MP2144

2A, 5.5V, 1.2MHz, 40µA I_Q, COT Synchronous Step Down Switcher

The Future of Analog IC Technology

DESCRIPTION

The MP2144 is a monolithic, step-down, switch-mode converter with internal power MOSFETs. It can achieve up to 2A continuous output current from a 2.5V–to-5.5V input voltage with excellent load and line regulation. The output voltage can be regulated to as low as 0.6V.

The constant-on-time control scheme provides fast transient response and eases loop stabilization. Fault condition protections include cycle-by-cycle current limiting and thermal shutdown.

The MP2144 is available in small TSOT23-8 package and requires only a minimal number of readily available standard external components.

The MP2144 is ideal for a wide range of applications including high-performance DSPs, FPGAs, smartphones, portable instruments, and DVD drivers.

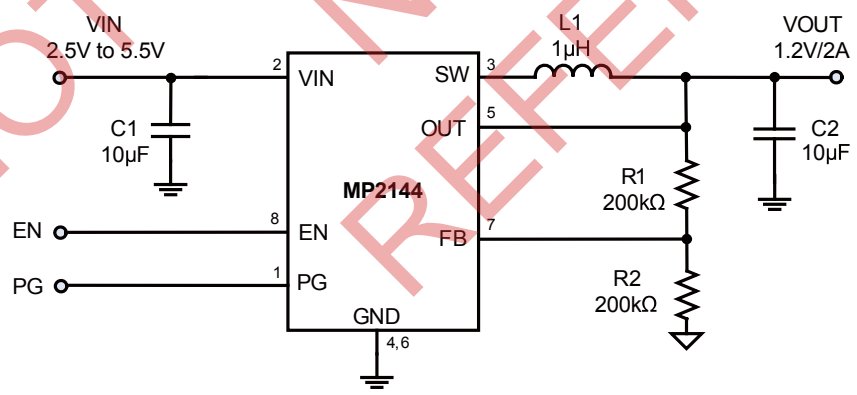
FEATURES

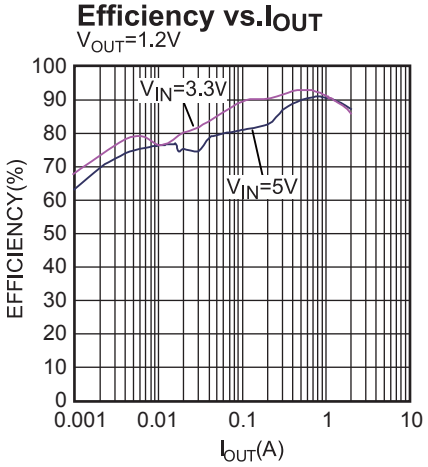
- Wide 2.5V-to-5.5V Operating Input Range
- Output Voltage as Low as 0.6V
- 100% Duty Cycle in Dropout
- Up to 2A Output Current
- Low IQ: 40µA
- 90mΩ and 60mΩ Internal Power MOSFET Switches
- Default 1.2MHz Switching Frequency
- EN and Power-Good for Power Sequencing
- Cycle-by-Cycle Over-Current Protection
- Auto Discharge at Power-Off
- Short-Circuit Protect with Hiccup Mode
- Stable with Low-ESR Output Ceramic Capacitors
- Available in a TSOT23-8 Package

APPLICATIONS

- Low Voltage I/O System Power
- Handheld/Battery-powered Systems
- Wireless/Networking Cards

TYPICAL APPLICATION



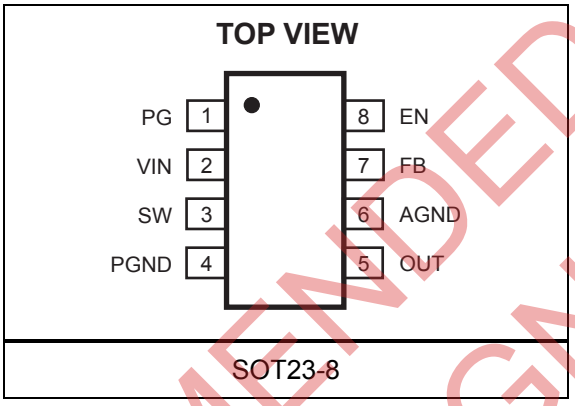


ORDERING INFORMATION

Part Number*	Package	Top Marking
MP2144GJ	TSOT23-8	ADL

* For Tape & Reel, add suffix –Z (e.g. MP2144GJ–Z);

PACKAGE REFERENCE



ABSOLUTE MAXIMUM RATINGS (1)

Supply Voltage V_{IN} 6V
V_{SW} ..... (-3V for < 5ns) to (V_{IN}+0.3V)
All Other Pins ..... -0.3V to +6 V
Junction Temperature ..... 150°C
Lead Temperature ..... 260°C
Continuous Power Dissipation (T_A = 25°C) (2)
…… 1.25W
Storage Temperature ..... -65°C to +150°C

Recommended Operating Conditions (3)

Supply Voltage V_{IN} ..... 2.5V to 5.5V
Output Voltage V_{OUT} ..... 0.6V to V_{IN} -0.5V
Operating Junction Temp. (T_J). -40°C to +125°C

Thermal Resistance (4) θ_{JA} θ_{JC}

	θ_{JA}	θ_{JC}	
TSOT23-8	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 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 PCB.

ELECTRICAL CHARACTERISTICS (5)

V_{IN} = 5V, T_A = 25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Feedback Voltage	V_{FB}	2.5V ≤ V_{IN} ≤ 5.5V	-1.5%	0.600	+1.5%	V/%
		T_A=-40°C to +85°C	-2%		+2%	
Feedback Current	I_{FB}	V_{FB} = 0.63V		10		nA
PFET Switch ON Resistance	R_{DSON_P}			90		mΩ
NFET Switch ON Resistance	R_{DSON_N}			60		mΩ
Switch Leakage		V_{EN} = 0V, V_{IN} = 5V V_{SW} = 0V and 5V		0.1	2	μA
PFET Current Limit			3.3	3.8		A
NFET Switch Sinking Current	I_{NSW}	V_{OUT}=1.2V, V_{FB}=0.7V		100		μA
ON Time	t_{ON}	V_{IN}=5V, V_{OUT}=1.2V		200		nS
		V_{IN}=3.6V, V_{OUT}=1.2V		277		
Switching frequency	f_s	V_{IN}=5V, V_{OUT}=1.2V, I_{OUT}=1A	-20%	1200	+20%	kHz
		T_A=-40°C to +85°C	-25%	1200	+25%	kHz
Minimum OFF Time	$t_{MIN-OFF}$			50		ns
Soft-Start Time	t_{SS-ON}			1.3		ms
Soft-Stop Time	t_{SS-OFF}			1		ms
Power-Good Upper Trip Threshold	PG_H	FB voltage with respect to the regulation		+10%		%
Power-Good Lower Trip Threshold	PG_L			-10%		%
Power-Good Delay	PG_D			110		μs
Power-Good Sink Current Capability	V_{PG-L}	Sink 1mA			0.4	V
Power Good Logic High Voltage	V_{PG-H}	V_{IN}=5V, V_{FB}=0.6V	4.9			V
Power Good Internal Pull-Up Resistor	R_{PG}			500		kΩ
Under-Voltage Lockout Threshold Rising			2.0	2.2	2.4	V
Under-Voltage Lockout Threshold Hysteresis				150		mV
EN Input Logic Low Voltage					0.4	V
EN Input Logic High Voltage			1.2			V
EN Input Current		V_{EN}=2V		2		μA
		V_{EN}=0V		0.1		μA
Supply Current (Shutdown)		V_{EN}=0V		0.1		μA
Supply Current (Quiescent)		V_{EN}=2V, V_{FB}=0.63V, V_{IN}=3.6V		40		μA
Thermal Shutdown				150		°C
Thermal Hysteresis				30		°C

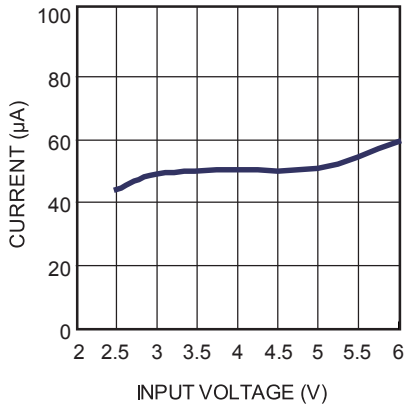
Notes:

5) Guaranteed by design.

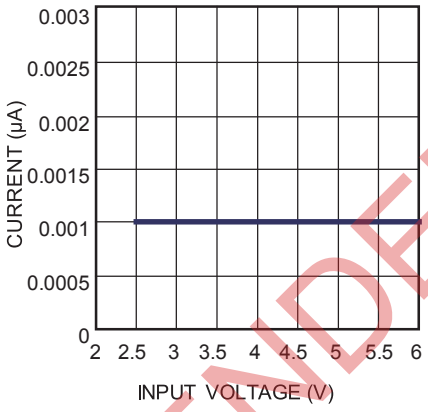
TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 5V, V_{OUT} = 1.2V, L = 1.0μH, C_{OUT}=22μF, T_A = 25°C, unless otherwise noted.

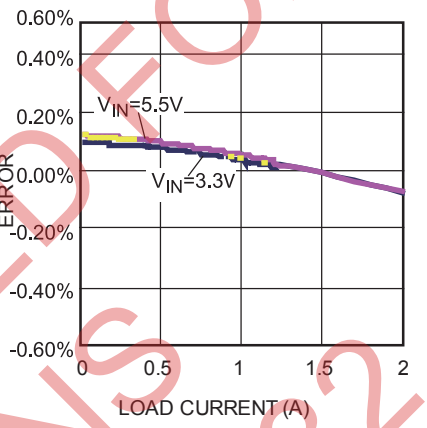
Quiescent Current vs. Input Voltage



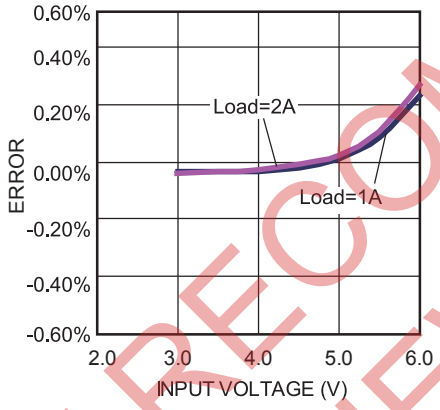
Shutdown Current vs. Input Voltage



Load Regulation

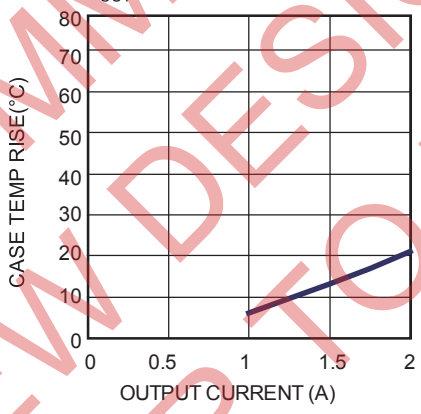


Line Regulation



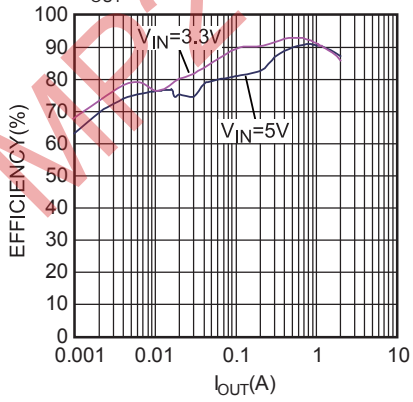
Case Temp Rise

V_{OUT}=3.3V



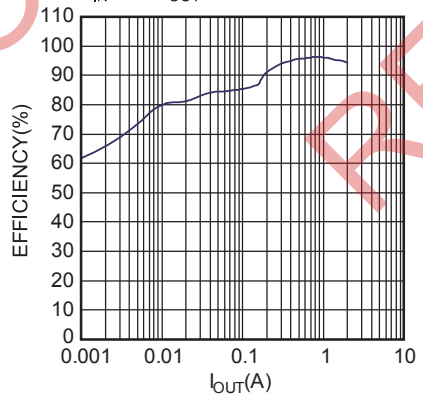
Efficiency vs.I_{OUT}

V_{OUT}=1.2V



Efficiency vs.I_{OUT}

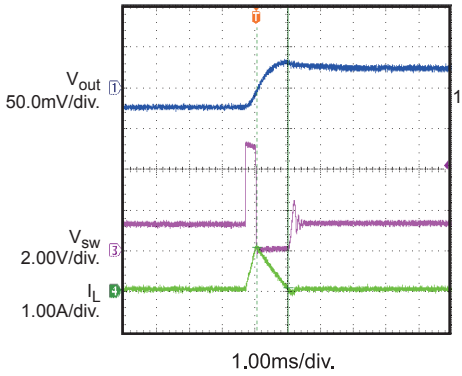
V_{IN}=5V, V_{OUT}=3.3V



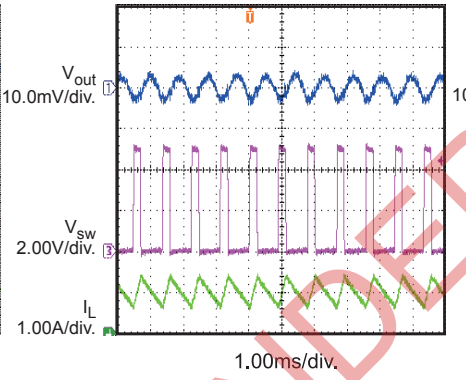
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 1.0μH, C_{OUT}=22μF, T_A = 25°C, unless otherwise noted

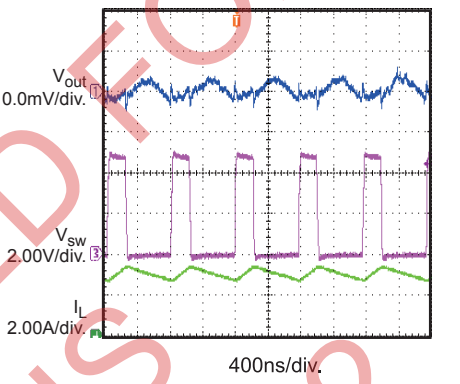
Output Ripple
I_{OUT}=0A



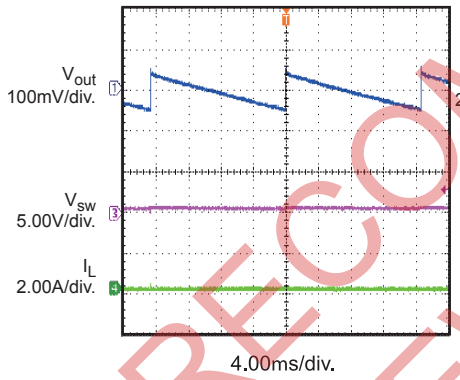
Output Ripple
I_{OUT}=1A



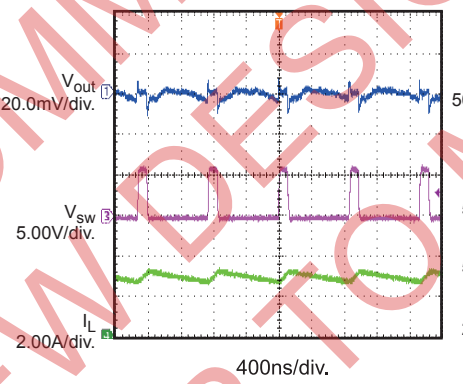
Output Ripple
I_{OUT}=2A



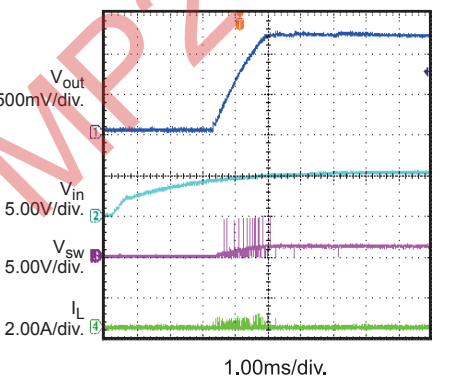
Output Ripple
V_{IN} = 6V, V_{OUT} = 0.6V, I_{OUT}=0A



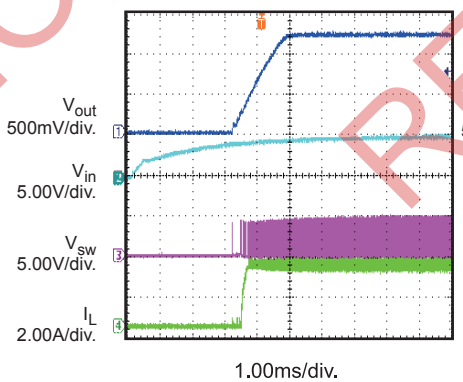
Output Ripple
V_{IN} = 6V, V_{OUT} = 0.6V, I_{OUT}=2A



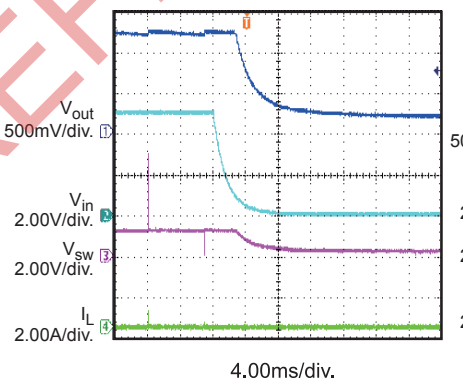
VIN Power Up without Load



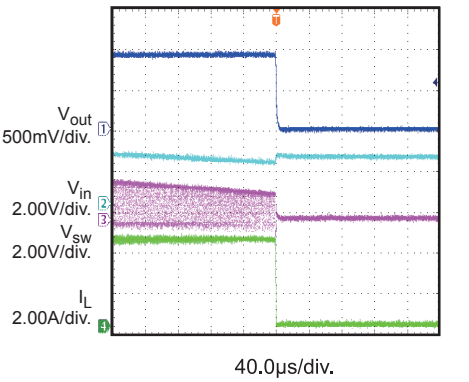
VIN Power Up with 2A Load



VIN Shut Down without Load



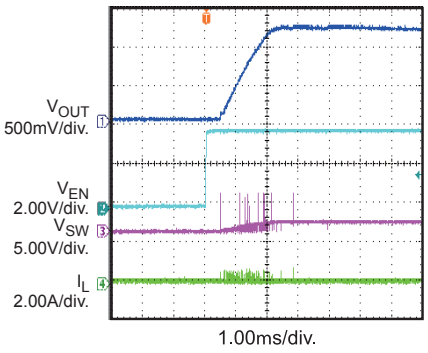
VIN Shut Down with 2A Load



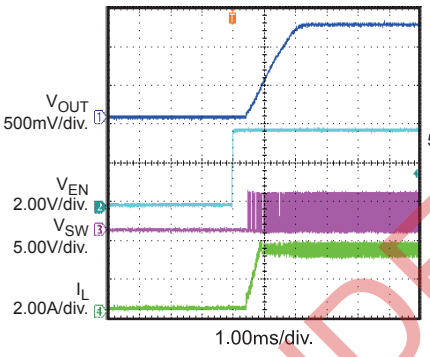
.TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 1.0μH, C_{OUT}=22μF, T_A = 25°C, unless otherwise noted.

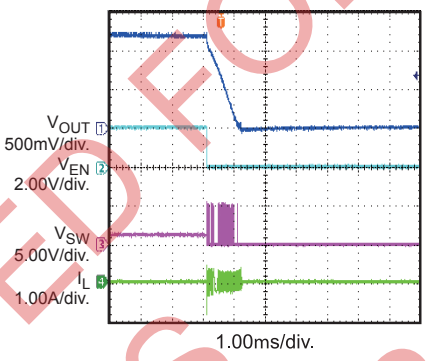
EN Start Up without Load



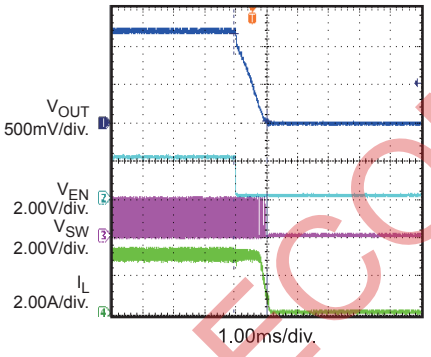
EN Start Up with 2A Load



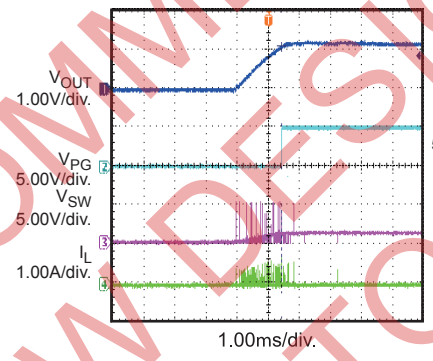
EN Shut Down without Load



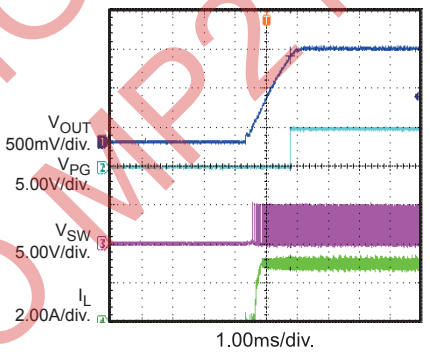
EN Shut Down with 2A Load



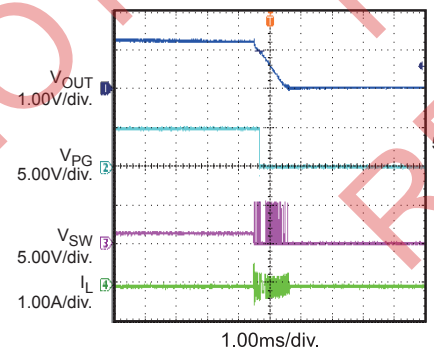
Power Good On without Load



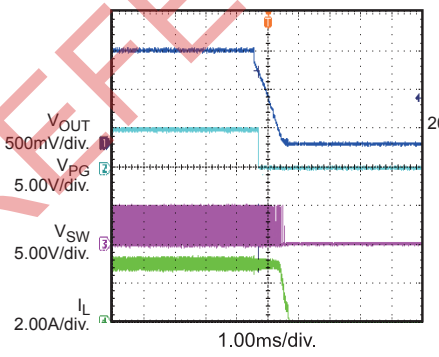
Power Good On with 2A Load



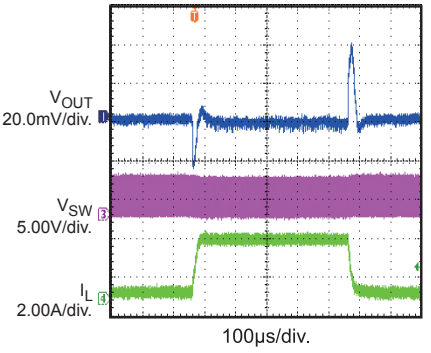
Power Good Off without Load



Power Good Off with 2A Load



Load Transient Response

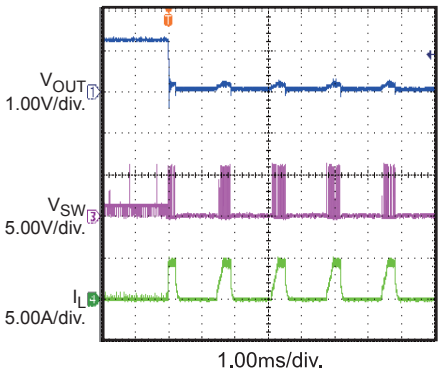


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 1.0µH, C_{OUT}=22µF, T_A = 25°C, unless otherwise noted.

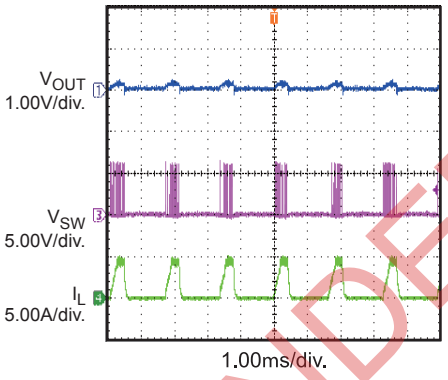
Short Circuit Entry

V_{IN}= 6V



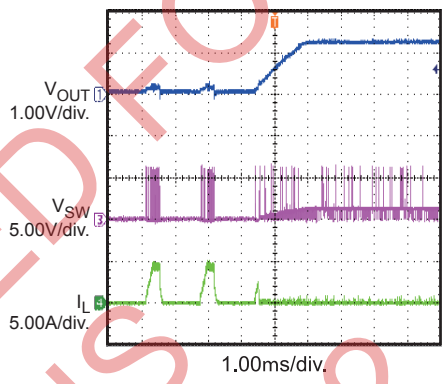
Short Circuit

V_{IN}= 6V



Short Circuit Recovery

V_{IN}= 6V



PIN FUNCTION

TSOT23 Pin #	Name	Description
1	PG	Power Good Indicator. The output of this pin is an open drain with an internal pull up resistor to IN. PG is pulled up to VIN when the FB voltage is within 10% of the regulation level. If the FB voltage is out of that regulation range, it is LOW.
2	VIN	Supply Voltage. The MP2144 operates from a +2.5V-to-+5.5V unregulated input. C1 prevents large voltage spikes from appearing at the input.
3	SW	Switch Output
4	PGND	Power Ground
5	OUT	Input Sense. For output voltage sense.
6	AGND	Analog Ground. Internal control circuit reference.
7	FB	Feedback. Connect an external resistor divider from the output to GND to set the output voltage.
8	EN	On/Off Control

FUNCTIONAL BLOCK DIAGRAM

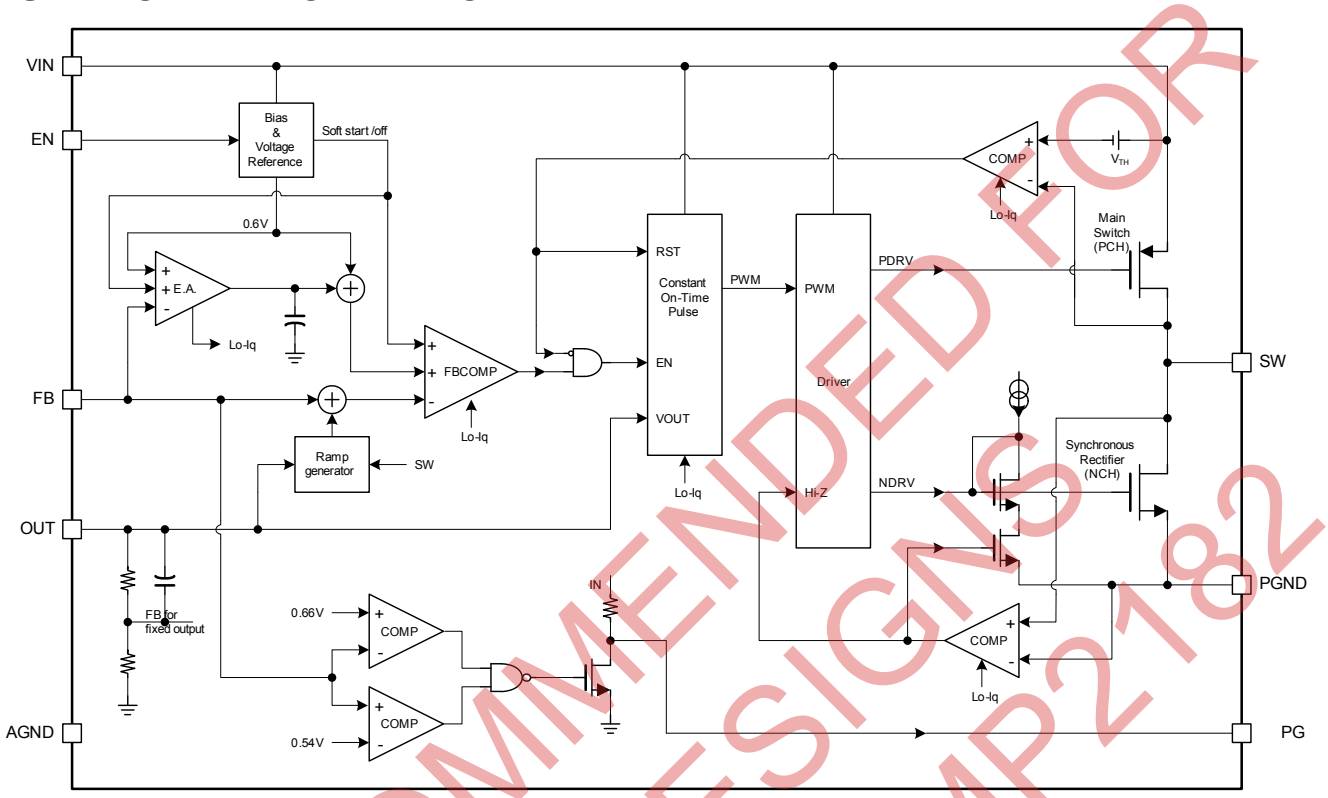


Figure 1: Functional Block Diagram

OPERATION

The MP2144 uses constant on-time control with input voltage feed-forward to stabilize the switching frequency over its full input range. At light load, the MP2144 employs proprietary control over the low-side MOSFET (LS-FET) and inductor current to eliminate ringing on switching node and improve efficiency.

Constant-On–Time Control

When compared to fixed-frequency PWM control, constant-on–time control offers advantages including simpler control loop and faster transient response. By using input voltage feed-forward, the MP2144 maintains a nearly constant switching frequency across the entire input and output voltage range. The on-time of the switching pulse can be estimated as:

$$t_{ON} = \frac{V_{OUT}}{V_{IN}} \cdot 0.833\mu s$$

To prevent inductor current runaway during the load transient, the MP2144 has a fixed minimum off time of 50ns. However, this minimum off time limit does not affect the operation of the MP2144 in steady state in any way.

Light-Load Operation

Under light-load conditions, the MP2144 uses a proprietary control scheme to save power and improve efficiency: it gradually ramps down the LS-FET current to its minimum instead of turning off the LS-FET immediately when the inductor current starts to reverse. The gradual current drop avoids ringing at the switching node that always occurs in discontinuous conduction mode (DCM) operation.

Enable

When the input voltage exceeds the under-voltage lockout (UVLO) threshold—typically 2.2V—the MP2144 can be enabled by pulling the EN pin higher than 1.2V. Leaving EN pin floating or grounded will disable the MP2144. There is an internal 1MΩ resistor from the EN pin to ground.

Soft-Start/Stop

MP2144 has a built-in soft-start that ramps up the output voltage at a constant slew rate that avoids overshooting at startup. The soft-start time is typically about 1ms. When disabled, the MP2144 ramps down the internal reference voltage to allow the load to linearly discharge the output.

Power GOOD Indictor

MP2144 has an open drain with a 500kΩ pull-up resistor pin for power good (PG) indication. When the FB pin is within ±10% of the regulatory voltage (0.6V), the PG pin is pulled up to VIN by the internal resistor. If the FB pin voltage is outside the ±10% window, the PG pin is pulled to ground by an internal MOSFET. The MOSFET has a maximum R_{dson} of less than 100Ω.

Current limit

The MP2144 has a 3.3A minimum current limit for the high side switch (HS-FET). When the HS-FET hits its current limit, MP2144 enters hiccup mode until the current drops to prevent the inductor current from rising and possibly damaging the components.

Short Circuit and Recovery

The MP2144 also enters short-circuit protection (SCP) mode when it hits the current limit, and tries to recover from the short circuit by entering hiccup mode. In SCP, the MP2144 disables the output power stage, discharges a soft-start capacitor, and then enacts a soft-start procedure. If the short-circuit condition still holds after soft-start ends, the MP2144 repeats this operation until the short circuit ceases and output rises back to regulation level.

APPLICATION INFORMATION

COMPONENT SELECTION

Setting the Output Voltage

The external resistor divider sets the output voltage (see the Typical Application schematic on page 1). The design of the feedback resistor R1 must account for both stability and dynamic response, and thus can not be too large or too small. Choose an R1 value between 120kΩ and 200kΩ. R2 is then given by:

$$R2 = \frac{R1}{\frac{V_{out}}{0.6} - 1}$$

The feedback circuit is shown in Figure 2.

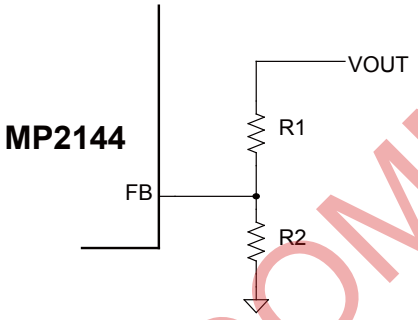


Figure 2: Feedback Network

Table 1 lists the recommended resistors values for common output voltages.

Table 1: Resistor Values for Common Output Voltages

V_{OUT} (V)	R1 (kΩ)	R2 (kΩ)
1.0	200(1%)	300(1%)
1.2	200(1%)	200(1%)
1.8	200(1%)	100(1%)
2.5	200(1%)	63.2(1%)
3.3	200(1%)	44.2(1%)

Selecting the Inductor

A 0.82μH to 4.7μH inductor is recommended for most applications. For the best efficiency, chose an inductor with a DC resistance less than 15mΩ. For most designs, the inductance value can be derived from the following equation.

$$L_1 = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times \Delta I_L \times f_{OSC}}$$

Where ΔI_L is the inductor ripple current.

Choose an inductor current to be approximately 30% of the maximum load current. The maximum inductor peak current is:

$$I_{L(MAX)} = I_{LOAD} + \frac{\Delta I_L}{2}$$

Selecting the Input Capacitor

The input current to the step-down converter is discontinuous, and requires a capacitor 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 with X5R or X7R dielectrics are highly recommended because of their low ESR values and small temperature coefficients. For most applications, a 10μF capacitor is sufficient. For higher output voltage, 47uF may be needed to increase system stability.

Since the input capacitor 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 worse case condition occurs at VIN = $2V_{OUT}$, where:

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

For simplification, choose an input capacitor whose RMS current rating is greater than half of the maximum load current.

The input capacitor can be electrolytic, tantalum, or ceramic. When using electrolytic or tantalum capacitors, use a small, high-quality, ceramic capacitor (0.1μF) placed as close to the IC as possible. When using ceramic capacitors, make sure that they have enough capacitance to prevent excessive voltage ripple at the input.

The input voltage ripple caused by capacitance can be estimated by:

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

Selecting the Output Capacitor

The output capacitor (C2) maintains the output DC voltage. Use Ceramic capacitors. Low ESR capacitors keep the output voltage ripple low. The output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L_1} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times f_S \times C2}\right)$$

Where L_1 is the inductor value and R_{ESR} is the equivalent series resistance (ESR) value of the output capacitor.

Using 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:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_S^2 \times L_1 \times C2} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

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

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L_1} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times R_{ESR}$$

The characteristics of the output capacitor also affect the stability of the regulation system.

PCB Layout Recommendation

Proper layout of the switching power supplies is very important, and sometimes critical for proper function. For the high-frequency switching converter, poor layout design can result in poor line or load regulation and stability issues.

The high current paths (GND, IN, and SW) should be placed very close to the device using short, direct, and wide traces. The input capacitor needs to be as close as possible to the IN and GND pins. The external feedback resistors should be placed next to the FB pin. Keep the switching node SW short and away from the feedback network.

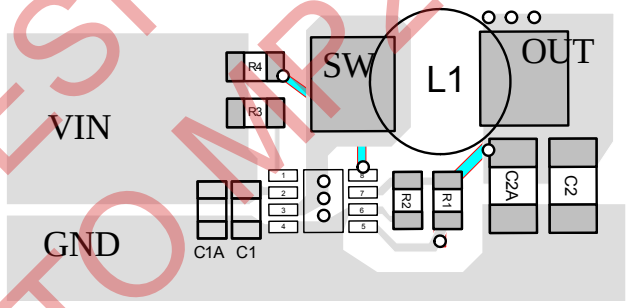


Figure 3: Layout Recommendation

TYPICAL APPLICATION CIRCUIT

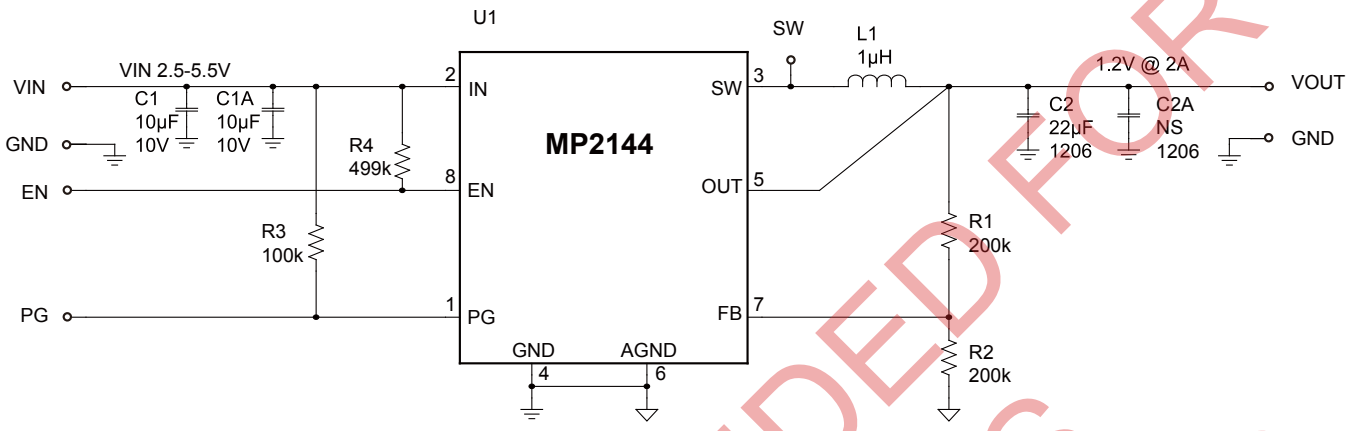
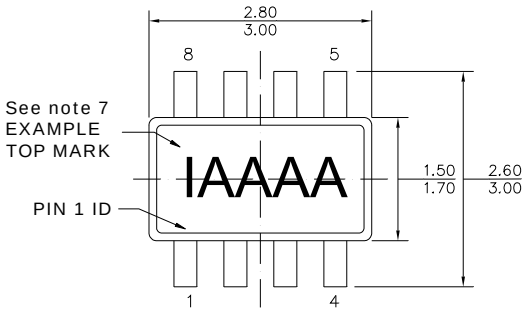


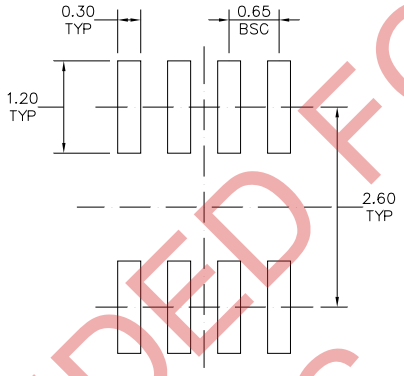
Figure 4: MP2144 Typical Application Circuit

PACKAGE INFORMATION

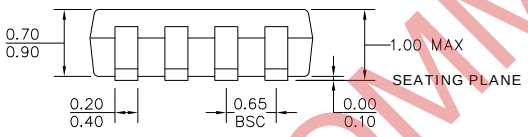
TSOT23-8



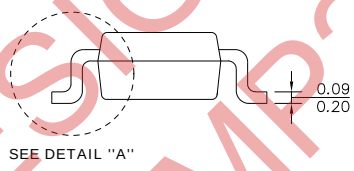
TOP VIEW



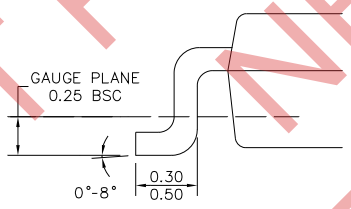
RECOMMENDED LAND PATTERN



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) JEDEC REFERENCE IS MO-193, VARIATION BA.
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)