The Future of Analog IC Technology®

MP2363

3A, 27V, 365KHz Step-Down Converter

DESCRIPTION

The MP2363 is a non-synchronous step-down regulator with an integrated Power MOSFET. It achieves 3A continuous output current over a wide input supply range with excellent load and line regulation.

Current mode operation provides fast transient response and eases loop stabilization.

Fault condition protection includes cycle-by-cycle current limiting and thermal shutdown. Adjustable soft-start reduces the stress on the input source at turn-on. In shutdown mode, the regulator draws 20μA of supply current.

The MP2363 requires a minimum number of readily available external components to complete a 3A step-down DC to DC converter solution.

The MP2363 is available in 8-pin SOICN and PDIP packages.

EVALUATION BOARD REFERENCE

Board Number	Dimensions
EV2363DN-00A	2.0"X x 1.9"Y x 0.4"Z

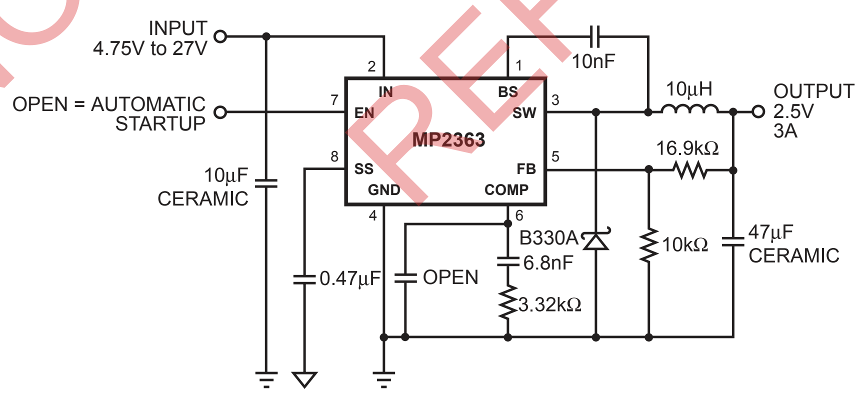
FEATURES

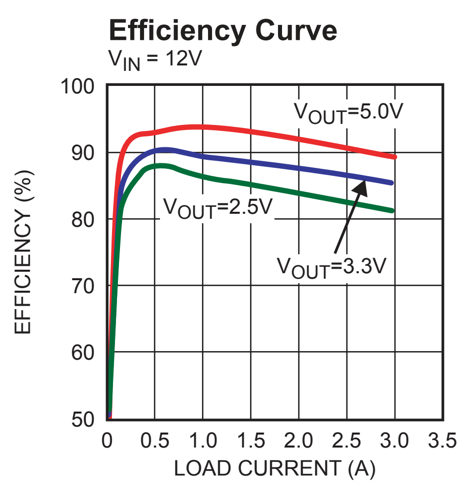
- 3A Continuous Output Current, 4A Peak Output Current
- Programmable Soft-Start
- 100mΩ Internal Power MOSFET Switch
- Stable with Low ESR Output Ceramic Capacitors
- Up to 95% Efficiency
- 20μA Shutdown Mode
- Fixed 365KHz frequency
- Thermal Shutdown
- Cycle-by-Cycle Over Current Protection
- Wide 4.75V to 27V Operating Input Range
- Output is Adjustable From 0.92V to 21V
- Under Voltage Lockout

APPLICATIONS

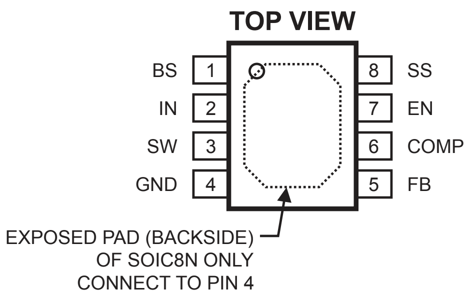
- Distributed Power Systems
- Battery Chargers
- Pre-Regulator for Linear Regulators

TYPICAL APPLICATION





PACKAGE REFERENCE



Part Number*	Package	Temperature
MP2363DN	SOIC8N	–40°C to +85°C
**MP2363DP	**PDIP8	

* For Tape & Reel, add suffix –Z (eg. MP2363DN–Z)
For RoHS Compliant Packaging, add suffix –LF (eg. MP2363DN–LF–Z)

** Contact Factory for Availability

ABSOLUTE MAXIMUM RATINGS (1)

Supply Voltage V_{IN} .... –0.3V to +28V
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 27V
Ambient Operating Temp .... –40°C to +85°C

Thermal Resistance (3) θ_{JA} θ_{JC}

SOIC8N .... 50 ...... 10 ... °C/W
PDIP8 .... 104 ..... 45 ... °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.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Shutdown Supply Current		V_{EN} = 0V		20	30	μA
Supply Current		V_{EN} = 3V, V_{FB} = 1.4V		1.0	1.2	mA
Feedback Voltage	V_{FB}	4.75V ≤ V_{IN} ≤ 27V	0.90	0.92	0.94	V
Error Amplifier Voltage Gain (4)	A_{VEA}			400		V/V
Error Amplifier Transconductance	G_{EA}	ΔI_{COMP} = ±10μA	500	800	1120	μA/V
High-Side Switch On-Resistance (4)	$R_{DS(ON)1}$			100		mΩ
Low-Side Switch On-Resistance	$R_{DS(ON)2}$			6		Ω
High-Side Switch Leakage Current		V_{EN} = 0V, V_{SW} = 0V		0.1	10	μA
Short Circuit Current Limit			4.5	5.7		A
Current Sense to COMP Transconductance	G_{CS}			7.0		A/V
Oscillation Frequency	f_S		315	365	415	KHz
Short Circuit Oscillation Frequency		V_{FB} = 0V	20	35	50	KHz
Maximum Duty Cycle	D_{MAX}	V_{FB} = 0.8V		88		%
Minimum On Time (4)	T_{ON}			120		ns
EN Threshold Voltage			0.9	1.2	1.5	V
Enable Pull Up Current		V_{EN} = 0V	0.9	1.4	2.2	μA
Under Voltage Lockout Threshold		V_{IN} Rising	2.37	2.54	2.71	V
Under Voltage Lockout Threshold Hysteresis				210		mV
Thermal Shutdown (4)				160		°C

Note:
4) Guaranteed by design.

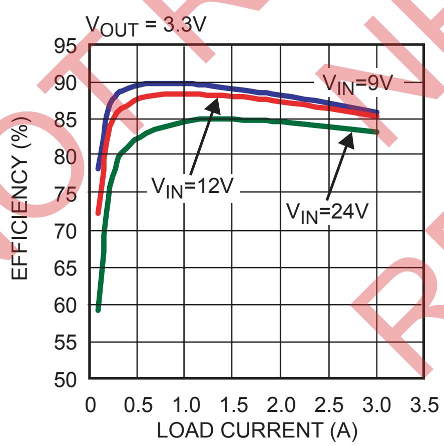
PIN FUNCTIONS

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 10nF 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 27V power source. Bypass IN to GND with a suitably large capacitor to eliminate noise on the input to the IC. See *Input Capacitor* section of Application Information.
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 the exposed pad on backside to Pin 4.
5	FB	Feedback Input. FB senses the output voltage to regulate said voltage. Drive FB with a resistive voltage divider from the output voltage. The feedback threshold is 0.92V. See *Setting the Output Voltage* section of Application Information.
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* section of Application Information.
7	EN	Enable Input. EN is a digital input that turns the regulator on or off. Drive EN higher than 2.71V to turn on the regulator, lower than 0.9V to turn it off. For automatic startup, leave EN unconnected.
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. Soft-start cap is always recommended to eliminate the start-up inrush current and for a smooth start-up waveform.

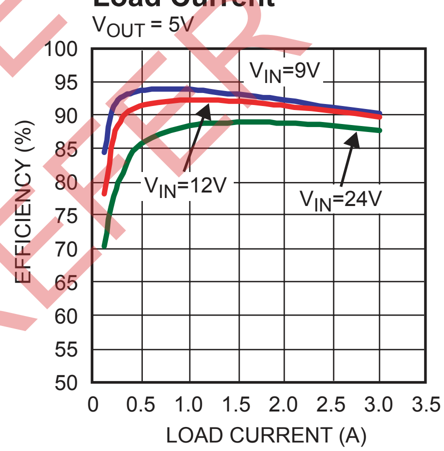
TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 12V, V_{OUT} = 2.5V, L = 15µH, C1 = 10µF, C2 = 22µF, T_A = +25°C, unless otherwise noted.

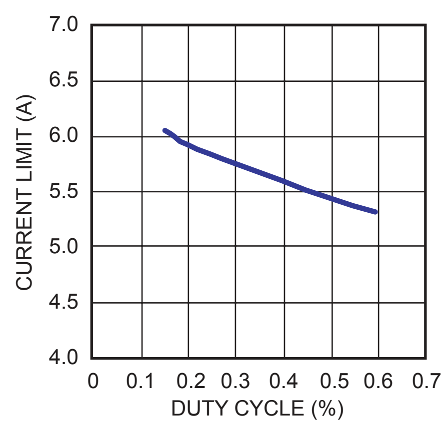
Efficiency Curve vs Load Current



Efficiency Curve vs Load Current



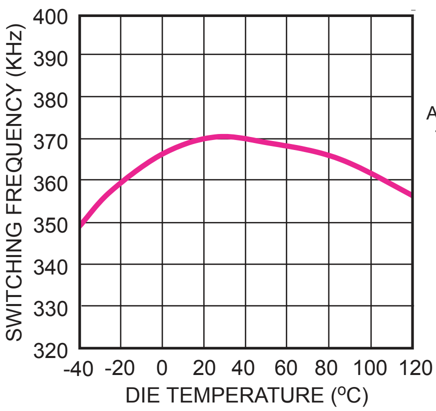
Limit Current vs Duty Cycle



TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

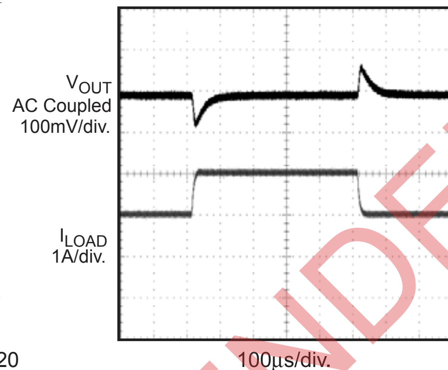
V_{IN} = 12V, V_{OUT} = 2.5V, L = 15µH, C1 = 10µF, C2 = 22µF, T_A = +25°C, unless otherwise noted.

Switching Frequency vs Die Temperature



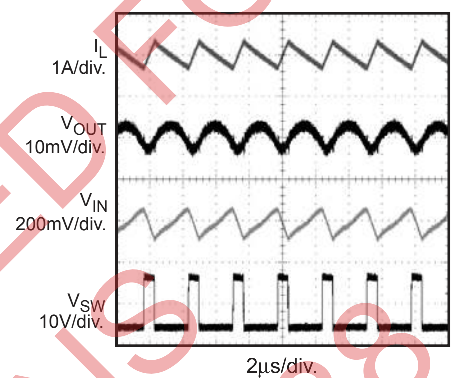
Load Transient Response

I_{OUT} = 1 to 2A step at 0.8A/µs



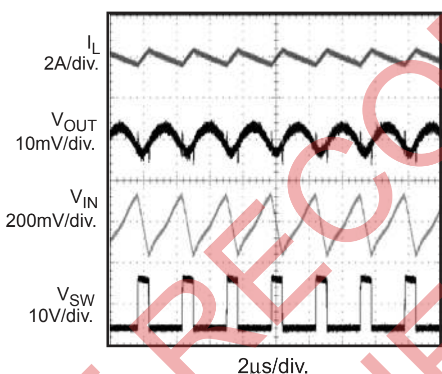
Steady State Test

I_{OUT} = 1.5A Resistive Load



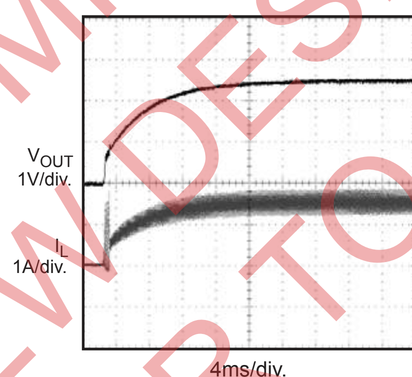
Steady State Test

I_{OUT} = 3A Resistive Load



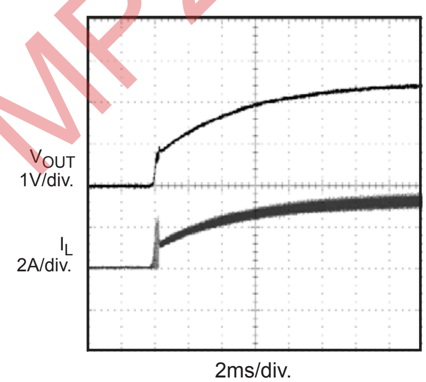
Startup through Enable

I_{OUT} = 1.5A Resistive Load



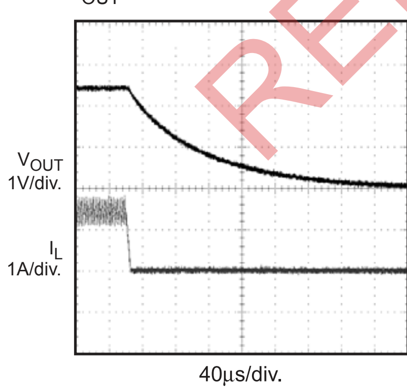
Startup through Enable

I_{OUT} = 3A Resistive Load



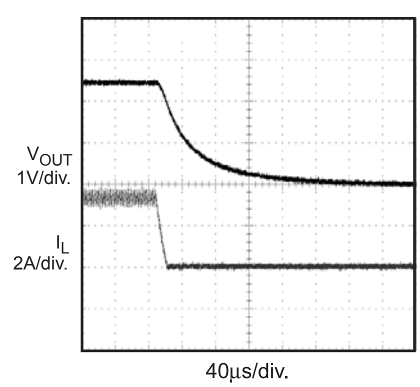
Shutdown through Enable

I_{OUT} = 1.5A Resistive Load



Shutdown through Enable

I_{OUT} = 3A Resistive Load



OPERATION

The MP2363 is a current-mode step-down regulator. It regulates an input voltage between 4.75V to 27V down to an output voltage as low as 0.92V, and is able to supply up to 3A of load current.

The MP2363 uses current-mode control to regulate the output voltage. The output voltage is measured at the FB pin through a resistive voltage divider and amplified through the internal error amplifier. The output current of the transconductance error amplifier is presented at COMP where a network compensates the regulation control system. The voltage at COMP 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 MOSFET requires a gate voltage greater than the input voltage, a boost capacitor connected between SW and BS drives the gate. The capacitor is charged by an internal 5V supply while SW is low.

An internal 10Ω switch from SW to GND is used to insure that SW is pulled to GND when SW is low to fully charge the boost.capacitor.

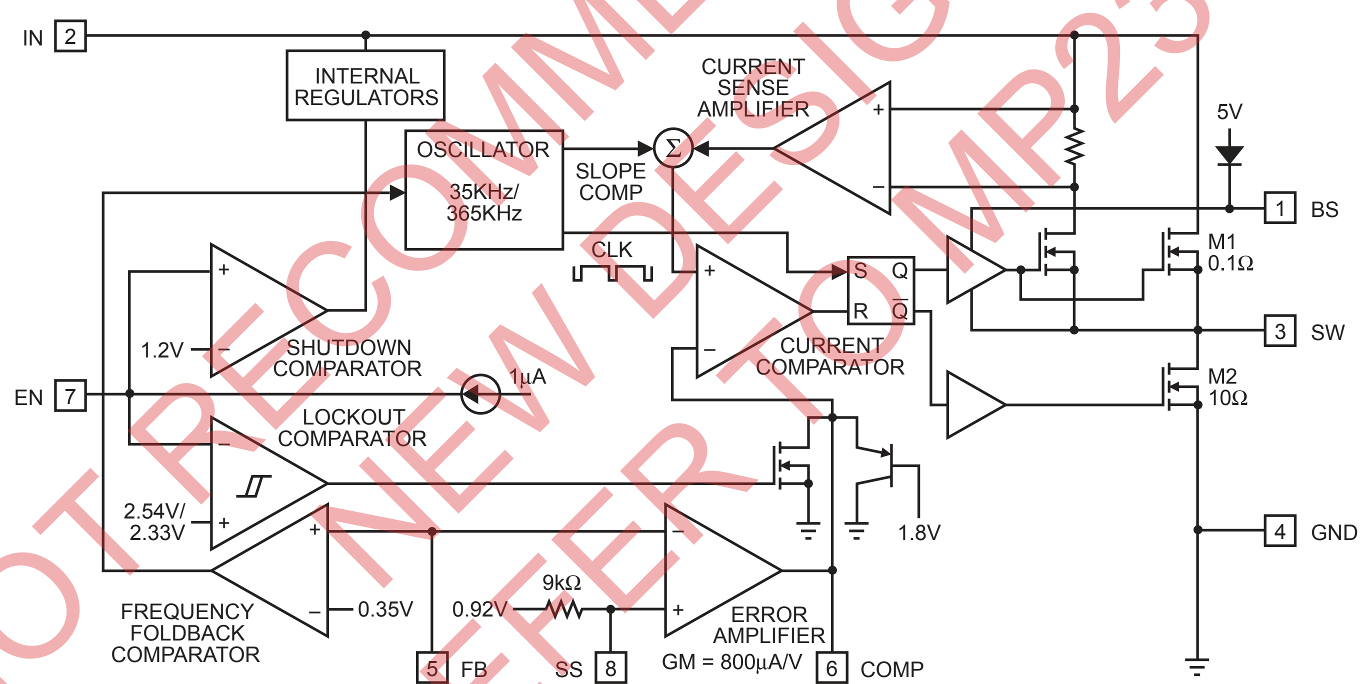


Figure 1—Functional Block Diagram

APPLICATION INFORMATION

COMPONENT SELECTION (Refer to the Typical Application Circuit on page 10)

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:

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

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

Thus the output voltage is:

$$V_{OUT} = 0.92\times\frac{R1+R2}{R2}$$

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

$$R1 = 10\times(\frac{V_{OUT}}{0.92}-1)(k\Omega)$$

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:

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

Where V_{IN} is the input voltage, f_S is the 365KHz 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 and f_S is the 365KHz switching frequency.

Table 1 lists a number of suitable inductors from various manufacturers. The choice of which style inductor to use mainly depends on the price vs. size requirements and any EMI requirement.

Table 1—Inductor Selection Guide

Vendor/ Model	Core Type	Core Material	Package Dimensions (mm)		
			W	L	H
Sumida					
CR75	Open	Ferrite	7.0	7.8	5.5
CDH74	Open	Ferrite	7.3	8.0	5.2
CDRH5D28	Shielded	Ferrite	5.5	5.7	5.5
CDRH5D28	Shielded	Ferrite	5.5	5.7	5.5
CDRH6D28	Shielded	Ferrite	6.7	6.7	3.0
CDRH104R	Shielded	Ferrite	10.1	10.0	3.0
Toko					
D53LC Type A	Shielded	Ferrite	5.0	5.0	3.0
D75C	Shielded	Ferrite	7.6	7.6	5.1
D104C	Shielded	Ferrite	10.0	10.0	4.3
D10FL	Open	Ferrite	9.7	1.5	4.0
Coilcraft					
DO3308	Open	Ferrite	9.4	13.0	3.0
DO3316	Open	Ferrite	9.4	13.0	5.1

Output Rectifier Diode

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

Choose a diode whose maximum reverse voltage rating is greater than the maximum input voltage, and whose current rating is greater than the maximum load current. Table 2 lists example Schottky diodes and manufacturers.

Table 2—Diode Selection Guide

Diode	Voltage/Current Rating	Manufacture
SK33	30V, 3A	Diodes Inc.
SK34	40V, 3A	Diodes Inc.
B330	30V, 3A	Diodes Inc.
B340	40V, 3A	Diodes Inc.
MBRS330	30V, 3A	On Semiconductor
MBRS340	40V, 3A	On Semiconductor

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.

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:

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

I_{LOAD} is the load current, V_{OUT} is the output voltage, and V_{IN} is the input voltage. The worst-case condition occurs at $V_{IN} = 2V_{OUT}$, where:

$$I_{C1} = \frac{I_{LOAD}}{2}$$

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:

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

Output Capacitor

The output capacitor (C2) 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 L is the inductor 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 MP2363 can be optimized for a wide range of capacitance and ESR values.

Compensation Components

MP2363 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, 7A/V, and R_{LOAD} is the load resistor value.

The system has two 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, 800μA/V.

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 can cause system instability. A good rule of thumb is to set the crossover frequency to approximately one-tenth of the switching frequency. Switching frequency for the MP2363 is 365KHz, so the desired crossover frequency is around 36.5KHz.

Table 3 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 3—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	4.7–10μH	47μF Ceramic	3.32kΩ	6.8nF	None
3.3V	6.8–10μH	22μFx2 Ceramic	4.02kΩ	8.2nF	None
5V	10–15μH	22μFx2 Ceramic	6.49kΩ	10nF	None
12V	15–20μH	22μFx2 Ceramic	15kΩ	4.7nF	None

To optimize the compensation components for conditions not listed in Table 2, 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 (which typically has a value no higher than 37.5KHz).

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 365KHz 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:

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

Soft-Start Capacitor

To reduce input inrush current during startup, a programmable soft-start is provided by connecting a capacitor (C4) from pin SS to GND. The soft-start time is given by:

$$t_{SS}(ms) = 45 \times C_{SS}(\mu F)$$

To reduce the susceptibility to noise, do not leave SS pin open. Use a capacitor with small value if you do not need soft-start function**.**

PCB Layout Guide

PCB layout is very important to achieve stable operation. Please follow these guidelines and take Figure2 and 3 for references.

1) Keep the path of switching current short and minimize the loop area formed by Input cap, high-side MOSFET and schottky diode.

2) Keep the connection of schottky diode between SW pin and input power ground as short and wide as possible.

3) Ensure all feedback connections are short and direct. Place the feedback resistors and compensation components as close to the chip as possible.

4) Route SW away from sensitive analog areas such as FB.

5) Connect IN, SW, and especially GND respectively to a large copper area to cool the chip to improve thermal performance and long-term reliability. For single layer, do not solder exposed pad of the IC.

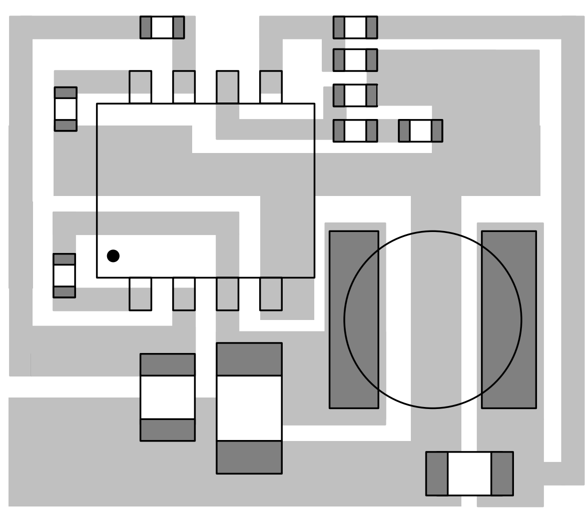
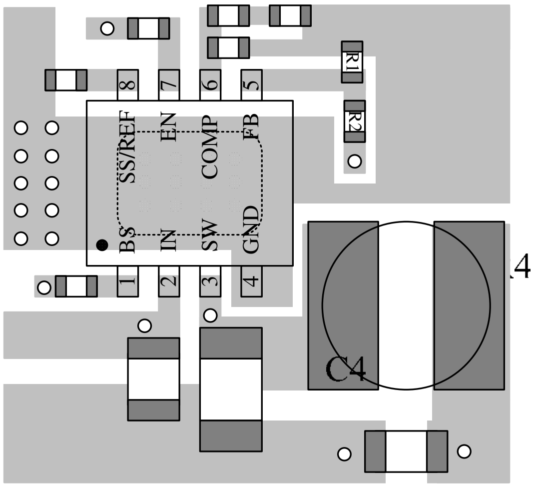
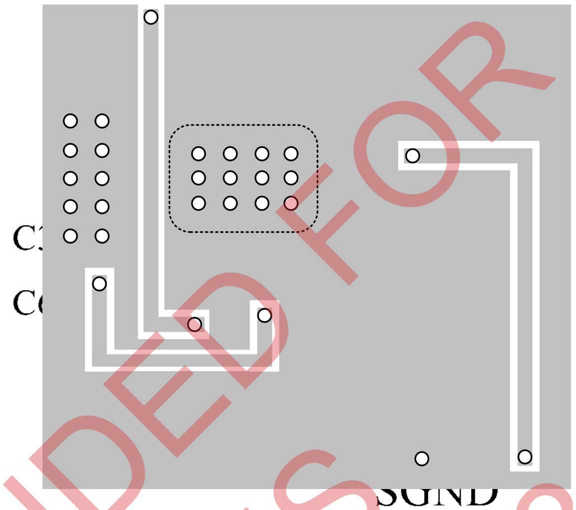


Figure2—PCB Layout for Single Layer



Top Layer



Bottom Layer

Figure3—PCB Layout for Double Layer

External Bootstrap Diode

An external bootstrap diode may enhance the efficiency of the regulator, the applicable conditions of external BST diode are:

- V_{OUT}=5V or 3.3V;
- Duty cycle is high: $D = \frac{V_{OUT}}{V_{IN}} > 65\%$

In these cases, an external BST diode is recommended from the output of the voltage regulator to BST pin, as shown in Fig.4.

The recommended external BST diode is IN4148, and the BST cap is 0.1~1μF.

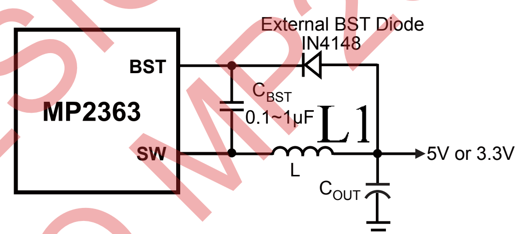


Figure 4—Add Optional External Bootstrap Diode to Enhance Efficiency

TYPICAL APPLICATION CIRCUITS

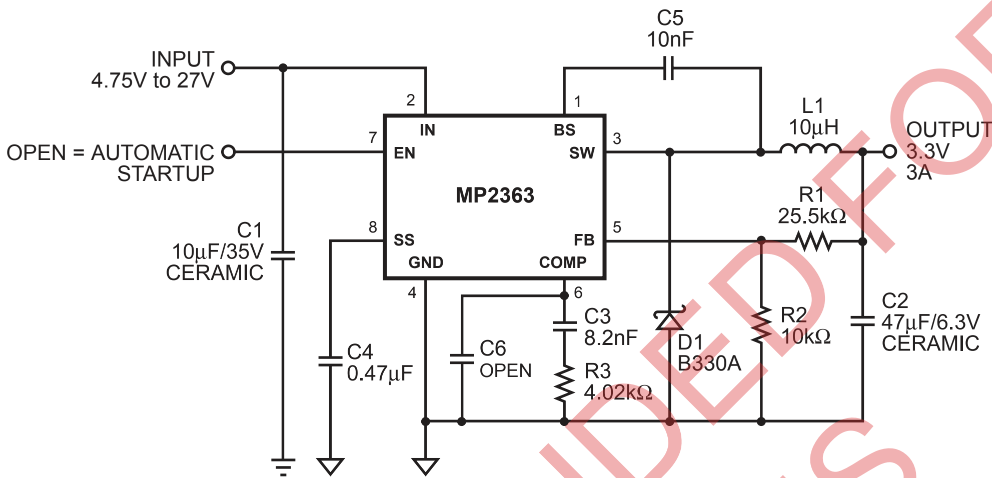


Figure 5—MP2363 for 3.3V Output with 47µF, 6.3V Ceramic Output Capacitor

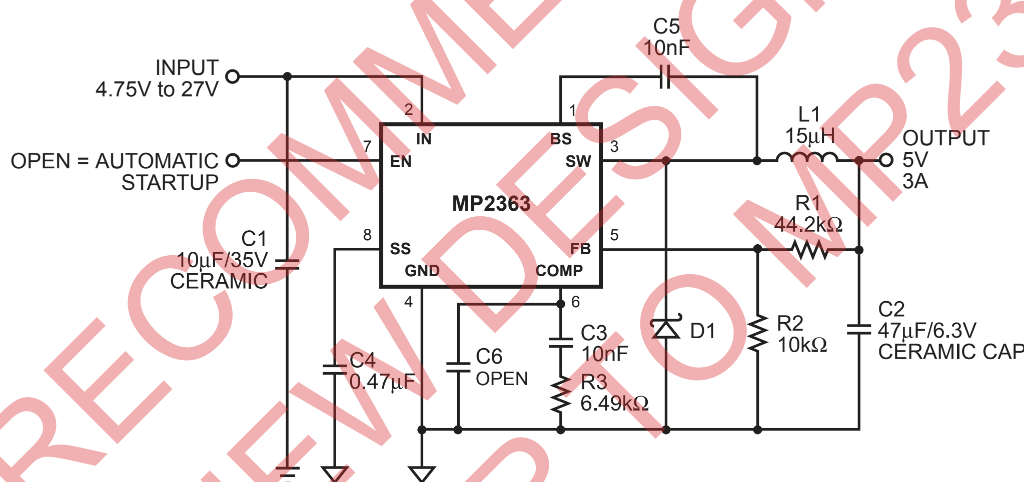
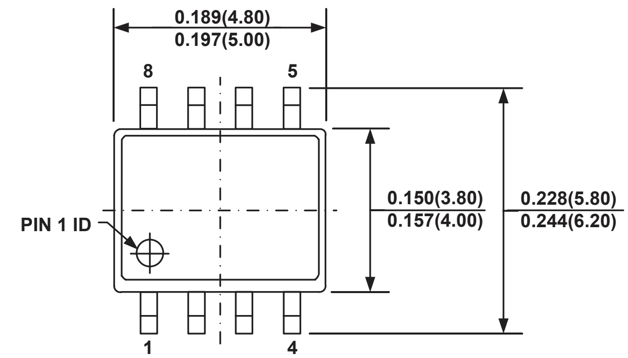


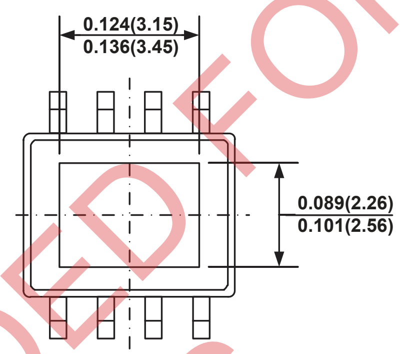
Figure 6—MP2363 for 5V Output with 47µF, 6.3V Ceramic Output Capacitor

PACKAGE INFORMATION

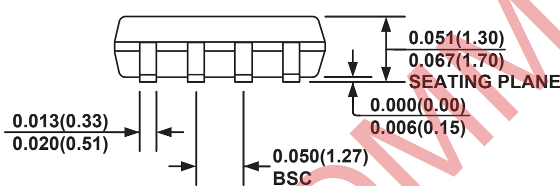
SOIC8N (EXPOSED PAD)



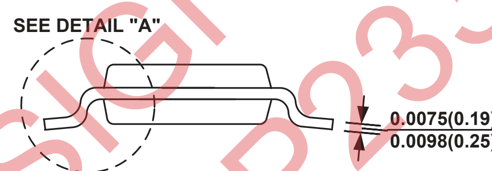
TOP VIEW



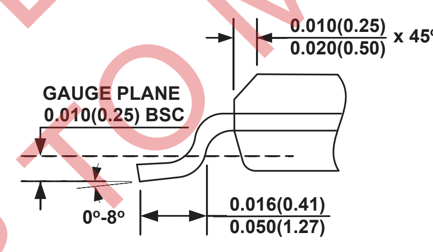
BOTTOM VIEW



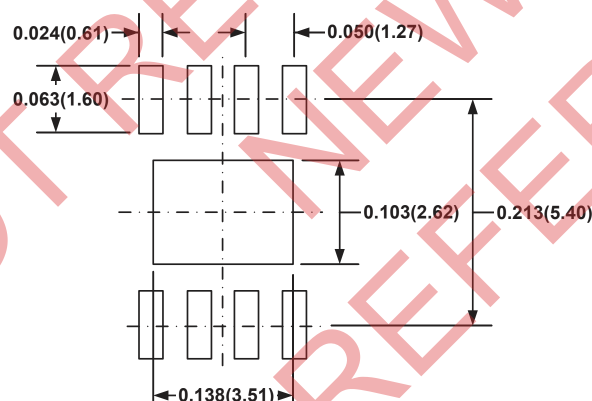
FRONT VIEW



SIDE VIEW



DETAIL "A"



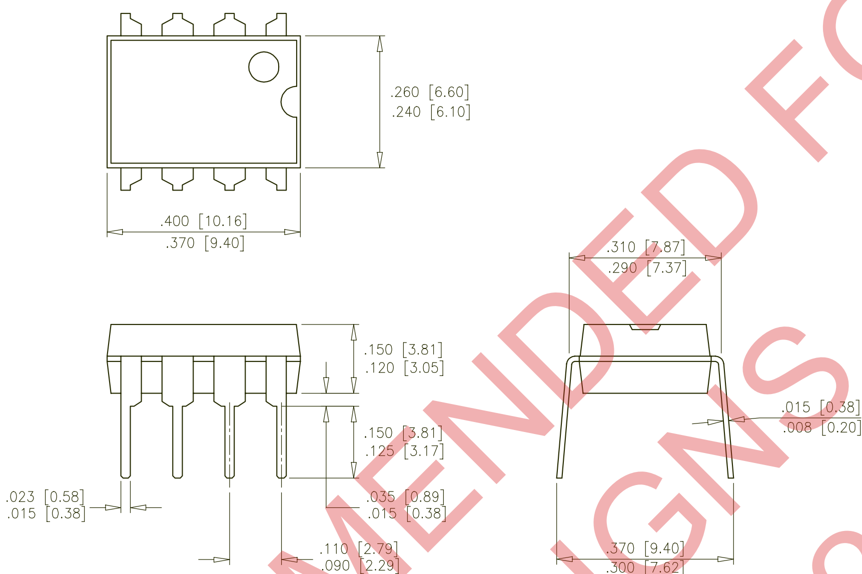
RECOMMENDED LAND PATTERN

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.

PACKAGE INFORMATION *(continued)*

PDIP8



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