MPQ4419

1A, 36V, High-Efficiency, Synchronous Step-Down Converter, AEC-Q100 Qualified

DESCRIPTION

The MPQ4419 is a high-efficiency, synchronous, rectified, step-down, switch-mode converter with built-in power MOSFETs. It offers a very compact solution that achieves 1A of continuous output current, with excellent load and line regulation across a wide input supply range.

The MPQ4419 uses synchronous mode operation to achieve higher efficiency over the output current load range. Current-mode operation provides fast transient response and eases loop stabilization.

Full protection features include over-current protection (OCP) and thermal shutdown.

The MPQ4419 requires a minimal number of readily available, standard external components, and is available in a compact TSOT23-8 package.

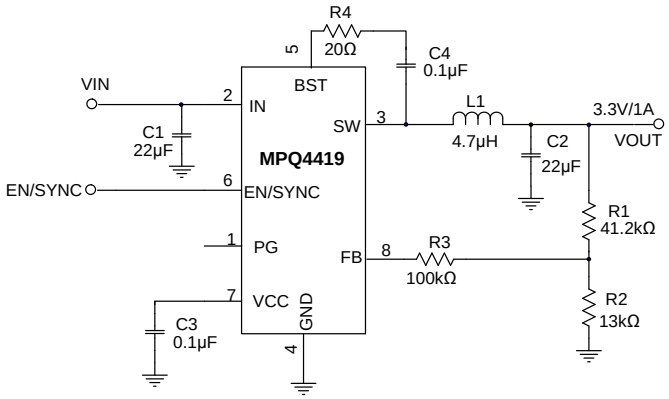
FEATURES

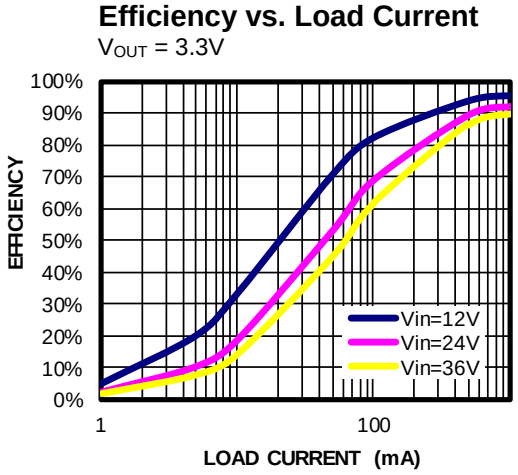
- Wide 4V to 36V Continuous Operating Input Range
- 90mΩ/55mΩ Low $R_{DS(ON)}$ Internal Power MOSFETs
- High-Efficiency Synchronous Mode
- Default 410kHz Switching Frequency
- Synchronizes to a 200kHz to 2.2MHz External Clock
- High Duty Cycle for Automotive Cold Crank Conditions
- Forced Continuous Conduction Mode (FCCM)
- Internal Soft Start
- Power Good
- Over-Current Protection (OCP), Hiccup Mode, and Thermal Shutdown
- Output Adjustable from 0.8V
- Available in a TSOT23-8 Package
- Available in AEC-Q100 Grade 1

APPLICATIONS

- Automotive Applications
- Industrial Control Systems
- Distributed Power Systems

TYPICAL APPLICATION





ORDERING INFORMATION

Part Number*	Package	Top Marking	MSL Rating**
MPQ4419GJ-AEC1	TSOT23-8	*See Below*	1

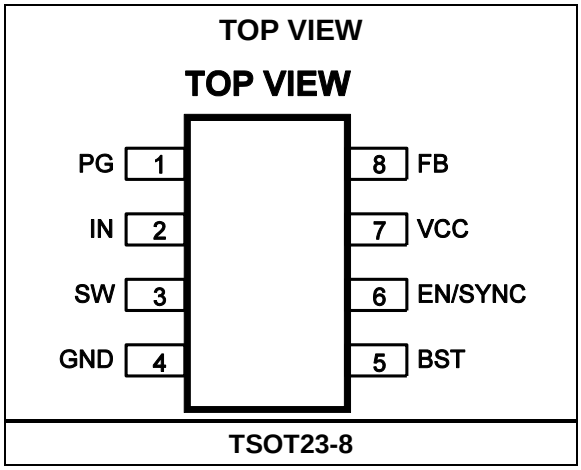
* For Tape & Reel, add suffix –Z (e.g. MPQ4419GJ-AEC1–Z).
** Moisture Sensitivity Level Rating.

TOP MARKING

BUFY

BUF: Product code of MPQ4419GJ-AEC1
Y: Year code

PACKAGE REFERENCE



PIN FUNCTIONS

Pin #	Name	Description
1	PG	**Power good.** The output of PG is an open drain, and goes high if the output voltage (V_{OUT}) exceeds 90% of the nominal voltage.
2	IN	**Supply voltage.** The MPQ4419 operates from a 4V to 36V input rail. A decoupling capacitor to ground must be placed close to IN pin to minimize switching spikes.
3	SW	**Switch output.** SW is the output of the internal power switch.
4	GND	**System ground.** GND is the reference ground of the regulated output voltage. GND requires special consideration during PCB layout. For the best results, connect the GND pin to system ground with copper traces and vias.
5	BST	**Bootstrap.** A capacitor connected between SW and BST is required to form a floating supply across the high-side switch driver. It is strongly recommended to place a 20Ω resistor between SW and BST to reduce SW voltage spikes.
6	EN/SYNC	**Enable/synchronize.** Drive EN/SYNC high to enable the MPQ4419. Apply an external clock to EN/SYNC to change the switching frequency.
7	VCC	**Bias supply.** Decouple VCC with a 0.1µF to 0.22µF capacitor. Select a capacitor that does not exceed 0.22µF.
8	FB	**Feedback.** Connect FB to the tap of an external resistor divider from the output to GND to set V_{OUT}. When the FB voltage (V_{FB}) is below 660mV, the frequency foldback comparator lowers the oscillator frequency to prevent current limit runaway during a short-circuit fault condition.

ABSOLUTE MAXIMUM RATINGS (1)

Supply voltage (V_{IN}) ..... -0.3V to +40V
Switching voltage (V_{SW}) ..... -0.3V to +41V
V_{BS} ..... V_{SW} + 6V
All other pins ..... -0.3V to +6V (2)
Continuous power dissipation (T_A = 25°C) (3)
TSOT23-8 ..... 1.25W
Junction temperature ..... 150°C
Lead temperature ..... 260°C
Storage temperature ..... -65°C to +150°C

ESD Ratings

Human body model (HBM) ..... ±2000V
Charged device model (CDM) ..... ±750V

Recommended Operating Conditions

Continuous supply voltage (V_{IN}) ..... 4V to 36V
Output voltage (V_{OUT}) ..... 0.8V to 0.9 x V_{IN}
Operating junction temp (T_J) .... -40°C to +125°C

Thermal Resistance (4) θ_{JA} θ_{JC}

TSOT23-8	100	55	°C/W

Notes:

1) Absolute maximum ratings are rated under room temperature unless otherwise noted. Exceeding these ratings may damage the device.
2) For details on EN's absolute max rating, see the EN/SYNC Control section on page 14.
3) 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 produces an excessive die temperature, causing the regulator to go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
4) Measured on JESD51-7, 4-layer PCB.

ELECTRICAL CHARACTERISTICS

V_{IN} = 12V, 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
Shutdown supply current	I_{SHDN}	V_{EN} = 0V			8	μA
Quiescent supply current	I_Q	V_{EN} = 2V, V_{FB} = 1V, no switching		0.6	0.8	mA
High-side MOSFET (HS-FET) on resistance	R_{ON_HS}	V_{BST-SW} = 5V		90	155	mΩ
Low-side MOSFET (LS-FET) on resistance	R_{ON_LS}	V_{CC} = 5V		55	105	mΩ
Switch leakage	I_{LKG_SW}	V_{EN} = 0V, V_{SW} = 12V			1	μA
Current limit	I_{LIMIT}	Under 40% duty cycle	3.4	5.6	7.8	A
Oscillator frequency	f_{SW}	V_{FB} = 750mV	320	410	500	kHz
Foldback frequency	f_{FB}	V_{FB} < 400mV	70	100	130	kHz
Maximum duty cycle	D_{MAX}	V_{FB} = 750mV, 410kHz	92	95		%
Minimum on time (5)	t_{ON_MIN}			70		ns
SYNC frequency range	f_{SYNC}		0.2		2.4	MHz
Feedback voltage	V_{FB}	T_J = 25°C	780	792	804	mV
			776		808	
Feedback current	I_{FB}	V_{FB} = 820mV		10	100	nA
EN rising threshold	V_{EN_RISING}		1.15	1.4	1.65	V
EN falling threshold	$V_{EN\_FALLING}$		1.05	1.25	1.45	V
EN threshold hysteresis	V_{EN_HYS}			150		mV
EN input current	I_{EN}	V_{EN} = 2V		4	6	μA
		V_{EN} = 0		0	0.2	μA
V_{IN} under-voltage lockout (UVLO) rising threshold	$INUV_{RISING}$		3.3	3.5	3.7	V
V_{IN} UVLO falling threshold	$INUV_{FALLING}$		3.1	3.3	3.5	V
V_{IN} UVLO threshold hysteresis	$INUV_{HYS}$			200		mV
VCC regulator	V_{CC}	I_{CC} = 0mA	4.6	4.9	5.2	V
VCC load regulation		I_{CC} = 5mA		1.5	4	%
Soft-start time	t_{SS}	V_{OUT} from 10% to 90%	0.55	1.45	2.45	ms
Thermal shutdown (5)			150	170		°C
Thermal hysteresis (5)				30		°C
PG rising threshold	PG_{VTH_RISING}	As a percentage of V_{FB}	86	90	94	%
PG falling threshold	$PG_{VTH\_FALLING}$	As a percentage of V_{FB}	80	84	88	%

ELECTRICAL CHARACTERISTICS *(continued)*

V_{IN} = 12V, 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
PG threshold hysteresis	PG_{VTH_HYS}	As a percentage of V_{FB}		6		%
PG rising delay	PG_{TD_RISING}		40	90	160	µs
PG falling delay	$PG_{TD\_FALLING}$		30	55	95	µs
PG sink current capability	V_{PG}	Sink 4mA		0.1	0.3	V
PG leakage current	I_{LKG_PG}			10	100	nA

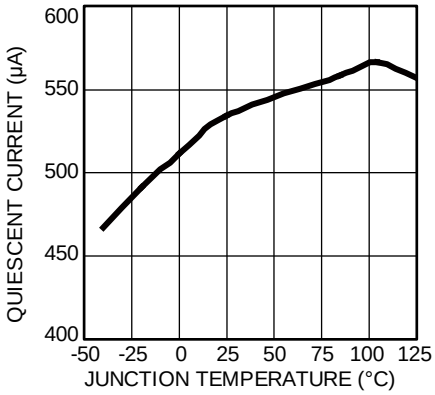
Note:

5) Derived from bench characterization. Not tested in production.

TYPICAL CHARACTERISTICS

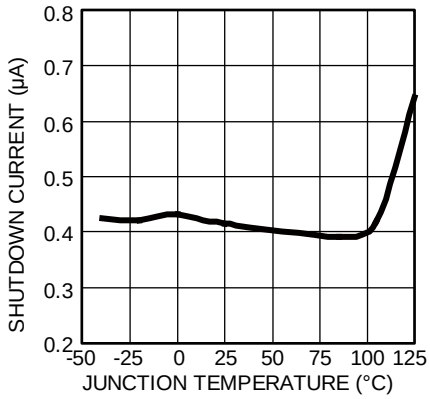
Quiescent Current vs. Junction Temperature

V_{IN} = 12V



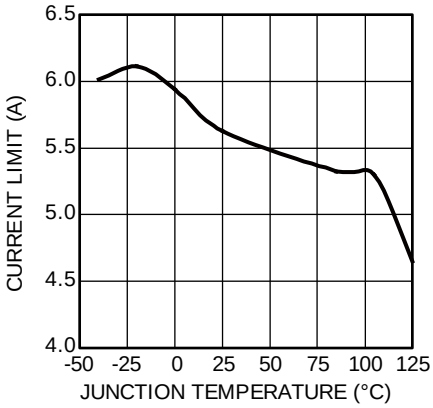
Shutdown Current vs. Junction Temperature

V_{IN} = 12V



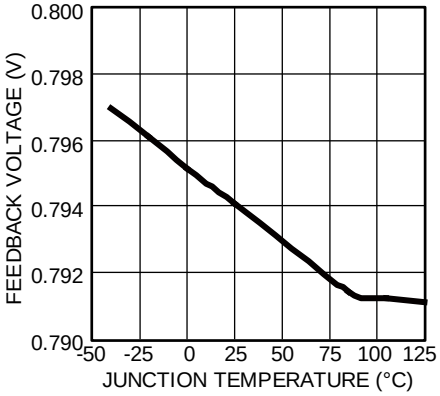
Current Limit vs. Junction Temperature

Duty cycle = 40%



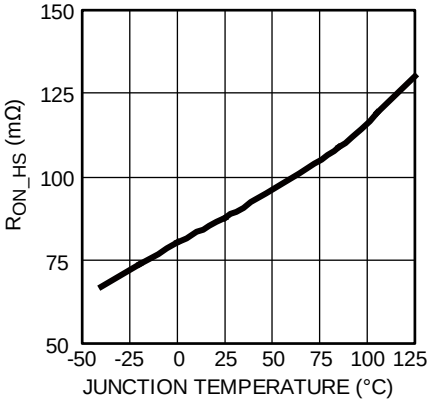
Feedback Voltage vs. Junction Temperature

V_{IN} = 12V



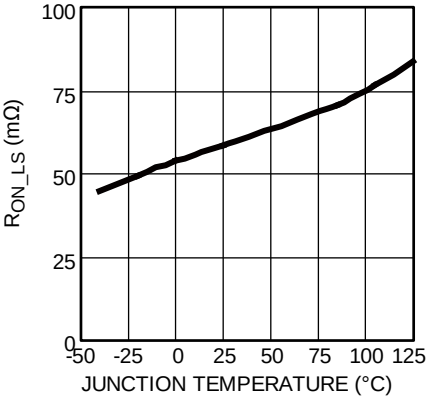
R_{ON_HS} vs. Junction Temperature

V_{IN} = 12V, BST - SW = 5V



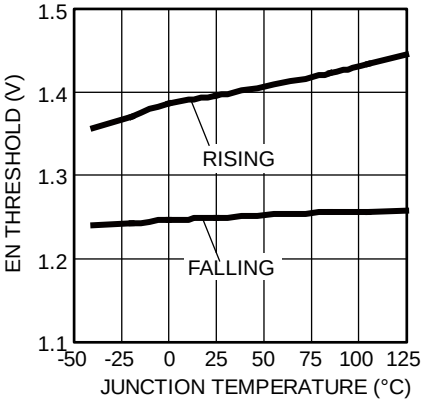
R_{ON_LS} vs. Junction Temperature

V_{IN} = 12V, V_{CC} = 5V

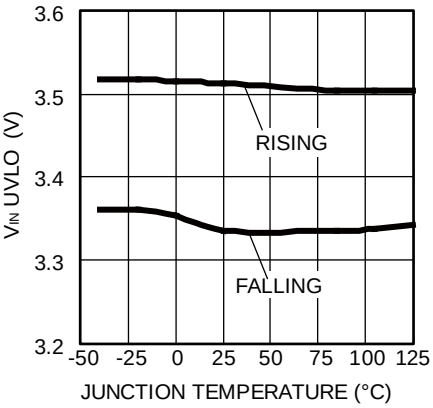


EN Threshold vs. Junction Temperature

V_{IN} = 12V

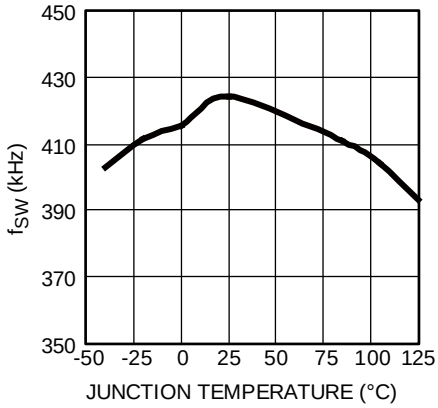


V_{IN} UVLO vs. Junction Temperature



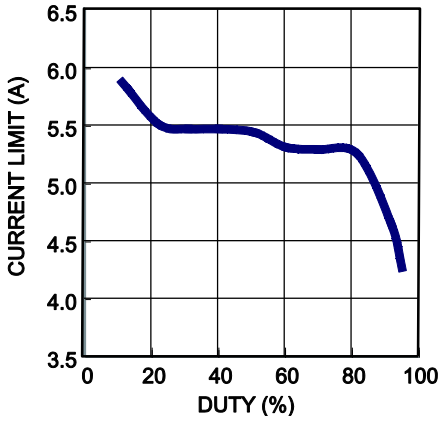
f_{SW} vs. Junction Temperature

V_{IN} = 12V



TYPICAL CHARACTERISTICS *(continued)*

Current Limit vs. Duty

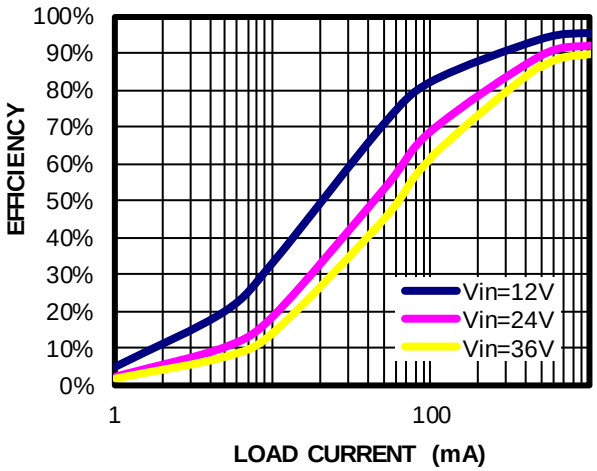


TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 12V, V_{OUT} = 3.3V, L = 10µH, R_{BST} = 20Ω, T_A = 25°C, unless otherwise noted.

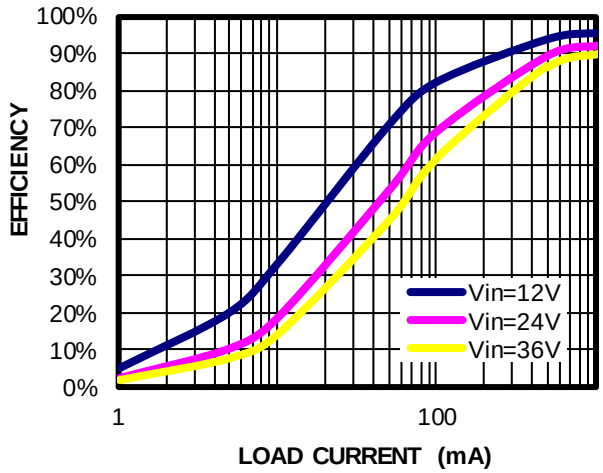
Efficiency vs. Load Current

V_{OUT} = 3.3V

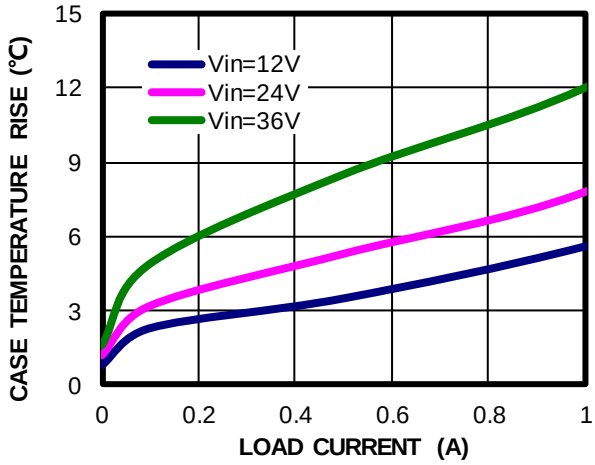


Efficiency vs. Load Current

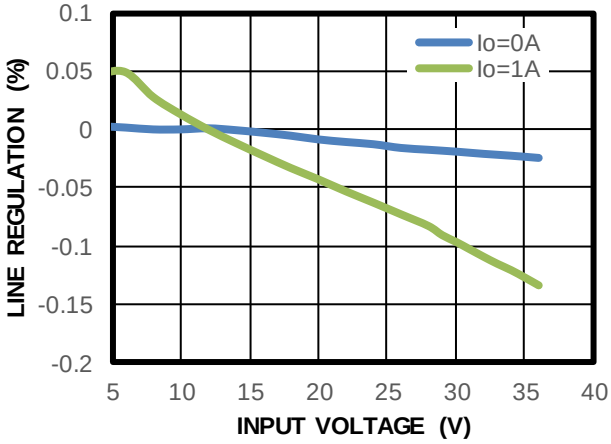
V_{OUT} = 5V



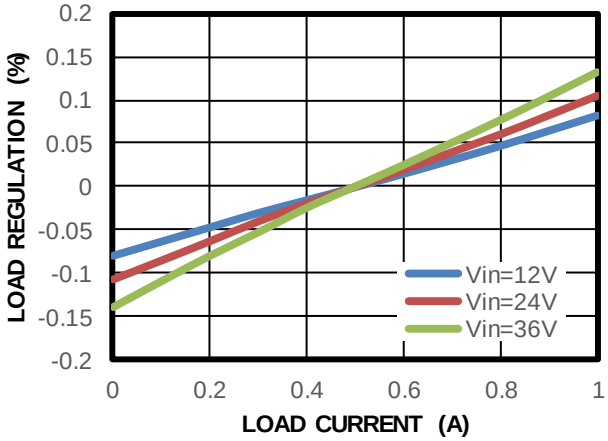
Case Temperature Rise



Line Regulation



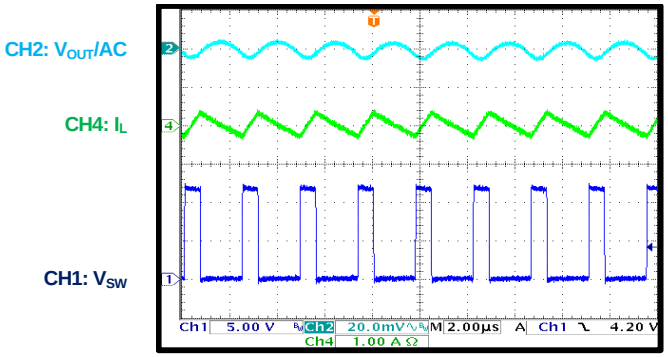
Load Regulation



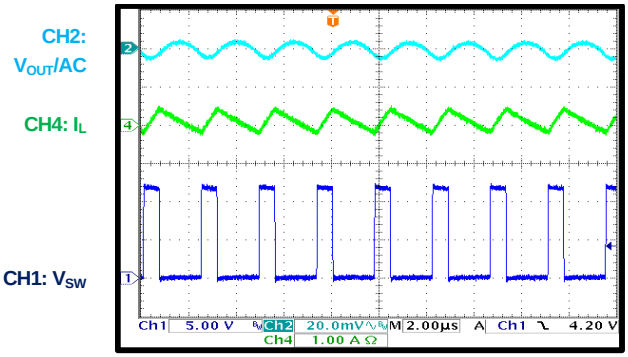
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 3.3V, L = 10µH, R_{BST} = 20Ω, T_A = 25°C, unless otherwise noted.

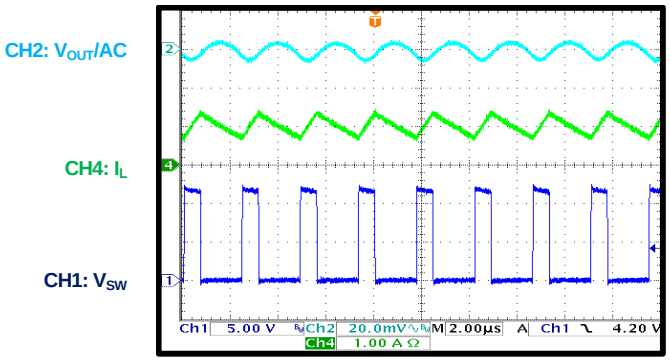
Steady State
I_{OUT} = 0A



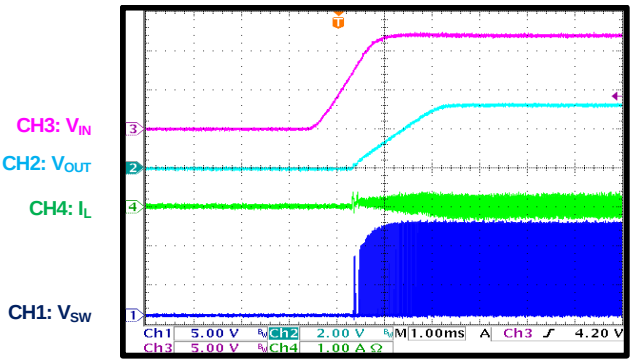
Steady State
I_{OUT} = 0.1A



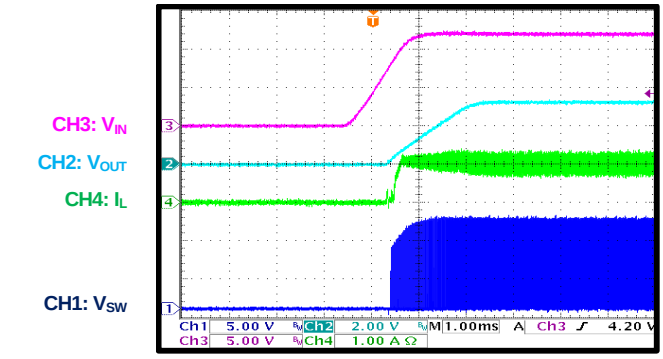
Steady State
I_{OUT} = 1A



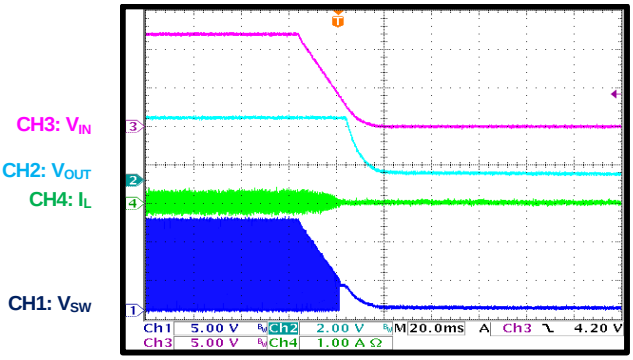
Start-Up through VIN
I_{OUT} = 0A



Start-Up through VIN
I_{OUT} = 1A



Shutdown through VIN
I_{OUT} = 0A

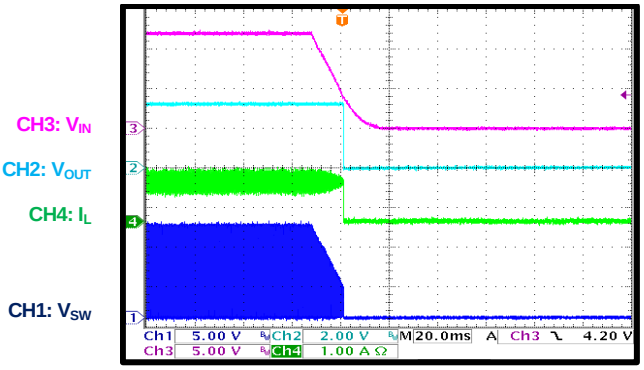


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 3.3V, L = 10µH, R_{BST} = 20Ω, T_A = 25°C, unless otherwise noted.

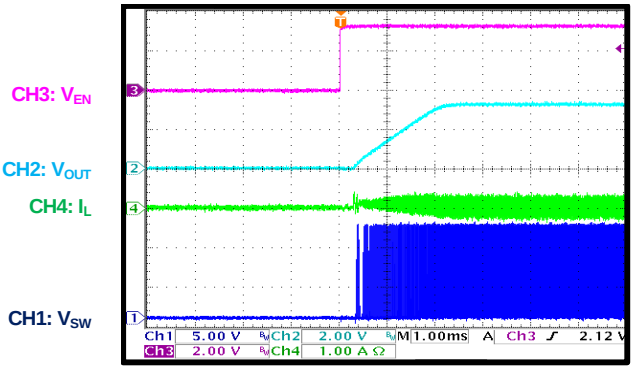
Shutdown through VIN

I_{OUT} = 1A



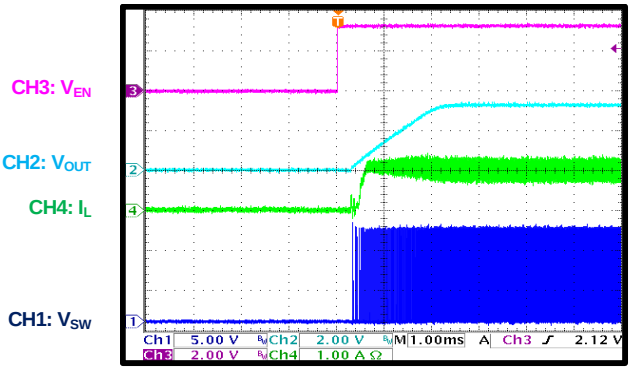
Start-Up through EN

I_{OUT} = 0A



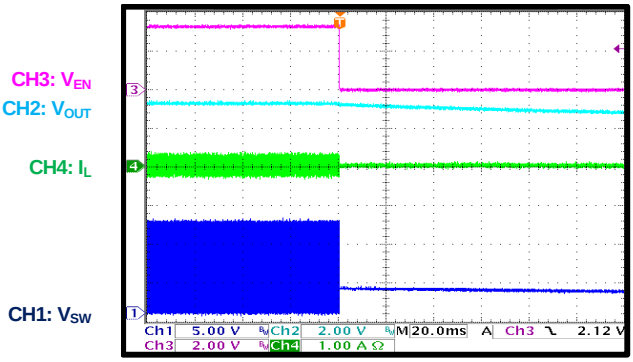
Start-Up through EN

I_{OUT} = 1A



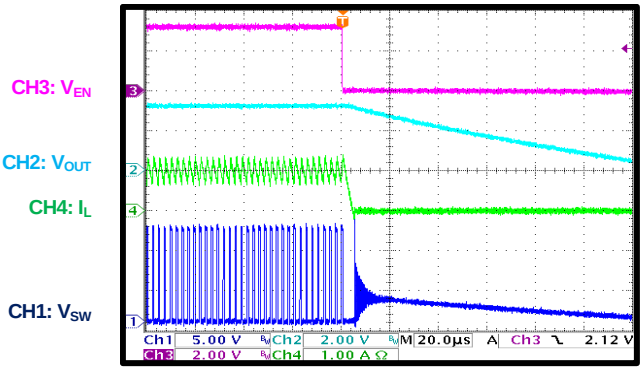
Shutdown through EN

I_{OUT} = 0A



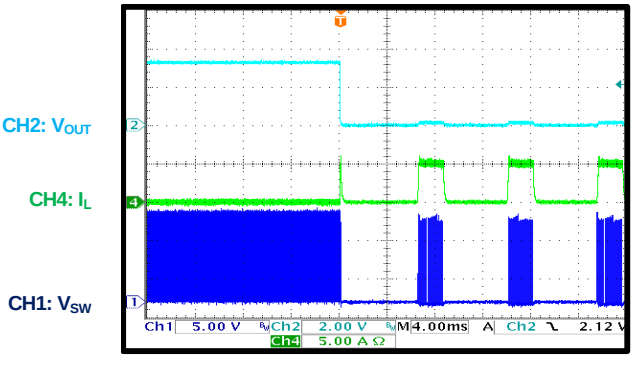
Shutdown through EN

I_{OUT} = 1A



SCP Entry

I_{OUT} = 0A to short circuit

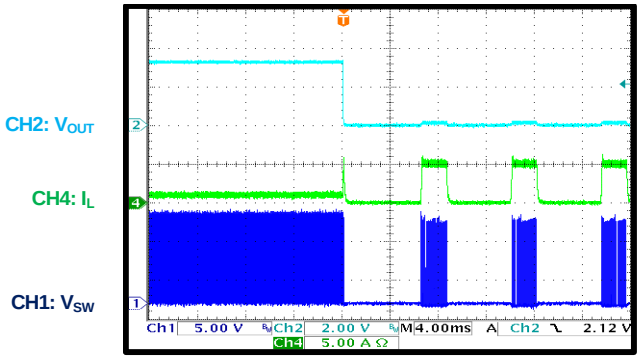


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 3.3V, L = 10µH, R_{BST} = 20Ω, T_A = 25°C, unless otherwise noted.

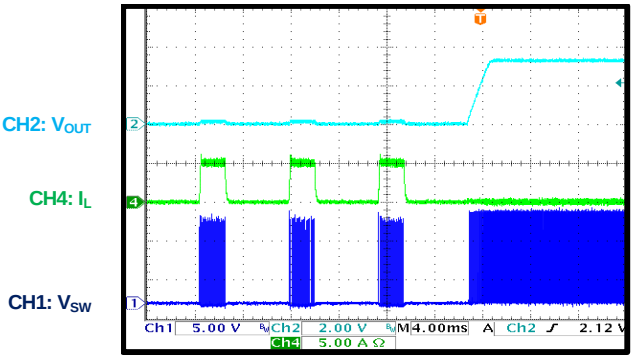
SCP Entry

I_{OUT} = 1A to short circuit



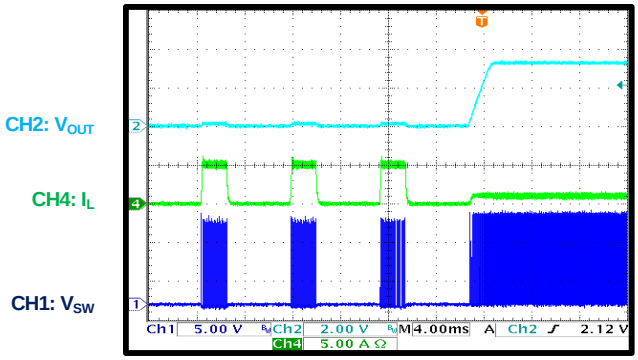
SCP Recovery

Short circuit to I_{OUT} = 0A

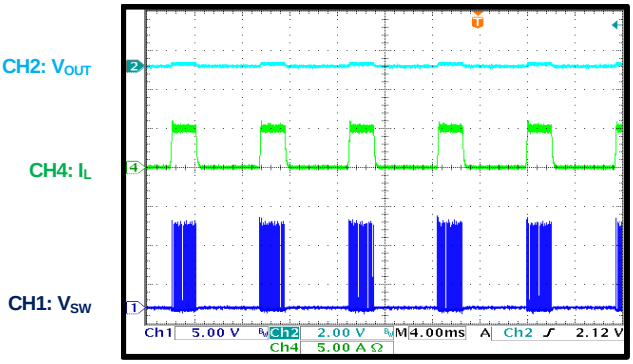


SCP Recovery

Short circuit to I_{OUT} = 1A

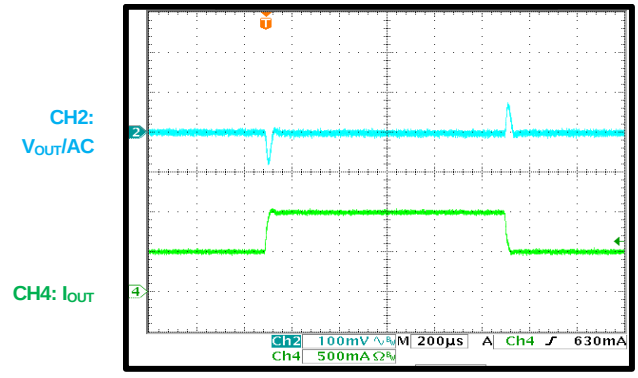


SCP Steady State



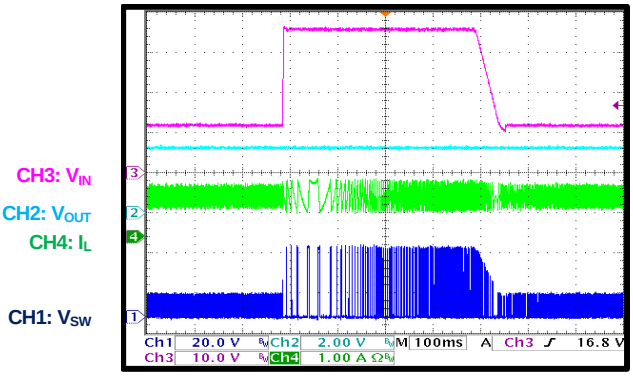
Load Transient

I_{OUT} = 0.5A to 1A, 1.6A/µs



Load Dump

V_{IN} = 12V to 36V, I_{OUT} = 1A

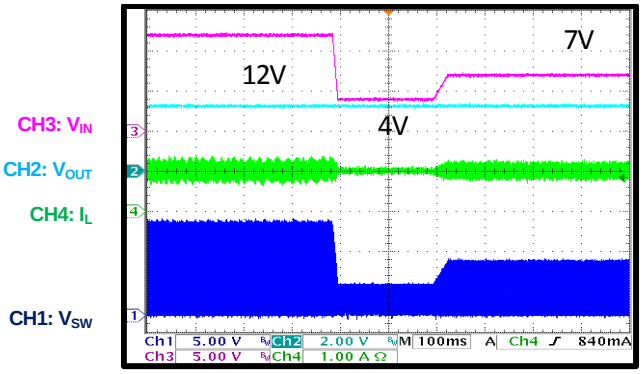


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 3.3V, L = 10µH, R_{BST} = 20Ω, T_A = 25°C, unless otherwise noted.

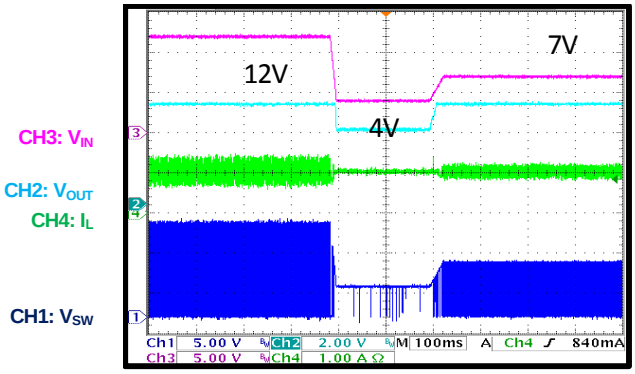
Cold Crank

V_{OUT} = 3.3V, I_{OUT} = 1A



Cold Crank

V_{OUT} = 5V, I_{OUT} = 1A



FUNCTIONAL BLOCK DIAGRAM

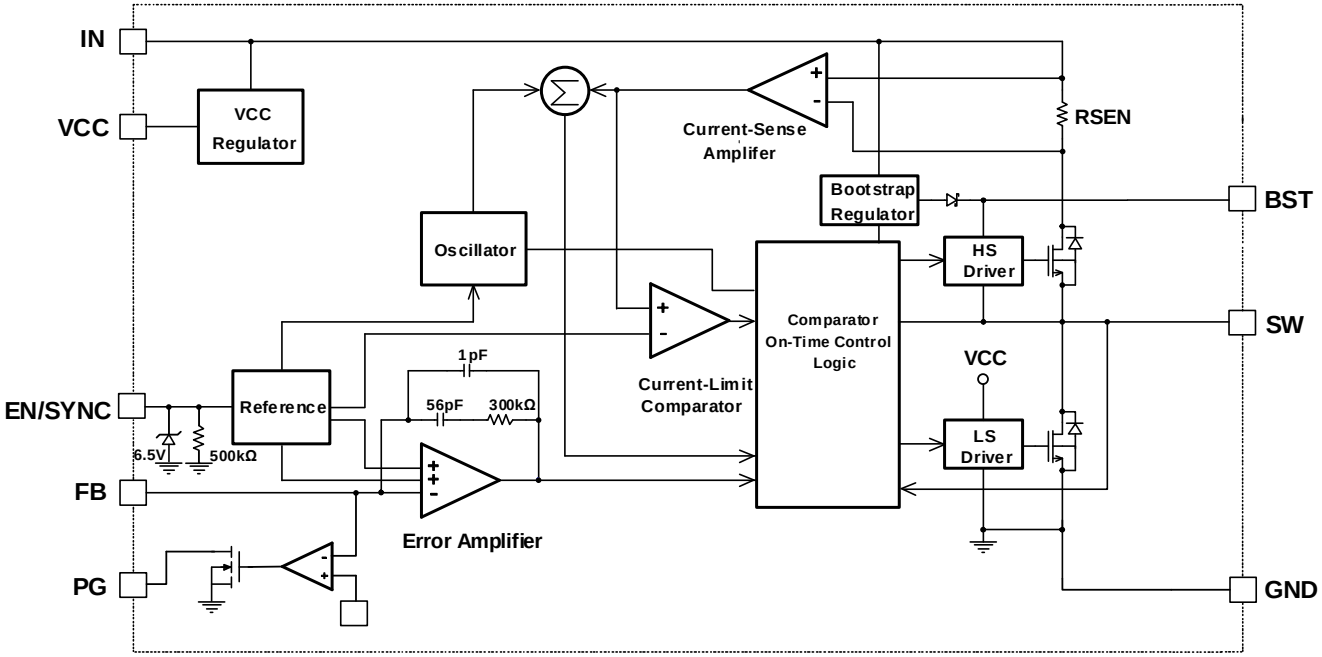


Figure 1: Functional Block Diagram

OPERATION

The MPQ4419 is a high-efficiency, synchronous, rectified, step-down, switch-mode converter with built-in power MOSFETs. It offers a very compact solution that achieves 1A of continuous output current, with excellent load and line regulation across a wide input supply range.

The MPQ4419 operates in a fixed-frequency, peak current control mode to regulate the output voltage (V_{OUT}). An internal clock initiates a PWM cycle. The integrated high-side power MOSFET (HS-FET) turns on and remains on until its current reaches the value set by the COMP voltage (V_{COMP}). When the power MOSFET is off, it remains off until the next clock cycle starts. If the current in the power MOSFET does not reach the current value set by COMP within 95% of one PWM period, the power MOSFET is forced off.

Internal Regulator

The 5V internal regulator powers most of the internal circuitries. This regulator takes the input voltage (V_{IN}) and operates in the full V_{IN} range. When V_{IN} exceeds 5.0V, the output of the regulator is in full regulation. When V_{IN} falls below 5.0V, the output of the regulator decreases following V_{IN}. A 0.1µF decoupling ceramic capacitor must be placed at VCC.

Error Amplifier (EA)

The error amplifier (EA) compares the FB voltage (V_{FB}) against the internal 0.8V reference (V_{REF}) and outputs V_{COMP}, which controls the power MOSFET current. The optimized internal compensation network minimizes the external component count and simplifies control loop design.

EN/SYNC Control

EN/SYNC is a digital control pin that turns the regulator on and off. Drive EN/SYNC high to turn the regulator on; drive EN/SYNC low to turn the regulator off. An internal, 500kΩ resistor from EN/SYNC to GND allows EN/SYNC to be floated to shut down the chip.

EN/SYNC is clamped internally using a 6.5V series Zener diode (see Figure 2). Connect the EN/SYNC input through a pull-up resistor to any voltage connected to V_{IN}. The pull-up resistor limits the EN/SYNC input current below 150µA.

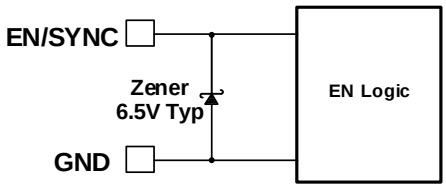


Figure 2: Zener Diode (6.5V Typ)

For example, with 12V connected to V_{IN}, R_{PULLUP} ≥ (12V - 6.5V) / 150µA = 36.7kΩ.

Connecting EN/SYNC directly to a voltage source without a pull-up resistor requires limiting the voltage amplitude below or equal to 6V, in order to prevent damage to the Zener diode.

To use the synchronous function, connect a 200kHz to 2.2MHz external clock to EN/SYNC. The external clock should be connected at least 2ms after V_{OUT} is set. The internal clock's rising edge is synchronized to the external clock's rising edge when the external clock is connected. The external clock's signal pulse width should be shorter than 1.7µs.

Under-Voltage Lockout (UVLO)

Under-voltage lockout (UVLO) protects the chip from operating at an insufficient supply voltage. The MPQ4419's UVLO comparator monitors the voltage of the internal regulator (V_{CC}). The UVLO rising threshold is about 3.5V, and its falling threshold is 3.3V.

Internal Soft Start (SS)

Soft start (SS) prevents the converter output voltage from overshooting during start-up. When the chip starts up, the internal circuitry generates a soft-start voltage (V_{SS}) that ramps up from 0V to 1.2V. When V_{SS} is below V_{REF}, V_{SS} overrides V_{REF} so the EA uses V_{SS} as the reference. When V_{SS} exceeds V_{REF}, the EA uses V_{REF} as the reference. The SS time (t_{SS}) is internally set to 1.5ms.

Over-Current Protection (OCP) and Hiccup Mode

The MPQ4419 uses cycle-by-cycle over-current limiting when the inductor current peak value exceeds the set current-limit threshold. If V_{OUT} drops until V_{FB} is below the under-voltage (UV) threshold (typically 84% below the reference), then the MPQ4419 enters hiccup mode to periodically restart the part.

This protection mode is especially useful when the output is dead-shorted to ground.

The average short-circuit current is reduced greatly to alleviate thermal issues and protect the regulator. The MPQ4419 exits hiccup mode once the over-current (OC) condition is removed.

Thermal Shutdown

Thermal shutdown prevents the chip from operating at exceedingly high temperatures. When the silicon die temperature exceeds 170°C, the entire chip shuts down. When the temperature drops below its lower threshold (typically 140°C), the chip is enabled again and resumes normal operation.

Floating Driver and Bootstrap Charging

An external bootstrap capacitor (C_{BST}) powers the floating power MOSFET driver. A dedicated internal regulator charges and regulates the bootstrap capacitor voltage to about 5V (see Figure 3).

When the voltage between the BST and SW nodes drops below the regulation limit, a PMOS pass transistor connected from V_{IN} to BST turns on. The charging current path goes from V_{IN} to BST to SW. The external circuit should provide enough voltage headroom to facilitate charging. As long as V_{IN} is sufficiently greater than SW, C_{BST} remains charged. When the HS-FET is on, V_{IN} is approximately equal to V_{SW}, so C_{BST} cannot charge. When the LS-FET is on, V_{IN} - V_{SW} reaches its maximum for fast charging. Figure 3 shows the charging path.

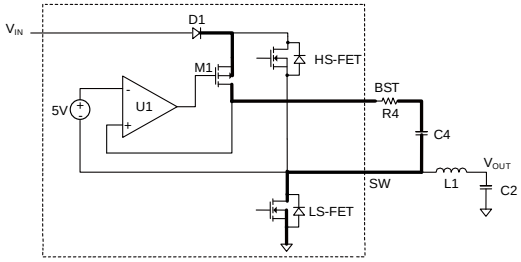


Figure 3: Internal BST Charging Path when the LS-FET is On

When the HS-FET and LS-FET are both off, V_{SW} is equal to V_{OUT}, so the difference between V_{IN} and V_{OUT} can charge C_{BST}. Figure 4 shows the charging path.

The floating driver has its own UVLO protection, with a rising threshold of 2.2V and hysteresis of 150mV. A 20Ω resistor placed between the SW and C_{BST} is strongly recommended to reduce SW voltage spikes.

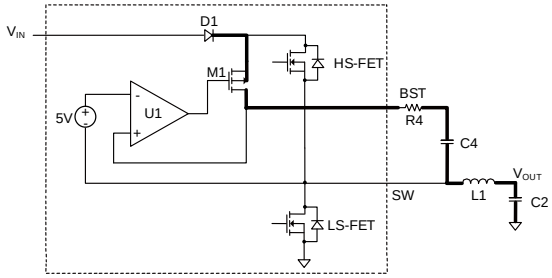


Figure 4: Internal BST Charging Path when the HS-FET and LS-FET are Both Off

Start-Up and Shutdown

If both V_{IN} and EN/SYNC exceed their appropriate thresholds, the MPQ4419 starts up. The reference block starts first, generating a stable reference voltage and current, and then the internal regulator is enabled. The regulator provides a stable supply for the remaining circuitries.

Three events can shut down the chip: EN/SYNC low, V_{IN} low, and thermal shutdown. In the shutdown procedure, the signaling path is blocked first to avoid any fault triggering. V_{COMP} and the internal supply rail are then pulled down. The floating driver is not subject to this shutdown command.

Power Good (PG)

The MPQ4419 has a power good (PG) output. PG is the open drain of the MOSFET. It should be connected to VCC or another voltage source through a resistor (e.g. 100kΩ). In the presence of an input voltage, the MOSFET turns on so that PG is pulled low before SS is ready. Once V_{FB} reaches 90% of V_{REF}, PG is pulled high after a delay (typically 90μs). When V_{FB} drops to 84% of V_{REF}, PG is pulled low. PG is also pulled low if thermal shutdown occurs or if EN/SYNC is pulled low.

APPLICATION INFORMATION

Setting the Output Voltage

The external resistor divider sets V_{OUT} (see the Typical Application Circuit section on page 19). The feedback resistor (R1) also sets the feedback loop bandwidth with the internal compensation capacitor. Choose R1 to be about 40kΩ. R2 can then be calculated with Equation (1):

$$R2 = \frac{R1}{\frac{V_{OUT}}{0.792V} - 1} \quad (1)$$

It is strongly recommended to use a T-type network when V_{OUT} is low (see Figure 5).

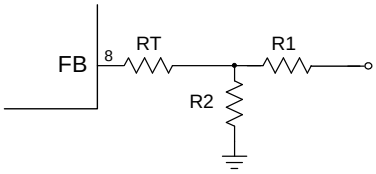


Figure 5: T-Type Network

RT + R1 is used to set the loop bandwidth. The higher RT + R1 is, the lower the bandwidth is. To ensure loop stability, it is strongly recommended to limit the bandwidth below 40kHz based on the 410kHz default switching frequency (f_{SW}). Table 1 lists the recommended T-type resistor values for common output voltages.

Table 1: Resistor Selection for Common Output Voltages

V_{OUT} (V)	R1 (kΩ)	R2 (kΩ)	RT (kΩ)
3.3	41.2 (1%)	13 (1%)	100 (1%)
5	41.2 (1%)	7.68 (1%)	100 (1%)

Selecting the Inductor

Use a 1µH to 10µH inductor with a DC current rating at least 25% greater than the maximum load current for most applications. For the highest efficiency, an inductor with a small DC resistance is recommended. For most designs, the inductance value can be calculated with Equation (2):

$$L_1 = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times \Delta I_L \times f_{OSC}} \quad (2)$$

Where ΔI_L is the inductor ripple current.

Choose the inductor ripple current to be approximately 30% of the maximum load current. The maximum inductor peak current can be calculated with Equation (3):

$$I_{L(MAX)} = I_{LOAD} + \frac{\Delta I_L}{2} \quad (3)$$

Use a larger inductor for improved efficiency below 100mA under light-load conditions.

V_{IN} Under-Voltage Lockout (UVLO) Setting

The MPQ4419 has an internal, fixed, under-voltage lockout (UVLO) threshold. The rising threshold is 3.5V, and the falling threshold is about 3.3V. For applications that require a higher UVLO point, an external resistor divider between EN/SYNC and IN can be used to achieve a higher equivalent UVLO threshold (see Figure 6).

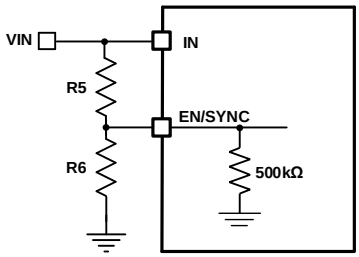


Figure 6: Adjustable UVLO Using a EN/SYNC Divider

The UVLO rising and falling thresholds can be calculated with Equation (4) and Equation (5), respectively:

$$INUV_{RISING} = (1 + \frac{R5}{500k\Omega \,//\, R6}) \times V_{EN\_RISING} \quad (4)$$

$$INUV_{FALLING} = (1 + \frac{R5}{500k\Omega \,//\, R6}) \times V_{EN\_FALLING} \quad (5)$$

Where V_{EN_RISING} is 1.4V, and $V_{EN\_FALLING}$ is 1.25V.

When selecting R5, ensure that it is large enough to limit the current flowing into EN/SYNC to below 150µA.

Selecting the Input Capacitor

The step-down converter has a discontinuous input current, and requires a capacitor to supply AC current to the converter while maintaining the DC input voltage. For the best performance, use low-ESR capacitors. Ceramic capacitors with

X5R or X7R dielectrics are recommended for their low ESR and small temperature coefficients. For most applications, a 22µF ceramic capacitor is sufficient to maintain the DC input voltage. It is strongly recommended to use another, lower-value capacitor (e.g. 0.1µF) with a small package size (0603) to absorb high-frequency switching noise. Place the smaller capacitor as close to IN and GND as possible (see PCB Layout Guidelines on page 18).

Since C1 absorbs the input switching current, it requires an adequate ripple current rating. The RMS current in the input capacitor can be estimated with Equation (6):

$$I_{C1} = I_{LOAD} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)} \quad (6)$$

The worst-case condition occurs at $V_{IN} = 2V_{OUT}$, calculated with Equation (7):

$$I_{C1} = \frac{I_{LOAD}}{2} \quad (7)$$

For simplification, choose an input capacitor with an 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, add a small, high-quality ceramic capacitor (e.g. 1µF) placed as close to the IC as possible. When using ceramic capacitors, ensure that they have enough capacitance to provide a sufficient charge to prevent an excessive voltage ripple at input. The input voltage ripple caused by the capacitance can be estimated with Equation (8):

$$\Delta V_{IN} = \frac{I_{LOAD}}{f_{SW} \times C1} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad (8)$$

Selecting the Output Capacitor

The output capacitor (C2) maintains the DC output voltage. Ceramic, tantalum, or low-ESR electrolytic capacitors are recommended. For best results, use low-ESR capacitors to keep the output voltage ripple low. The output voltage ripple can be estimated with Equation (9):

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_{SW} \times L_1} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times f_{SW} \times C2}\right) \quad (9)$$

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

For ceramic capacitors, the capacitance dominates the impedance at the switching frequency and causes the majority of the output voltage ripple. For simplification, the output voltage ripple can be estimated with Equation (10):

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_{SW}^2 \times L_1 \times C2} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad (10)$$

With tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output voltage ripple can be approximated with Equation (11):

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_{SW} \times L_1} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times R_{ESR} \quad (11)$$

The characteristics of the output capacitor also affect the stability of the regulation system. The MPQ4419 can be optimized for a wide range of capacitance and ESR values.

BST Resistor and External BST Diode

A 20Ω resistor in series with C_{BST} is recommended to reduce SW voltage spikes. Higher resistance is better for SW spike reduction, but compromises efficiency.

An external BST diode can enhance the efficiency of the regulator when the duty cycle is high (>65%). A power supply between 2.5V and 5V can be used to power the external bootstrap diode. Either V_{CC} or V_{OUT} can be used as the power supply in this circuit (see Figure 6).

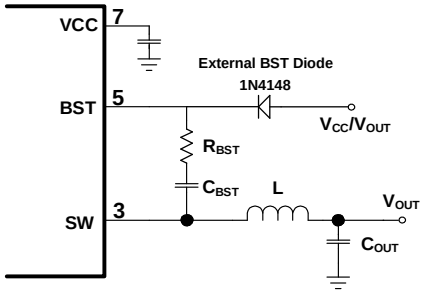


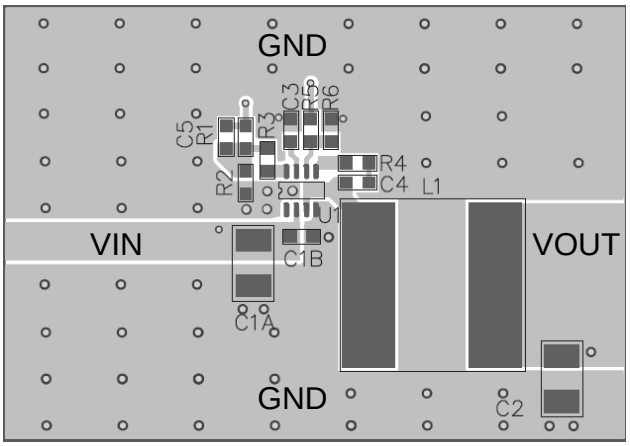
Figure 6: Optional External Bootstrap Diode to Enhance Efficiency

The recommended external BST diode is IN4148, and the recommended BST capacitance is 0.1µF to 1µF.

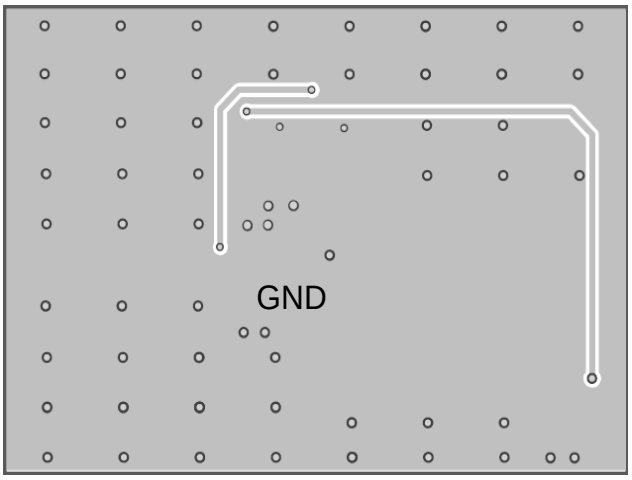
PCB Layout Guidelines

Efficient PCB layout, especially input capacitor and VCC capacitor placement, is critical for stable operation. For the best results, refer to Figure 7 and follow the guidelines below:

1. Place the ceramic input capacitor, especially the small package size (0603) input bypass capacitor, as close to IN and GND as possible.
2. Keep the connection between the input capacitor and IN as short and wide as possible.
3. Place the VCC capacitor as close as possible to VCC and GND.
4. Make the trace from VCC to the capacitor to GND as short as possible.
5. Use a large ground plane, connected directly to GND.
6. If the bottom layer is the ground plane, add vias near GND.
7. Route SW and BST away from sensitive analog areas, such as FB.
8. Place the T-type feedback resistor close to the chip to ensure that the trace connecting to FB is as short as possible.



Top Layer



Bottom Layer

Figure 7: Recommended PCB Layout

TYPICAL APPLICATION CIRCUIT

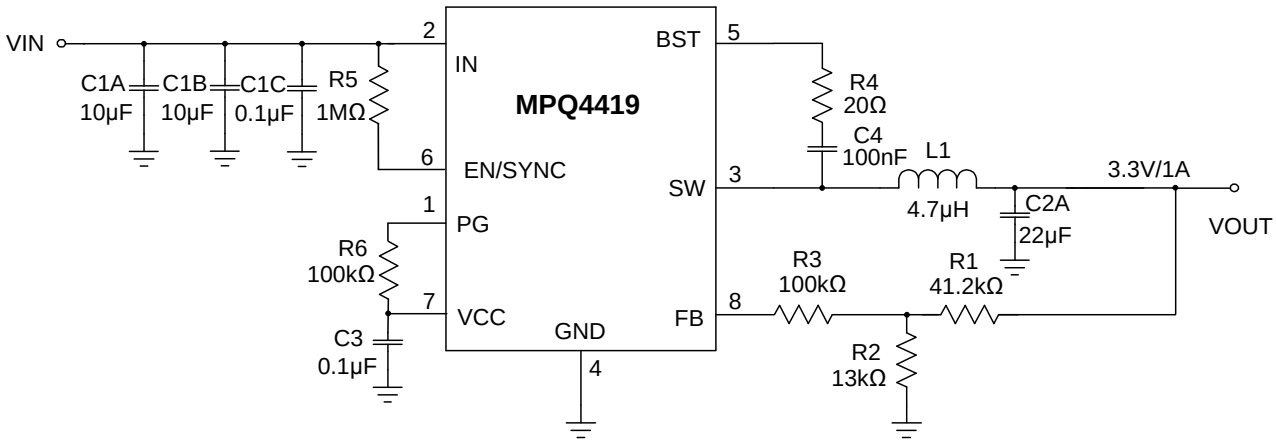
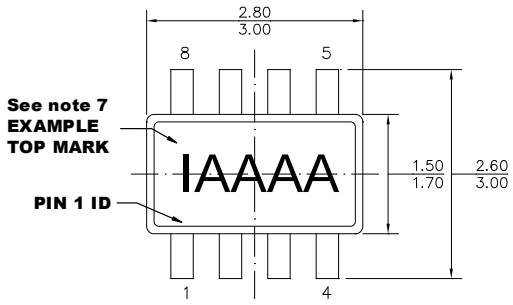


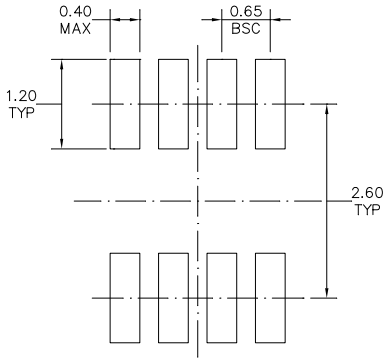
Figure 8: 3.3V Output Typical Application Circuit

PACKAGE INFORMATION

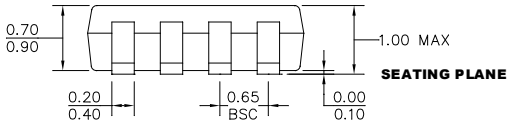
TSOT23-8



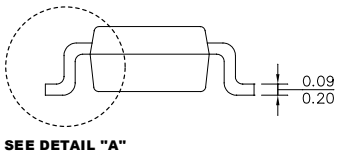
TOP VIEW



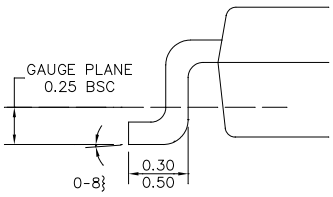
RECOMMENDED LAND PATTERN



FRONT VIEW



SIDE VIEW

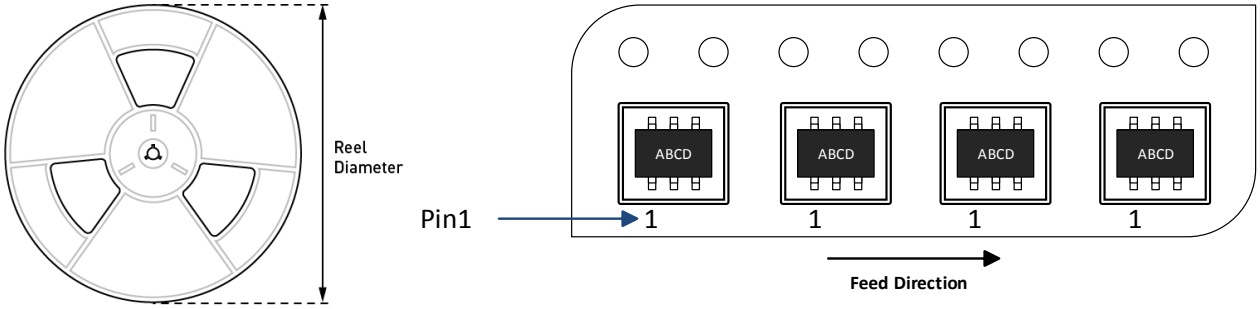


DETAIL "A"

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 MARKING FROM LEFT TO RIGHT (SEE EXAMPLE TOP MARKING).

CARRIER INFORMATION



Part Number	Package Description	Quantity/ Reel	Quantity/ Tray	Quantity/ Tube	Reel Diameter	Carrier Tape Width	Carrier Tape Pitch
MPQ4419GJ-AEC1–Z	TSOT23-8	3000	N/A	N/A	7in	8mm	4mm

REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	3/5/2021	Initial Release	-
1.01	6/3/2021	Update the error code to figure 2 to shut down the chip. EN/SYNC is clamped internally using a 6.5V series Zener diode (see **Error! Reference source not found.**). Connect the EN/SYNC input through a pull-up resistor to any voltage connected to V_{IN}. The pull-up resistor limits the	Page14