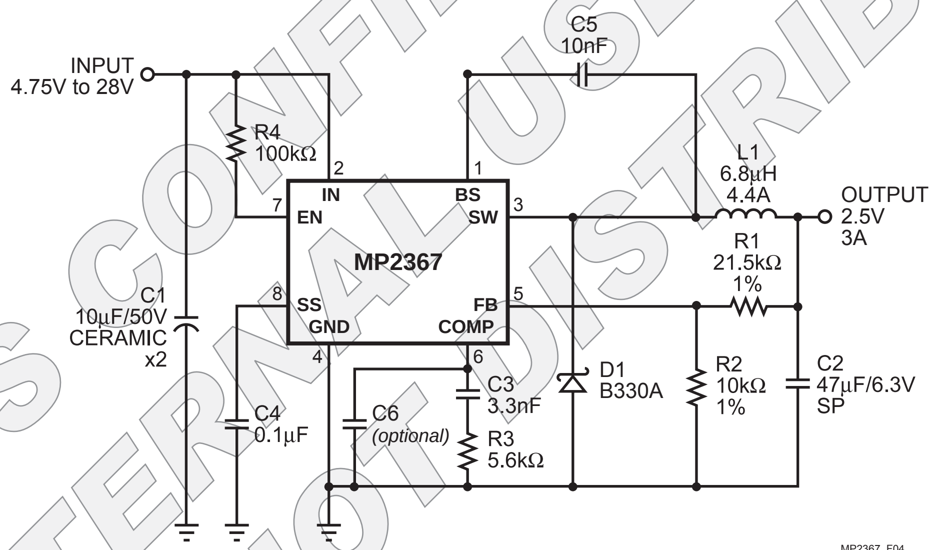


Figure 4—MP2367 with Panasonic 47µF, 6.3V Solid Polymer Output Capacitor

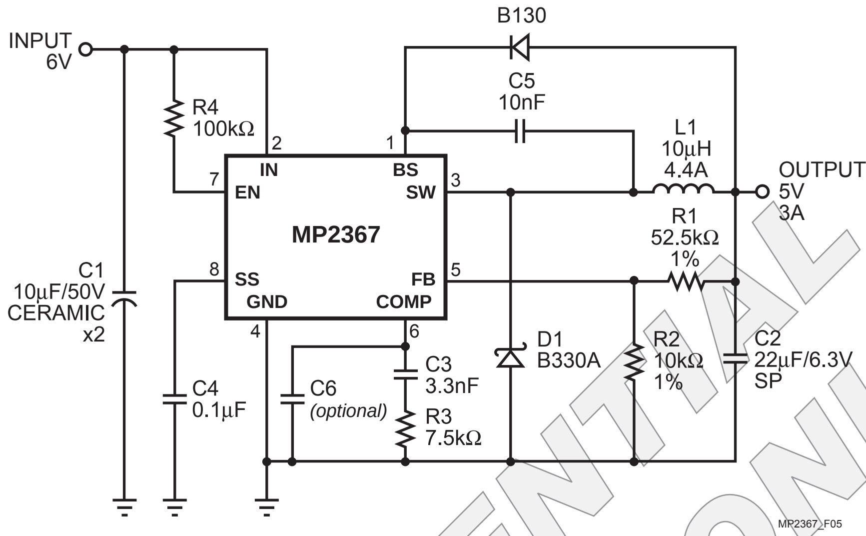
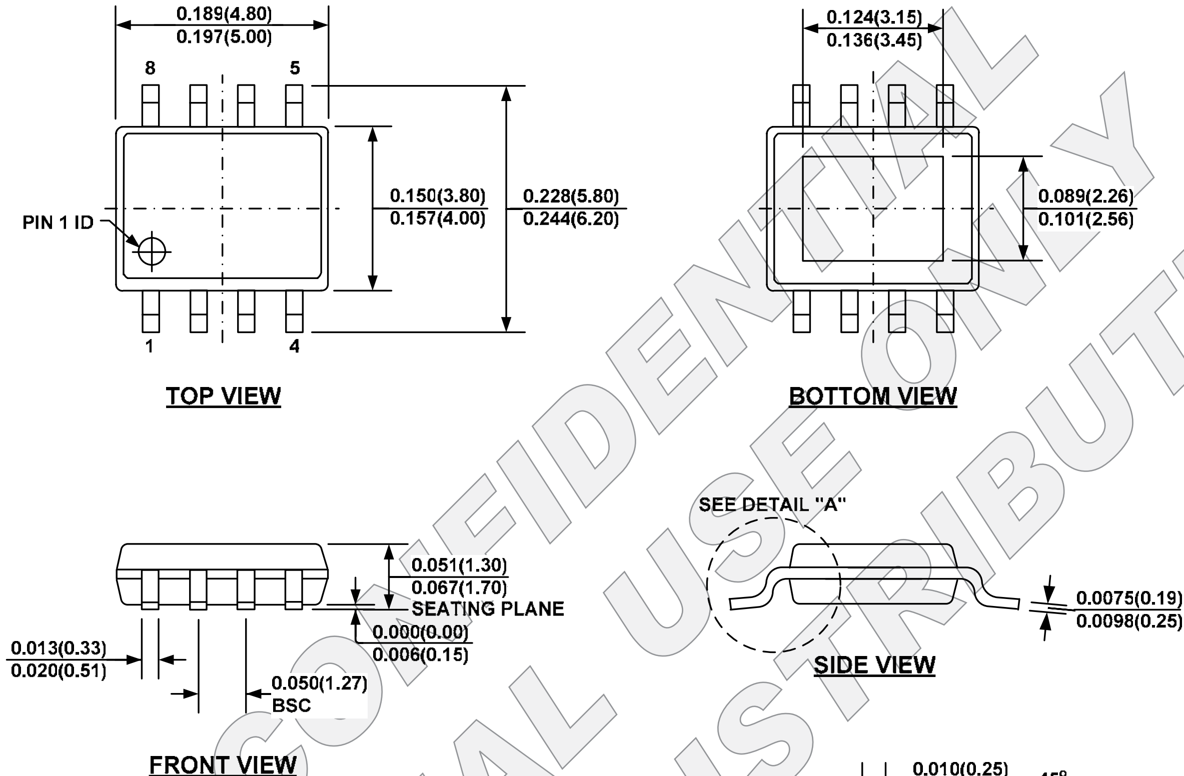
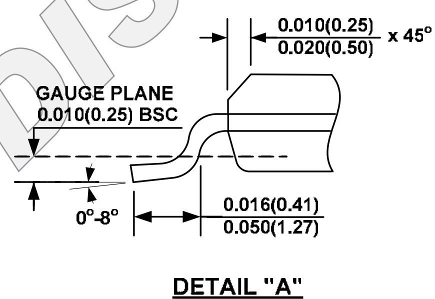


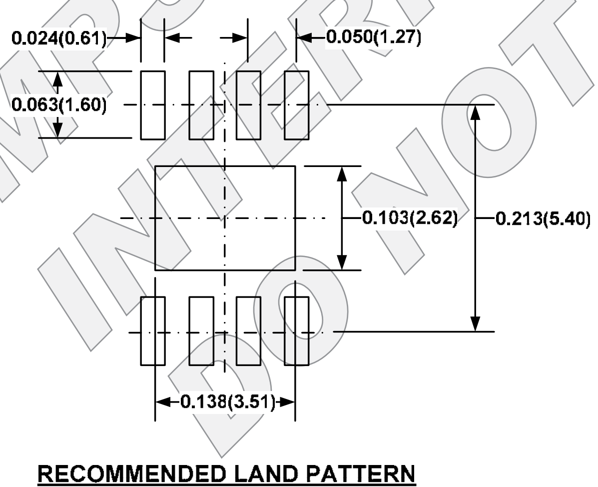
Figure 5—MP2367 Application Circuit with V_{IN} = 6V and V_O = 5V

PACKAGE INFORMATION

SOIC8N (EXPOSED PAD)







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.