MPQ2143

3A, 5.5V, 1.2MHz, 40µA I_Q, COT Synchronous Step-Down Switcher AEC-Q100 Qualified

NOT RECOMMENDED FOR NEW DESIGNS, REFER TO MPQ2179

DESCRIPTION

The MPQ2143 is a monolithic, step-down, switch-mode converter with internal power MOSFETs. It can achieve up to 3A continuous output current from a 2.5V–to-5.5V input voltage with excellent load and line regulation. The output voltage can be regulated as low as 0.6V.

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

The MPQ2143 is available in small TSOT23-8 package and requires only a minimal number of readily-available standard external components.

The MPQ2143 is ideal for a wide range of applications including high-performance DSPs, FPGAs, smartphones, portable instruments, and DVD drivers.

FEATURES

- Guaranteed Industrial/Automotive Temp
- Wide 2.5V-to-5.5V Operating Input Range
- Output Voltage as Low as 0.6V
- 100% Duty Cycle in Dropout
- Up to 3A Output Current
- Low I_Q: 40µA
- 80mΩ and 40mΩ 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
- Available in AEC-Q100 Grade 1

APPLICATIONS

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

All MPS parts are lead-free, halogen free, and adhere to the RoHS directive. For MPS green status, please visit MPS website under Quality Assurance.

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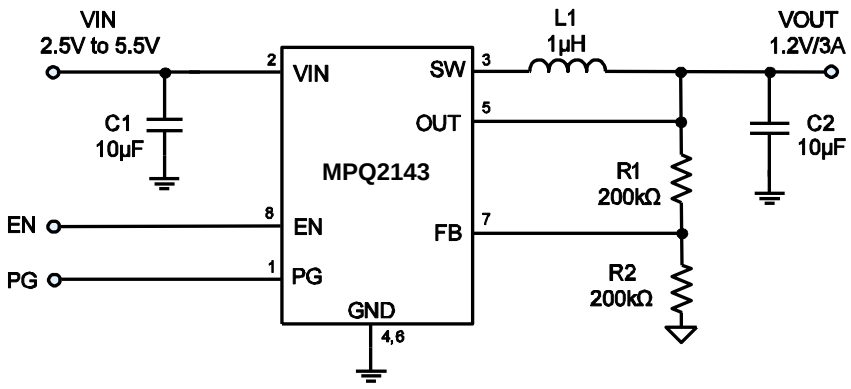
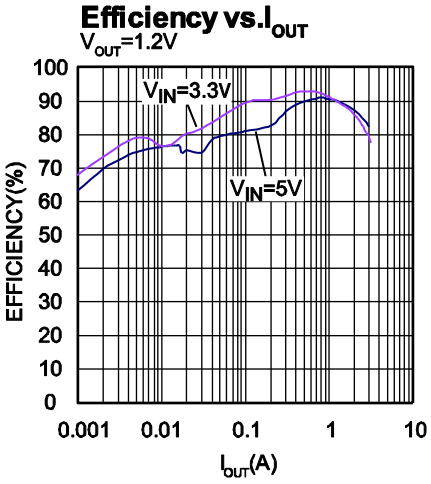
TYPICAL APPLICATION





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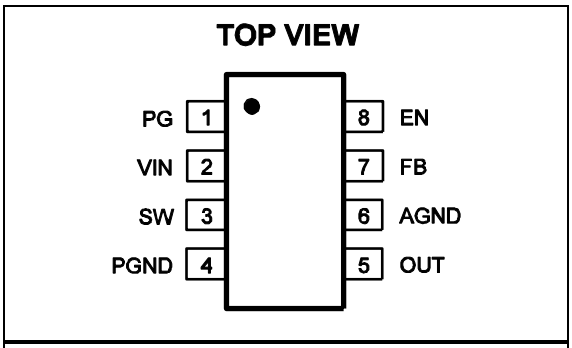
ORDERING INFORMATION

Part Number	Package	Top Marking
MPQ2143DJ*	TSOT23-8	ACE
MPQ2143DJ-AEC1**	TSOT23-8	ACE

* For Tape & Reel, add suffix –Z (e.g. MPQ2143DJ–Z);
For RoHS compliant packaging, add suffix –LF (e.g. MPQ2143DJ–LF–Z)

PACKAGE REFERENCE



SOT23-8

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.

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ELECTRICAL CHARACTERISTICS

V_{IN} = 5V, T_J= 40°C to + 125°C, Typical values are at T_J=+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_J=-40ºC to +125ºC	-2%		+2%	
Feedback Current	I_{FB}	V_{FB} = 0.63V		10		nA
PFET Switch ON Resistance	R_{DSON_P}			65		mΩ
NFET Switch ON Resistance	R_{DSON_N}			40		mΩ
Switch Leakage		V_{EN} = 0V, V_{IN} = 5V, T_J=+25°C		0.1	2	µA
		T_J=-40°C to +125°C			35	
PFET Current Limit		T_J=+25°C	4.2	4.8		A
		T_J=-40°C to +125°C	4.0			
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_J=-40ºC to +125ºC	-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 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, T_J=+25°C	4.9			V
		T_J=-40°C to +125°C	4.85			
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

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ELECTRICAL CHARACTERISTICS *(continued)*

V_{IN} = 5V, T_J= 40°C to + 125°C, Typical values are at T_J=+25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
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(5)				150		°C
Thermal Hysteresis(5)				30		°C

Notes:

5) Guaranteed by design.

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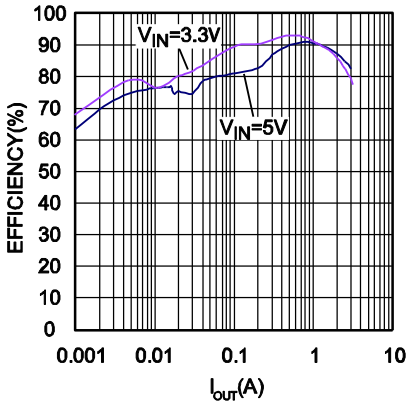
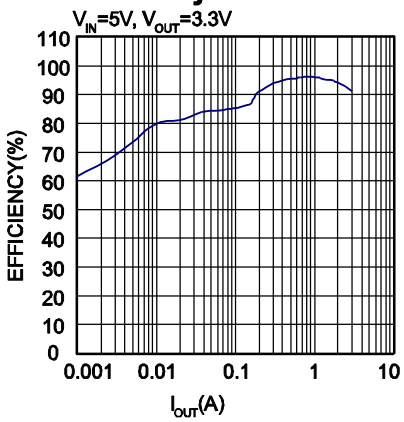
TYPICAL PERFORMANCE CHARACTERISTICS

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

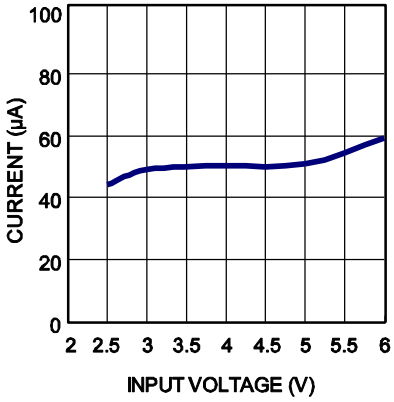
Efficiency Vs.Iout



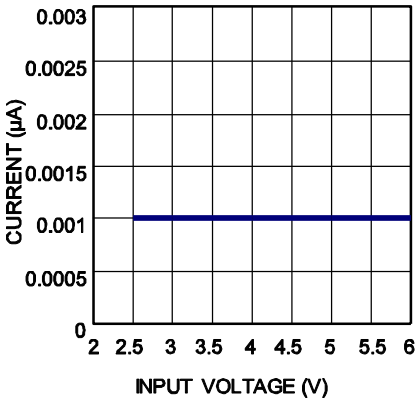
Efficiency Vs.Iout



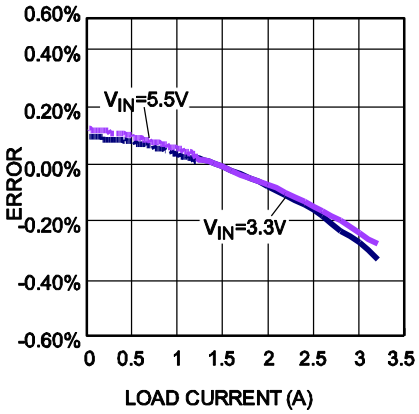
Quiescent Current vs. Input Voltage



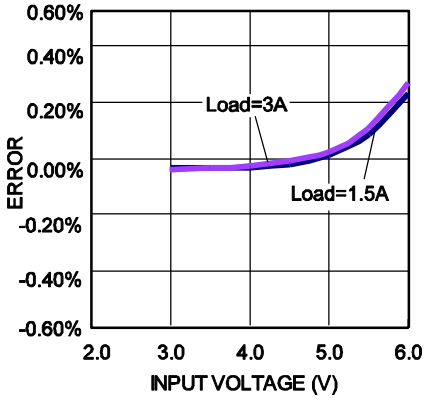
Shutdown Current vs. Input Voltage



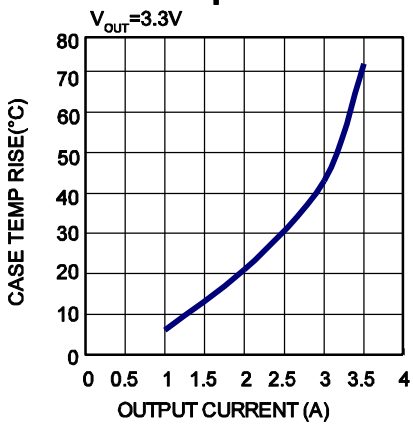
Load Regulation



Line Regulation



Case Temp Rise



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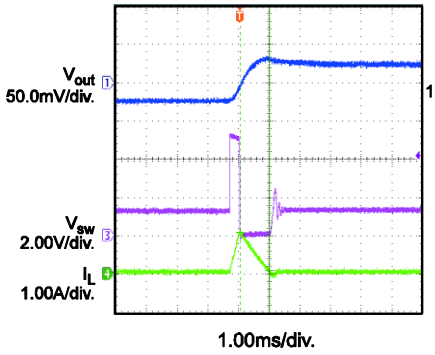
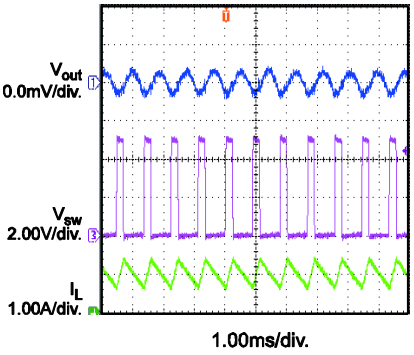
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

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

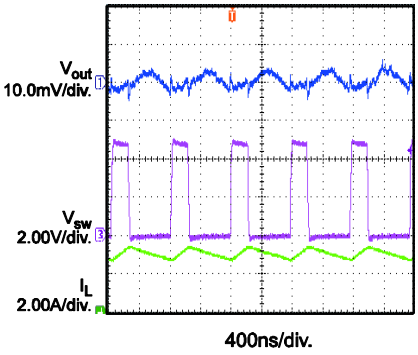
Output Ripple
I_{OUT}=0A



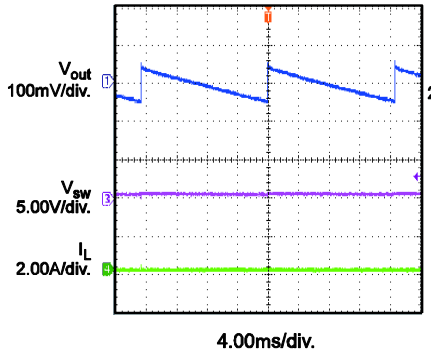
Output Ripple
I_{OUT}=1A



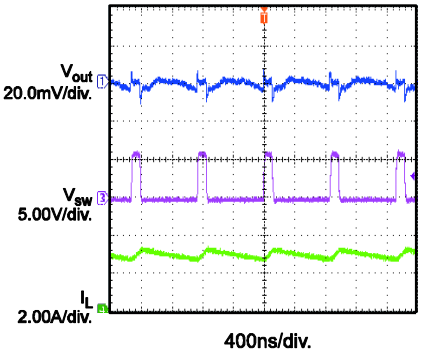
Output Ripple
I_{OUT}=3A



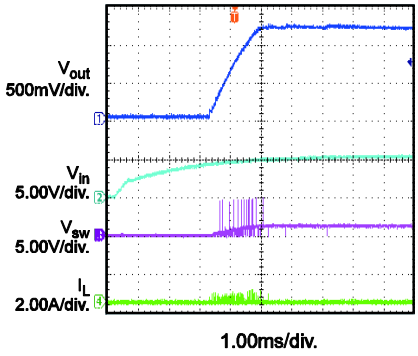
Output Ripple
V_{IN} = 6V, V_{OUT} = 0.6V, I_{OUT}=0A



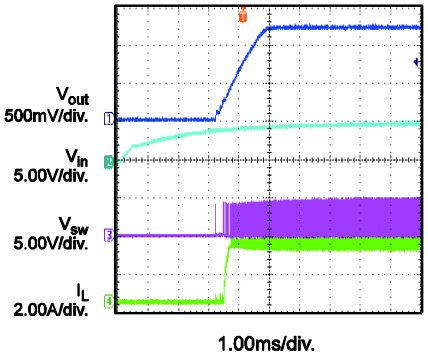
Output Ripple
V_{IN} = 6V, V_{OUT} = 0.6V, I_{OUT}=3A



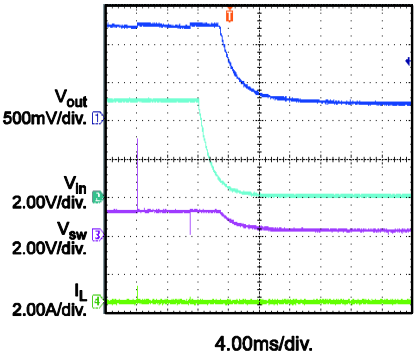
VIN Power Up without Load



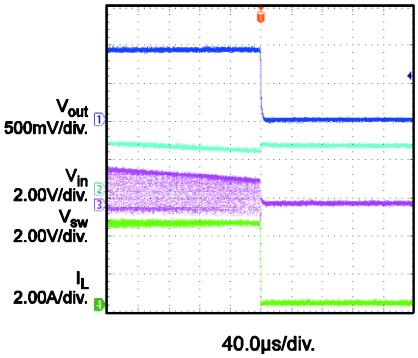
VIN Power Up with 3A Load



VIN Shut Down without Load



VIN Shut Down with 3A Load



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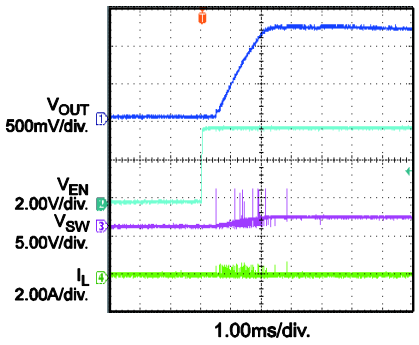
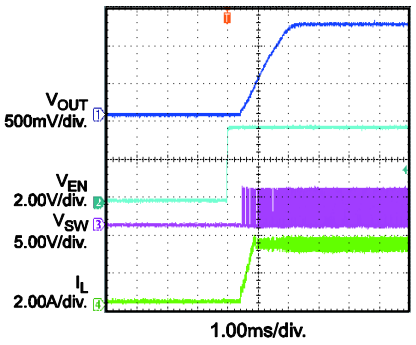
.TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

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

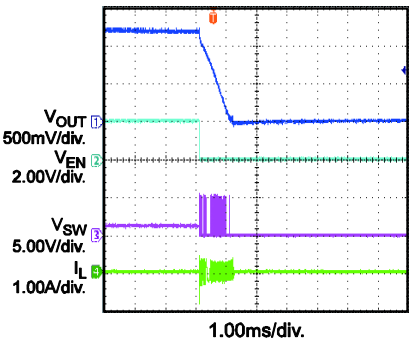
EN Start Up without Load



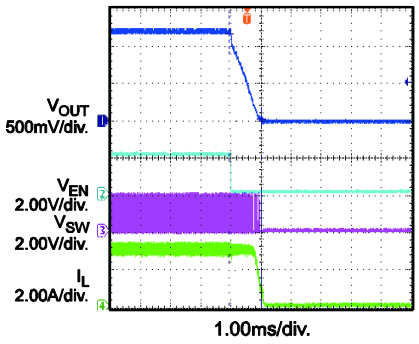
EN Start Up with 3A Load



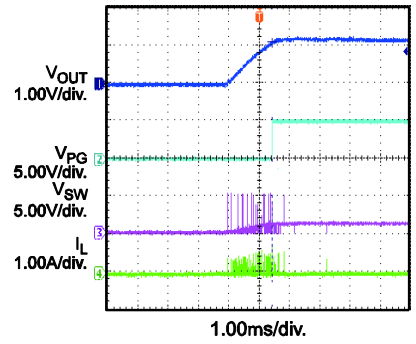
EN Shut Down without Load



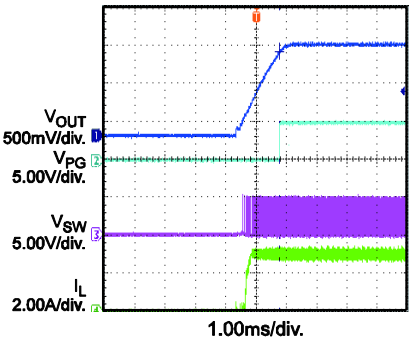
EN Shut Down with 3A Load



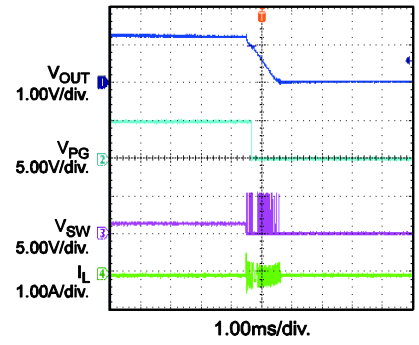
Power Good On without Load



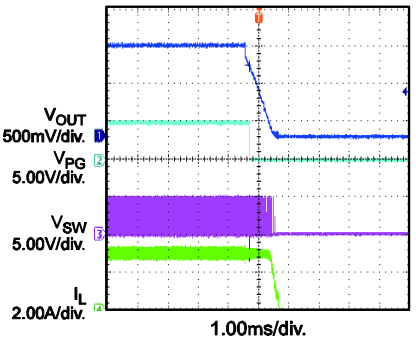
Power Good On with 3A Load



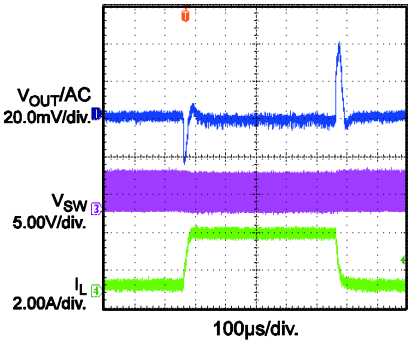
Power Good Off without Load



Power Good Off with 3A Load



Load Transient Response



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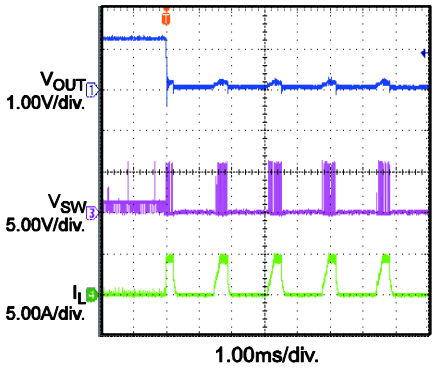
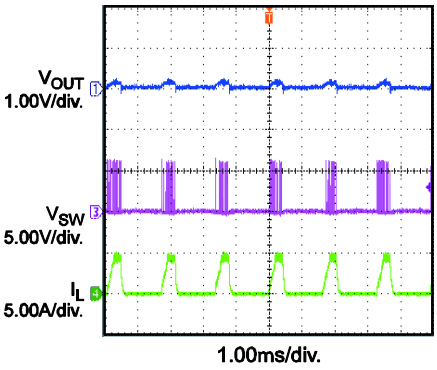
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

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

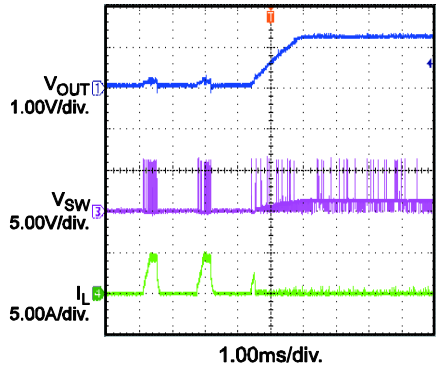
Short Circuit Entry
V_{IN}= 6V



Short Circuit
V_{IN}= 6V



Short Circuit Recovery
V_{IN}= 6V



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PIN FUNCTIONS

TSOT23 Pin #	Name	Description
1	PG	Power-Good Indicator. The pin output is an open drain that connects to VIN by an internal pull-up resistor. PG is pulled up to VIN when the FB voltage is within 10% of the regulation level. If FB voltage is out of that regulation range, it is LOW.
2	VIN	Supply Voltage. The MPQ2143 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 feedback
6	AGND	Analog ground. Reference for the internal control circuit.
7	FB	Feedback pin. Connect an external resistor divider from the output to GND to set the output voltage.
8	EN	On/Off Control

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FUNCTIONAL BLOCK DIAGRAM

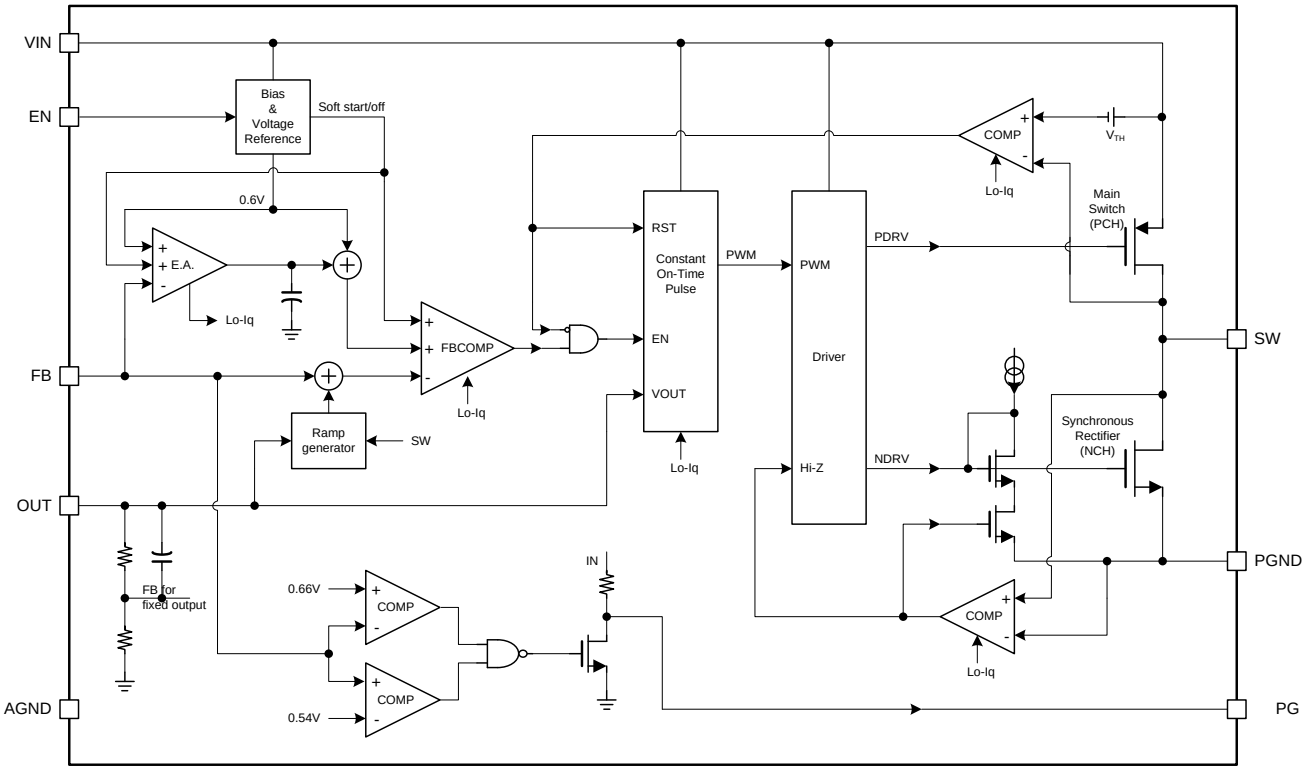

Figure 1: Functional Block Diagram

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OPERATION

The MPQ2143 uses constant on-time control with input-voltage feed-forward to stabilize the switching frequency over its full input range. At light load, the MPQ2143 employs a proprietary control over the low-side MOSFET (LS-FET) and inductor current to eliminate ringing on switching node and to improve efficiency.

Constant On-Time Control

When compared to fixed-frequency PWM control, constant on-time control offers a simpler control loop and faster transient response. By using input-voltage feed-forward, the MPQ2143 maintains a nearly constant switching frequency across the entire input and output voltage range. The switching pulse ON time 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 MPQ2143 has a fixed minimum OFF time of 50ns. However, this minimum OFF time limit does not affect the operation of the MPQ2143 in steady state in any way.

Light Load Operation

In light load condition, the MPQ2143 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 MPQ2143 is enabled by pulling the EN pin above 1.2V. Leaving the EN pin floating or grounded will disable the MPQ2143. There is an internal 1MΩ resistor from the EN pin to ground.

Soft-Start/Stop

MPQ2143 has built-in soft start (SS) that ramps up the output voltage (V_{OUT}) at a constant slew rate that avoids overshoot during start-up. The soft-start time (t_{SS}) is typically about 1.3ms. When disabled through EN, the MPQ2143 ramps down the internal reference voltage (V_{REF}) to linearly discharge V_{OUT}. Soft stop feature is only activated by EN turning off. When discharging the output, the buck converter transfer the energy to the input voltage (V_{IN}). If the output capacitance is very high and the input capacitance is low, V_{IN} rises and may exceed its absolute maximum rating (6V). See the Application Information section on page 12 to design the input capacitance and output capacitance to ensure safe operation during soft stop.

Power GOOD Indictor

MPQ2143 has an open drain with 500kΩ pull-up resistor pin for power good (PG) indication. When the FB pin is within ±10% of regulation 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 MPQ2143 has a 4.8A current limit for the high side switch (HS-FET). When the HS-FET hits its current limit, the MPQ2143 enters hiccup mode until the current drops to prevent the inductor current from building and possibly damaging the components.

Short Circuit and Recovery

The MPQ2143 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 MPQ2143 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 MPQ2143 repeats this operation until the short circuit ceases and output rises back to regulation level.

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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 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 as Figure 2.

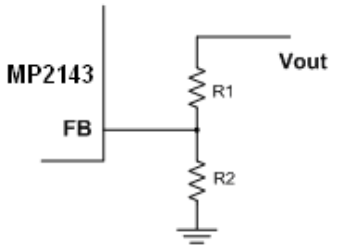

Figure 2: Feedback Network

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 highest 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, use 47μF to improve 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 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 input. The input voltage ripple caused by capacitance can be estimated by:

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

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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 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.

A high output capacitance (C2) can introduce risk of damage during soft stop. V_{IN} is charged up by C2 discharge during soft stop, and damage may occur if V_{IN} exceeds its absolute maximum rating (6V). For simplification, C2 should meet the following criteria:

$$C2 < \frac{C1}{V_{OUT}^2} \times \left(36 - V_{IN}^2\right)$$

For example, if V_{OUT} = 3.3V, V_{IN} = 5V, and input capacitor C1 = 20μF, then C2 should be less than 20μF.

For larger output capacitance applications than the above calculation, avoid shutdown through EN.

PCB Recommendation of MPQ2143

Proper layout of the switching power supplies is very important, and sometimes critical for proper operation. For high-frequency switching converters, poor layout could lead to 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.

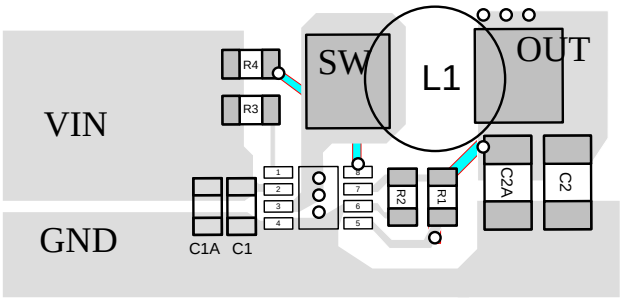

Figure 3: Layout Recommendation

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TYPICAL APPLICATION CIRCUITS

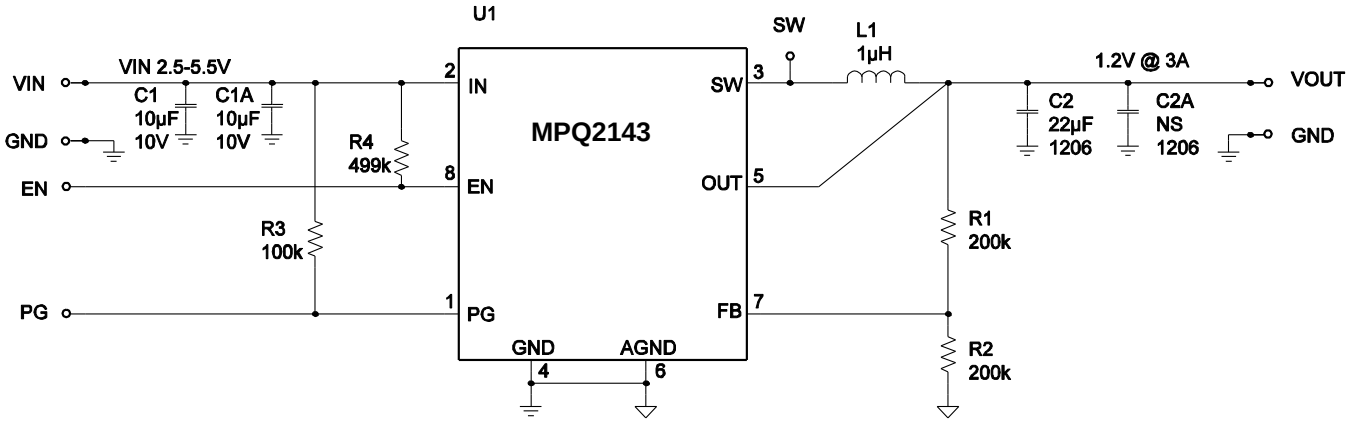

Figure 4: MPQ2143 Typical Application Circuit

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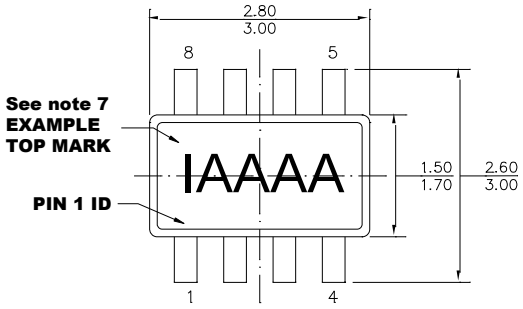
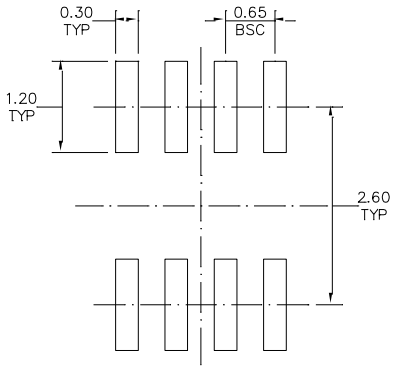
PACKAGE INFORMATION

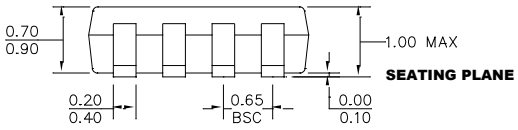
TSOT23-8



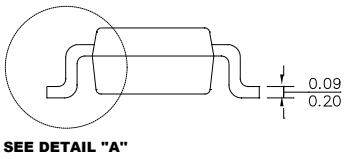
TOP VIEW



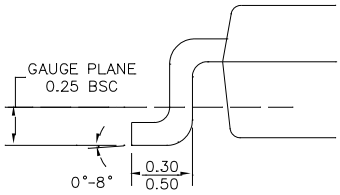
RECOMMENDED LAND PATTERN



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)

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REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	10/14/2015	Initial release	-
1.01	06/23/2020	Changing page 3 & 4, move the (5) to OTP	3, 4
1.02	10/15/2024	Corrected the soft start time from “1ms” to “1.3ms” in Soft-Start/Stop section; Added additional description to the Soft-Start/Stop section	11
		Added additional description and selection request to the Selecting the Output Capacitor section	13
		Updated Revision History formatting	16

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